Grupa LOTOS S.A.	**TECHNICAL SPECIFICATION**	Spec. No. 2421
	Reciprocating Compressors	

Contents

1 Subject of specification 3
2 Scope of validity 3
2.1 Order of precedence 3
2.2 Local regulations 3
2.3 Standards/norms 3
2.4 Deviations 4
3 Guarantees 4
4 Design Criteria 4
4.1 General 4
4.2 Basic Design 5
4.3 Valves 6
4.4 Pistons and piston rods 7
4.5 Crankshafts, bearings and crossheads 7
4.6 Non-Lubricating Compressor 7
4.7 Stuffing boxes and packing 8
4.8 Compressor frame lubrication 8
4.9 Cylinder and packing lubrication 8
4.10 Flywheel 9
4.11 Baseplates, soleplates and rails 9
4.12 Anchor bolts 9
4.13 Special tools 9
4.14 Materials 9
4.15 Vibrations 10
4.16 Piping and Appurtenances 10
4.17 Design Approaches 12
4.18 Controls and Instrumentation 13
4.19 Capacity Control 14

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4.20 Drivers 15
4.21 Gears 15
4.22 Couplings and Guards 15
4.23 Nameplate 16
5 Inspection and Testing 16
5.1 General 16
5.2 Inspections and Testing 16
6 Painting 17
7 Documentation 17
8 Relevant documents 19
8.1 Grupa LOTOS S.A. specifications 19
8.2 Standards 19
9 Record of changes 20

1 Subject of specification

This specification used in conjunction with other technical specifications of Grupa LOTOS S.A. establishes the minimum requirements for the design, fabrication, inspection and testing of reciprocating compressors intended for work in Grupa LOTOS S.A. plants.

2 Scope of validity

This specification applies to the preparation of tender documents, inquiries and contracts concerning new investments and modernization projects planned by Grupa LOTOS S.A.
It shall also be a basis for preparing both detailed specifications and inquiries for individual or package unit supplies. This specification shall be read in conjunction with the applicable ISO/API standard and Grupa LOTOS S.A. Specification no. 2400 – General Requirements for Machines and Drives.

Reference to other industrial standards for compliance shall be interpreted as an integral part of this specification.

2.1 Order of precedence

In case of conflicts existing between this specification and other documents, the following order of precedence shall govern:

- The current Polish legislation
- Terms of purchase order / contract and other requirements agreed in writing Grupa LOTOS S.A.
- Data Sheets approved by Grupa LOTOS S.A.
- This specification
- Other Specifications
- Drawings and other documents
- Standards

2.2 Local regulations

Reciprocating compressor units shall be designed, constructed and installed in compliance with all applicable national and local laws and regulations, Grupa LOTOS S.A. specifications and current technical standards referred to in purchase order documents.

2.3 Standards/norms

Reciprocating compressors shall be designed and delivered in accordance with API standard 618 5th ed. or newer including requirements stated herein. Other standards may be used if agreed with Grupa LOTOS S.A.

Small compressors used in auxiliary systems may be designed according to the manufacturer's standards.

Applicable standard shall be stated in data sheets.

2.4 Deviations

Any deviation from this specification and the relevant specifications, standards and related documents including proposals, which the bidder claims to be economically and / or technically superior solutions, must be submitted in writing for review and approval by Grupa LOTOS S.A. Non-approved exceptions are not acceptable by Grupa LOTOS S.A.

The Supplier must report in writing any ambiguity in this or any other specifications of Grupa LOTOS S.A. or non-compliance with the referred documents / standards and obtain a written explanation from Grupa LOTOS S.A.

3 Guarantees

All materials, design and construction shall be subject to the conditions and guarantees required by the purchase order.

The checking of drawings, the intermediate and final inspections of the compressor by Grupa LOTOS S.A. as well as the release for shipping shall not relieve the Supplier from his responsibility for the compliance of the compressor with the terms and conditions of the purchase order.

4 Design Criteria

4.1 General

4.1.1 Compressors, drivers and auxiliaries shall be installed inside a dedicated shelters. The shelter construction should assure the reliable operation of the all main and auxiliary compressor systems and to make possible the free access to these systems in case of maintenance.

4.1.2 Compressors, drivers and auxiliaries placed outside the shelters (for each particular case is required GLSA acceptance) must be designed for unsheltered outdoor operation in applicable weather condition and in proper explosion zone, unless otherwise specified in the data sheets.

4.1.3 The over-all mechanical and aerodynamic performance of the compressor unit shall be the compressor Supplier's responsibility. Compressors driven by induction motors shall be selected for the actual motor speed corresponding to rated load conditions and not the synchronous speed.

4.1.4 The compressor Supplier shall have unit responsibility for all equipment unless otherwise stated in the purchase orders. The entire system consists of compressors, drivers, power transmissions and associated auxiliary equipment. The unit responsibility includes, but is not limited to engineering responsibility for the following:

- Rating and selection of power and speed transmission components
- Equipment layout, baseplate design, foundation and grouting requirements
- Piping layout, coordination with subvendors and purchaser as required
- Torsional and lateral analysis
- Acoustical simulation study and mechanical analysis
- Piston rod sealing system design
- Lube oil system design (lube oil and cylinder/packing lubrication if required)
- Cooling system design

- Logic, interlock system integration, coordination with purchaser
- Vibration, rod drop and bearings /valves temperature system design and coordination of all units in the train.
- Obtaining and transmitting all equipment engineering data to the purchaser
- Coordination of all physical and performance interfacing require meeting the applicable specifications, codes and standards
- Coordination of all assembly and testing requirements of the train components
- Coordination of site activities for the unit until final acceptance
- Sound level requirements acc. applicable regulations, Grupa LOTOS S.A. specification and/or other attachments of the purchase order.

4.1.5 The Supplier shall only offer such reciprocating compressors as have already been applied similar design for the same or similar conditions and proved themselves.

4.1.6 The design shall concur with the latest state of the art and be in accordance with the standards stated in this specification and the data sheets.

4.1.7 Reciprocating Compressor design recommended by the Supplier shall be mutually agreed to and in compliance with applicable laws and standards. Supplier shall indicate where specifications require excessive measures that result in non-standard material supply. The Supplier is obligated to identify such deviations.

4.1.8 These specifications do not apply to plant or instrument air compressors unless otherwise specified in the data sheets.

4.2 Basic Design

4.2.1 Where possible, compressors shall be furnished as complete packages including driver, gears, couplings, lubrication and cooling system, intercoolers, separators, pulsation suppression devices, package mounted instrumentation and capacity control system.

4.2.2 Where winterization is specified, mutual provisions shall be made for the complete drainage of the compressor, auxiliary equipment, all steam and water lines (to the sewer) and oil lines (to the sump). Freeze protection shall be provided for gauges, small piping (with heaters or oil circulation), pressurized lube oil lubrication system, electric motor and local control panels.

4.2.3 The Supplier shall review and comment on Grupa LOTOS S.A. piping and foundation drawings.

4.2.4 The design data of utilities given in the data sheets refer to the system. Data at connection interfaces can slightly differ.

4.2.5 The pressure drops across silencers, pulsation suppression devices, intercoolers, separators and inter-connecting piping shall be stated separately by the Supplier before the order is placed.

4.2.6 Pressure drops across throttles, orifices plates, etc. for pulsation suppression, silencers, check valves, etc. to be justified by the machinery Supplier are to be taken into account by him during designing provided these components are included in his scope of supplies.

4.2.7 Compressors and drivers shall be suitable for the maximum differential pressure specified by Grupa LOTOS S.A. and the differential pressure developed due to operation at minimum specified suction pressure and blow off pressure of stage discharge safety valves.

4.2.8 Compressors shall be designed for continuous, heavy-duty service. The Supplier's recommendations for rotating speeds and piston speeds will generally be based on Supplier's experience with similar size machines in similar service. The rotating and piston speeds shall not exceed 600 rpm and 4

m/sec. unless otherwise specified in the data sheet. Hydrogen compressors in continuous service shall be limited to 350 rpm maximum speed unless otherwise specified in the data sheets.

4.2.9 When the maximum discharge temperature is 150°C or more a high discharge temperature alarm and shutdown set at 175°C is required. For any hydrocarbon-lubricated compressor handling air or other oxygen-bearing gas at a discharge pressure above 20 bar(g), lower temperature limits shall be used as specified in the applicable data sheets. When non-metallic piston rings, rod packing or valves are furnished, rated discharge temperature shall not exceed 120°C, alarm shall be set at 135°C, and shutdown, when required, shall be set at 150°C. The Supplier shall submit his experience on this matter with the proposal.

4.2.10 Compressors shall have horizontal cylinders unless otherwise specified in the data sheets. All horizontal cylinders shall have bottom discharge connections without exception. Major equipment parts such as cylinders and compressor frames shall be shouldered or doweled to ensure accuracy of alignment. All cylinders shall be double-acting. Cylinders must be supported by cold supports and must be independent of discharge piping.

Replaceable liners shall be provided for all cylinders. Liners shall not come in contact with cooling medium (wet liners) and shall be held in place by positive mechanical means. Press-fit only liners are not permitted. Supplier shall state compliance with this type of construction in his quote.

4.2.11 Compressor cylinders, distance pieces, and crankcase shall be fastened to each other by means of studs or through bolts. Handheld plates and cover plates shall be attached by means of studs and through bolts. Tapped holes for stud bolts shall not penetrate corrosion allowance. All cylinder heads shall be fitted with eye bolts and jacking screw to facilitate dismantling.

4.2.12 Cylinder cooling shall be provided according to the API 618 standard.

For services with forced coolant circulation systems, Supplier shall state on the data sheets in the proposal the cooling water rates and temperatures, together with the pressure loss figures for each cylinder jacket.

4.2.13 Cooling water systems shall be designed for conditions stated in API 618 5th ed. unless specified otherwise in the data sheet. Provisions shall be made for complete drainage.

4.2.14 A complete description of piston, rings and rod packing design (including materials of construction and cylinder bore finish) shall be included in the proposal. Generalized manufacturing drawings shall be available for review during the proposal stage of the order.

4.3 Valves

4.3.1 Valve and unloader designs shall be in accordance with API 618 and shall be suitable for operation with any gas specified on the data sheet. Pneumatically (or hydraulically) controlled suction valve unloaders that have a positive seal shall be furnished. Each individual unloading device shall be provided with a visual indication of its position and its load (loaded or unloaded) condition, unless otherwise specified in the data sheet. Installation and torqueing procedures shall be included in the instruction manual to prevent operating valves leakage.

4.3.2 The contact surfaces of metallic valve discs and seats shall be furnished as near Ra of 0,2 μm as the material involved permits. Where conformable materials are applied, and not metal-to-metal contact takes place, the Supplier's standard finish shall be acceptable. Valve seats shall be repairable by lapping. They shall not contain fixed pins or disc guides. Weight of the heaviest valve assembly shall be included in the proposal. In hydrogen service, cadmium plated, piano-wire coil springs are required.

4.3.3 Only milled valve plates shall be used.

4.3.4 Valve plates or discs made of plastics (e.g. Polyether Etherketone /PEEK/) are preferred (Grupa LOTOS S.A. approval of applied ring/plate material is a must).

4.4 Pistons and piston rods

4.4.1 Locking nuts attaching the piston rod to the piston and crosshead shall be tightened to Supplier's standard but as a minimum the Supplier's tightening procedure must ensure a pre-stress level of twice the operating stress of the rod.

4.4.2 Pistons shall be preferable segmented. Pistons with rider rings are preferred – for pistons in hydrogen rich gas service rider rings are a must. Construction and material of rider and piston rings shall be a subject for Grupa LOTOS S.A. approval.

4.4.3 Tail rods, if used, shall have forged steel enclosures which will contain the rod in the event of rod failure.

4.4.4 Compressor rod and/or crosshead pin loading at any specified operating condition shall not exceed 80% of Supplier's maximum continuous (not peak) duty rating. Loading calculations shall be based on relieving pressure specified for the stage. Calculation for such loading shall include inertial as well as gas forces.

4.4.5 When hydrogen sulphide is specified to be present in the gas (2 ppm or greater) then piston rod with Colmonoy Number 6 hard facing 0,5 mm (0.020 inches) minimum shall be provided unless Supplier’s experience requires other material combination.

4.5 Crankshafts, bearings and crossheads

4.5.1 Supplier shall supply a Tangential Force versus Crank Angle Diagram (based on cross-head pin loading).

4.5.2 The crankshaft shall have counterweights to ensure good balance in all working conditions.

4.5.3 If specified in the data sheet explosion-relief devices shall be provided on the crankcase. Apertures shall be directed downward, away from the operator's face, and a rapid closure device shall feature a flame arresting mechanism to prevent secondary explosions.

4.5.4 Spacer elements between the cylinder and the crankcase:

- compressors for toxic gases or gases containing 30 mol.% or more hydrocarbons shall be fitted with two chamber-type spacer elements with a vent and a drain and airtight covers on the chamber adjacent to the cylinder
- for compressors for gases containing more than 30% hydrogen the spacer element adjacent to the crankcase shall have ventilated safety covers preventing gas penetration to the crankcase

4.6 Non-Lubricating Compressor

4.6.1 In case of non-lubricating compressors completely oil free delivery must be ensured under all conditions.

4.6.2 Neither oil nor oil-mist may enter the process gas chambers in the machine during start-up, run-down, shut-down, full- and part-load operation.

4.6.3 Non-lubricated cylinders for air shall be designed with simple, extra long distance pieces type B.

4.6.4 Vents and drains min. 25 mm (1 inch) and lateral openings with tight closing covers shall be provided for each chamber.

4.7 Stuffing boxes and packing

4.7.1 Glands shall be stainless steel where packing cooling is required. Packing cooling shall be provided for hydrogen service. Cooling shall be provided for all PTFE packing unless otherwise stated on the data sheet or agreed by Grupa LOTOS S.A.

4.7.2 Nitrogen Purging
If necessary, and / or specified in the data sheet, the piston rod packings shall be purged with nitrogen. For that a complete pressure control station per compressor shall be provided with the minimum equipment as follows:

- Instruments (flow indicator, pressure gauge)
- Alarm for low pressure
- Filter

4.7.3 Piping downstream the filter shall be made of stainless steel.

4.7.4 For toxic gases the seals shall be designed in such a way that under no circumstances the medium can enter the crankcase.

4.8 Compressor frame lubrication

4.8.1 Lube oil pumps located external to the compressor frame must have flanged connections for oil inlet and outlet. Lube oil pumps located on the inside of the compressor frame may have screwed connections if space limitations prevent the use of flanges.

4.8.2 The cooler shall be shell and tube type with cooling water on tube side unless otherwise specified. Tubes shall be as specified on the data sheets. The tube sheets, shell and channel shall be of carbon steel construction. Coolers shall be provided with insolating valves on the oil side.

4.8.3 The filter shall be full-flow duplex type with continuous flow transfer valves. Filtration shall be 10 microns (nominal) or less, otherwise specified on the applicable data sheets.

4.8.4 A thermostatically-controlled electric immersion heater shall be supplied.

4.8.5 All compressors shall be provided with a protected crankcase oil level gauge with the required oil level clearly marked. All compressors shall be furnished with weatherproof, dust-tight crankcase covers suitable for the climatic conditions stated on the data sheet. Oil relief or control valves shall be located outside the crankcase so that adjustments may be made while the compressor is operating.

4.9 Cylinder and packing lubrication

4.9.1 Pump and other components shall be located so as to provide convenient accessibility to frame lubrication system components and other compressor appurtenances. This will involve mounting the lubricator on the side (not top) of the crankcase. Lubrication system shall include pump with strainer, fine filter, no-flow indicators in the manifold and glycerine filled pressure gauge between pump and first distribution blocks. Not less than two (2) lubrication points shall be provided inside cylinder for cylinders up to 305 mm (12-inch) diameter. Not less than three (3) lubrication points inside cylinder shall be provided for cylinders over 305 mm (12-inch) diameter. Additional lubrication points may be provided acc. to Supplier's standard or if specified on applicable data sheets.

4.9.2 All non-lube cylinders (but no liners) shall be drilled, and plugged for possible future lubrication.

4.9.3 Protection for failure of the cylinder and packing lubricators shall be provided and shall consist of a low pressure or flow switch with alarm connected to the discharge of an extra lubricator pump

circulating oil back to the reservoir. This pump shall have its suction tube shortened so that it will lose suction when the reservoir oil drops below 70 percent of full level.

4.10 Flywheel

The compressor flywheel shall be designed in such a way that the maximum degree of irregularity at the most unfavourable operating point at drive powers up to 200 kW does not exceed 1 : 80 and in excess of 200 kW - 1 :100.

4.11 Baseplates, soleplates and rails

4.11.1 Compressor and drive shall be mounted on a common baseplate. Should this not be possible, separate baseplates shall be provided for compressor and drive.

4.11.2 If soleplates or rails are specified in the data sheets, they shall be provided by the compressor Supplier

4.12 Anchor bolts

4.12.1 The anchor bolts shall be supplied by the compressor Supplier unless otherwise specified.

4.12.2 Anchor bolts shall have sufficient projection to receive two (2) heavy hex nuts.

4.12.3 The Supplier will provide the shims required for erection and levelling of the machines during installation.

4.13 Special tools

Compressors of power equal or greater than 750 kW and/or of speed equal or lesser than 360 rpm s shall be provided with an integral pneumatic piston-type barring device. On single bearing motor-drive applications, a suitable motor shaft cradle shall be provided for maintenance purposes unless otherwise specified in the data sheets.

4.14 Materials

4.14.1 Materials shall be as specified in the data sheets according to applicable API, ASTM, EN, AISI standards and specifications.

4.14.2 The Supplier is responsible for the material selection to meet the specified operating conditions.

4.14.3 The Supplier may offer as option alternative materials, if based on his experience, it would be a more economic selection without any negative impact with regard to reliability and safety of the machines.

4.14.4 When ultrasonic inspection is specified, procedures and acceptance criteria shall be submitted to Grupa LOTOS S.A. for approval.

4.14.5 Overlays are permitted if already successfully applied (reference needed) and approved by Grupa LOTOS S.A.

4.14.6 In general, crank-end and head-end cylinder heads must be of the same material as the cylinder. Welded joints on pressure castings (cylinders) shall have full penetration, be stress relieved and 100% radiographed.

4.14.7 Repairs to castings by welding, and plugging, or by any other means, may be made only with approval of Grupa LOTOS S.A., obtained in writing before the work is commenced. The compressor Supplier's proposal must clearly state that he can and will conform to the requirements.

4.14.8 All shop welding (construction and production welds) shall be carried out in accordance with the standards stated in the data sheet.

4.14.9 The standards listed in the data sheets also apply to the welder qualifications and the quality of the welding.

4.14.10 All root weld seams of piping in the oil systems shall be welded with shield gas. The same also applies to the piping fabrication on site. All pipes in compressor Supplier scope of supply are subject to the same test and inspection conditions as for the piping of the process plant, independent whether they are fabricated in the workshop or on site.

4.14.11 The notch impact strength values shall be mentioned in the Supplier's quote.

4.14.12 If required in the data sheets, the notch impact strength values have to be verified by material testing.

4.14.13 In selecting materials when hydrogen sulphide is specified to be present (2 ppm or greater) in the gas, the hardness of carbon and low alloy steel parts shall not exceed HRC 22. The yield strength of these parts shall not exceed 620 N/mm². Components fabricated by welding shall be heat treated so that both the weld and the heat affected zones meet this hardness limitation. Permitted exceptions to this requirement are valve plates and springs where greater hardness has proven necessary.

4.14.14 The Supplier may offer cast iron for pressures up to 70 bar(g) if it is within Supplier's experience and significant record of references can be provided. This satisfactory experience shall have been proven on gas of molecular weight equal or lower than the requested application and at the operating temperature not exceeding 165°C. No increased stress allowance shall be given for nodular iron over cast iron for any cylinder. It shall be the Supplier's responsibility to furnish cast or forged steel cylinders when the stress levels of cylinders exceed the allowable values for cast iron. Fabricated steel cylinders are not acceptable.

4.14.15 All welders and procedures shall be qualified in accordance with applicable AWS / ISO standard. All welding procedures shall be submitted for review unless otherwise specified in the data sheet.

4.15 Vibrations

4.15.1.1 The maximum allowable effective vibration velocity (Veff) measured on the cylinder end is as follows:

- horizontal compressors < 8 mm/s
- vertical compressor < 12 mm/s

4.15.1.2 The allowable effective vibration velocity Veff = 4,5 mm/s shall not be exceeded at the crankcase.

4.15.1.3 The compressor Supplier shall ensure that excitations (gas flow or mechanical origin) caused by the machine do not cause unacceptable vibration and stress to the piping.

4.16 Piping and Appurtenances

4.16.1 General piping requirements

- Suction and discharge gas connections must be flanged. Screwed connections are not acceptable.
- Cast iron flanges shall be flat-faced. The flange facing and drilling shall be in accordance with ANSI standards, unless otherwise specified in the data sheets.
- Where ANSI standards require a raised face or RTJ, the thickness of the raised face of RTJ shall be included in the total required thickness of the flange.

- Where through bolting cannot be used, studs shall be furnished. Machine bolts and studs shall be of high tensile steel for steel cylinders.
- Process gas piping and valves shall confirm to the applicable Grupa LOTOS S.A. piping specification as indicated in the data sheets and purchase order documents.
- Compression connectors are not allowed for product and utility lines. Metal-to-metal sealing welding end connections is preferred.

4.16.2 Forced-feed lubricator piping requirements

Compression fittings shall be used. These shall be Swagelok or Grupa LOTOS S.A. approved equal.

4.16.3 Coolant piping requirements

Supplier shall provide valves and unions in coolant inlet and outlet lines to each compressor cylinder. Unless otherwise specified, Supplier shall furnish all the coolant piping. Cooling water inlet and outlet connections to the cylinder may be threaded however, break flanges shall be provided to facilitate disassembly of cylinders. Where through cooling is specified, the cooling water piping shall be manifolded and terminated with flanges. If flexible metal connections are specified, they shall be mounted adjacent to each cylinder cooling water inlet and outlet connection. Piping shall be industry standard for the service intended.

4.16.4 Drain and Vent Piping

- Machine-internal degassing/vent lines are to be made of stainless steel and designed for the maximum end pressure of the cylinder.
- The design must ensure that leakage gas from the piston rod seals is safely carried off. The venting line shall be capable of discharging the gas in case of seal failure without exceeding max. allowable working pressure.

4.16.5 Scope of Piping Supply

The compressor Supplier shall provide the following lines within the limits stated by Grupa LOTOS S.A.:

- internal gas lines with flanges
- utility lines (oil, sealing-fluid, etc.),
- drain lines,
- vent lines.

All necessary valves, pipe supports, supports for instruments and flange connections (incl. those for hydrostatic tests on site) are included in the Supplier's scope. Instrumentation and nozzles for a test run in the plant are also included in the Supplier’s scope. This equipment shall be designed in such a way that the measuring instruments can be installed when the machine is running.
Flanged relief valves shall be provided by Supplier at the discharge of each cylinder stage. Type and calculation shall be submitted to Grupa LOTOS S.A. for approval.

4.16.6 Pulsation and Vibration Control Requirements

- When specified in the data sheets, the compressor Supplier shall carry out the pulsation, vibration and acoustical studies. The battery limits on suction side and discharge side of the compressor unit for the pulsation suppression calculation shall be defined jointly by the compressor Supplier and Grupa LOTOS S.A. during the contract negotiation. These limits shall be preferably a vessel having a large internal gas volume. They shall be extended (as necessary) up to a point where pulsation has no longer any effect on the piping when API 618 design approach 2 or 3 is used. Grupa LOTOS S.A. will supply the isometrics of piping

within the battery limits. There isometrics of piping shall be validated by the studies and approved by the compressor Supplier in final.

- The compressor Supplier shall be responsible for the determination of the static and dynamic loads (both forces and moments) acting on the supplied equipment at the pipe connections and determination of the displacement associated with these loads. If pipe fixed points are not at the supply limit the analysis of the piping system shall be extended up to the next fixed points. Grupa LOTOS S.A. will supply the necessary drawings and isometrics of the piping outside the supply limits for studies as mutually agreed.
- Any proposed modifications to the piping system components shall be agreed with Grupa LOTOS S.A. prior to finalizing the acoustic simulation study.
- Acoustic simulation study reports shall be submitted to the Grupa LOTOS S.A. for review and approval. The report shall include full details of pulsation levels for each harmonic at each point considered in the piping system, plotted against API limits on a linear amplitude scale.
- Mechanical analysis shall include acceptance criteria, primary material details (thickness/type) and stress concentration factors.

4.17 Design Approaches

4.17.1 Pulsation Analysis design approach shall be carried out according API 618 unless otherwise specified in the data sheet.

4.17.2 In case of design approach 2 or 3, the following applies:

- If the calculation of the pulsation study indicates, that the existing pulsation at battery limits still has an influence for the connected piping system the calculation shall be extended up to that piping part, that the existing pulsation has no influence for the further connected piping system.
  The calculation shall indicate that within the battery limits of the calculated piping system no acoustical resonance arise and the natural frequency of the piping system including connected vessels are not in the stimulation limits of the compressor speed range and its harmonical speeds.
- It shall be demonstrated that the peak-to-peak pulsations resulting from the evaluation have no detrimental effects upon valve action, valve life, rod load, crank torque or excess power. Peak-to-peak pulsations shall never exceed values given in the applicable ISO (API).
- This is to be applied on the entire operating range specified.
- Acoustic resonances and natural frequencies of the individual piping sections are not allowed in the specified operating-speed range and its exciting harmonic frequencies.

4.17.3 Pulsation suppression devices

- Pulsation suppressing equipment shall be designed, constructed and stamped in accordance with the applicable ASME code unless otherwise specified in the data sheets.
- Following completion of the acoustic simulation study the compressor Supplier may propose reduced volume pulsation dampers shall the study indicate that there would still be acceptable pulsation and stress levels in accordance with API 618.
- The use of internals in pulsation suppression devices requires Grupa LOTOS S.A. specific approval.

- If the use of internals is accepted, the mechanical response study shall include a finite element stress analysis to the internal components. Acceptable stress levels shall be in compliance with the project pressure vessel code.
- Proof of tensile strength of pressure vessels in accordance with applicable codes.
- Statically loaded pressure vessels which are also admitted by fluctuating stress (load) and by load cycle (loading and unloading) (e.g. pulsation dampers, separators on suction and discharge side, gas cooler etc.) and can be excited by the compressor, a calculation concerning fatigue strength shall be carried out.
- The Supplier shall supply a support system for pulsation dampers. Drain and pressure connections shall be provided with valves in accordance with job specific piping standards specifications, unless otherwise specified in the data sheets. Pressure and temperature taps shall be provided in each damper nozzle immediately adjacent to cylinder.
- Carbon steel inside surfaces of pulsation dampers and gas piping shall be thoroughly coated with magnacoat or an approved equal protection. Immediately preceding coatings, pulsation dampers and gas piping must be absolutely clean, free or dirt, weld splatter, products of corrosion such as scale, rust flakes or powder, or any foreign matter that might damage the system.

4.17.4 Intercoolers, Aftercoolers, Separators and Silencers

- Intercoolers, aftercoolers, separators and silencers shall be designed, constructed and stamped in accordance with the applicable ASME code unless otherwise specified in the data sheets. All coolers shall be in accordance with the applicable Grupa LOTOS S.A. specification, and other attachments of the purchase documents. All connections to intercoolers and aftercoolers shall be flanged. If these connections are 40 mm (1 1/2 inches) or smaller, welding neck flanges shall be used and the flanges shall be supported and braced in four directions.
- A separate pot for collecting condensate shall be provided on the outlet of each cooler unless otherwise specified in the data sheets. Condensate collecting pots shall be provided with automatic drain taps and connections for high-level alarm and high level trip points.
- Calculation of the required process coolers (inter-, after, bypass coolers), separators, pulsation suppression devices and silencers within scope of the compressor Supplier is to be carried out at the maximum stage discharge pressure and maximum fluctuating stress. In the case of turbine drive, the trip speed is to be taken into account, unless otherwise specified in the data sheets. Delivered coolers, separators, pulsation dampers and silencers are to be designed for 1,1 times the safety valve blow-off pressure.
- Interstage and final coolers of process compressors shall be designed in compliance with TEMA Class R.

4.18 Controls and Instrumentation

4.18.1 General

- The scope of supply, manufacturer, type, design and installation of the instruments to be supplied by the compressor Supplier are stated in the data sheets or in the order-specific Grupa LOTOS S.A. standards.
- The compressor Supplier shall coordinate the instrumentation of the drive and other equipment of the train.
- All instrumentation shall be fully mounted and piped. An instrument air header shall be provided where all users are connected in accordance with the applicable instrument

specification. All instrument cables shall be wired to skid mounted junction boxes in accordance with the instrument specifications.

- All instrumentation shall be readily accessible and rigidly supported. Vibration isolation shall be considered for all based-mounted instruments and gauge boards.
- All controls and instrumentation shall be suitable for outdoor installation unless otherwise specified in the data sheets.
- All instrumentation shall be constructed of materials resistant to corrosion due to the process fluid with which they will or may come into contact internally, and to ambient air environment to which they are externally exposed.

4.18.2 Supply requirements

The Supplier scope of supply with regard to package instrumentation shall include, but shall not be limit to following (see also relevant data sheets).

- Local gauge boards for driver, compressor and auxiliaries
- A local panel for the complete compressor/driver train and auxiliaries
- The supply and installation of all necessary instrumentation to monitor and control the safe start up, running and shutdown of the compressor driver train and auxiliaries.
- Wiring the above instruments to junction boxes. Inside junction boxes all wiring terminator shall be provided with identification tags.
- All instrument air piping and tubing.
- Control cabinets that is to be installed in a control room in extend as agreed

  (Supplier shall provide dimensional and power requirements of the control cabinets together with full description and maximum distance from the compressor train along cable path).

4.18.3 Design requirements

- Supplier shall provide complete design documentation concerning local instruments, local control panel and control room cabinets. The documentation must enable implementation of controls and protections to DCS and/or PLC. Documentation shall be in compliance with the Grupa LOTOS S.A. specification no. 6400.
- Grupa LOTOS S.A. shall approve all set points.

4.19 Capacity Control

4.19.1 Manual pneumatic (hydraulic) unloaders are defined as pneumatically (hydraulically) operated devices, each complete with a manual switch to actuate. Such actuating switches will be mounted in the local compressor control panel or on the compressor frame specified on the data sheets. Data sheets will also indicate approximate control ranges required. Such steps will be subject to review after selection of machine and final cylinder sizing. The Supplier shall check compressor operation at all specified loads to assure that satisfactory compressor operation can be achieved.

4.19.2 When clearance pockets are specified, they shall be of the two-position type (pocket either open or closed) or variable pocket clearance type. Pneumatic actuated unloader shall be provided when the compressor is specified for automatic start-up or for re-acceleration following temporary electric power failure. Plug type unloaders shall be supplied with indicators actuated by valve movement to show loaded or unloaded position. Installation and torqueing procedures shall be supplied in the instruction manual to prevent operating valve leakage.

4.19.3 When valve unloaders or cylinder pockets are furnished, drawings and data on valve or pocket covers must be provided by the Supplier in order to prove that stems will not bind due to cover deflection under pressure and that they are properly sealed. Maintenance, assembly and tightening procedures shall be presented together with Supplier drawings within bid documents for approval by Grupa LOTOS S.A.

4.20 Drivers

4.20.1 In general, anticipated process variations will be described on the compressor data sheets. However, the determination of the thermodynamic properties of the gases involved and their effect on the design and performance of the compressor is solely the Supplier's responsibility.

4.20.2 Where a gearbox with flexible coupling is included in the system, the inertia of the rotating parts of the combined driver compressor installation shall be sufficient to limit total cyclic irregularity of the rotating system to 1% of rated speed at full loading and partial cylinder loading (when step unloading is specified). For other cases, cyclic irregularity shall not exceed 1.25% of rated speed.

4.20.3 The electric motor shall be furnished in accordance with the applicable Grupa LOTOS S.A. specifications and the motor data sheets.

4.20.4 For motor drivers, the complete shaft train shall be engineered to withstand 3- and/or 2 phase terminal short circuit and re-switching after net interruption etc.. Further details will be given in the data sheets.

4.20.5 Steam turbine drivers - General purpose steam turbines and special purpose steam turbines shall be in accordance with the applicable Grupa LOTOS S.A. specification.

4.21 Gears

4.21.1 Reduction gears are to be avoided, if possible

4.21.2 If reduction gears are used, they shall be designed considering cyclic torque changes of the compressor during all operating conditions. Under no circumstances the mean transmission power of the reduction gear during continuous operation shall be less than two times the maximum power at the compressor shaft.

4.21.3 Belt gears - If belt gears are approved, static conducting V-belts must be used.

4.22 Couplings and Guards

4.22.1 Unless otherwise specified, the compressor Supplier shall furnish all couplings and guards for the connecting shafts of the compressors, gear if any, and driver. Coupling and provisions for couplings shall be in accordance with the applicable ISO (API) standard.

4.22.2 For a direct-coupled unit, couplings with elastic elements or diaphragm coupling shall be furnished and accurately aligned. All couplings shall be rated for continuous operation at driver rated power, including service factors. For motor drivers with sleeve bearings, couplings shall be designed to limit axial movement of motor rotors.

4.22.3 Safety guards shall be furnished on all moving parts which may be hazardous to personnel. Guards shall meet applicable regulatory requirements, and be fabricated steel, easily removable and sufficiently rigid to withstand deflection and prevent rubbing as a result of bodily contact. Coupling guards shall be designed for a vertical loading of at least 1000N. If explosion protection is specified, a non-sparking material shall be used. Aluminum is not allowed. All guards shall conform to ISO (OSHA) requirements. Guards shall be provided with eye bolts for lifting purpose.

4.23 Nameplate

4.23.1 A stainless steel nameplate containing, at a minimum, the following information shall be permanently attached at an easily accessible place on the compressor.

- Supplier's name and serial number
- Model, size and date of production
- Grupa LOTOS S.A. purchase order number and tag number
- Rated capacity, m^3/h
- Rated suction and discharge pressure for each stage bar(g)
- Required power at rated capacity and rated differential pressure kW
- Rated compressor speed rpm

5 Inspection and Testing

5.1 General

5.1.1 For general requirements refer to Grupa LOTOS S.A. specification no. 2400 – "General requirements for machines and drivers."

5.1.2 The suppler and his major sub-suppliers shall have an implemented and reference proven quality assurance system. The quality system shall comply with ISO 9000/9001 requirements or an equivalent international proven quality assurance standard that is acceptable to the Grupa LOTOS S.A.

5.2 Inspections and Testing

5.2.1 All inspection and tests according to Supplier's standard for the application and according to the applicable specifications listed in the data sheets shall be performed. The scope of tests and inspections and optional tests which are specified in the data sheets have to be summarized in the Inspection and Test Plan (ITP) submitted to Grupa LOTOS S.A. for approval.

5.2.2 The ITP shall show each inspection or test plan point for all equipment and shall include the following information:

- the inspection or test activity reference number indicated on a flow chart
- the inspection methods
- reference to the relevant documents (i.e. procedures, specifications and drawings which control the specific operation)
- the quality characteristics to be verified at each inspection or test point and the acceptance criteria
- reference to and examples of the specific forms used by the Supplier to document the results of each inspection or test.

5.2.3 The Supplier shall verify by testing and certify that hardness of all parts, welds and heat affected zones are within the allowable values. The chosen method of testing shall be submitted to Grupa LOTOS S.A. for approval. Grupa LOTOS S.A. shall have access at any time to the Supplier's quality control program for review. Grupa LOTOS S.A. reserves the right to conduct surface and subsurface inspection on all the compressor's parts.

5.2.4 Certified copies of all test data shall be submitted to Grupa LOTOS S.A. as requested in the data sheets.

5.2.5 All manufacturing errors or deviations affecting the mechanical integrity and/or performance of major components shall be documented and proposed repair schemes submitted for approval to Grupa LOTOS S.A. within 14 days of discovery of error or deviation.

5.2.6 No repair shall be made without Grupa LOTOS S.A. prior concurrence based on the mutually agreed procedure involved. Submittal of these procedures shall be made within 30 days of receipt of the purchase order, unless otherwise specified in the data sheets.

5.2.7 Except as approved by Grupa LOTOS S.A. all equipment shall be presented for inspection in an unpainted state.

5.2.8 Acceptance of factory tests shall not constitute a waiver of requirements to meet the specified plant operating conditions, nor relieves the Supplier of his contractual responsibilities.

5.2.9 All spare parts shall be subject to the same inspection and full material certification as the main order.

6 Painting

Painting shall be in accordance with specification no. 2400.

7 Documentation

Documentation delivered with pump unit shall be in accordance with API 618. Documentation for auxiliary equipment delivered by Supplier which is not addressed in the above mentioned standard e.g. frequency converter, shall be in accordance with applicable Grupa LOTOS S.A. specification. If such specification does not exist, manufacturer's standard documentation is acceptable.

Supplier shall ensure that the following data/documents are included in the final documentation.

Dimensional outline drawing

- total weight and the weight of the heaviest elements for repair purposes, rotor/impeller weight for rotating machines
- position of the centre of gravity for machines of a weight exceeding 1500 kG
- location of flanges and the dimensions of flanges, venting, draining openings, and of other threaded connections
- location of the lubricating points
- the values of the maximum allowable forces and torques on flanges and the maximum differences in their position during cold and hot working condition
- direction of rotation
- static and dynamic foundation loads
- tolerances for levelling the foundation plate on the foundation
- dimensions of the foundation plate (base frame) and location of the foundation bolts
- type and technical data of the piston rod seal
- type, dimensions and number of the foundation bolts
- type and the technical data of the drive
- type of the coupling, the distance between shaft faces, the length of the spacer

- type and the technical data for gear.

Pipeline documentation

Pipeline documentation within the scope of supply of the machine shall be in accordance to the requirements of specification no. 6100.

Instrumentation and electric documentation

Documentation of the instrumentation and electrical discipline shall include the following:

- list of control and measuring instruments
- technical characteristics of the instruments and their set points
- wiring diagrams and control logic diagrams
- drawing of the control panel
- assembly drawings and list of materials
- installation, operation and maintenance manuals for individual equipment.

Operation and maintenance manuals

Operation and maintenance manuals shall include the following:

- the data sheet
- the report on the factory tests of the machine with the characteristic curves from these tests
- technical description of the machine
- technical description of the auxiliary equipment
- assembly and disassembly instructions
- operation manual (start-up, adjustment/regulation, shutdown)
- the maintenance and repair manual
- cross-section drawings of the machine, its subassemblies and auxiliary equipment with a list of parts including their construction materials and the manufacturer's code numbers
- the minimum and maximum clearance for mated parts
- the torques and the sequence of bolts tightening
- list of antifriction bearings, stating their symbols, the name of the manufacturer, the place of installation and their number (i.e. quantity) in a single machine. This applies also to elements used for mounting the bearing, such as bearing housings, bearing sleeves etc.
- the maximum allowable bearing temperature
- the allowable vibration level
- lubrication and cooling diagrams
- operating parameters for oil systems (pressure and temperature)
- list of oils and greases with recommendation (identification and the name of the manufacturer) and their substitutes, if any, as well as their physical and chemical characteristics, quantities required for the first filling (the capacity of the oil system or the greasing chamber), life time till the first replacement and the replacement frequency, expected annual consumption.

Manufacturer Data Book

MDB documentation shall include the following:

- Ex certificates
- material certificates
- heat treatment reports
- NDT reports
- pressure test reports
- functional test reports
- information on already applied lubricants

8 Relevant documents

8.1 Grupa LOTOS S.A. specifications

Any "Technical Specification" issued by GRUPA LOTOS S.A. listed in Contract Files.

8.2 Standards

Codes and standards listed below form part of this specification. Each publication shall be the latest revision and addendum in effect at the Contract award, unless otherwise specified:

- API Std 618– Reciprocating Compressors for Petroleum, Chemical and Gas Industry Services
- API Std 613 – Special Purpose Gear Units for Petroleum, Chemical and Gas Industry Services
- API Std 671 – Special-Purpose Couplings for Refinery Service
- API Std 614 – Lubrication, Shaft-Sealing and Control-Oil Systems for Special-Purpose Applications
- API Std 670 – Machinery Protection Systems
- API Std 684 – Tutorial on the API Standard Paragraphs Covering Rotor Dynamics and Balancing: An Introduction to Lateral Critical and Train Torsional Analysis and Rotor Balancing
- API Std 686 – Recommended Practices for Machinery Installation and Installation Design
- ISO 1217 Displacement compressors – Acceptance tests
- TEMA Cl. R – Mechanical Standards, Heat Exchanger
- ASME Code Sect.VIII, Div.1 – Pressure Vessels and Heat Exchanger
- EN ISO 12100 Safety of Machinery – General principles for design – Risk assessment and risk reduction
- EN ISO 3744 Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Engineering methods for an essentially free field over a reflecting plane

- ISO 10816 (applicable part) – Mechanical Vibration-Evaluation of Machine Vibration by Measurement on non-rotating parts
- ISO 21940-32 – Mechanical Vibration - Rotor Balancing; Shaft and Fitment Key Convention
- EN 10204 – Metallic Products-Type of Inspection Documents
- ISO 10474 – Steel and steel products – Inspection documents
- ASTM A435/A435M-90 - Standard Specification for Straight-Beam Ultrasonic Examination of Steel Plates
- ASTM A578/A578M-07 - Standard Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications
- MSS Standards - MSS-SP-6-2012 Standard Finishes for Contact Faces of Pipe Flanges and Connecting-end Flanges of Valves and Fittings
- EN ISO 3651-2 Determination of resistance to intergranular corrosion of stainless steels – Part 2: Ferritic, austenitic and ferritic-austenitic (duplex) stainless steels – Corrosion test in media containing sulfuric acid

9 Record of changes

No.	Date	Description	Introduced by
0		This specification entirely replaces the former Grupa LOTOS S.A. standard No. PR 07 245 with the same title.	T. Wójcik
1	30-11-2013 (rev.1)	Przegląd, aktualizacja, ujednolicenie i zmiany standardu w ramach zlecenia OK/990/2012	Redakcja zbiorowa. Koordynacja: T. Wróbel
-	31-08-2015	Page layout corrections, no contents changes.	T. Wróbel