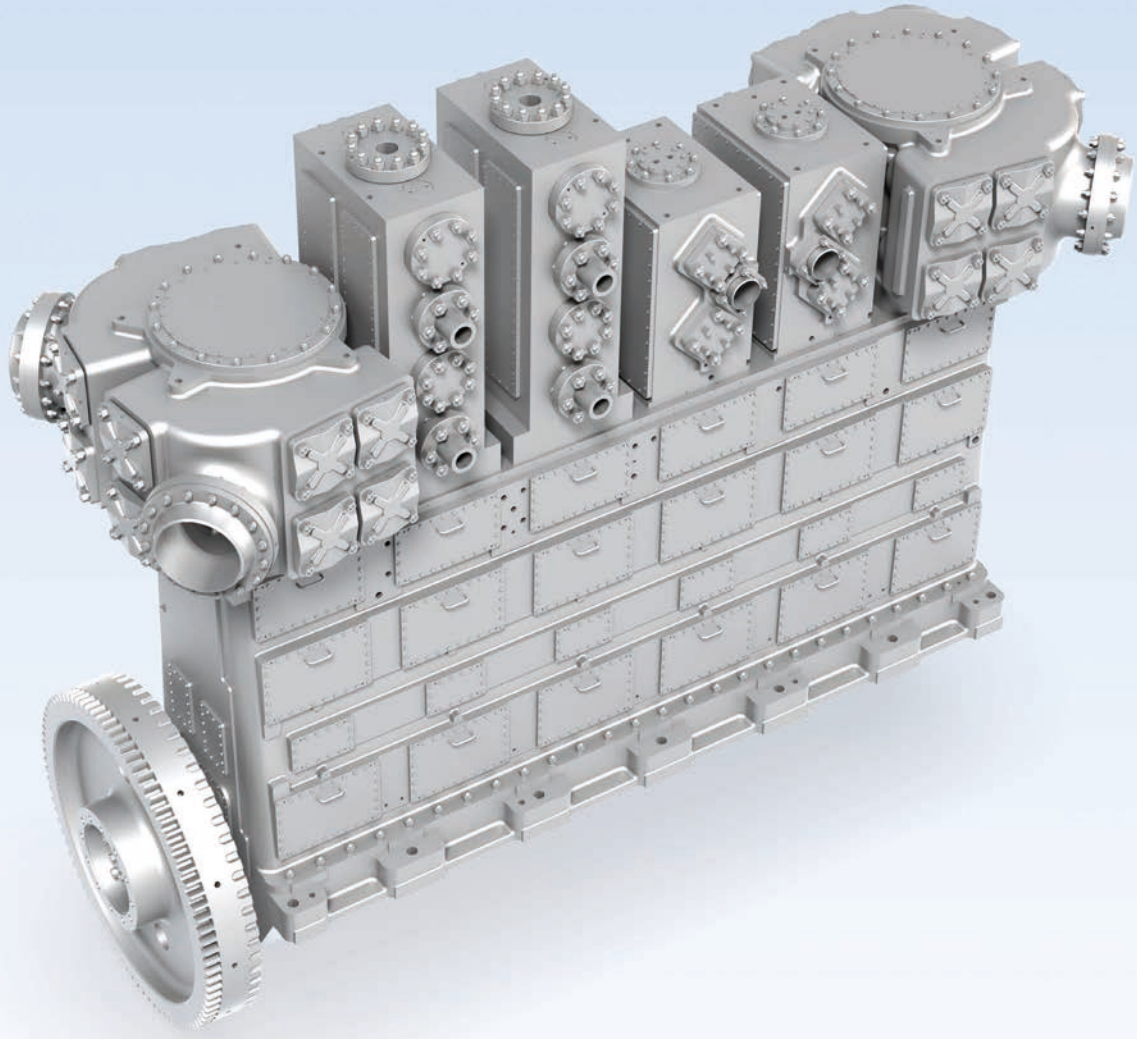
Burckhardt Compression

LABY®-GI COMPRESSORS

FULLY BALANCED RECIPROCATING COMPRESSORS WITH HIGHEST OPERATIONAL FLEXIBILITY



Compressors for a Lifetime™

MARKETS AND APPLICATIONS

FROM OFFSHORE OIL & GAS TO PROCESSING APPLICATIONS

INSTALLATIONS
- LNG carriers
- LNG FPSO
- FSRU
- Production platforms

GASES HANDLED
- Natural gas
- Ethylene
- Propylene
- Mixed hydrocarbons C_nH_m

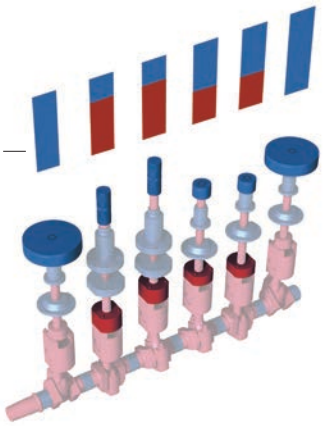
APPLICATIONS
- Boil-off gas handling
- Fuel gas handling
- Process gas handling
- Minimum send-out on FSRU
- Natural gas transmission
- Reliquefaction
- CO_2 re-injection

SPECIAL APPLICATIONS REQUIRING

– Strict vibration limits
– High discharge pressures up to 350 bara / 5'080 psia
– Lubricated or non-lubricated gas compression
– Handling of difficult or dangerous gas mixtures

LABY®-GI COMPRESSOR
PURPOSE-BUILT FOR TOUGH OFFSHORE DUTIES

Through detailed cooperation with recognized marine equipment and system suppliers, and the close relationship to well known end-users in the offshore market, Burckhardt Compression has developed a highly unique and flexible compressor solution that perfectly fits a wide range of individual customer requirements for highly demanding offshore applications.
Traditional engineering and our decades of experience are the foundation of the vertical, in-line, 6-crank, low speed reciprocating compressor. The innovative design results in a unique but highly effective, fully balanced machinery configuration.

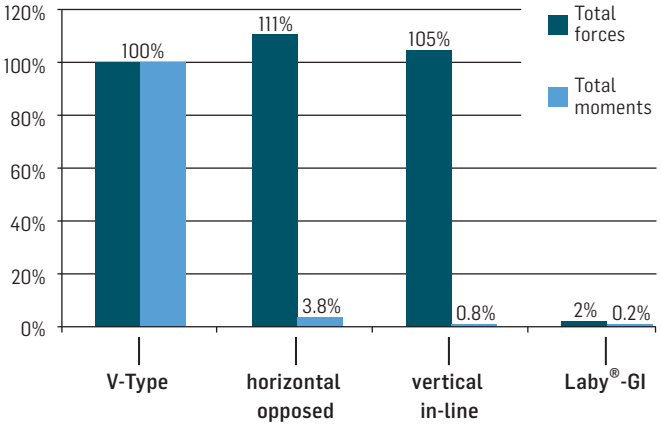


Complementary forces of piston (blue) and crosshead weights (red) for mass balancing

100% MASS BALANCING = 50x LESS TOTAL FORCES AND 5x LESS FREE MOMENTS

The fully balanced crankgear leads to a smooth running compressor. The compressor will not stimulate the connected offshore structure or interfere with the structural analysis of the naval architecture. Vice versa neither roll or pitch nor engine vibration, for example on a LNG carrier, will have the slightest influence on the compressor system and its auxiliaries.

Resulting benefits:
– No free forces and moments
– No influence on supporting offshore structure



Free forces and moments of different compressor types calculated up to the 10th order

MULTIPLE PURPOSE COMPRESSION

Robust supply of different consumer at different pressure levels with a single compressor. Supply of main and auxiliary engines, reliquefaction, vapotransfer or others.

Resulting benefit:
– One compressor for multiple applications

RECIPROCATING COMPRESSOR TECHNOLOGY – FOR BEST PROCESS CONTROLABILITY

The reciprocating compressor offers best process control due to the insensibility of this technology to changes of gas conditions such as suction, discharge, pressure, temperature and gas composition.

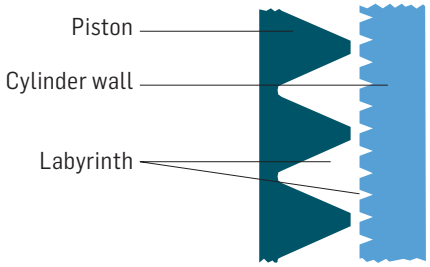
Resulting benefit:
– Simple and robust gasflow and pressure control

UNIQUE CYLINDER SEALING SYSTEM – FOR LOWEST WEAR AND BEST PERFORMANCE

Depending on the compression duty pressure and temperature requirements, we can offer either lubricated or non-lubricated cylinder sealing, allowing the selection of the very best technology according to individual stage process requirements. With the Laby®-GI Compressor we can provide cylinder configurations that fit your specifications best.

LABYRINTH SEALING – OIL-FREE AND CONTACTLESS COMPRESSION

In the piston and piston rod gland many tiny throttling points create a friction-less sealing effect. The avoidance of mechanical friction and the contactless cylinder results in a extremely long lifetime of sealing components with unmatched reliability and availability. The labyrinth sealing technology is insensitive to extreme changing temperatures. This proven design is in operation on hundreds of LPG carriers.



Oil-free compression for very low gas suction temperatures

Resulting benefits:

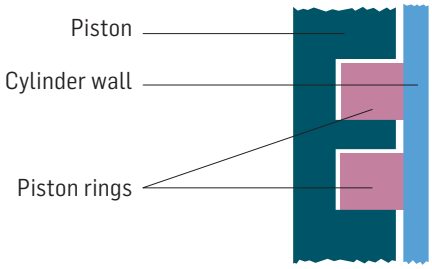
- No mechanical wear due to contactless seals
- Very low gas suction temperatures
- No pre-heating of the gas nor pre-cooling of the compressor needed
- Oil-free compression
- Longest lifetime
- Very low maintenance costs
- Full operation flexibility independent of gas conditions

RING SEALING SYSTEMS – TIME-TESTED WITH HIGH PRESSURES

These conventional sealing systems are successfully applied in a wide range of applications. The vertical alignment of the Laby®-GI provides low wear of the sealing and guiding elements on the piston and the piston rod, leading to highest durability of these wear parts In-house tribology research and the use of latest materials technology proven in our test facility, result in high pressure sealing elements designed for minimum wear and optimized gland performance.

Resulting benefits:

- For oil-lubricated high pressure sealing
- For pressures up to 350 bara / 5'080 psia
- For longest lifetime
- Low maintenance costs
- Optimized compressor efficiency



Lubricated compression for high pressures

DESIGN FEATURES
FOR MAXIMUM RELIABILITY AND SAFETY

KEY COMPRESSOR COMPONENTS – FOR BEST PERFORMANCE AND LONGEST LIFETIME

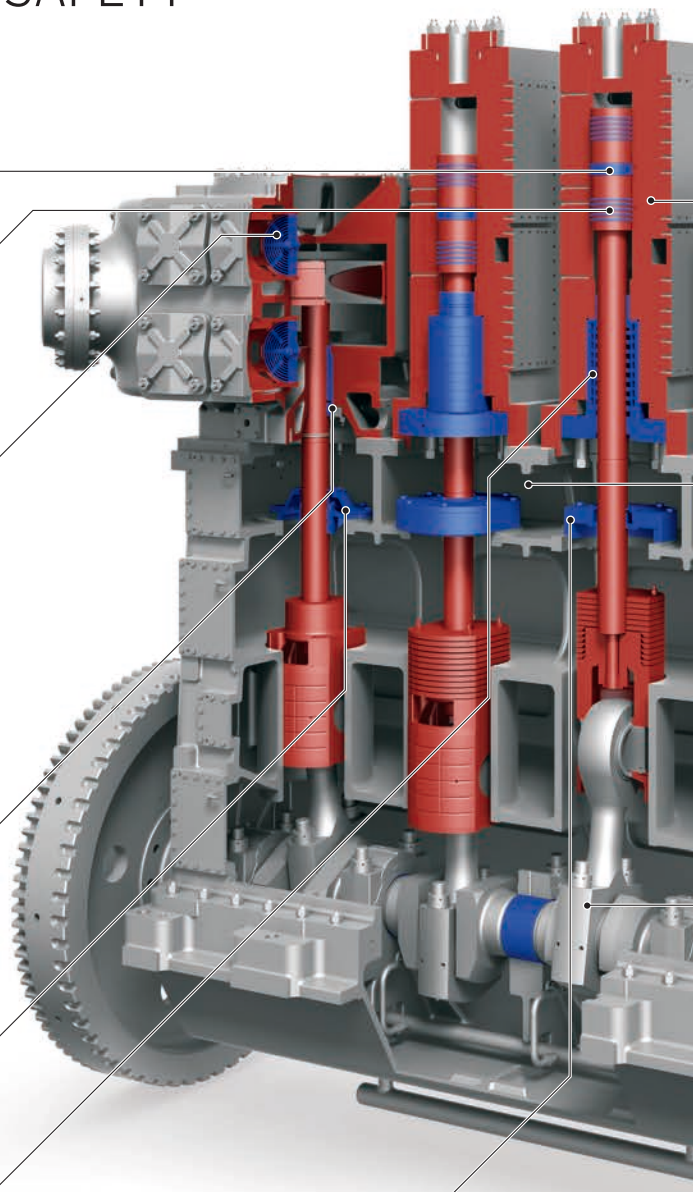
GUIDE RINGS
- Pressure relieved
- Very long lifetime
- Optimized mounting position

PISTON RINGS
- Decades of experience with lubricated and non-lubricated gas compression
- Various proprietary designs and materials for maximum durability
- Optimized wear compensation

COMPRESSOR VALVES
- Burckhardt Plate Valve™
- Burckhardt Poppet Valve™
- Manley® Valve, licensed by Burckhardt Compression
- Over 120 years of experience in design, manufacturing and service
- Selection and custom engineering according to application requirements
- Maximum durability due to in-house valve technology

PISTON ROD GLANDS
- Radially floating, self centering sealing elements with labyrinth sealing
- Contactless
- No friction
- No wear

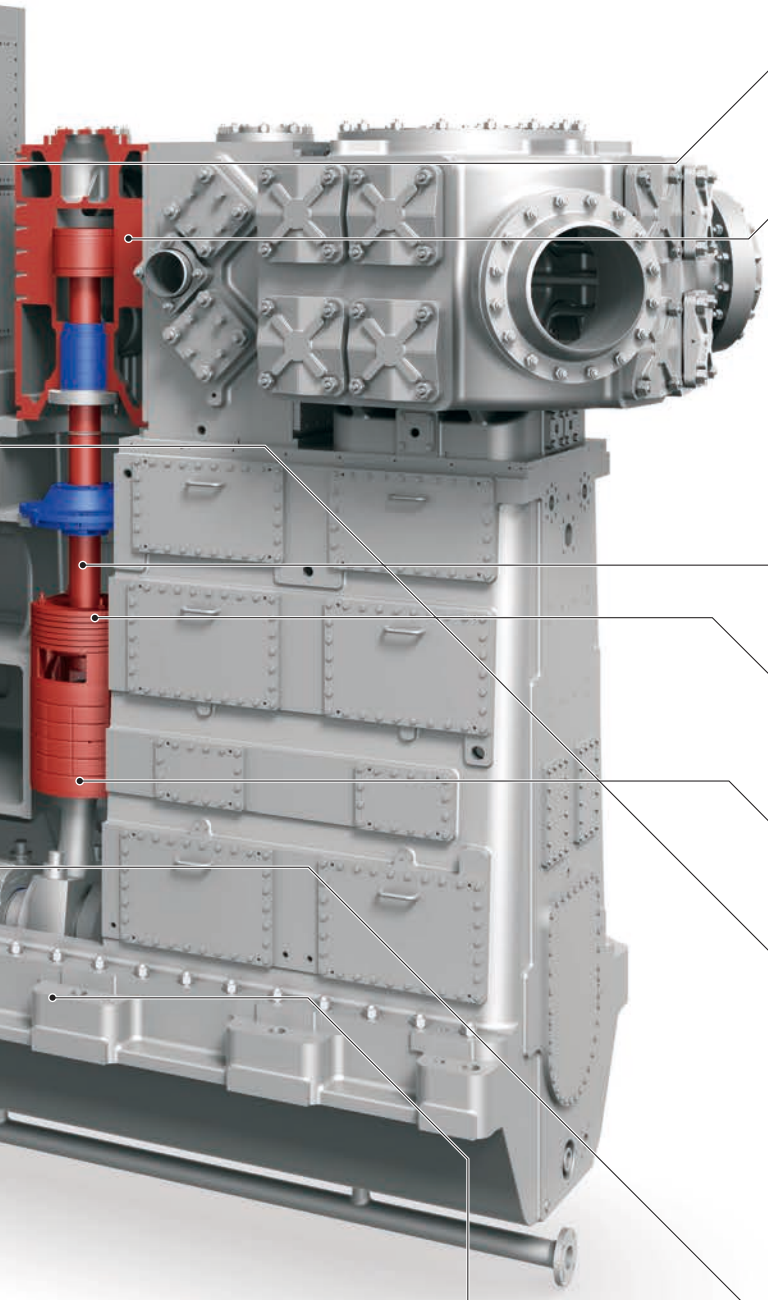
GUIDE BEARINGS
- Splash-lubricated
- For precise linear movement
- With exchangeable guide bush
- Various designs and materials
- No need for oil vapour removal equipment



PISTON ROD PACKINGS
- Leading technology based on decades of experience
- Various proprietary designs and materials for maximum durability
- Heterogeneous systems allowing high pressure non-lubricated gas compression
- Extremely high sealing efficiency and lifetime

OIL SCRAPERS
- Highly efficient oil removal
- Separate lubricated from non-lubricated area
- Material selection according to specific application
- Long lasting design for minimum lube oil consumption

IN-HOUSE DESIGNED AND MANUFACTURED MAIN PARTS – FOR RELIABILITY



HIGH PRESSURE CYLINDER ASSEMBLY
– Lubricated ring sealing technology
– Up to 350 bara / 5'080 psia discharge pressure
– Cylinder with replaceable liner (no shrink fit)

LOW PRESSURE CYLINDER ASSEMBLY
– Oil-free labyrinth sealing system between piston and cylinder and along the piston rod gland
– For low temperatures down to –160 °C (–256 °F)
– Insensitive to extreme variation in suction temperature
– Up to 100 bara / 1'450 psia discharge pressure
– Contactless
– No-friction
– No wear
– Cylinder integrated thermal barrier
– Material selection according to pressure and temperature requirements
– Simple 3-piece piston design

PISTON RODS
– Hardened or coated
– For highest wear resistance

MASS BALANCING
– Elimination of unbalanced forces and moments
– No vibration

CROSSHEADS
– Special design for mass balancing
– Rugged 1-piece design

MECHANICAL SHAFT SEAL (NOT ILLUSTRATED)
– Gastight crankgear
– No gas losses to the environment for highest safety and efficiency

RUGGED DESIGN – FOR DURABILITY

LUBRICATION SYSTEM (NOT ILLUSTRATED)
– Designed for offshore installations
– Insensitive to vibration and ship movement, for example on LNG carriers

CRANKGEAR
– Robust, heavy duty
– FEM optimized design
– Sealed, gastight design to avoid gas loss to the environment
– Single casing
– Dry sump

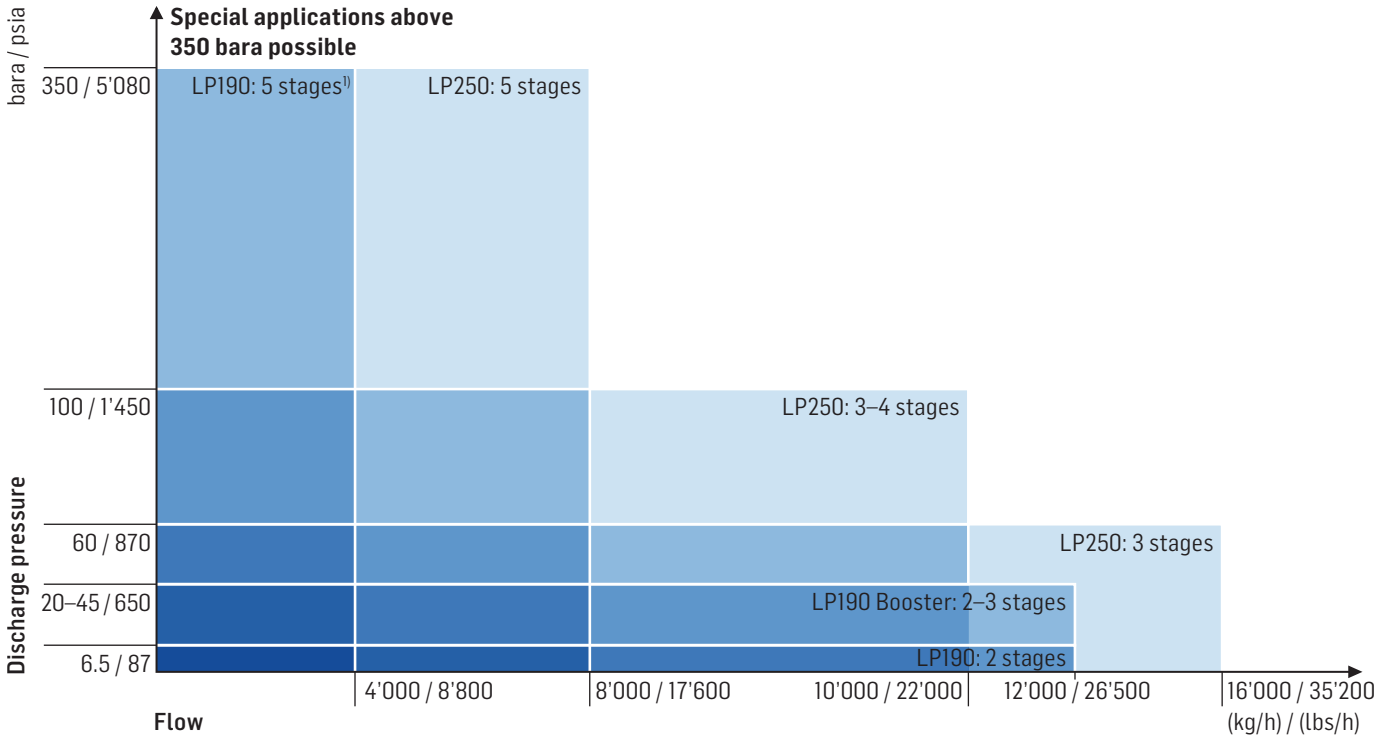
CRANKSHAFT
– Forged
– 6-crank design

VERTICAL, IN-LINE DESIGN
– Less wear due to reduced weight forces on piston and piston rod
– Small footprint, low room requirements
– 2 to 5 stage design
– Low speed for low wear

DISTANCE PIECE
– Frame-integrated
– Separates lubricated from non-lubricated areas
– Vented
– Pressurized

TECHNICAL DATA
COMPACT MODULAR DESIGNS

PERFORMANCE RANGE



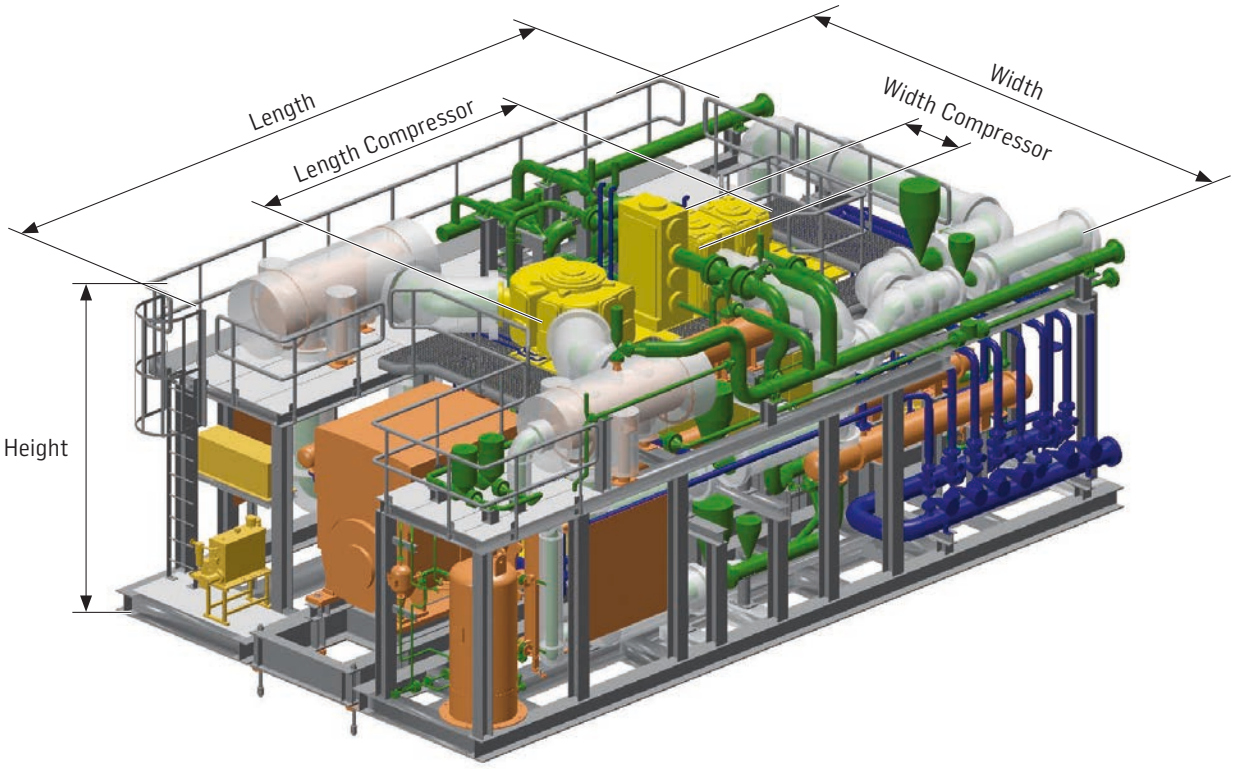
TECHNICAL DATA AND DIMENSIONS

Type	Rated Power kW / hp	Succ. Temp. °C / °F	Speed rpm	Compressor			Compressor Package2)		
				Length mm / in	Width mm / in	Height mm / in	Length mm / in	Width mm / in	Height mm / in
LP250	4'000 / 5'360	−160 to +45 / −256 to +113	520	5'600 / 220	2'200 / 86	4'800 / 189	13'000 / 470	7'000 / 275	5'200 / 205 3)
LP190	1'750 / 2'350	−160 to +45 / −256 to +113	750	3'900 / 154	1'400 / 55	3'200 / 126	10'000 / 394	5'000 / 197	5'000 / 197 3)

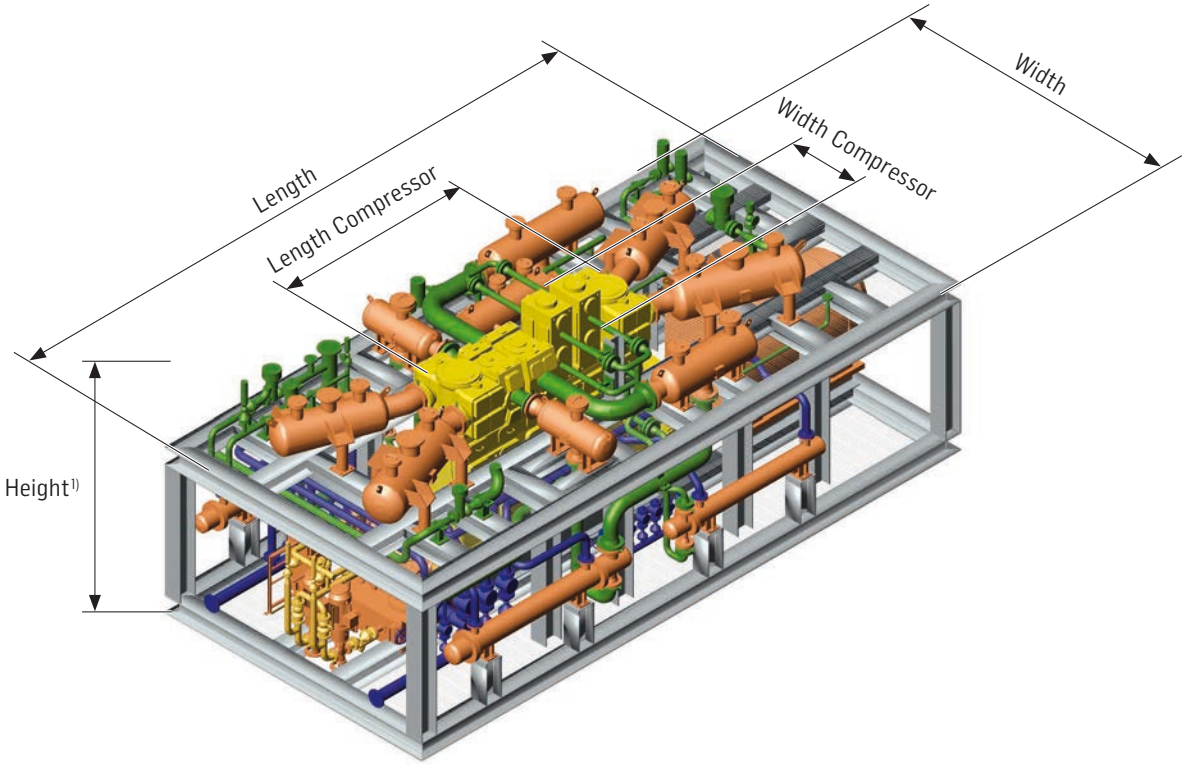
1) designed for three operating points: 3'000, 3'500 and 4'000 kg/h / 6'600, 7'700 and 8'800 lbs/h
2) approximate data: depends on specific contract execution
3) allows an extra 2'200 mm / 87 in for maintenance

Special package designs upon request.

COMPRESSOR PACKAGE LP250



COMPRESSOR PACKAGE LP190



1) Illustrated package shown without pressure piping and upper steel structure

HIGHEST OPERATIONAL FLEXIBILITY
FOR MAXIMUM EFFICIENCY

BEST SUITED FOR ALL KINDS OF PROCESS GASES AND PARAMETERS

Process gas	Operational challenge	Our compressor solution
LNG boil-off gas	– Wide range N_2 content – Varying suction temperatures and pressures	– Contactless labyrinth sealing – Insensitive to suction temperature variation
Other cryogenic gases	– Thermal expansion of compressor components	– Contactless labyrinth sealing
H_2S/CO_2 content of the gas	– Highly corrosive gas mixtures	– Adequate material selection and purging
Different gases at the same time	– Separation of gases – Optimum performance of all processes	– Multi-stage design with independent compression cycles – Easy control of compression parameters
CO_2 for re-injection	– Strict vibration limits – Large variation of the gas composition	– Fully balanced design – High flexibility concerning gas properties

The uniqueness of the Laby®-GI Compressor is also reflected by its flexible performance range allowing very simple operation and control. No other compressor can be operated as efficiently over such a wide range of process duty parameters. For example, the discharge pressure necessary for fuel gas system supply, is automatically available independent of:

– Alternating suction gas conditions:
  · Temperature (neither pre-heating of the gas nor pre-cooling of the compressor is necessary)
  · Pressure
  · Composition (e.g. N_2 content in natural gas)

– Part load condition:
  · Highly energy efficient from 0–100% capacity

– Specific application process requirements

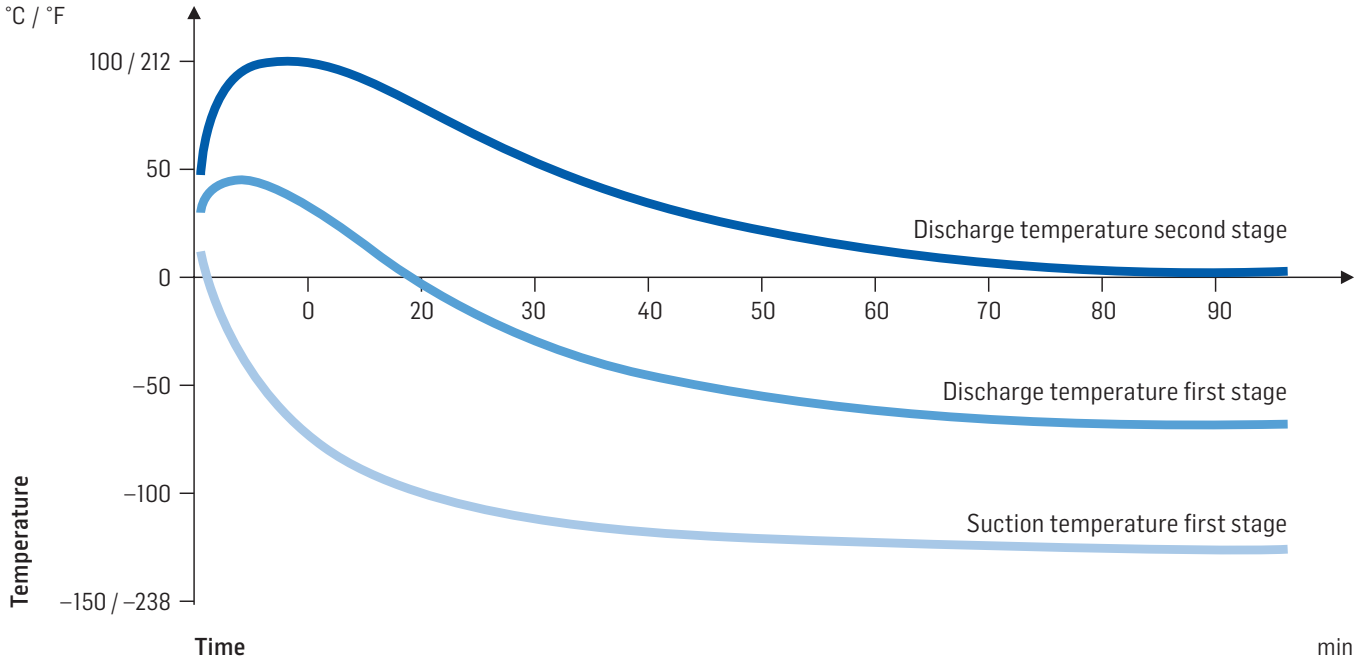
Unique technical features implemented during the compressor development and our decades of compressor know-how are the foundation of the Laby®-GI's flexibility.
Customization of selected compressor design elements for optimized system operation and control is one of the key competences of Burckhardt Compression. This unique compressor design together with our engineering expertise and system know-how can be applied to your specific application to provide you with an individual solution:

– Side streams can be taken out at a specific interstage pressure
– Different compression duties on a single compressor frame (e.g. separate cylinder used for natural gas compression and closed circuit refrigerant systems)

As a result of these individual options, the Laby®-GI Compressor will always perform with maximum efficiency.

WARM START-UP DIAGRAM OF A LABY®-GI COMPRESSOR

WITHOUT SPECIAL CONTROL NOR PRE-COOLING OF THE COMPRESSOR

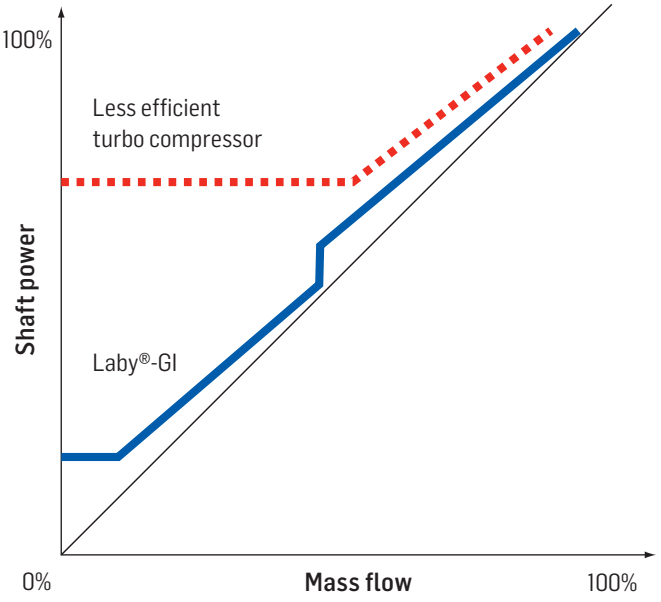


SIMPLE CAPACITY CONTROL CONCEPT

WITH APPROXIMATE PROPORTIONAL RATIO OF MASS FLOW AND SHAFT POWER
FOR HIGH TURN-DOWN EFFICIENCY OF THE LABY®-GI COMPRESSOR

The red dotted curve shows the performance of the capacity control on a turbo compressor, typically realized with adjustable inlet guide vanes. This arrangement allows an efficient control of the mass flow in a limited range. Below this range, the shaft power remains more or less constant. This results in comparably high energy consumption at low capacity.

The blue curve shows the result of the simple capacity control of the Laby®-GI with conventional valve unloaders and by-pass regulation almost following the optimum line of turn-down efficiency.



Laby®-GI Compressor package installed between the first two spherical LNG tanks on a FSRU

SIMPLE COMPRESSOR DESIGN AND PROVEN TECHNOLOGY

REDUCE YOUR COSTS FROM INSTALLATION TO SERVICE

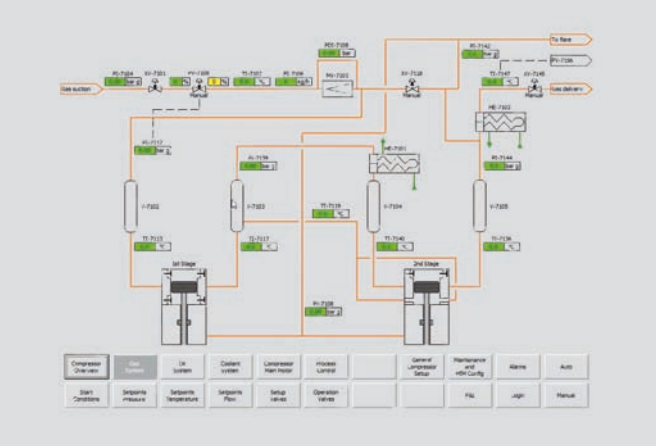
Remote locations, harsh seas, extreme climates, highly corrosive environment, difficult gases, customization and constraints, weight and dimensions – these are just some of the basic characteristics of offshore projects. Burckhardt Compression and the simple and robust design of the Laby®-GI Compressor accept all these challenges. The combination of simple design features and proven technology have created a compressor solution which is capable to cope with this tough offshore environment. The overall simplicity of our compressor solution results in a very short installation time, very simple operation and low and easy maintenance.
From basic mechanical maintenance up to the compressor control system, the entire concept of the Laby®-GI is designed for operation by crew members with basic mechanical skills training.

EASE OF INSTALLATION

- Modular, skid mounted, single-lift packages are made for easy handling resulting in a substantial reduction of installation time
- Integrated auxiliary modules (coolers, separators, valves, piping, purge, lubrication, instrumentation)
- All sub-systems incorporated with pre-defined tie-in points
- Taylor made solutions are also available for retrofitting

Modularity, skid mounting, turn-key installation

EASE OF OPERATION



Simple control concept and system

– Integrated control system as part of the ship control
– Very easy start-up and shut-down procedures that only requires aa minimum training of the crew

EASE OF MAINTENANCE

Good accessibility to all service components

– Simple mechanical maintenance procedures for reciprocating machinery can be carried out by the crew

CONSERVATIVE ENGINEERING MEETS INNOVATION

FOR HIGHEST RELIABILITY AND SAFETY

With the Laby®-GI Compressor Burckhardt Compression has found a way to combine conservative engineering and innovation that has been appreciated by our partners. The blending of proven technology, innovation and long experience leads to a robust design for toughest applications.

Proven technology and innovative design

Labyrinth sealing
contactless, no wear

Ring sealing
proven heterogeneous Redura® sealing systems

Fully balanced crankgear
simple and robust

Vertical, low speed design
functional and simple

Sealed and gastight crankgear
environmentally sound

YOUR BENEFITS

Highest reliability
- In-house developed and manufactured high quality key components
- Long MTBO (mean time between overhaul) and MTBF (mean time between failures)
- Low and easy maintenance
- Routine maintenance (typical for LNG BOG) – inspection and checking every 8'000 hrs
- Overhaul maintenance (typical for LNG BOG) – dismantling every 24'000 hrs

Highest safety levels
- Design assessment for type approval
- Approved high pressure safety concept

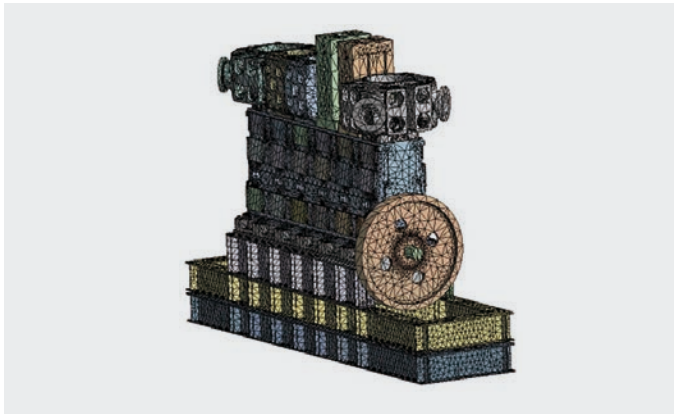
FULLY CERTIFIED

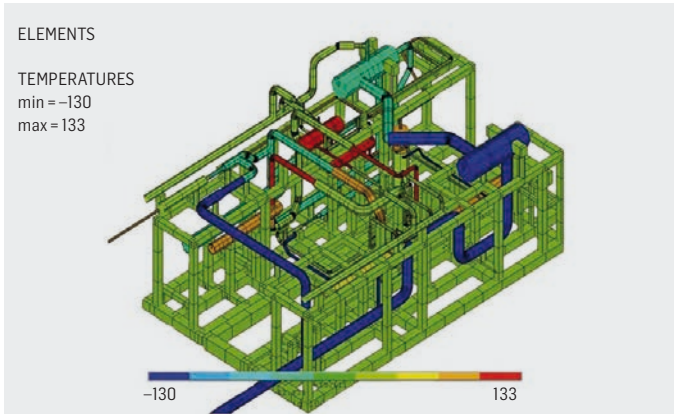
Long-term relationship and cooperation with all major certification authorities and classification societies underline the excellent track record of the Laby®-GI Compressor and all other compressors manufactured by Burckhardt Compression.


DET NORSKE VERITAS
DESIGN ASSESSMENT FOR
TYPE APPROVAL
Gas Compressor
Burckhardt Compression AG
Winterthur, Switzerland

Design assessment for type approval of the Laby®-GI

In-house manufactured key compressor components – the key for highly reliable compressors





Pulsation, vibration and roll studies as well as thermal analysis have been sucessfully performed for the complete compressor package

Typical LNG BOG installation with 32'000 hrs of operation. Icing of the cylinder at suction temperatures down to –160 °C (–256 °F)

LEADING COMPRESSOR TECHNOLOGY
FOR LOWEST LIFE CYCLE COSTS

The Laby®-GI Compressors are the result of the broad experience gained by Burckhardt Compression over many decades. The second to none design has been accomplished in close collaboration with our customers throughout the world. Based on their needs, Burckhardt Compression provides a robust and simple compressor design with a special focus on low maintenance. Decades of experience in compressor design, manufacturing, plant engineering and project execution have made us to the most reliable partner for our customers. We implemented this broad experience into our products and services. Certified Swiss manufacturing, quality management and committed workforce ensure a constant high quality level.

INITIAL COSTS
Due to latest advanced machining technology, highly efficient manufacturing processes and global sourcing, we are able to offer compressors at very competitive prices.

+

OPERATING COSTS
The high efficiency in all load conditions secures low energy consumption which accounts for the most significant part of overall operating costs. No extra requirements on the crew guarantee low expenditures on training. The high quality of our compressors results in a long MTBO.

+

MAINTENANCE COSTS
The overall design of the compressor and the simplicity guarantee lowest wear and therefore significant savings of spares and wear parts. All service work can be performed by the ship crew. Quick and reliable global spare parts logistics is a matter of course and will help you to get back into operation fast.

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LOWEST LIFE CYCLE COSTS
The over-all result of our continuous development are compressors with lowest life cycle costs.

Ease of operation – simple control system

SWISS DESIGN

ISO 9001:2008 BUREAU VERITAS Certification

MANUFACTURING
WITH STATE-OF-THE-ART MACHINING TECHNOLOGY

Cutting-edge 3D CNC Measurement Machine for quality inspection

Dörries Scharmann, Heavyspeed CNC Milling
Machine Centric table load: 40'000 kg, spindle stroke: 1'000 mm

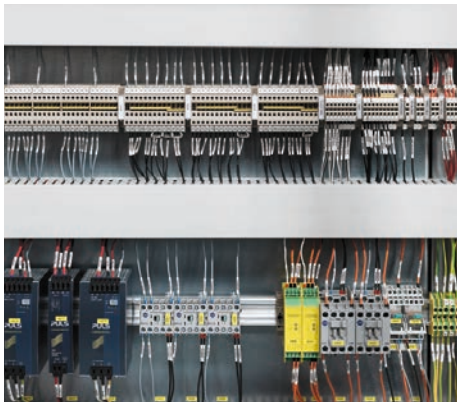
Okuma MacTurn550, CNC Multitasking Center.
One of the 10 machining centers

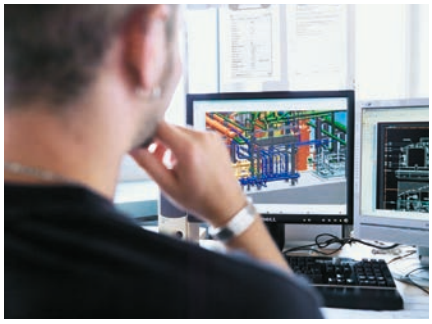
Okuma MacTurn350, Multitasking
Center. Fully automatic parts feeding

Dörries Scharmann, CNC Boring Mill
4 tables, spindle stroke: 600 mm

BURCKHARDT COMPRESSION

THOROUGH IN-HOUSE EXPERTISE ENSURING COMPREHENSIVE SUPPORT …

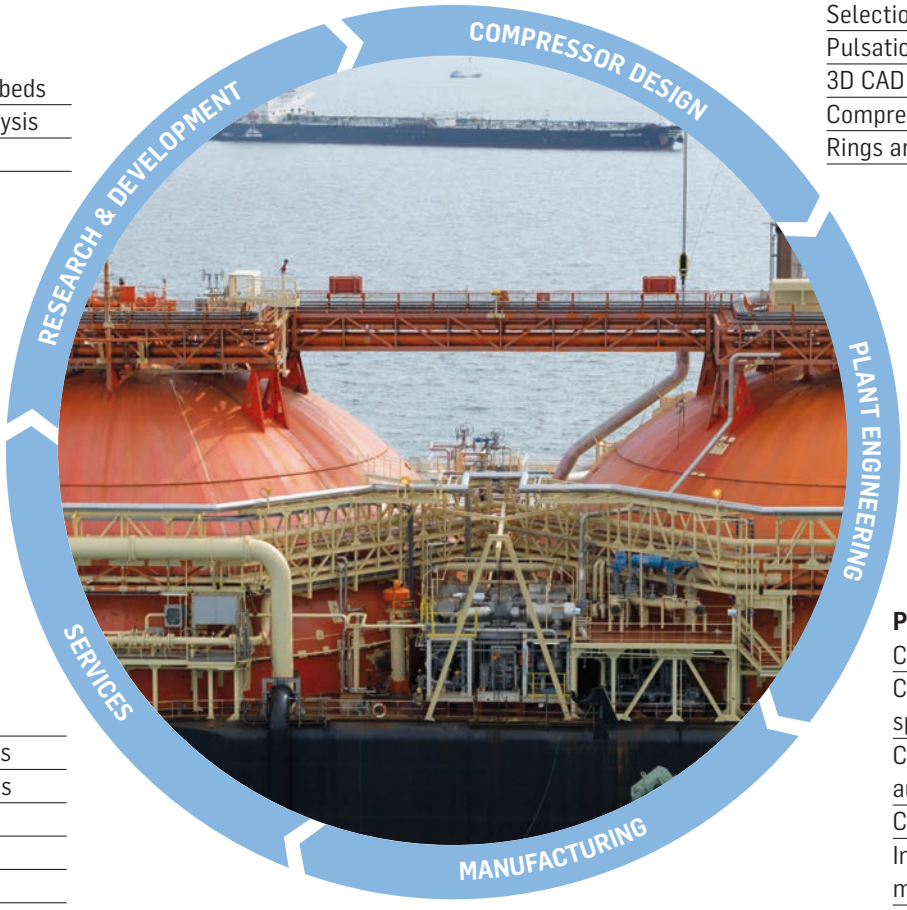




... FOR SHIPYARDS, SHIP OWNERS SHIP OPERATORS AND ENGINEERING PARTNERS

COMPRESSOR DESIGN
- Ship roll studies
- Instationary fluid dynamics
- Pre-sales support incl. detailed documentation
- Engineering analysis
- Feasibility study
- Selection and sizing
- Pulsation and vibration studies
- 3D CAD
- Compressor valves
- Rings and packings

RESEARCH & DEVELOPMENT
- Tribology incl. test beds
- Finite element analysis
- Mechatronics



PLANT ENGINEERING
- Contracting
- Customer and standard specifications
- Compressor and auxiliaries on modules
- Cooling water system
- Instrument and control, motors
- PLC programming
- Turn-key projects
- Skid mounted

SERVICES
- Remote locations
- Engineering services
- Spare parts logistics
- Revamps
- Field service
- Valve service
- Component repair
- Technical support
- Monitoring and diagnostics
- Training

MANUFACTURING
- State-of-the-art machining technology
- Corrosion protection
- CAM in-house machining
- Purchasing
- Assembly
- Test beds
- Quality assurance

SERVICES
THE FULL RANGE

BURCKHARDT VALVE SERVICE FAST VALVE SERVICE WITH EXTENSIVE GUARANTEE	– Analysis of valve condition – Tracking of valve history – OEM valve engineering – Valve cleaning and overhauls	– Complete quality inspection – State-of-the-art leak test – Root cause analysis – Corrosion protection
SPARE PARTS LOGISTICS OEM GUARANTEE AND BEST LIFE CYCLE COSTS	– Original spare parts with OEM guarantee – Spare parts frame agreements – Stock recommendations – Express service for emergencies – Over 16'000 parts on stock	– 12 month guarantee – Save time and money: use the Burckhardt e-Shop™ – the easy spare parts identification and ordering system
FIELD SERVICE ONSHORE AND OFFSHORE: BENEFIT FROM OUR SKILLED RECIP EXPERTS	– On-site assembly and installation – Erection/commissioning – High safety standards – SCC and HUET certified – Turn-key installations	– Start-up support – Service contracts/preventive maintenance – Plant overhaul/revision – 12 month guarantee
TECHNICAL SUPPORT PROFESSIONAL SUPPORT FROM OUR WELL TRAINED AND EXPERIENCED SPECIALISTS	– Performance analysis for optimized and efficient compressor operation – Start-up support – Troubleshooting – Root cause analysis	– Emergency availability 24/7 – On-site failure analysis – Online diagnostic support – Consulting
COMPONENT REPAIR SAVE MONEY AND GET "AS NEW" GUARANTEE	– Condition analysis – Recommendations concerning which parts can be repaired or need to be replaced	– Incorporation of the latest technology where possible – 12 month guarantee – Repair of crossheads, piston rods, cylinder liners, bearings, pistons
ENGINEERING SERVICES SOPHISTICATED IN-HOUSE SIZING AND ANALYSIS TOOLS	– State-of-the-art pulsation and vibration analysis – Finite element analysis – Unique analysis models for high pressure application	– Reverse engineering and reengineering for own as well as for other brand compressor systems – Dynamic analysis for any compressor parts

REVAMPS REJUVENATE OR TUNE YOUR COMPRESSOR	– Modernizing – Upgrades/retrofits – Relocation of machines – Debottlenecking – Turn-key installations	– Operation mode studies for own as well as for other brand compressor systems – Conversion from lubricated to non-lubricated conversions
MONITORING AND DIAGNOSTICS EXTEND MEAN TIME BETWEEN OVERHAUL	– Support for system evaluation – Comprehensive customized service from diagnostic service to predictive maintenance – Full-service agreements for maximum availability – Online diagnostic services	– Broad experience through compressor installations in various processes Burckhardt Compression recommends PROGNOST
COMPRESSOR TECHNOLOGY TRAINING HAVE YOUR OWN COMPRESSOR SPECIALISTS	– Theoretical and practical training from our compressor experts – Training center with full-size equipment (Laby®, Process Gas and Hyper Compressor)	– Standard trainings, customer specific programs on request
SERVICE CENTERS WORLDWIDE	Full range of services and top performing components through global organization and local service centers.	**24 hours emergency:** **+41 52 262 53 53**

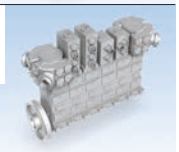
Burckhardt Compression

RECIPROCATING COMPRESSORS

LEADING TECHNOLOGY FOR
LOWEST LIFE CYCLE COSTS

Laby® Compressors
Contactless and oil-free

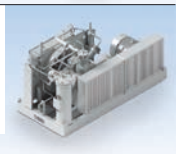
Laby®-GI Compressors
Fully balanced



Process Gas Compressors
API 618 – lowest life cycle costs

Hyper Compressors
Safe and reliable up to 3'500 bara / 51'000 psia

Standard High Pressure Compressors
Compact package for demanding applications



UPDATE COMPONENTS

BEST PERFORMANCE
AND LONGEST LIFETIME

- Compressor valves
- Redura® rings & packings
- Capacity control systems
- Capital parts
- Labyrinth piston compressor components
- Hyper/secondary compressor components

SERVICES

THE FULL RANGE

- Burckhardt Valve Service
- Spare parts logistics
- Field service
- Technical support
- Revamps & upgrades
- Component repair
- Condition monitoring & diagnostics
- Training

Burckhardt Compression AG
CH–8404 Winterthur
Switzerland
Tel.: +41 52 262 55 00
Fax: +41 52 262 00 51
24-hour emergency tel.: +41 52 262 53 53
info@burckhardtcompression.com
www.burckhardtcompression.com

Your local contact

Compressors for a Lifetime™

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