

GE Oil & Gas

Centrifugal & Axial Compressors



GE Centrifugal & Axial Compressors



- 3 Tradition, Experience and Innovation
- 4 Types and Characteristics
- 6 MCL / V series
- 8 BCL, RB, VH series
- 9 PCL series
- 10 SRL Integrally Geared series
- 11 SRL / DH series
- 12 Blowers D series
- 13 Axial Compressors AN series
- 14 Compressor Components
- 18 Oil and Gas Seal Systems
- 19 Control Systems
- 20 Test Facilities
- 21 Service
- 22 Training
- 23 Exploration and Production, Floating Production Units, LNG
- 24 Pipeline and Storage
- 25 Refinery and Petrochemicals
- 26 Compressor Specifications
- 27 Product Line Range

Tradition, Experience and Innovation

GE's Oil & Gas Business manufactures a complete range of centrifugal compressors for all major compression applications. They are used in oil & gas production, gas transportation, refinery and petrochemical industries, fuel gas boosting and other similar processes. We hold the record of key milestones for centrifugal compressor applications having designed and manufactured the first high pressure compressors for ammonia and urea plants, the most powerful compressors for offshore applications (over 30,000 HP) and re-injection compressors with delivery pressures as high as 10,000 psi (700 bar).

Specific requirements are met by custom configuring each compressor using standardized advanced technology components proven over a wide range of process conditions. This approach delivers reliable, high performance compressors for natural gas, refinery, petrochemical, GTL and LNG applications.

A highly skilled staff of local engineers and technicians provides on-site technical support for installation, commissioning, overhaul, repair and maintenance of our equipment.

Extensive research and development, advanced design procedures, modern manufacturing techniques and first hand on-site experience in compressor operation are behind the success achieved by our compressors.



Types and Characteristics

Horizontally-split compressors

Used primarily for low and medium pressure applications in ethylene and fertilizer plants, refineries, LNG for refrigeration, air compression, etc.

Propane Compressor for Qatar LNG Plant



Vertically-split barrel compressors

Used primarily for high pressure applications such as ammonia, urea and methanol synthesis, refinery recycle, natural gas compression and injection and hazardous gases.

BCL 405/C Re-injection Compressor offshore installation North Sea



Pipeline compressors

Used for low and medium pressure ratio pipeline service and in recycle applications such as those performed in methanol plants, etc.

Pipeline Centrifugal Compressor PCL 603



Axial compressors

Used for low pressure, high flow applications such as catalytic cracking plants, air service, air separation, LNG, nitric acid and GTL applications.

Mixed Refrigerant
Compressor for LNG Plant



Single stage overhung compressors

Used as boosters or recycle compressors in many petrochemical applications, such as polyethylene, polypropylene, ethylene oxide, chlorine, sulfuric acid plants, MVR.

DH Single Stage overhung
compressor for API 617
applications



Integrally geared compressors

Used for low and medium pressure air, steam and inert gas, and fuel gas service and in petrochemical applications.

SRL 603 for Air + Carbon
Monoxide - Belgium



MCL / V series

MCL compressors are designed in several sizes and pressure ratings to cover different applications. The compressor casing is either cast (cast-iron, cast steel) or fabricated. The diaphragms are cast-iron, cast steel or fabricated.

The impellers and diffusers are selected from a wide range of standard stages in accordance with the application and desired performance.

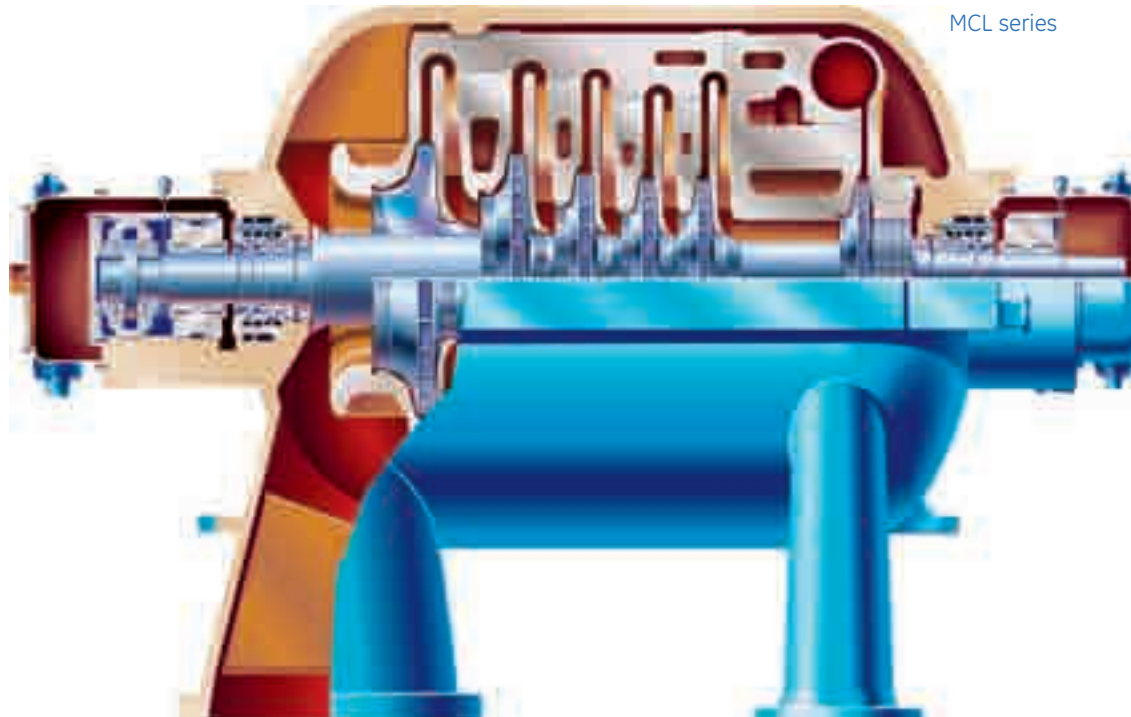
The radial and thrust bearings are of the tilting pad type.

Shaft-end seals are mainly dry gas seals but can be labyrinths or oil film seals.

Inter-stage leakages are controlled by labyrinths (static or rotating) or abradable seals.

Double flow models (DMCL) are used to compress very high flows. This solution allows the casing size and speed to remain within an acceptable range to couple the compressor to drivers and/or other compressor casings.

Different washing options can be offered as required.



2MCL Horizontally split compressor being machined



Horizontally split VS compressor for refrigeration service



Double stage models (2MCL) are used when intermediate cooling is required or when a process calls for two separate compression stages. 2MCL compressors have the same general features as the MCL type with the two compression stages in a back-to-back arrangement. Additional side stream nozzles can be provided with the 3MCL model for special requirements such as in refrigeration applications, particularly for propane in LNG plants. All connections can be oriented upward or downward to meet plant layout needs.



BCL, RB, VH series

These compressors are designed to cover a wide range of applications and pressures (hydrogen mixtures, hazardous gases, high pressure).

Casings can be rolled steel or forged with one or two end covers bolted or secured by shear rings.

For improved performance, diaphragms are, when practical, 100% machined.

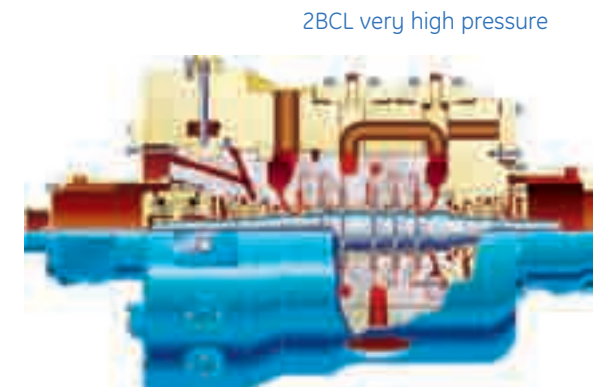
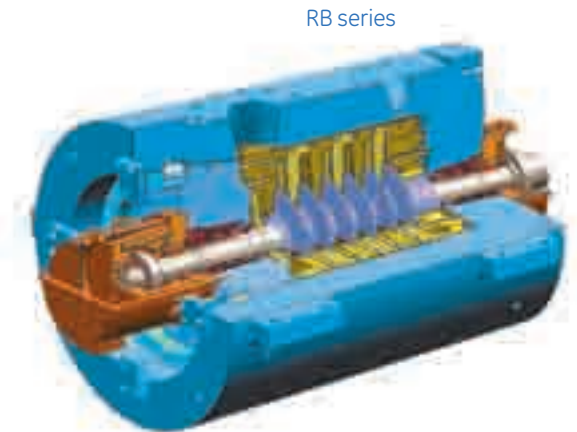
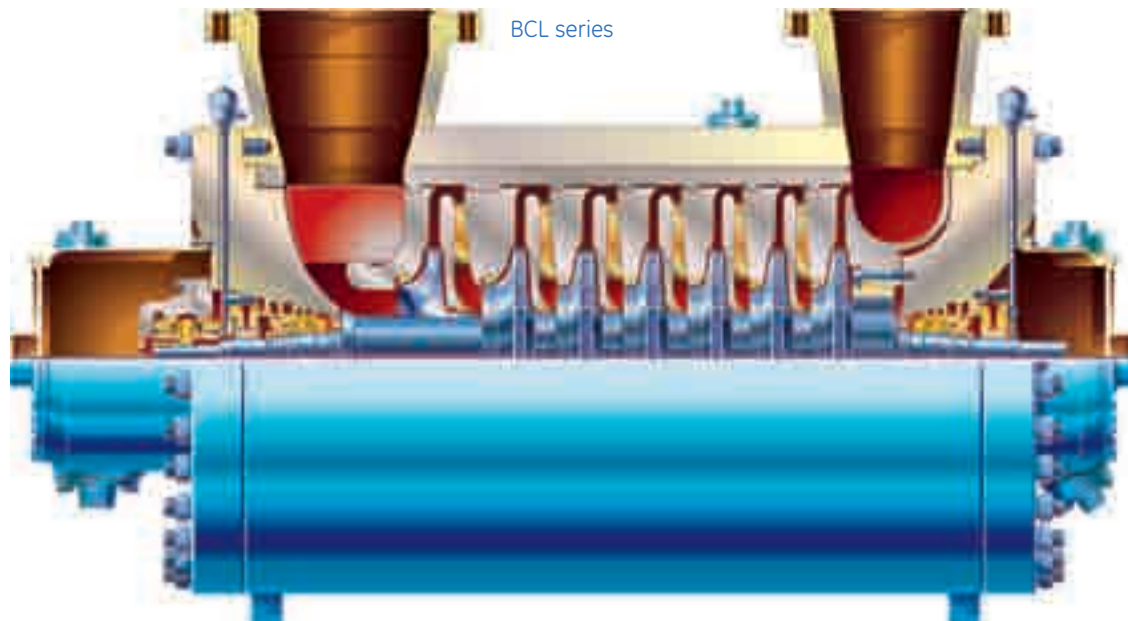
Radial and thrust bearings are of the tilting pad type. Active Magnetic Bearings are also available as an option.

End seals are of the dry gas type and other sealing solutions are also available.

In addition to conventional labyrinths, inter-stage seals can be abrasion or honeycomb seals to optimize the overall performance of the machine.

In-line, back-to-back or double flow configurations are also available.

Materials are adapted to the process requirements. Specific materials are selected to withstand the various forms of corrosion present in sour or acid gas applications based upon extensive experience in corrosive applications.



PCL series

These compressors have been designed to meet the range of flow and compression ratios required by gas pumping stations.

A variety of standard casing sizes are available to cover a wide range of gas flow.

The same casing can house different numbers of impellers to optimize performance in terms of efficiency, compression ratio and operating range.

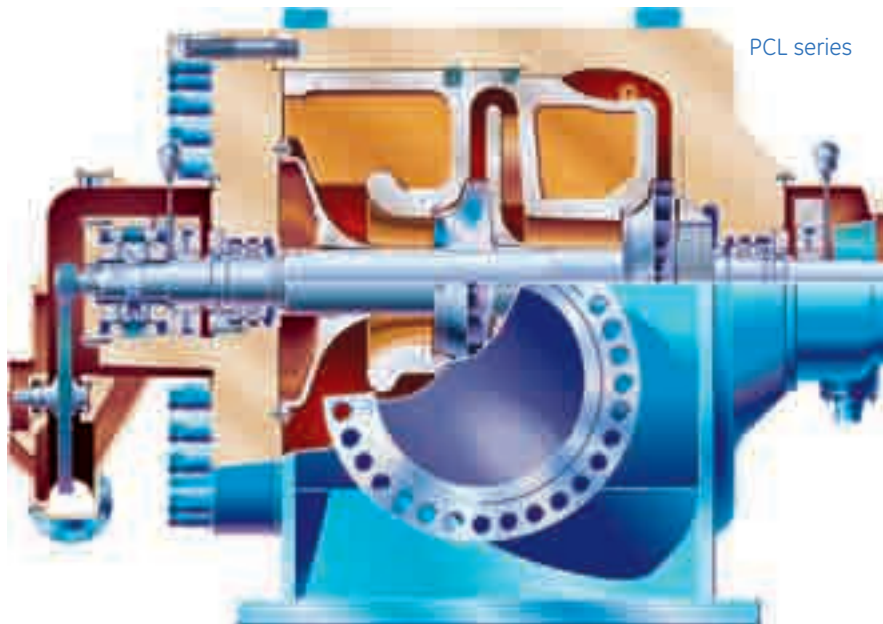
Field modification of the impeller configuration can be made to accommodate changes in operating conditions.

The compressor casings are made of forged steel to provide maximum material strength and metallurgical stability. Vibration-free operation is assured by positioning bearings at both casing ends which provides the necessary rigidity to the rotor.

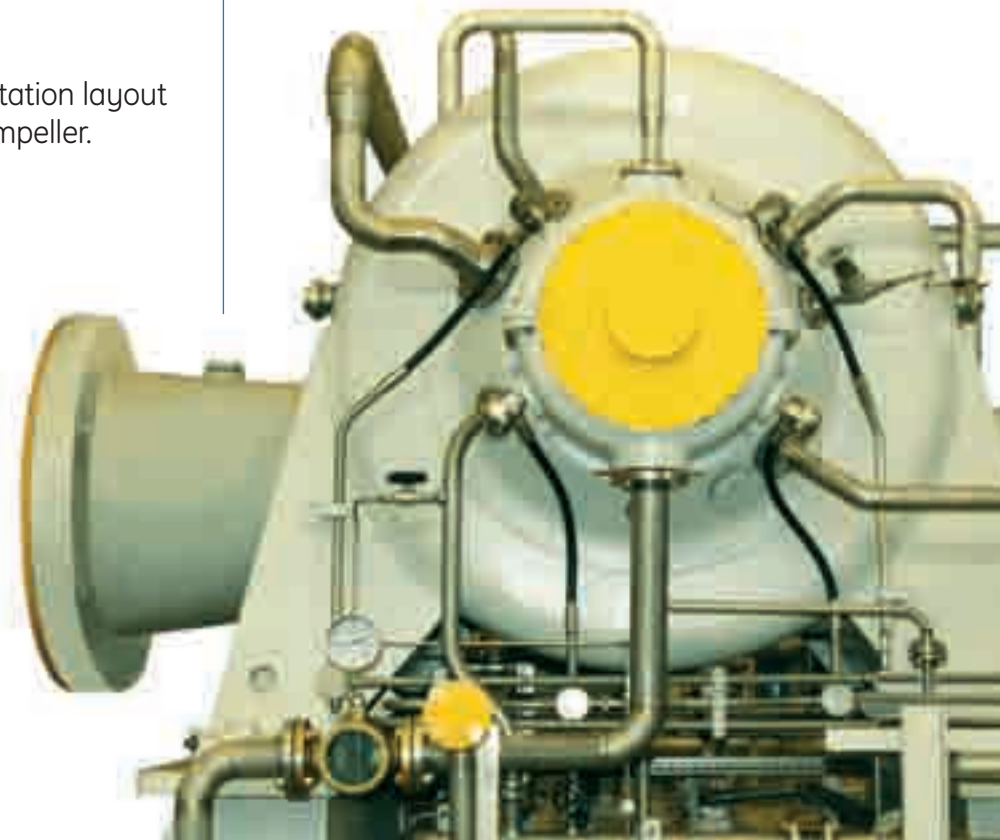
Dry gas seals are normally used to prevent gas leakage.

Floating bushing oil seals are also available on request.

The suction and delivery nozzles are generally located opposite each other to meet station layout requirements. Axial inlet is also available when the pressure ratio allows for a single impeller.

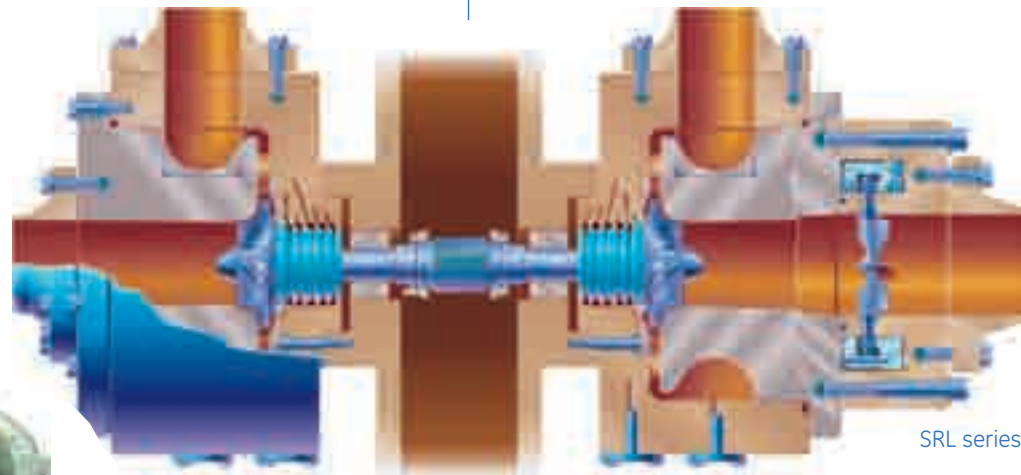


Pipeline Centrifugal Compressor
PCL 603



SRL Integrally Geared Series

Integrally Geared Compressors are used in several petrochemical applications, either for low-flow/high pressure, or high-flow/low pressure conditions. This type of compressor has a bull gear and from one to four high speed pinions. One or two impellers can be mounted on each pinion-shaft. Optimal impeller speed and the ability to inter-cool compression stages guarantee very high efficiency. Due to its rugged mechanical design, this type of machine has very high reliability and is easy to maintain. A large variety of gases can be handled by this compressor line with appropriate construction materials and seal systems. This line is designed for process air and gas service.



SRL / DH series

Overhung compressors are mainly used as boosters in petrochemical applications or for recycle in polypropylene and polyethylene plants.

The single-stage overhung configuration is simple and easy to maintain. Almost all gases can be handled by this type of compressor with appropriate construction materials and seal systems.



Blowers D series

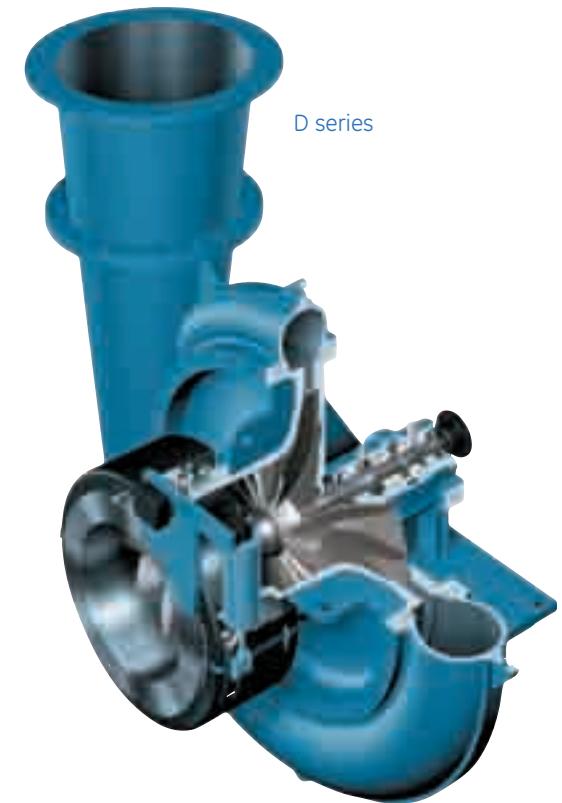
The Blower compressor is a low-pressure, single-stage overhung design typically utilized where a tough process gas application requires a relatively high flow of gas at a moderate differential pressure.

It features a compact, efficient design and the ability to handle a wide range of applications. Features like three-piece casing construction, horizontally split bearing housing and our exclusive impeller balance ring are examples of how this compressor is designed from the ground up to provide maximum reliability and serviceability to its operators.

These compressors offer a choice of models and seal options, as well as the design flexibility and optional equipment to conform to customer specifications.

Accessory packages include a variety of drivers, sound attenuation, a lubrication console and advanced control functions.

Optional API configurations also available.



Axial Compressors AN series

Axial compressors are designed for high volume, relatively low pressure applications and have high efficiency and a broad operating range.

An external fabricated horizontally split casing holds an inner stator blade carrier.

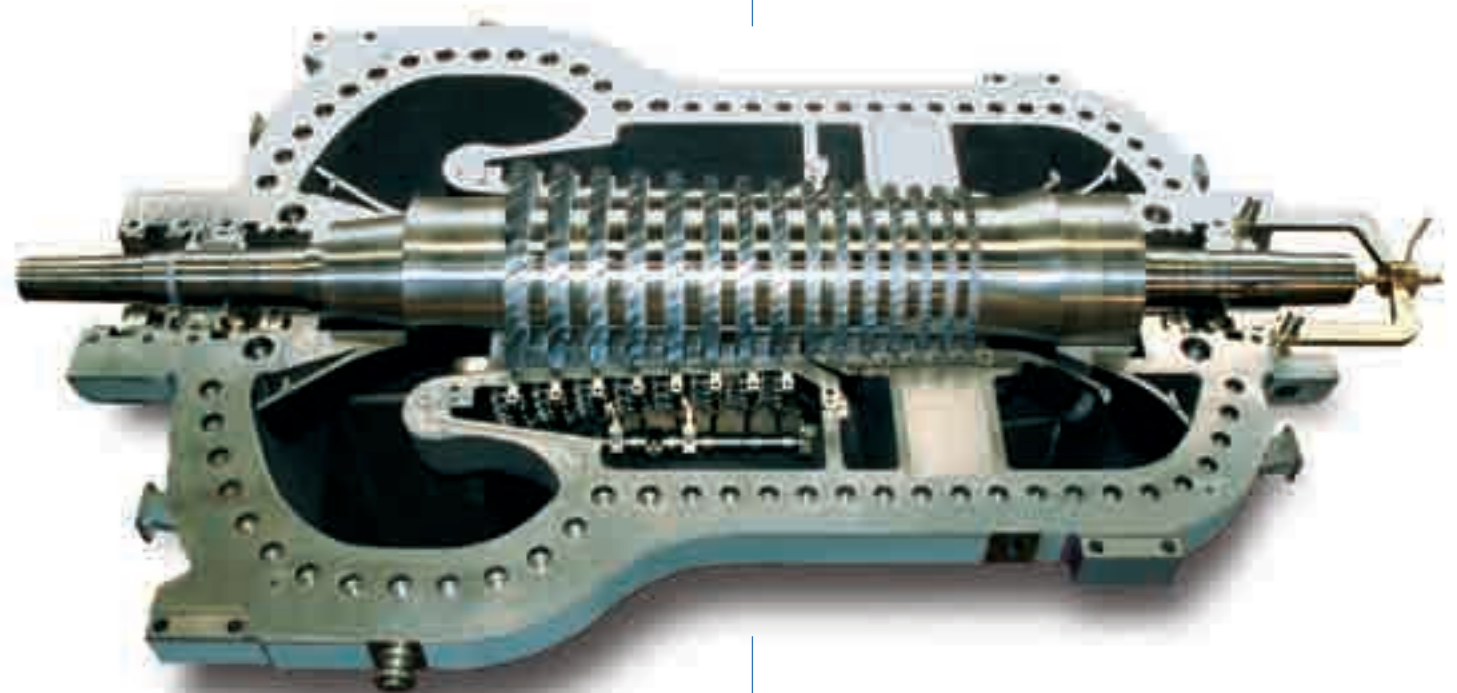
The first stator blading rows are adjustable by external devices for better performance control and for broader operability.

The number of blade rows is variable to better fit the process needs.

Both rotor and stator blades are robustly designed, for optimum aerodynamic and mechanical behavior.

The radial and thrust bearings are of the tilting-pad type. Shaft-end seals can be labyrinths either with extraction or buffer systems, oil film seals or dry seals depending on service requirements.

All connections can be oriented upward or downward to meet plant layout needs.



Compressor Components

Casings

Depending on the compressor family the casings can be

- Horizontally split
- Vertically split

Horizontally-split casings consist of two half casings joined along the horizontal center-line. All connections such as suction and discharge nozzles, side stream nozzles (if any)

and oil piping are normally fitted to the lower half so that the upper half becomes an easily removable cover. The casings may be cast-iron or cast or fabricated steel depending on the compressor duty, service temperatures, gas handled and compressor size.

Vertically split casings have different shapes and thickness depending on the pressure rating.

Casings up to 350 bars are steel cylinders with end covers either bolted or secured by shear rings. Nozzles can be welded to the

casing or machined directly.

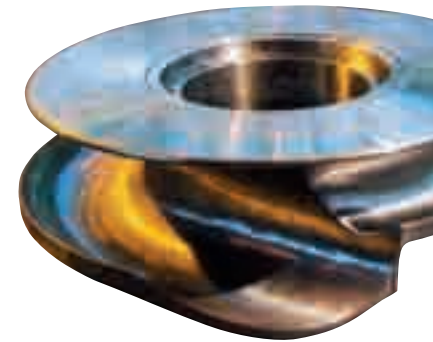
Casings with ratings over 350 bars are cup-shaped forgings with one end cover only. This cover is secured to the casing by a patented shear ring locking device.

Shear rings offer the advantage of being simple to assemble and provide the necessary sealing assurance for very high gas pressures.

By removing the end cover it is possible to remove the rotor diaphragm bundle assembly and to gain access to the internal components without removing the outer casing which remains connected to the plant piping package.

Diaphragms

Suction, intermediate and discharge diaphragms create the gas flow path within the stationary components. The suction diaphragm conveys the gas into the eye of the first impeller and can be fitted with adjustable guide vanes to optimize the inlet flow angle. Intermediate diaphragms perform the dual function of forming the diffuser passage (where gas



velocity is transformed into pressure) and the return passage to channel gas to the eye of the next impeller. The discharge diaphragm forms the diffuser for the last impeller as well as the discharge volute. The diaphragms are usually horizontally-split.

In the small to medium sizes of the MCL series, the upper half of the diaphragms is fixed to the upper half casing to facilitate inspection, and for the large sizes, it is fixed to the lower half of the diaphragms, while the barrel family internals are assembled into a bundle which can be easily extracted from the casing. The diaphragms are made of cast-iron, steel or stainless steel and when practical 100% machined to improve efficiency. Easily removable labyrinth seals are installed on the diaphragms at impeller shrouds, to prevent return flow from discharge to suction and on the shaft sleeves to eliminate interstage leakage.



Rotors

The rotor consists of shaft, impellers, sleeves, balance drum and thrust collar. Impellers are selected from a number of standard families. Each family groups a set of geometrically similar impellers with different flow coefficients to meet specific flow requirements. All geometries have been tested in the company's R & D laboratories. Impellers are shrunk on the shaft. Impellers may be either of the closed or open design. Closed impellers are made of forged steel. Their blades may be welded or brazed to both the disc and the shroud or milled from a solid disc and welded or brazed to the shroud. Solid weld-free impellers produced by milling or electrical discharge machining technology are also available.

The blades are generally back-swept to different angles in accordance with the required performance.

Open impellers are machined from solid forgings.

Each impeller is dynamically balanced and overspeed tested before assembly.

The rotor is balanced after the assembly of each individual component on the shaft.



Compressor Components

Seals

Shaft end seals eliminate or minimize the leakage of compressed gas or the entry of air into the compressor casing. Depending on the nature of the gas to be compressed and on the degree of sealing to be achieved, different types of seals may be used.



Labyrinth seals

They are used when the properties and pressure of a gas permit a minimal leakage. The labyrinths are made of light alloy or other corrosion-resistant material and are easily replaceable. The number of teeth and clearance depend on the operating conditions, as well as the geometry (plain, step, ring type, honey-comb, etc.). To minimize leakage, abradable seals are used. In this case the labyrinth teeth are fitted to the rotor and are in contact with an abradable material on the stator.

When no leakage whatsoever is permissible (poisonous or explosive gases, etc.) labyrinth seals are combined with extraction and/or injection systems.

Dry gas seals

Sealing is ensured by a gas lock created by the grooves machined into a rotating seal fitted on the rotor. Depending on the application it is possible to use gas - taken off the compressor at different levels: first impeller diffuser, intermediate or discharge nozzles or an insert gas.

Hydrostatic and hydrodynamic forces balance to maintain a clearance of a few microns between the rotating seals and the stationary face. This very small clearance reduces gas leakage to a negligible amount.

Different patented solutions are available to temper the seals to prevent liquid or hydrate formation or for controlling the temperature of the seal.

Extensive experience has been accumulated on dry gas seal systems that have been developed to meet specific process requirements.

Oil seals and mechanical seals are available at request, tend to be replaced by Dry Gas Seals.

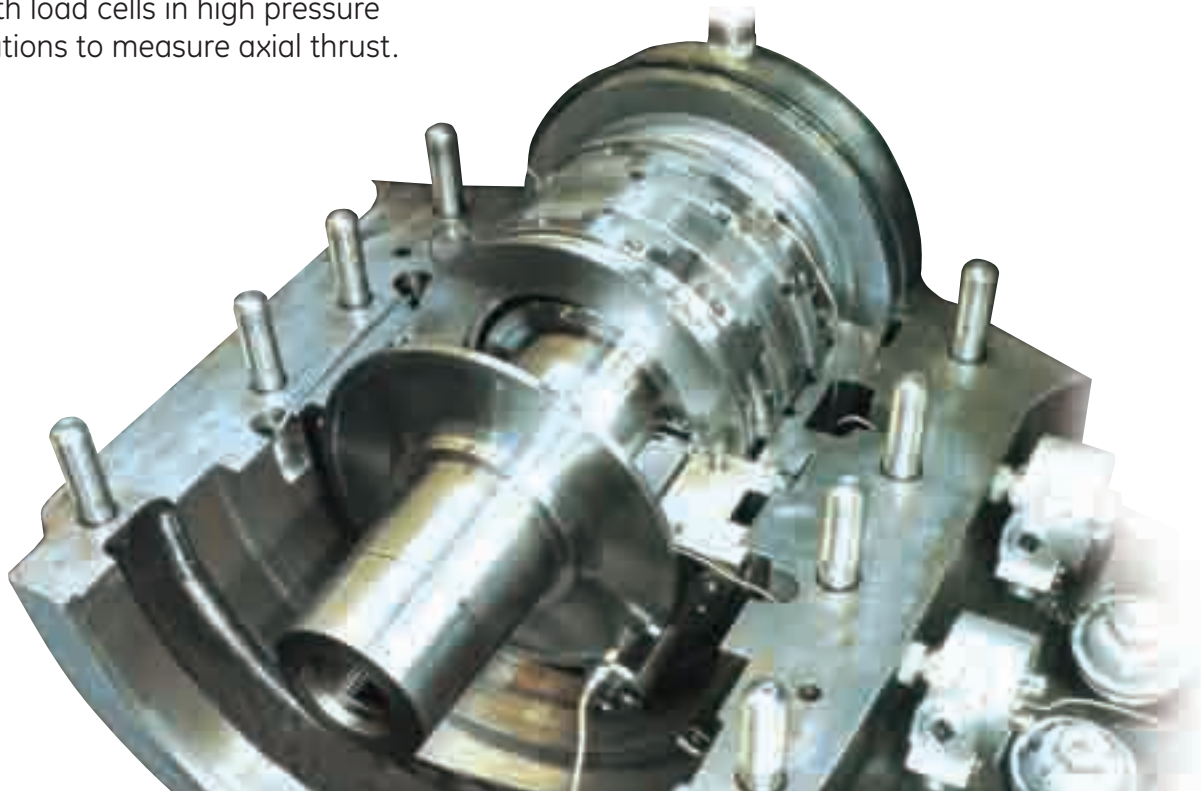
Bearings

Hydrodynamic bearings

- Journal bearings
Tilting pad bearings are generally used, and are normally equipped with thermocouples to monitor the bearing temperature.
- Thrust bearings
Double-acting, tilting pad bearings with an equalizing device are typically installed. The bearing pads can be fitted with thermocouples for temperature monitoring and with load cells in high pressure applications to measure axial thrust.

Active magnetic bearings

- In recent years several machines have been equipped with active magnetic bearings. Operating on the principle of electromagnetic suspension, the active magnetic bearings perform the same functions as hydrodynamic journal and thrust bearings with two major advantages:
- reduced mechanical losses owing to the absence of friction
 - adjustable axial and radial position and stiffness of the rotor and damping characteristics of the bearings.



Oil and Gas Seal Systems

Oil systems

Pre-engineered solutions, designed in accordance with API 614 are implemented for continuous compressor operation. Integrating the experience from the large number of units in operation ensures high reliability and short cycle times.

The oil system can be a separate console or be integrated with the compressor base plate for compact packages that are easy to install on-shore or off-shore including special criteria for FPSO applications.

The lube oil system provides lube oil to the radial and thrust bearing of the compressor, to the gear box, and to the driver (except for some gas turbines).

A seal oil system supplying filtered oil to the liquid film rings or to mechanical type seals at the required pressure and temperature can be provided upon request.

The seal oil system may also be combined with the lube oil system. In this case the same oil reservoir is used for both functions.



Gas seal systems

These systems are available to cover the needs of the different Dry Gas Seal configurations.

They provide, as a sub assembly, the required buffer gas for the primary, secondary and tertiary seals, and the instrumentation to properly monitor the seals.



Control Systems

With extensive experience as a manufacturer of compressors and all types of drivers, and engineering and field services for compression stations, our specialized teams develop systems to control the equipment packages and the associated auxiliaries or processes as required.

Control systems:

Our Integrated Driver-Compressor Control system is a complete integrated solution, providing protection and monitoring to maximize the security of the compressor against potentially harmful surge conditions, while enhancing process efficiency and availability. This integrated control system provides critical process control for the entire compression train, its auxiliaries and related process equipment. Compatible with a variety of drivers and compressors, it runs on the GE Mark family of control platforms or on GE Fanuc PLC's as dictated by the applications. Simplex, Dual, and TMR control system redundancy options are available.

Combining the driver and load compressor control in a single platform provides advantages to the customer:

- Common spares for both driver and compressor control systems reduce the overall inventory requirements
- A smaller physical footprint means that compressor control hardware can be included in the same cabinet as the driver control hardware.
- The same Technical Advisor can handle commissioning and startup of both the compression train and driver.
- Common software tools and diagnostics for maintenance of driver and compressor controls simplify maintenance and uprates, and also reduce startup time and cost.
- Training time and costs are reduced with a single control system used for both driver and compressor controls. This applies to both initial and on-going training costs over the life of the control system.

Anti-surge protection and process control

Anti-surge control algorithms implemented within the integrated control system are based on the knowledge acquired through our expertise as a leading compressor manufacturer and experience on thousands of applications. Different control strategies are available to meet the needs of the application. All provide both closed and open loop controls to better react to small and large process disturbances. Different process control and load bearing functions can be provided.

Dynamic simulation

Dynamic simulations ranging from a single loop to a more complete process configuration are possible to define anti-surge valves, hot by pass requirements, piping optimization for improved compressor protection and starting conditions for electric motor drives.

Test Facilities

Centrifugal compressors are carefully tested throughout the manufacturing process in order to guarantee a perfect match to their design criteria and to assure long lasting, continuous operation.

The following tests are typically carried out on components and assembled machines:

- casing: hydraulic pressure test
- impellers: ultrasonic and dye penetrant liquid tests; over speed testing
- impellers/rotors: over-speed testing
- mechanical run test

Optional tests may be performed based on the specific job requirements. For example:

- performance tests (with air or other gases in an open or closed loop)
- full load - performance tests (including flammable gases) to check rotor stability and the performance of the machine
- mechanical string test.

Numerous indoor and outdoor test beds together with a sophisticated system for data acquisition and processing of test results distinguish the Florence, Massa and Le Creusot facilities.

We have the largest and most complete testing capability in the industry to perform tests under actual load and pressure conditions (including LNG and re-injection) for trains driven by gas turbines or electric motors.



Service

GE's Oil & Gas business provides a complete set of services to support the entire centrifugal & axial compressor product line. We offer an extensive portfolio of proactive and interactive service products such as condition-based maintenance, Conversions, Modifications and Uprates (CM&Us) and Contractual Service Agreements (CSAs) complementing the traditional service offerings of OEM spare parts, repairs, and field services.

Our innovations are not limited to mechanical engineering. We have developed business solutions such as remote monitoring & diagnostics to help drive customer value by providing higher equipment reliability, availability, and productivity at a predictable cost.

Other advanced information-based developments include electronic parts catalogs, and e-commerce solutions.

Global Services engineers are backed up by our new product design engineering groups and by the GE Global Research Center - hundreds of creative minds working to provide the high-tech products and business solutions for the 21st century.



Training

GE's Oil & Gas business offers Training for the Operation and Maintenance of our complete line of machinery and equipment.

This Training can be provided either at the client's site or at the Learning Center located at the GE Infrastructure Oil & Gas headquarters in Florence, Italy. Instructors are field-seasoned experts who combine their understanding of theory with practical experience.

The quality training that they provide is a prerequisite for improving the skills of operating and maintenance personnel, to ensure safety, and superior equipment efficiency and availability.

Courses and documentation are designed to meet Customer needs, focusing on the GE machinery and equipment actually installed at their sites.

Traditional training tools are augmented with computer-based training and interactive multimedia technology. Courses and technical literature can be provided in a variety of languages.



CENTER OF EXCELLENCE FOR TRAINING

Florence Learning Center Facilities:

- 5600 m² of Space
- More than 20 Training Rooms
- Speedtronic Mark V & Mark VI
- Bently Nevada Simulators
- Laboratories
- Multimedia Rooms
- Conference Center
- Auditorium Seating for 230 (under completion)

TRAINING SOLUTIONS:

- For all level in your organization
- Tailored for your specific needs
- Prescheduled offerings or on request
- Provided in various languages
- Formal classroom training and interactive learning

COVERED EQUIPMENT

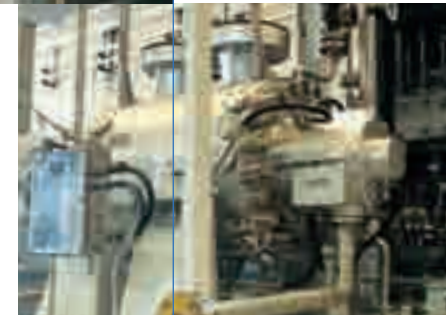
Nuovo Pignone, Thermodyn, Rotoflow, Bently Nevada and other GE equipment.

Exploration and Production, Floating Production Units, LNG

BCL 406/B + BCL 305/C + BCL 305/D compressor driven by MS5002 Gas Turbine installed in Venezuela



BCL 406/B + BCL 305/C driven by MS5002 Gas Turbine installed on Nkossa platform - Congo



Ekofisk platform - North Sea



Mixed refrigerant train AN 200 axial compressor and 2BCL 806 Centrifugal Compressor, driven by MS7001E-A Gas Turbine - Malaysia

Pipeline and Storage

The PCL 802 centrifugal compressor boosting natural gas on board the main Ekofisk platform



PCL 800 San Fergus



A PCL 1002 booster compressor on the Soyuz gas pipeline



GDF Chemery Gas Storage



Storage to Pipeline Compressor
Gazprom



PCL compressor installed in
Transcanada pipeline

Refinery and Petrochemicals

Ammonia synthesis
Mesaieed - Qatar



Ammonia synthesis



Refrigeration train in an
Ammonia plant, Turkmenistan



Steam recompression
evaporation - USA



Urea synthesis compressor
trains in a petrochemical
plant - Qatar

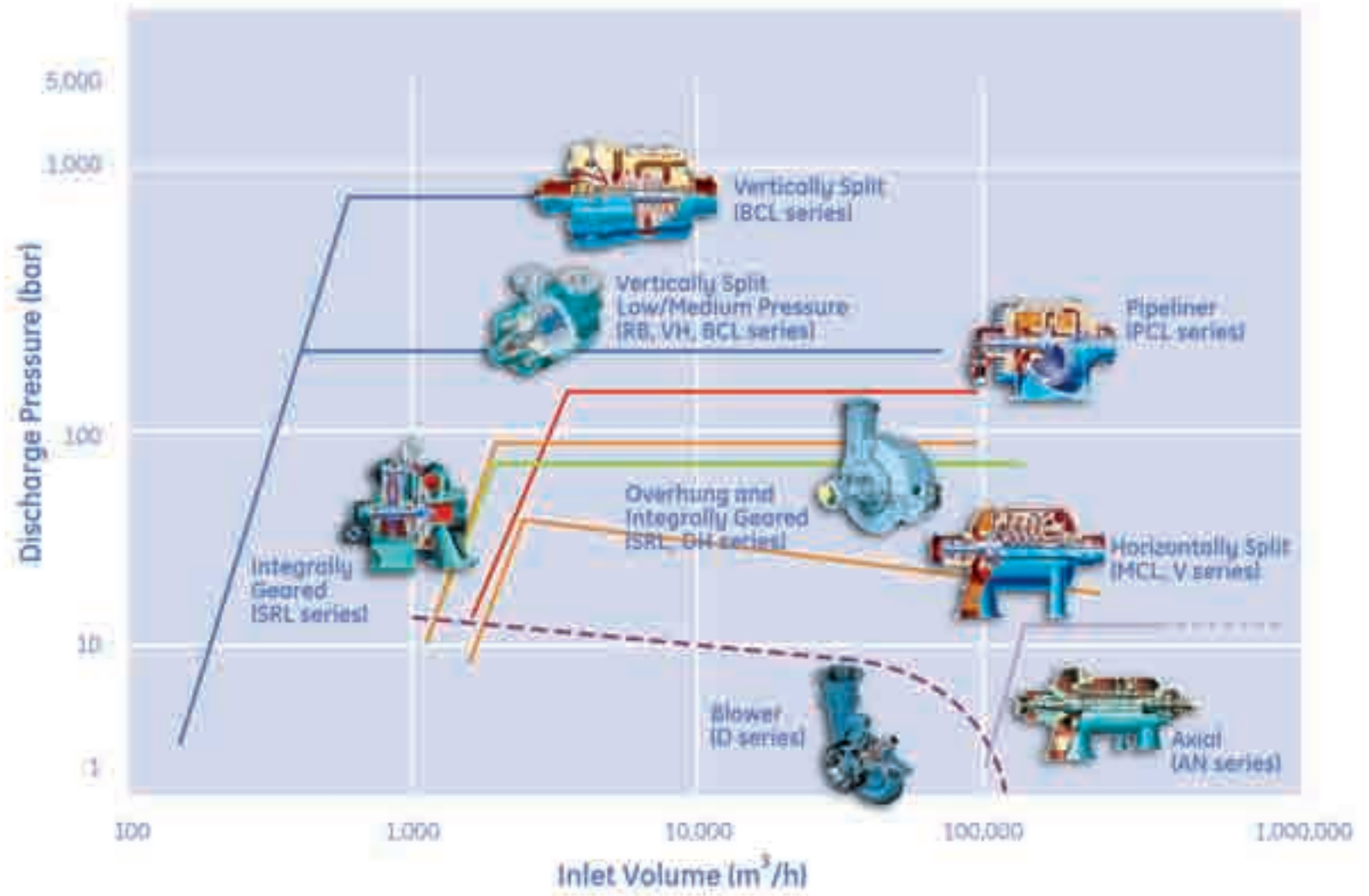


Compressor Specifications

COMPRESSOR FAMILY AND TYPE

Model Designation	number of units installed	Experience	Upstream	Gas Rejection Enhanced Recovery	Gas Lift	Gas Production and Processing	Fuel Gas Boosting	Gas Gathering	Midstream	Gas Liquefaction (LNG)	Gas Pipeline	Gas Storage	Downstream	Ethylene & Derivatives	Fertilizer	Refinery (Cracking)	Refinery (H ₂ Recycle)	GTL	Air Separation	Minimum Suction Pressure bar (psig)	Inlet Flow Range m ³ /h (acfm)	Maximum Discharge Pressure bar (psig)	Maximum Power kW (HP)	Speed Range - rpm	Driver Type	Comments
Centrifugal Vertical Split LP/MP	1917	855							167	28			895													
BCL, RB, RH, VH				●	●	●	●		●	●	●			●	●	●	●	●	●	-0.9 (-13)	up to 60,000 (up to 35,300)	200 (2,900)	40,000 (54,400)	3,000-20,000	GT; EM; ST High Speed Motors available	Sour and Acid gas Active mag bearings
Centrifugal Vertical Split HP	531	531		●																83 (1200)	up to 15,000 (up to 8,800)	700 (10,000)	30,000 (40,800)	7,000-18,000	GT or EM	Re-injection: Ultra High Pressure Sour Gas
Pipeliners	545							545																		
PCL											●									20 (290)	up to 100,000 (up to 58,800)	130 (1,900)	40,000 (54,400)	3,600-13,000	GT; VSIDS; hydraulic converter or High Speed Motors	Oil free trains (AMB)
Centrifugal Horizontally Split	1362	141						107					1114													
MCL, V					●		●		●				●	●	●	●	●	●	●	-0.9 (-13)	up to 500,000 (up to 294,000)	40 (580)	70,000 (95,200)	3,000-15,000	ST; EM or VSIDS	Cryogenic down to -100°C available
Integrally Geared	71					●	●						●													
SRL						●	●						●							-0.9 (-13)	up to 350,000 (up to 206,000)	70 (1,000)	15,000 (20,400)	3,000-50,000	EM; ST possible	Open closed impellers high mach stages
Overhung	331																									
SRL, DH													●							-0.9 (-13)	up to 100,000 (up to 58,800)	86 (1,250)	14,900 (20,000)	1,200-20,000	EM	Single stage
Blower	931																									
D													●							-0.9 (-13)	up to 408,000 (up to 240,000)	14 (200)	6,000 (8,000)	2,000-20,000	EM	Single stage
Axial	29																									
AN									●				●					●	●	-0.9 (-13)	100,000-600,000 (58,800-353,000)	25 (360)	70,000 (95,200)		ST; GT; VSIDS possible	Variable Stator Vanes
Total	5717	1527						819	28				2009													

Product Line Range



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