Reciprocating Compressors
Performance, reliability and innovation.

Introduction

The current range of GE reciprocating compressors is backed by a full century of experience. In addition to the original Nuovo Pignone product line, designed and manufactured in Florence, Italy, the GE product portfolio also includes machines that began as the Gemini brand of high speed reciprocating compressors, currently built in Oshkosh, Wisconsin, USA.

Today, GE is a world-leading manufacturer with a complete line of technologically advanced and work-proven API 618 and API 11P machines. Over 20,000 reciprocating compressors have been installed worldwide, wherever reliability and long life are essential to business success. Process applications include refineries, petrochemicals, herbicides, LDPE, blast-off, refrigeration and air. Natural gas applications include wellhead gas gathering, vapor recovery, gas re-injection, gas lift, pipeline gas transmission, gas storage, and fuel gas boosting.

Typically, the API 618 compression systems are engineered and offered directly by GE’s Oil & Gas business, while high-speed API 11P units are available through a network of authorized packagers and distributors that provide complete, cost-effective compression packages including a driven unit and a direct coupled reciprocating gas engine with necessary auxiliaries.

The success of the current generation of process compressors is the result of constant technological innovation that draws on the global resources and unmatched experience of GE. For example, an ethylene hyper-compressor rated for continuous duty with delivery pressure of up to 3500 bar requires the rigorous application of both modern design tools and proven product experience. These capabilities and technologies are employed throughout our lines of reciprocating compressors to provide greater efficiency, reliability, and safety.

The modular construction of GE reciprocating compressors is based on the use of standardized, well-proven components. Ease of maintenance is one benefit, full customization at a reasonable cost is another. Our compressors are designed and manufactured using the Six-Sigma Quality system to deliver products with the highest level of performance, reliability, and availability. ALL of our reciprocating compressors are backed by GE’s Oil & Gas Global Services operation, which has a staff of experts that can provide installation, start-up and maintenance services anywhere in the world.
Crankcase
The compressor crankcases are single piece cast iron castings. All medium and high power frames and 6 or 6 cylinder small power frames are equipped with tight-tolerance transverse spacers, fitted above the bearing housings between the two sides of the frame. This solution creates an extremely stiff, closed body, with an even distribution of stresses and strains. Large openings are provided in the crankcases, to cut the time and cost of maintenance procedures.

Crosshead Extensions
Crosshead extensions are made of cast iron and machined to exacting tolerances, to ensure optimum alignment of crosshead, cylinders and piston assemblies. The crosshead extensions are integral with the crankcase for the small OA, OC, HA, HB and all high speed models, while in larger frames they are separate components.

Crankshaft
All crankshafts are single-piece steel forgings. All feature balancing counterweights to minimize free inertia forces and moments. Counterweights of high-speed machines are integral with the shaft, while others are bolted-on.

API 618 Features

Longer working life.

Bearing
Proprietary design Al-Sn (Aluminum-Tin) bi-metallic main and big end bearings are standard on all machines. They feature a much higher load capacity than the older tri-metallic bearings and do not require any adjustment at installation. The traditional central circumferential groove is replaced by two oil feeders positioned at 90 degrees with respect to the area where the maximum pin load occurs. The main bearings are split in the vertical plane to relieve the most heavily loaded area of surface discontinuities, increasing load capability and reliability still further. Bearings can be replaced without removing the shaft: big end and frame main bearings are identical in all machines with an open top frame.

Connecting rod
The connecting rods are made of die-forged steel. Small end bushings are of the tri-metallic type (steel shell, leaded bronze layer, galvalnic white metal flash). An internal axial channel through the rod ensures reliable lubrication at both big and small ends.

Crosshead
Crossheads are made of steel and equipped with simply sized replaceable shoes. Specific loads are kept to a minimum, resulting in an extremely high working life. Shoes are completely machine-finished and interchangeable. They do not require any manual adjustment or shimming.
Hydraulic tightening devices
Depending on machine size, the main threaded connections (piston to piston rod, piston rod to crosshead, connecting rod to big end tie rods, frame crosspieces, anchor bolts, high pressure cylinder bolting) are hydraulically tightened. This method has many advantages including simple and safe operation, the highest resistance to loosening, simultaneous tightening of parallel tie rods, repeatability, and the absence of secondary bending or torsion effects on bolting.

Distance piece
All compressors are equipped with distance pieces between the crankcase and the cylinders. The distance pieces are available in many different configurations, among them single or double, pressurized or purged with inert gas, and vented to the atmosphere. The optimum configuration is selected in accordance with the process needs and Customer specifications.

Frame lubrication
The crank gear is lubricated by a forced feed system. A main mechanical pump driven by the compressor shaft and an auxiliary electric pump with similar flow are standard. On request, twin electric motor driven pumps may be supplied. All lube oil filters are of the twin type with changeover valve, to allow filter maintenance during machine operation. Standard lube oil coolers are single, shell and tube, once again a twin-arrangement or different types of coolers may be supplied on request.

API 618 Features
Higher safety & reliability.

Connecting rod hydraulic tightening.

Cylinder valves
GE’s proprietary valves are designed to hold power losses to a minimum, while ensuring the longest possible life for internal parts. PEEK is the standard material for rings up to 350 bar. Finger or plug type valve unloaders are available on request. A dynamic simulation of the behaviour of cylinder valve rings is carried out for each application, it takes into account all aspects of working conditions, including piping pressure pulsations when required. The results of this simulation provide direction for final valve trimming; a complete range of standard interchangeable valve internals is available for this purpose.

Suction valve assembly. Suction valve components including PEEK rings and finger unloader.
API 618 Features

Cylinder lube oil console divider block type with a large capacity tank.

Double compartment piston rod packing with nitrogen buffering.

API 618 Features

1. Cylinder lube oil console divider block type with a large capacity tank.
2. Double compartment piston rod packing with nitrogen buffering.

Construction Materials

A wide range of materials is available to suit specific applications. For example, compressors can be manufactured in accordance with NACE standards for use in a sour gas environment. Different types of surface hardening and hard coatings, including tungsten carbide, are available for piston rods and cylinder liners.
Instrumentation and controls
Provision for installation of a complete set of control and monitoring instrumentation (temperature, vibration, displacement etc.) is standard on all compressors; pressure indicator taps are provided on all cylinders. Actual instrumentation systems follow Customer specifications, and may range from single instruments to a complete diagnostic system, enabling confident predictive maintenance of the unit.

A proprietary design control panel SCENETRON™ is also available on request, as is a wide selection of different step and/or continuous capacity control systems. Among them are valve unloaders, additional clearance pockets, recycle systems, and variable speed drives. A special automatically and continuously operated additional clearance pocket has recently been developed to make possible very precise capacity control with virtually no variation in thermodynamic efficiency.

API 618 Features
Advanced technology.

Drivers
GE’s Oil & Gas business has extensive experience with the use of every conceivable driver for a reciprocating compressor, on a wide range of applications. Among current installations are gas and steam turbines, variable and fixed speed electric motors, and gas engines. Over the years, the company has developed a unique in-house capability for the design of complete trains, including the specification of all components and the execution of both transient and steady state torsional analyses.

Direct gas and steam turbine drivers are available for high speed, high efficiency operation, with variable speed drive capability for load-following applications. GE's Oil & Gas business offers a range of drivers for various applications, including gas turbine drivers, variable speed electric motors, and other specialized solutions.

API 618 Features
Piping pulsation and vibration analysis and control
Piping pulsation and vibration analysis and control capabilities have been under development at GE since 1965 when the first analogue simulator became available. Today, a team of world-class Oil & Gas specialists deals exclusively with piping acoustic pulsation and mechanical vibrations using one of the most advanced computer programs, developed entirely in house. Among its many capabilities, this program provides the input data for “cylinder-manifold analyses” using advanced finite element analysis of the cylinder/pulsation bottle assembly. Cylinder-manifold analyses have been a standard part of our pulsation and vibration studies since 2002. The Oil & Gas team is also able to conduct an analysis for a complete LDPE plant (pressures up to 3500 bar), including the primary booster compressor, the hyper compressor, the reactor, the vessels, and the complete interconnecting piping.

Seamless teamwork with the rest of the Oil & Gas Engineering Department ensures an optimized integrated design of the plant and compressor components from the acoustic and vibration standpoint. The ability of the compressor manufacturer to perform all necessary pulsation and vibration analysis activities gives the Customer the great benefit of a single-source of responsibility for this highly critical function.
API 11P High Speed Reciprocating Compressors

Every year energy companies around the world choose high speed reciprocating compressors to meet their gas compression needs. Today’s energy companies recognize that these compressors provide an economic, flexible and reliable method to develop their oil and gas resources.

To serve the needs of our Customers in the oil and gas industry, GE offers a full line of oil and gas resources.

GE API 11P compressors are integrated into a package by a global network of authorized packagers and distributors. The compressor is matched with a driver, coolers, controls and piping onto a single skid, allowing the complete compressor package to be easily moved to a new location. This concept lowers your installation, site construction and re-application costs.

Our compressors are also designed to be direct connected via a flexible coupling to a variety of economical prime movers, including reciprocating natural gas engines (720 to 1800 RPM) and electric motors (750RPM to 1800 RPM). A variety of compressor frame strokes allows the compressor to be perfectly matched to the optimum driver.

It is the nature of natural gas production that field pressures and flows often change. Therefore greater productivity can be attained if the compressor is easily adaptable to the new operating conditions. Many of our compressors feature field replaceable cylinder liners which allow the cylinder bore to be increased or decreased as conditions change. In many cases, there is no need to modify the on-skid piping and accessories, further lowering modification costs. Also, in case of damage to the cylinder bore, it is less expensive and less time consuming to replace a liner than a complete cylinder. A variety of capacity control devices are also available, including our patented variable volume clearance pockets, featuring generous clearance volumes. The ensures that horsepower is not wasted.

The modular design of GE high speed reciprocating compressors allows frames and cylinders to be matched and re-arranged with only minor changes to the skid. For example, many cylinders will fit on as many as three different frames. Also, cylinders are designed to have identical flange connections, helping to keep inventory levels for idle machinery and spare parts to a minimum.

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Cylinder Pressure Ranges by Application:

<table>
<thead>
<tr>
<th>Cylinder Pressure Ranges</th>
<th>High</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas Reinjection</td>
<td>1150</td>
<td>1100</td>
</tr>
<tr>
<td>CNG Fueling</td>
<td>1250</td>
<td>1200</td>
</tr>
<tr>
<td>Gas Gathering</td>
<td>1550</td>
<td>1500</td>
</tr>
<tr>
<td>Fueling</td>
<td>2050</td>
<td>2000</td>
</tr>
<tr>
<td>Port Storage</td>
<td>2500</td>
<td>2400</td>
</tr>
</tbody>
</table>

Reliable

GE High Speed API 11P Reciprocating Compressors use a balanced opposed design to minimize vibration by equalizing the opposing reciprocating forces on the crankshaft. Heavy, ribbed frames distribute reciprocating stresses evenly for greater strength and longer life. Many compressor cylinders are water jacketed to lower operating temperatures, provide thermal stability, and improve valve life.

Compressor Horsepower Selection Chart

<table>
<thead>
<tr>
<th>HP</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60</th>
<th>65</th>
</tr>
</thead>
<tbody>
<tr>
<td>Psig</td>
<td>150</td>
<td>200</td>
<td>250</td>
<td>300</td>
<td>350</td>
<td>400</td>
<td>450</td>
<td>500</td>
<td>550</td>
<td>600</td>
<td>650</td>
<td>700</td>
</tr>
<tr>
<td>Psig</td>
<td>700</td>
<td>750</td>
<td>800</td>
<td>850</td>
<td>900</td>
<td>950</td>
<td>1000</td>
<td>1050</td>
<td>1100</td>
<td>1150</td>
<td>1200</td>
<td>1250</td>
</tr>
</tbody>
</table>

Example: Given = P1 = 70 Psig, P2 = 650 Psig, MMSCFD = 8.0

Result: 140 Bhp/ MMSCFD = 8 X 140 = 1200 Total BHP.

* Note: MMSCFD measured at 14.7 psia, and 60F, suction temp = 100F, Natural Gas K=1.26, SG=.65
The need to install a complex compression plant at a remote site or in a hostile environment often presents logistical problems which require heavy outlays or extended schedules when using conventional techniques. A simpler solution can be found in pre-packaging. A complete factory-built and pre-tested unit, designed for ease of transport and final assembly, can achieve dramatic savings.

GE has developed unique in-house resources dedicated to the design, assembly and testing of complete compression packages. Solutions range from simple skid-mounted compressors for onshore applications to standalone modules ready to be installed offshore platforms.

A 3-D CAD system is used to develop the plant layout. It is also capable of generating an accurate ergonomic design, detecting and correcting spatial interference, and automatically generating piping isometrics and the associated bill-of-materials.

GE reciprocating compressors for oil and gas applications are subjected to thorough inspection and testing throughout the manufacturing process, in order to ensure the highest quality and a long, productive life. All machines receive a full speed run-in test with a shop motor. The standard Quality Control Plan can be integrated with particular Customer requests, from simple additional checks on components to a running test of complete compression plants, either no-load or full load. In carrying out these and other tests, GE Customers can take advantage of some of the largest and most complete testing facilities in the compressor industry.

To achieve and maintain the highest technological and quality level of our products, all design, procurement, manufacturing and testing activities are carried out in accordance with a rigorous Quality Management System (QMS) based on the most widely accepted international code, ISO 9001 Ed. 00. An internal Certified Calibration Center is used to calibrate all measuring and testing instruments in the company's plants. The QMS in operation at GE's Oil & Gas business is certified by Lloyd's Register Certification.

Optimal solutions.
Global Services

Our Global Services group is dedicated to maintaining and servicing more than 3,000 installed GE reciprocating compressors. It serves as a single point of contact for Customers, providing easy and prompt access for both preventive and emergency maintenance.

The range of available services includes:

- Installation, commissioning and start-up (supervision or turnkey).
- Technical assistance; event analysis, troubleshooting, and advice on operational matters.
- Parts, overhauls and repairs; revamping/improvement of existing units; Conversions, Modifications and Uprates (CM&Us).
- On-condition maintenance through advanced monitoring and diagnostics programs.

GE’s Oil & Gas business is constantly developing innovative solutions to put the latest technology and processes to work for our Customers. For example, we were among the first to offer a continuous monitoring system for small and big end bearings based on passive sensors (no power source necessary) mounted on the connecting rods, with the receiving unit installed in a small, robust container close to the compressor.

GE offers training for the operation and maintenance of our complete line of machinery and equipment. Training can be provided either at the client’s site or at the GE Learning Center, located at the Oil & Gas headquarters in Florence, Italy. Instructors are field-experienced experts who combine their understanding of theory with extensive practical experience. The training they provide is valued by our Customers for improving the skills of their operations and maintenance personnel, to assure safety and superior equipment efficiency and availability.

Courses and documentation are customized to meet the specific needs of our Customers, focusing on the GE machinery and equipment actually installed at their sites.

Effectiveness and efficiency:

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.

GE 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 users (upon completion)

Training Solutions:

- Suitable for all levels of personnel
- Tailored to your organization’s specific needs
- Pre-scheduled offerings or on request
- Provided in various languages
- Formal classroom training and interactive learning

Equipment Covered:

Stem Turbines, Gas Turbines, Centrifugal Compressors, Reciprocating Compressors, Expanders, Pumps, Control Panels and other oil and gas industry equipment offered by GE.
Extensive experience in a broad range of processing applications

Covering the needs of all Natural Gas applications
Frame Ratings

A full century experience, characterized by intense and never ending focus on technology improvements, the broadest line of compressors coupled with the most varied applications in all sectors, and the toughest records achieved, make GE an unquestionable world leader in oil and gas applications.

API 618 Series O and H Process Compressors
Designed in accordance with API 618, for heavy-duty applications in process applications, these units fit the broadest and most stringent market requirements.

API 618 and vertical Natural Gas Compressor Series AVTN, BVTN, HM, SHM
AVTN, BVTN: vertical standard compressors for fuel gas service.
HM, SHM: high-speed API 618, heavy-duty models, designed for continuous duty in the oil and gas industry. Onshore and offshore applications. Wide cylinder line, lubricated and un lubricated.
SHMB: fully balanced, designed for vibration-free applications, offshore and onshore.

Series P Hypercompressor
Unique, compact hypercompressors for the extremely demanding conditions of LDPE production.

API 11P High Speed Reciprocating Compressors
Balanced opposed high-speed compressors of rugged design for heavy-duty service in oil and gas field applications.

<table>
<thead>
<tr>
<th>Frame Size</th>
<th>No. of Throws</th>
<th>Max. Power Capability (*) (kW)</th>
<th>Piston Rod Diameter (mm)</th>
<th>Stroke (mm)</th>
<th>Max. Speed (rpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OA</td>
<td>1</td>
<td>120 (90)</td>
<td>1.125 (28.6)</td>
<td>3 (76.2)</td>
<td>1800</td>
</tr>
<tr>
<td>H</td>
<td>1-2</td>
<td>400 (300)</td>
<td>1.125 (28.6)</td>
<td>3 (76.2)</td>
<td>1800</td>
</tr>
<tr>
<td>A</td>
<td>2-4</td>
<td>800 (600)</td>
<td>1.375 (34.9)</td>
<td>3.5 (88.9)</td>
<td>1800</td>
</tr>
<tr>
<td>B</td>
<td>2-4</td>
<td>1600 (1200)</td>
<td>1.75-2.0 (44.5-50.8)</td>
<td>3.5-4.5-5.0 (88.9-114.3-127.0)</td>
<td>1200-1500-1800</td>
</tr>
<tr>
<td>DP</td>
<td>2-4</td>
<td>2400 (1800)</td>
<td>1.5-2.0 (38.1-50.8)</td>
<td>4.25-5.0-6.0 (108-127.0-152.4)</td>
<td>1200-1500-1600</td>
</tr>
<tr>
<td>ES</td>
<td>2-4-6</td>
<td>7200 (5400)</td>
<td>2.25 (57.2)</td>
<td>5.0-6.0-7.0 (127.0-152.4-177.8)</td>
<td>1000-1200-1500</td>
</tr>
<tr>
<td>FS</td>
<td>2-4-6</td>
<td>7200 (5400)</td>
<td>2.5 (63.5)</td>
<td>5.0-6.0-7.0 (127.0-152.4-177.8)</td>
<td>1000-1200-1500</td>
</tr>
<tr>
<td>SHMB</td>
<td>2-4</td>
<td>5900 (4400)</td>
<td>2.5 (63.5)</td>
<td>6.0 (152.4)</td>
<td>1200</td>
</tr>
<tr>
<td>SHM</td>
<td>2-4-6</td>
<td>8800 (6600)</td>
<td>2.5 (63.5)</td>
<td>6.0 (152.4)</td>
<td>1200</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frame Size</th>
<th>No. of Cylinders</th>
<th>Max. Power Capability (*) (kW)</th>
<th>Piston Rod Diameter (mm)</th>
<th>Stroke (mm)</th>
<th>Max. Speed (rpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PK</td>
<td>4-24</td>
<td>60,000</td>
<td>–</td>
<td>400 max.</td>
<td>310</td>
</tr>
</tbody>
</table>

* – at maximum speed and maximum number of cylinders
** – maximum number of cylinders with twin 12 cylinder frames

FPO - Cristina to provide hi-res