Sour Gas Applications

Experience matters

GE's Oil & Gas business has pioneered the manufacturing and testing of very high pressure sour gas centrifugal compressors. The Karachaganak compressors that were full load tested in 2000 and early 2003 operate at a nominal discharge pressure of 560 bar with gas containing 5% H_2S.
They are the first in the world to be used in this challenging application. To achieve this leap in technological capabilities, a substantial research & development effort on materials, gaskets, rotor-dynamics and dry gas seals was necessary.
Since then we have achieved another milestone with a compression train with a nominal discharge pressure of 630 Bar operating on gas with a H_2S content of greater than 15%. Recently, we have tested a new re-injection train at a discharge pressure of 800 Bar for compression of extremely sour gas (18% H_2S, 5% CO_2).

Safety is not optional

GE's compressors are designed with special focus on rotor dynamics and gas sealing to avoid, toxic release or overpressure situations.
Vibration is minimized at all operating conditions by using very rigid shafts. Gas seals for both the casing and shaft are designed to maximize redundancy and with the greatest possible consideration to safety.

Karachaganak (Kazakhstan)
550 Bara with 5% H_2S

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GE imagination at work

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GE
Oil & Gas

High Pressure Gas Re-injection

Premium Technology Enhancing Oil Recovery while Protecting the Environment

GE's Oil & Gas business is a world leader in compression of natural gas for high-pressure re-injection with over 30 years of experience in this field.
The industry's first machine with a discharge pressure of 427 bar was installed by GE's Nuovo Pignone division in the early 1970s at the Hassi Messaoud Plant in Algeria.
The innovative design approaches, the extensive testing capabilities and the high reliability demonstrated in all installations have positioned us as the leading manufacturer of compressors for this type of application.
The innovation continues today with research and development aimed at designing compression trains with discharge pressures of 1000 bar and higher associated with high content of acid gas.

Hassi Messaoud - Algeria

Installations

Over 200 high-pressure compression trains with more than 350 compressor bodies have been produced by GE's Oil & Gas business in the last 30 years. About half of these train configurations are driven by GE MS5002 gas turbines and more than 50 have nominal discharge pressures greater than 500 bar. While heavy-duty gas turbine drivers have generally been used for compression trains for onshore applications, the majority of our high pressure offshore installations use GE aeroderivative gas turbine drivers.

Pigap - Venezuela
MS5002 Gas Turbine driving
Centrifugal Compressors
BCL406B+BCL305C+BCL305D

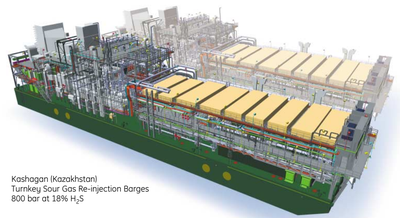
N'kossa - Congo
MS5002 Gas Turbine driving
Centrifugal Compressors
BCL406B+BCL307C

Tengiz Field - Kazakhstan
MS5002 Gas Turbine driving
Centrifugal Compressors
BCL305B+BCL304C+BCL304D

Design

High-pressure re-injection compressor design is one of the most demanding challenges in the field of turbomachinery. For this reason GE invests continually in research and development efforts focused on producing advanced technology designs and new calculation codes to meet the ever increasing challenges of the industry.
Rotordynamics: The impact of high gas density on impellers and balancing drum seals can cause rotor stability problems potentially leading to subsynchronous vibration phenomena. Maximizing rotor stiffness and bearing damping together with the use of special seals are used to ensure safe lateral behavior in the most critical and challenging high pressure machines.
Rotating Stall: The low flows typical of high pressure applications together with the high gas densities make these machines particularly susceptible to rotating stall. The strong aerodynamic excitations associated with this phenomenon could severally limit the operation of the machine. In order to avoid the occurrence of potential rotating stall problems, pre-designed and tested stages are used. Extensive R&D has been conducted using both computational and experimental techniques to identify advanced solutions to achieving a broader operating range.
To this end, an optimized diffuser shape (pinch) and low solidity vaned diffusers have now been qualified, and compressor internals can be easily adjusted on the basis of test results.
Performance: The extreme pressure and density of the gas make the prediction of performance computationally challenging.
Equations of state have been validated, even in the presence of sour gas, through extensive laboratory programs at pressures up to 1000 bar. The extensive use of validated standard stages completely removes uncertainty in performance evaluation as verified by full load tests conducted at our facilities and site performance.
Shaft end sealing: Recently, dry gas seals (DGS) have replaced oil seals in re-injection applications. The increased reliability of dry gas seals allows differential dynamic pressures up to 425 bar. The use of DGS in high pressure applications is now a standard in compressor technology.
Casing Sealing System: The trend toward high sour gas applications has required major efforts in the design of machines for zero leakage to the environment. This objective has been successfully achieved through the introduction of:

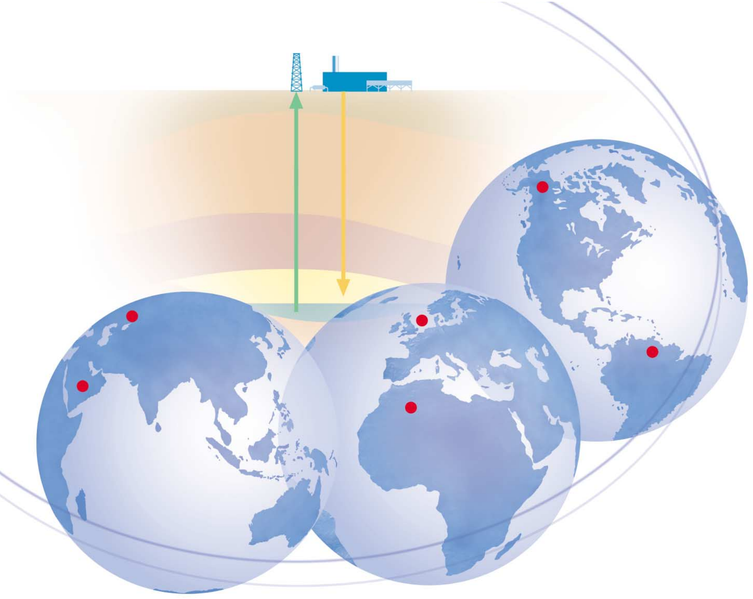
- new, more reliable gasket designs;
- new, patented gas leakage recovery system.



Kashagan (Kazakhstan)
Turnkey Sour Gas Re-injection Barges
800 bar at 18% H_2S

Compression Islands

GE integrates its equipment (turbines, compressors, expanders, air coolers, valves, etc.) into optimized engineered solutions to meet Customer requirements. Islands are typical solutions for on-shore installations. In addition to the equipment, the GE offering includes system engineering (electrical, mechanical, instrumentall), the supply of the necessary balance of plant items (gas separators and coolers, valves, piping, electrical and control systems), start-up/commissioning and project management.
Compression Islands are offered under single source and responsibility; i.e., guarantees and a warranty are given on the entire system instead of on the equipment only. Upon Customer request, the supply and responsibility can be extended to the entire station, adding all necessary auxiliary systems.



GE's Oil & Gas Business Technology Milestones

1973 — Algeria –
- First Re-injection Unit, 6200 PSIA - 427 bar

1975 — North Sea –
First Unit Full Load
- Tested in Florence at 10,000 PSIA - 690 bar

1978 — Algeria –
- World's Largest Re-injection Plant (1,200,000 HP installed)

1995 — Venezuela –
- WW Highest Operating disch. pressure, 9,150 PSIA– 630 bar

1996 — North Sea –
- First Tandem Dry Gas Seal for Very High Pressure Application: Dynamic 2300 psia - 159 bar

1997 — Algeria –
- First Re-injection train driven by an MS5002D Gas Turbine

1999 — Kazakhstan –
- WW First Sour Gas Re-injection, 5% H_2S @ 8000 PSIA - 550 bar

2000 — Alaska –
- WW Highest Pressure Operating Dry Gas Seal, Dynamic 4980 PSIA - 343 bar

2001 — Kazakhstan –
- 18% H_2S Gas Re-injection at 9150 PSIA– 630 bar

2005 — Kazakhstan –
Gas Re-injection Technology Growth
- Discharge Pressure (10700 PSIA – 800 bar)
- Gas Composition (18% H_2S - 5%CO_2)
- Highest Dry Gas Seal (6100 PSIA)

Antisurge Control Valves

All antisurge control valves are designed, manufactured and tested in-house. A fully balanced design with low friction forces enables fast and smooth operation of these flow control elements. Multistage trims are designed to limit both noise levels and kinetic energy developed during throttling operations. Extensive R&D effort has been devoted to achieving high reliability and extremely low fugitive emission levels for all the operating conditions.

Air Cooled Heat Exchangers

Pipe and Bend Air Cooled Heat Exchangers are manufactured by GE Oil & Gas in Vibo Valentia, Italy. Since the late 60s, we have manufactured more than 10,000 API 661 quality bundles from in-house designs developed to meet the demanding specifications of our Customers. We have the manufacturing experience, capabilities and specialized equipment needed for the production of bundles from special materials (incoloy, titanium, alloy steel, etc.) suitable for high pressure sour gas applications.

Full load testing of Re-injection Turbocompressors

Between 1975 (North Sea) and 2005 (Kazahkstan) more than 40 turbocompressor units for re-injection applications with discharge pressures in excess of 200 bar were full load tested by GE's Oil & Gas business. The full load string tests in the outdoor test bed shown in the photos were carried out with all auxiliaries including lube and seal systems, control panels and fully instrumented process panels. The test arrangement must be as close as possible to the final configuration to reproduce mechanical and thermodynamic performance in the field. All of the critical features of the machine are fully verified including:

- Thermodynamic performance (pressure ratio, efficiency, surge limit, etc.),
- Rotordynamics, critical speed and verification of all potential excitation phenomena such as rotating stall.
- Shaft end seal behavior and auxiliary systems.
- Control system for the complete train.
- Coolers.

Kashagan Turbocompressor Units:
Testing In Massa Plant

Kashagan (Kazakhstan)
Centrifugal Compressors
BCL404B+BCL404C+BCL304E