SIEMENS

Compression Solutions

Centrifugal Compressors

Enhancing the product portfolio: Pipeline and barrel compressors

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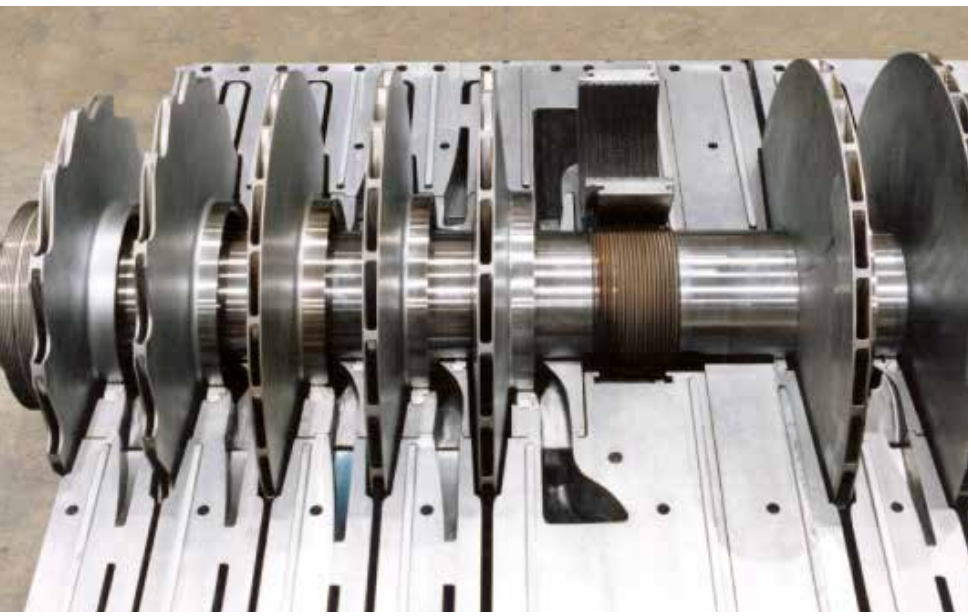
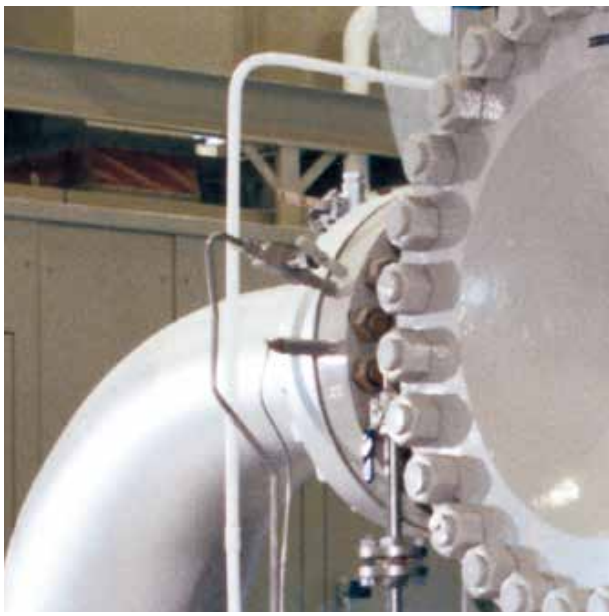




Pipeline and Barrel Compressors

Efficiency and reliability in natural gas compression equipment

The RFA36 and RFA24 are among the most efficient pipeline compressors available today, demonstrating the performance that is derived in part from a rich Cooper- Bessemer® heritage. Siemens pipeline and multi-stage barrel compressors are designed around API 617 requirements and apply advanced technology to continue to deliver cost-effective production.

Pipeline Compressors

The RFA36 is the first in a more efficient generation of industry leading centrifugal compressors. With field–proven efficiencies of up to 91 percent, the RFA can save hundreds of thousands of dollars annually in energy costs compared to conventional pipeline compressors of similar capacity. This outstanding performance is achieved through design improvements based on the most recent advances in fluid dynamics.

Siemens also offers more conventional beam–style centrifugal pipeline compressors that achieve efficiencies of up to 90 percent. Engineered for peak aerodynamic efficiency, Siemens pipeline compressors are installed on most major natural gas pipeline systems throughout the world. They perform reliably in a variety of compression applications in all kinds of climates.

For over 65 years, more than 980 pipeline compressors have been installed in countries across the globe.

Barrel Compressors

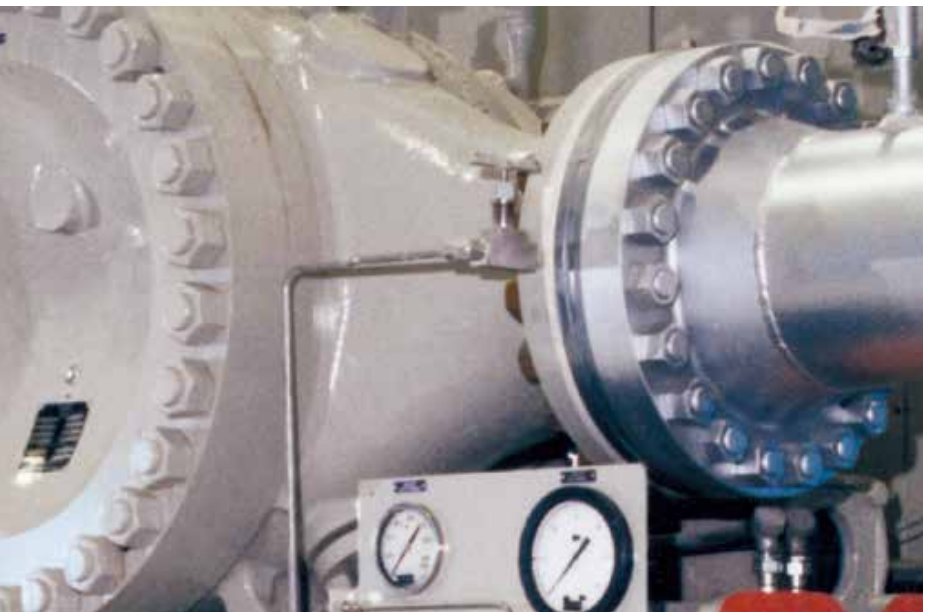
Siemens multi–stage, vertically split centrifugal barrel compressors are used in natural gas gathering, storage, gas lift and reinjection service worldwide. Aerodynamic efficiency, performance flexibility and high reliability are characteristic of Siemens barrel compressors. Sized to meet a wide range of flow and pressure requirements in continuous, full–load operation, they offer high dependability, even when handling natural gases containing large amounts of hydrogen sulfide, carbon dioxide and water.

Over 740 barrel compressors have been built, with more than 500 units installed in natural gas handling applications, including over 60 units designed for sour gas service. In high pressure reinjection, there are standard Siemens designs up to 4,500 psig (310 barg) maximum working pressure.

Compressor Packages

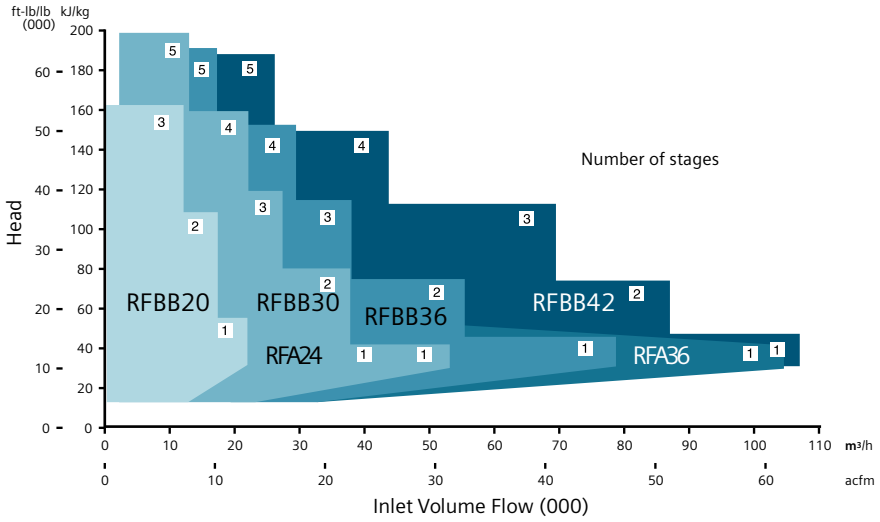
Siemens is an experienced packager of complete compression systems, including modules for offshore compression. Custom designed units are available for harsh arctic, offshore and desert environments.

Siemens acquired the Rolls-Royce aero-derivative gas turbine and compressor business effective December 1, 2014. References to Siemens and products are intended to refer to such business as acquired and incorporated into Siemens as from such effective date.

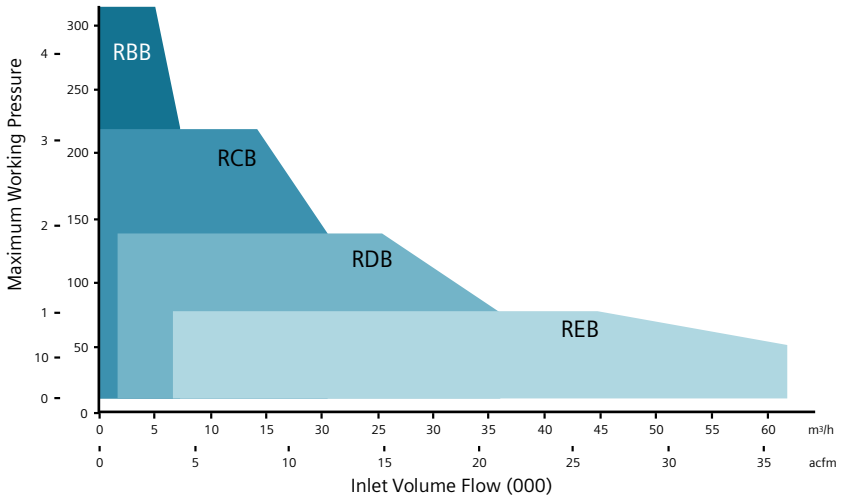


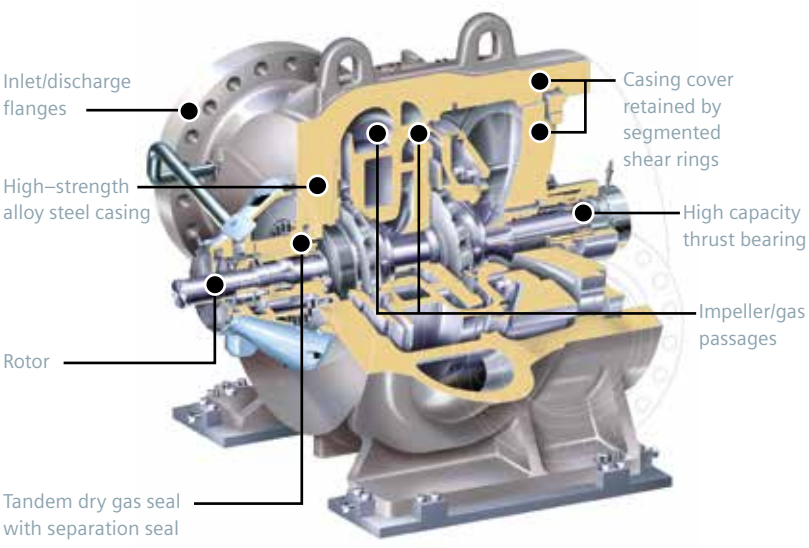
"Engineered for peak aerodynamic efficiency, Siemens pipeline compressors are installed on most major natural gas pipeline systems throughout the world."

Pipeline Compressors



Barrel Compressors





Pipeline compressors

Design advancements have resulted in Siemens conventional pipeline compressors delivering up to 90 percent efficiencies, while the RFA achieves up to 91 percent. Siemens compressors are designed to API 617 for the widest customer acceptance. State–of–the–art aerodynamic engineering of the entire gas path provides peak efficiencies while providing a wide operating map.

Siemens conventional pipeline centrifugal compressors can accommodate up to five compression stages for higher head applications.

- Six standard frames have flange sizes from 20 to 42 inches (510 to 1,070 mm).
- Design inlet flows range from 1,000 to 62,800 acfm (1,700 to 106,500 m^3/h).
- Pressure capabilities up to 3,220 psig (222 barg). Power ratings up to 75,000 hp (56,000 kW) at design speeds from 3,600 to 13,800 rpm.

Applications

Many units are adapted to perform efficiently in a variety of unique duties not limited to pipeline applications, including:

- Major oil and gas customer operates a 40 MW synchronous motordriven RF3BB42 compressor with variable inlet guide vanes at the output end of their gas plant in Alberta, Canada to boost pressure up to pipeline levels.
- Series/parallel gas storage units for a Canadian gas transmission company, each with tandem or triple pipeline compressors driven by an Industrial RB211 gas turbine.
- 4, 10, 18, and 30 MW pipeline compressors in North American transmission service, driven by variable speed, synchronous motors.

RFA36 and RFA24

The RFAs are the most efficient, proven pipeline compressors in service to date, featuring axial inlet, tangential discharge and a single–stage, spherically shaped cast casing.

They are compact, rugged units that weigh only two–thirds as much as a conventional compressor. The casing is typically cast from high–strength alloy steel. To minimize downtime, the aerodynamic and bearing/seal assemblies are removed toward the coupling end leaving the main piping undisturbed.

Journal and thrust bearings are of the tilting–pad type. For highest capacity, the bearings use individually lubricated pads to reduce bearing temperature and increase reserve capacity.

"Standard casings are cast to offer generous flow passages and a near spherical shape for compactness, high strength and top performance."

Conventional designs

Siemens conventional beam–style pipeline compressors offer high head capability through the use of multiple impellers and minimizes parasitic losses and starting torque requirements whilst maintaining very high efficiencies.

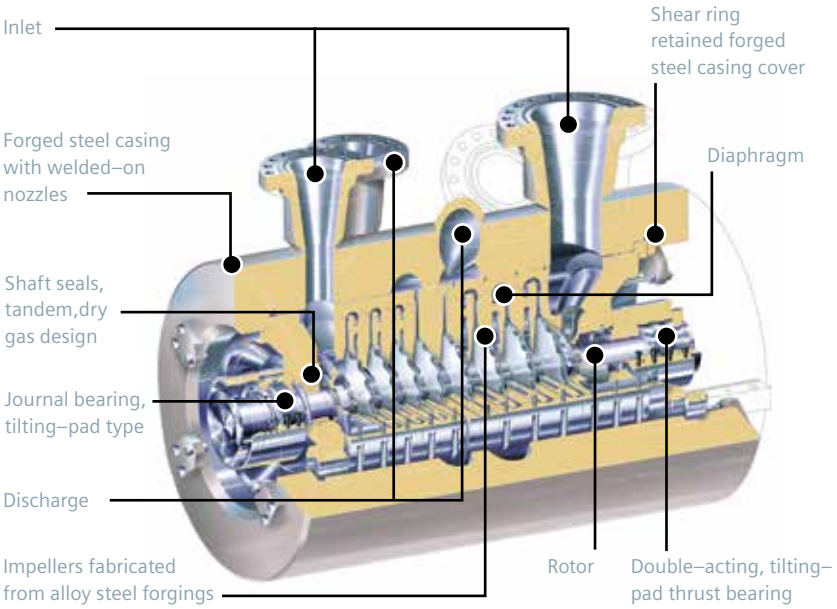
Impellers are designed for maximum aerodynamic efficiency and constructed of high–strength, forged alloy steel. All impellers are fully shrouded and welded design or are single piece milled design. Impellers are followed by a vaned or vaneless diffuser and a carefully–matched cast volute. On most frame sizes, movable inlet guide vanes are available for increased flexibility with fixed– or variable–speed drivers. Special materials are available for corrosive applications.

Standard casings are cast to offer generous flow passages and a near spherical shape for compactness, high strength and top performance. Main flanges are horizontally opposed to neutralize pipe forces and movements. Shear ring segments or bolts retain the main cover. Magnetic bearings are available as an option.

Impellers are tested to 115 percent of maximum design speed, while casings are hydrostatically tested to 150 percent of design working pressure.

Model	RFBB20	RFA24	RFBB30	RFBB36	RFA36	RFBB42
Maximum working pressure, psig (barg)	2,000 (140)	2,000 (140)	3,220 (222)	2,250 (155)	1,800 (125)	1,500 (105)
Max flange size, inches (mm)	20 (510)	24 (610)	30 (760)	36 (910)	36 (910)	42 (1,070)
Number of stages	1–4	1	1–5	1–5	1	1–5
Maximum power, BHP (kW)	20,000 (14,900)	20,000 (14,900)	75,000 (56,000)	75,000 (56,000)	50,000 (37,300)	75,000 (56,000)
Design speed range, rpm	9,000–13,800	9,000–13,800	3,600–8,000	3,600–6,666	3,600–9,500	3,600–6,666
Impeller diameter, inches (mm)	10–26 (250–660)	12–26 (305–660)	20–35 (508–889)	24–51 (610–1,295)	24–51 (610–1,295)	24–51 (610–1,295)
Max design inlet flow, acfm (m^3/h)	12,720 (21,600)	25,300 (43,000)	30,800 (52,300)	45,400 (77,100)	60,500 (102,800)	62,800 (106,500)

NOTE: Specifications given in this brochure are subject to change without notice.



Multi–stage barrel compressors

Siemens barrel compressors are available in four frame sizes with up to nine compression stages. Standard configurations are available up to 4,500 psig (310 barg) maximum working pressures and up to 35,000 acfm (60,300 m3/h) flows. Power ratings up to 75,000 hp (56,000 kW) at design speeds from 3,500 to 13,800 rpm.

Applications

Siemens centrifugal barrel compressors are found in a variety of natural gas compression applications. Installations range from single units to multiple–unit trains, driven by gas turbines or electric motors. Complete systems for onshore or offshore service are designed, manufactured, tested, installed and supported by Siemens

Each compression project is analyzed to select the most aerodynamically flexible and efficient frame and rotor combination. For optimum performance and production economy, each barrel frame size is based on families of standard stages.

Vaneless or vaned, parallel–walled diffusers are used for maximum performance. Aerodynamic thrust loads are compensated by balance drums or center seals. Each rotor system is custom designed, based on extensive analyses of lateral and torsional response to maximize operating reliability.

Casings are forged with welded–on nozzles. For ease of maintenance, the new configuration joins the end covers, aerodynamic and rotor assemblies, as well as the bearings and seals into a single cartridge that can be installed and withdrawn as one piece. The cartridge is retained in the casing using segmented shear rings to avoid the need for hydraulic torquing equipment. It is estimated that a full cartridge change–out can be accomplished in less than 24 hours.

Shaft seals are available as tandem dry gas type or wet film bushing seals. The dry gas seal designs include buffered barrier seals to prevent their contamination by lube oil.

Journal and thrust bearings, with horizontally split housings to improve maintainability, are of a tilting–pad type with renewable pads and collars. All thrust bearings accept equal thrust loading in either direction and are self leveling.

Impellers are tested to 115% of maximum design speed, while casings are hydrostatically tested to 150% of design max working pressure.

"For ease of maintenance, the new configuration joins the end covers, aerodynamic and rotor assemblies, as well as the bearings and seals into a single cartridge that can be installed and withdrawn as one piece."

Shear rings removed

Single cartridge design for easier removal

Cartridge removed

Model	RBB	RCB	RDB	REB
Maximum working pressure, psig (barg)	4,500 (310)	3,220 (222)	2,000 (140)	1,200 (85)
Max flange size, inches (mm)	16 (405)	20 (508)	24 (610)	30 (762)
Max discharge flange size, inches (mm)	12 (305)	16 (406)	20 (508)	20 (508)
Number of stages	1–9	1–9	1–9	1–9
Maximum power, BHP (kW)	35,000 (26,100)	50,000 (37,300)	60,000 (44,700)	75,000 (56,000)
Design speed range, rpm	8,000–13,800	5,000–11,500	4,500–8,500	3,500–6,500
Impeller diameter, inches (mm)	12–17 (305–432)	18–22 (458–560)	24–28(610–711)	28–34 (711–863)
Max design inlet flow, acfm (m^3/h)	6,000 (10,200)	13,500 (23,000)	22,000 (37,000)	35,500 (60,300)

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String test performed on Industrial RFBB36

Package equipment

Centrifugal compressors engineered to suit gas and steam turbines, and fixed– or variable–speed electric motors

Siemens works with our customers from project planning and manufacturing to installation and service. Our comprehensive compressor systems include drivers, package components, baseplates, speed increasers and oil consoles.

Lube and Seal Oil/Seal Gas Systems

Siemens generally provides lube and seal gas systems on all units. Seal oil instead of dry gas seal systems are also available. The systems include pumps, motors, coolers, filters and instrumentation selected to provide and monitor the required oil flow and pressures. The lube oil and gas seal systems are in general compliance to API 614.

Controls

Complete microprocessor–based control systems are provided for individual units, multiple units and station control.

Our quality standards are exemplified by our ISO 9001 certification. Factory testing includes a full closed–loop system simulation that tests the operation of the hardware and the software for functionality and dynamic response.

Control systems include:

- Integrated control of gas turbine or motor driven compressor packages
- Complete unit sequencing of the driver, accessories and compressor
- Complete unit monitoring and protection
- Equipment Health Management
- Compressor surge protection
- Compressor load sharing
- Compressor suction or discharge control
- Data communication
- Interface with DCS systems
- Installation supervision, commissioning and training

Training programs are available that instruct users on the operation of their control systems and provide insight into how the controls interact with the mechanical equipment and process. Control systems are supported by a global Technical Support and Field Service organization.

“Factory testing includes a full closed–loop system simulation that tests the operation of the hardware and the software for functionality and dynamic response.”

Worldwide manufacturing, testing and sourcing

Centrifugal compressors manufactured by Siemens are tested and packaged at its Mount Vernon, Ohio facility.

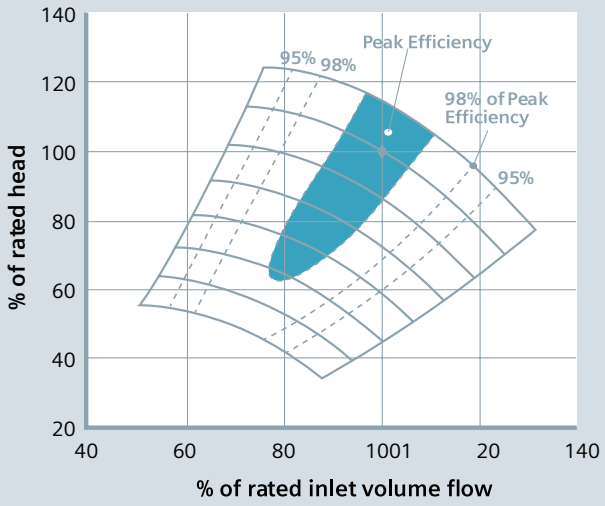
Impellers undergo fabrication and heat treatment to provide high durability and strength.

All critical components and the assembled unit receive thorough testing during and after manufacture. Impellers are balanced, then over–speed tested at 115 percent of maximum operating speed. Casings are tested for leaks, strength and design integrity in compliance to API 617.

Aerodynamic performance is proven through open– or closed–loop testing to confirm achievement of the contract efficiency, head and flow of the compressor at specified design and operating points. Full–load and full pressure Type 1 and Type 2 testing to ASME PTC 10 standards is also available.

The finished unit receives a final mechanical running test that includes a check of oil flows and vibration levels throughout the specified speed range. A static gas seal test confirms that all components will satisfactorily contain gas at the system’s rated pressure.

Typical Head-Flow Performance Curve for a Pipeline Compressor



Customer service and aftermarket support

Capabilities

Our customer service organization is built on the long–term commitment of Siemens to the successful operation and maintenance of customer power and compression equipment. With experienced field representatives and service centers worldwide, Siemens provides the technical support for unit commissioning and operation, as well as repair services, including contract maintenance.

Our genuine OEM replacement parts inventory and special diagnostic equipment keep our centrifugal compressors operating at top performance regardless of the application. An example of Siemens' commitment to providing complete life–cycle solutions is compressor "re–aero" services.

Re–Aero Services

Siemens compressor components are custom selected / designed to provide optimum performance at specific operating and site conditions. Often field conditions change over time. Even slight process condition changes may require an existing compressor to operate far enough from the original design point to warrant a new compressor aero design or upgraded components. For example, a small decrease in compressor efficiency can result in excessive fuel costs. Also, re–aero of an existing unit offers the opportunity to incorporate the latest aero design advancements for improved performance and efficiencies throughout the operating range. Siemens Customer Service Support staff will expertly evaluate your current compressor operating conditions and help identify opportunities to enhance efficiency. With the expertise to rebuild or replace the compressor aero components to restore maximum efficiency levels, Siemens can extend the life of your equipment investment far into the future.

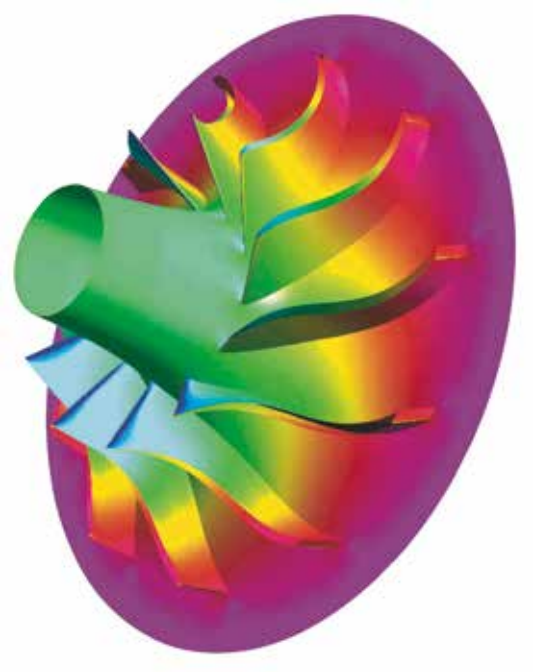
"Our genuine OEM replacement parts inventory and special diagnostic equipment keep our centrifugal compressors operating at top performance regardless of the application."

Experience combined with technology

The advancements of our centrifugal compressors come from more than 65 years of aerodynamic and mechanical design derived in part from the rich heritage of designing, manufacturing and servicing compressors under the Cooper–Bessemer® brand name. This legacy is now combined with the expertise behind one of the world's most respected names in engineering: Siemens.

State–of–the–art computer analysis continues to enhance efficiencies and long–term product integrity:

- Three–dimensional finite element analyses for stress optimization of casings, impellers, thrust balance drums and diaphragms.
- Lateral rotor dynamic programs, analyze rotor response and stability.
- Forced and unforced torsional programs analyze the complete driver and driven systems.
- Fluid dynamic programs accurately predict compressor performance under specified operating conditions and gas mixtures.
- Three–dimensional CAD/CAM systems and CFD analysis aid the optimization and refinement of compressor aerodynamic designs while reducing lead times.



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