



GE Power Systems

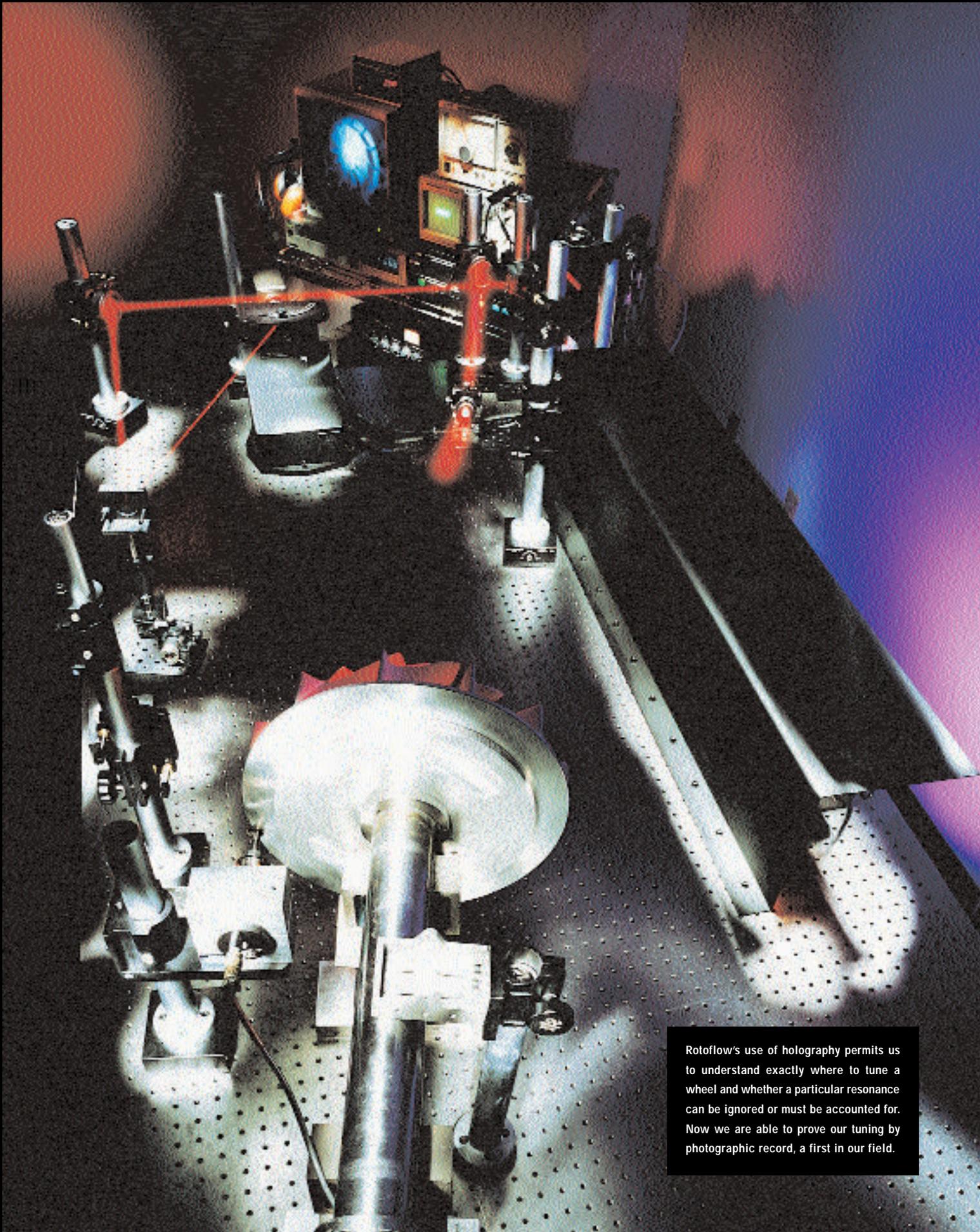
Oil & Gas

Rotoflow



Expanding Your Plant's Success

Rotoflow turboexpanders for hydrocarbon applications



Rotoflow's use of holography permits us to understand exactly where to tune a wheel and whether a particular resonance can be ignored or must be accounted for. Now we are able to prove our tuning by photographic record, a first in our field.

A ROTOFLOW TURBOEXPANDER EXPANDS YOUR PLANT'S PROFITS

*Rotoflow pioneered the
use of the turboexpander in
the natural gas processing industry.*

John Wilkinson
The Ortloff Corporation

The Rotoflow edge: High efficiencies

Over the past 40 years we have been in service in the hydrocarbon area and our turboexpanders have won awards for their technology innovations and superior design.

Superior technology, however means nothing unless it delivers superior performance. And that is just what we pride ourselves on: the ability to manufacture the highest horsepower expander/compressors, and the ability to deliver up to the highest efficiencies in the industry - no matter what the process conditions.

Our high efficiencies are obtained through state-of-the-art design, the latest engineering and manufacturing tools, and 40 years of experience.

What does this mean to you? It means you can count on extra liquid recovery and compressor boost.

It means that when working with a large machine, our high efficiency can bring many thousands of dollars in savings per year as well as increased production for your company.

In natural gas applications, our turboexpanders

deliver top efficiency for cryogenic natural gas processing, such as dew point control, NGL recovery, ethane recovery and LNG production.

For petrochemical applications, our turboexpanders

offer far more refrigeration than a pressure reduction valve. Our high efficiencies result in hydrogen purification and liquefaction capabilities that will increase your liquid recovery.

Our turboexpanders can also be used to de-bottleneck flow, which in turn delivers more output. It's the ideal solution for LPG or ethylene recovery, MTBE and CO processing.

In gas pressure letdown applications, our turboexpanders

are exceptionally efficient for energy recovery from pressure reduction of large - volume gas streams to power plants.

A LITTLE ABOUT THE HISTORY OF ROTOFLOW IN TURBOEXPANDERS

Rotoflow has been, from the start, both the pioneer of and the leader in turboexpander technology in natural gas applications.

Dr. Judson S. Swearingen, founder of Rotoflow Corporation, Inc., initiated the program for building and operating the first hydrocarbon turboexpander.

ROTOFLOW OFFERS THE WORLD'S BEST HYDROCARBON TURBOEXPANDERS

Flexibility to handle changing plant conditions

Because our turboexpanders can handle such a wide operating range, we are able to maintain high efficiencies regardless of application.

Additionally, our unique, standard, stiff-shaft design means we are able to operate at any speed (from zero to maximum continuous speed), which further optimizes your process.

The broadest range of turboexpander products

Because of the years of experience we have in the hydrocarbon industry, we are able to quote on virtually any turboexpander application.

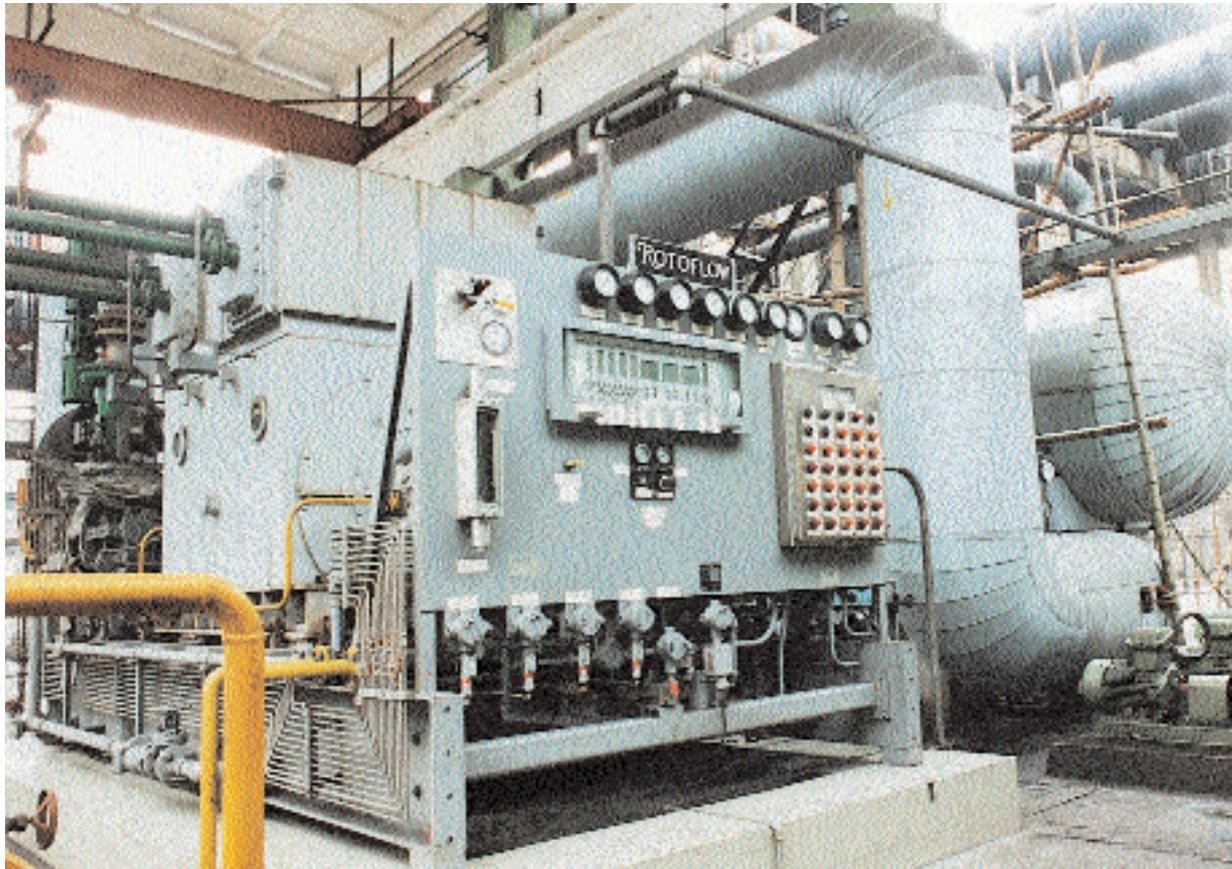
Our engineers and service personnel

are well-versed in process engineering and can recommend the right design and functionality to get the most out of your application.

TURBOEXPANDERS FOR HYDROCARBON APPLICATIONS

Inlet pressure:	up to 200 bar a (3,000 psia)
Inlet temperature:	-270° to 475°C (-450° to 900°F)
Inlet flow:	up to 500,000 kg/h (1,100,000 lb/h)
Speed:	up to 120,000 RPM
Gases handled:	All hydrocarbons including natural gas, ethylene, tail gas, H ₂ , CO, etc.

This expander/generator is installed in China's largest chemical coking plant and is used in a trigeneration process. The process provides 450,000 cubic meters of gas per day and one MW of electrical power.



The highest number of turboexpander references of any company

We've built over 3,500 quality units for a wide range of applications making it likely that our experience includes applications similar to yours. We are happy to furnish you with references.

ISO9001 Certification and EC Declaration of Conformity

Rotoflow recently received the European Community (EC) "Declaration of Conformity", a status that ensures that our turboexpanders conform to all relevant essential health and safety requirements of the Member States' Council relating to machinery.

When you buy a Rotoflow turboexpander, you can be sure that all quality standards have been met for ISO9001 certification.

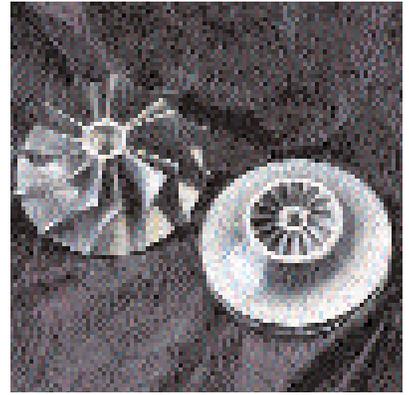
Continuous high availability with very low maintenance

We know that continuous operation with minimum maintenance and downtime is essential to your plant's profitability. Rotoflow turboexpanders are designed and engineered for a long and relatively maintenance-free operational life. The dynamically-balanced center section can be easily replaced or disassembled for inspection by operating personnel.

This expander/compressor has been installed in a Thai gas separation plant, to supplement another one which has been working continuously since 1985.



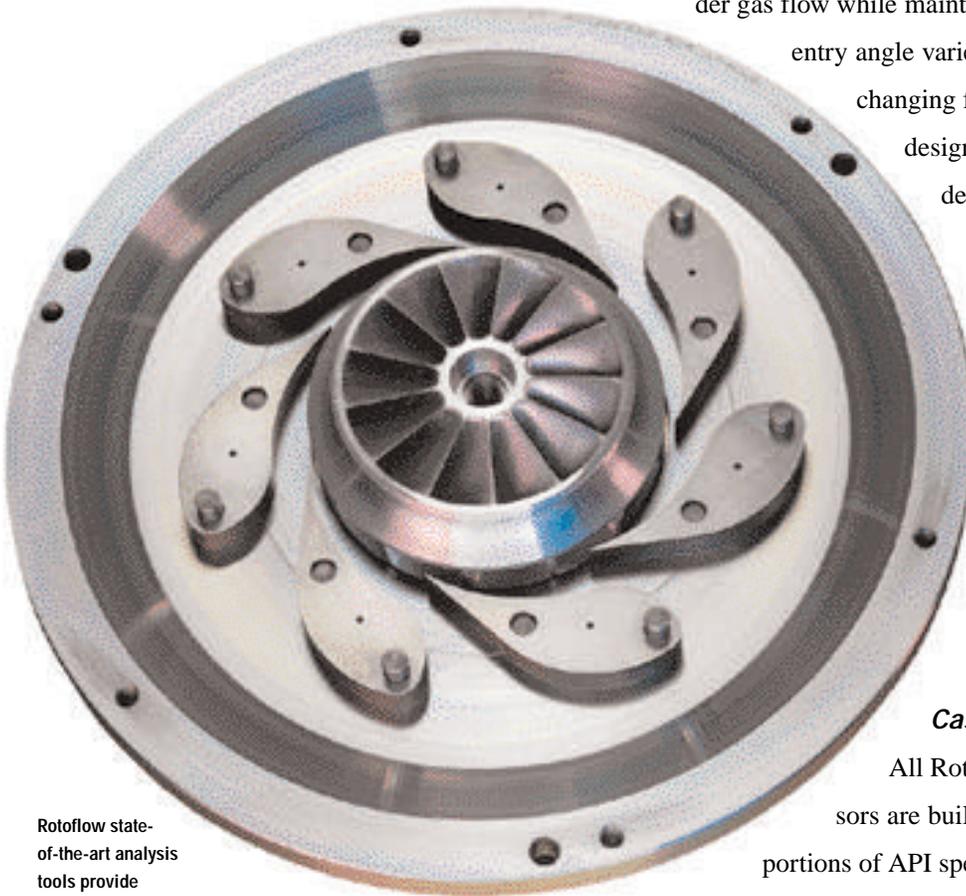
**MORE REASONS
TO "EXPAND" YOUR
BUSINESS WITH ROTOFLOW**



Variable flow nozzles

Rotoflow's patented variable flow inlet nozzles control the turboexpander gas flow while maintaining high operating efficiency. The entry angle varies in accordance to a wide range of changing flows. The flow control nozzle is designed to open well above the operating design point for start-up or emergency conditions.

The most prominent feature of Rotoflow's nozzle assembly is the elimination of blow-by and thus, no loss of efficiency. The entire nozzle assembly is located in the cold section and is isolated from the warm bearing housing by a thermal barrier.



Rotoflow state-of-the-art analysis tools provide for high-efficiency nozzle design.

Casings

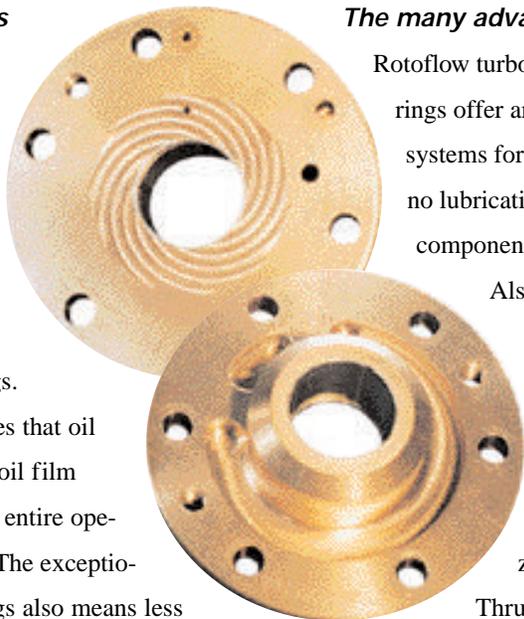
All Rotoflow turboexpanders and compressors are built to meet or exceed the applicable portions of API specifications with necessary exceptions. Our casings are hydrotested at 1.5 times the design pressure (within the limits of the design temperature range).

Advanced turboexpander wheel technology for maximum reliability

Wheels for Rotoflow turboexpanders are cast or milled out of aluminum, titanium or stainless steel to computer-generated profiles. All wheels are dynamically balanced and dye-penetrant inspected before and after over-speed testing to verify mechanical integrity. Open or closed wheel designs are available, depending on your specific application.

Single piece radial bearings

Two single piece journal type radial bearings are used to support the expander/compressor shaft. This patented, Rotoflow bearing design provides increased wear allowance and nearly nine times the oil film strength of conventional bearings. This exceptional stiffness ensures that oil whirl (half-speed gyration) and oil film resonance do not occur over the entire operating range of speed and flow. The exceptional strength of Rotoflow bearings also means less sensitivity to imbalance and a greater ability to withstand deposits on the wheels, such as ice or solid CO₂, and imbalance due to dust accumulation or wear. Tilting pad bearings are also available.



Spiral groove thrust bearings

Spiral grooves on the thrust bearings produce a strong hydrodynamic effect for high load-bearing capability.

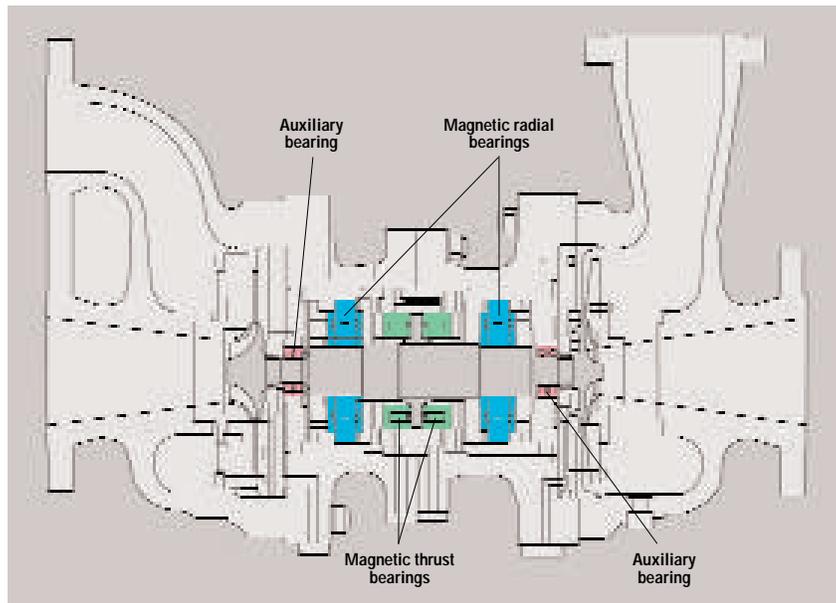
The many advantages of magnetic bearings

Rotoflow turboexpanders with active magnetic bearings offer an alternative to conventional oil bearing systems for many applications. Since they require no lubrication, you won't need any oil system components, pumps, filters, coolers, etc.

Also, the risk of process contamination is eliminated.

In an expander/compressor with magnetic bearings, the rotor assembly is supported by active magnetic radial bearings at each end, and a centralized active magnetic thrust bearing.

Thrust handling capabilities of Rotoflow turboexpanders with active magnetic bearings are enhanced by an automatic thrust control system. An electronic control system controls the position of the rotor by adjusting current to the electromagnets in response to signals from shaft position sensors. Sensors are combined to automatically cancel rotation signal harmonics, or elliptical or triangular deformation on the rotor surface.



ROTOFLOW'S TURBOEXPANDERS' STATE-OF-THE-ART DESIGN

1 Stiff shaft rotor design

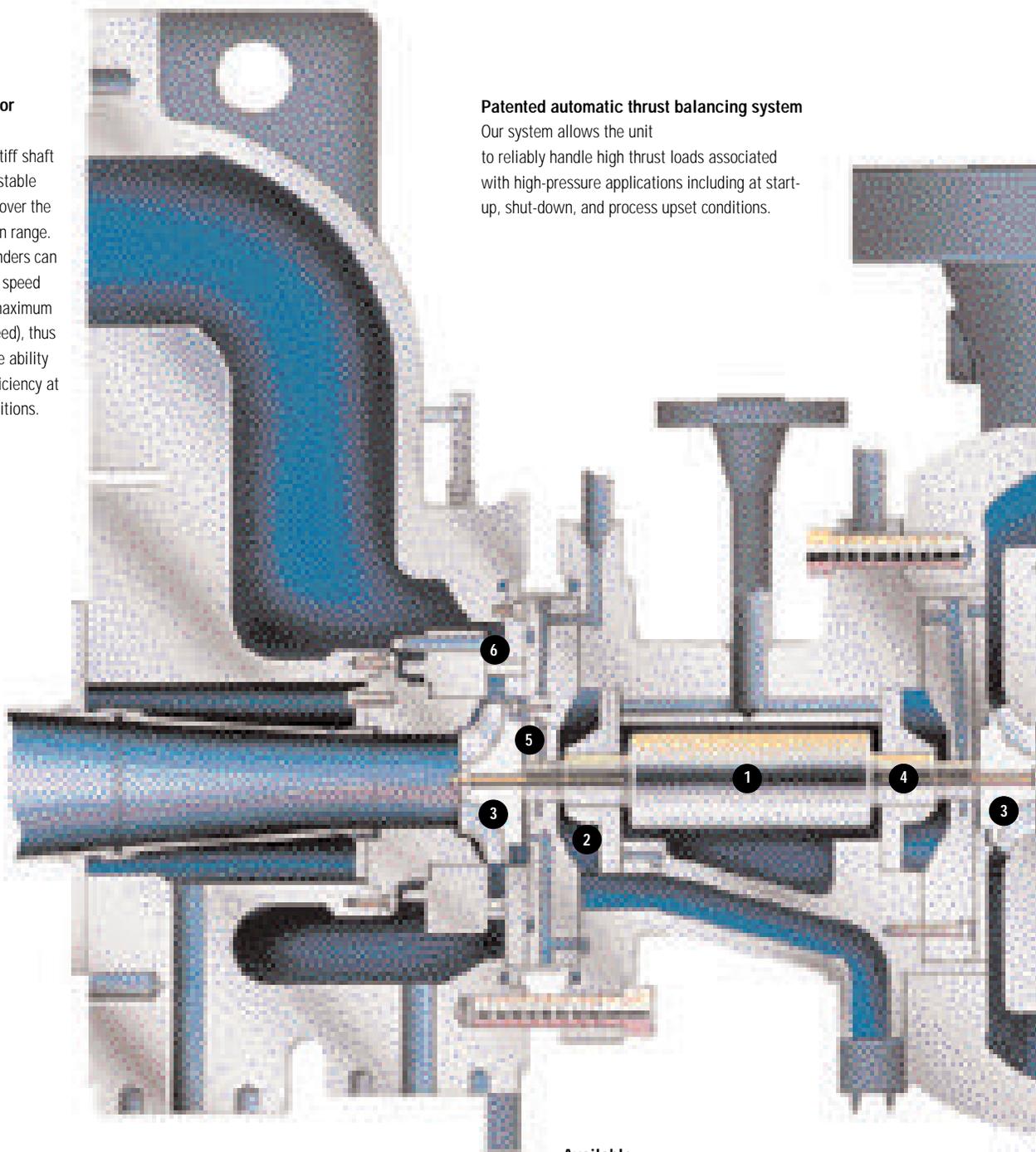
Our standard stiff shaft design means stable rotordynamics over the entire operation range. Our turboexpanders can operate at any speed (from zero to maximum continuous speed), thus giving them the ability to optimize efficiency at turndown conditions.

2 Fixed geometry bearings

Rotoflow patented bearings have lower clearance requirements than others, thus decreasing seal leakage losses.

3 High efficiency gas dynamic turboexpander and compressor wheels

Rotoflow machines have shown better prediction and higher efficiencies than other turboexpanders. Part of this success lies in the quality of our wheel designs. Each wheel is individually analyzed by advanced software which transforms precise blade curvature geometrics into ideal finish surfaces.



Patented automatic thrust balancing system

Our system allows the unit to reliably handle high thrust loads associated with high-pressure applications including at start-up, shut-down, and process upset conditions.

Wheel design to handle liquid formation in the wheel

This ensures minimal efficiency degradation or any effect on unit reliability.

Thrust bearings

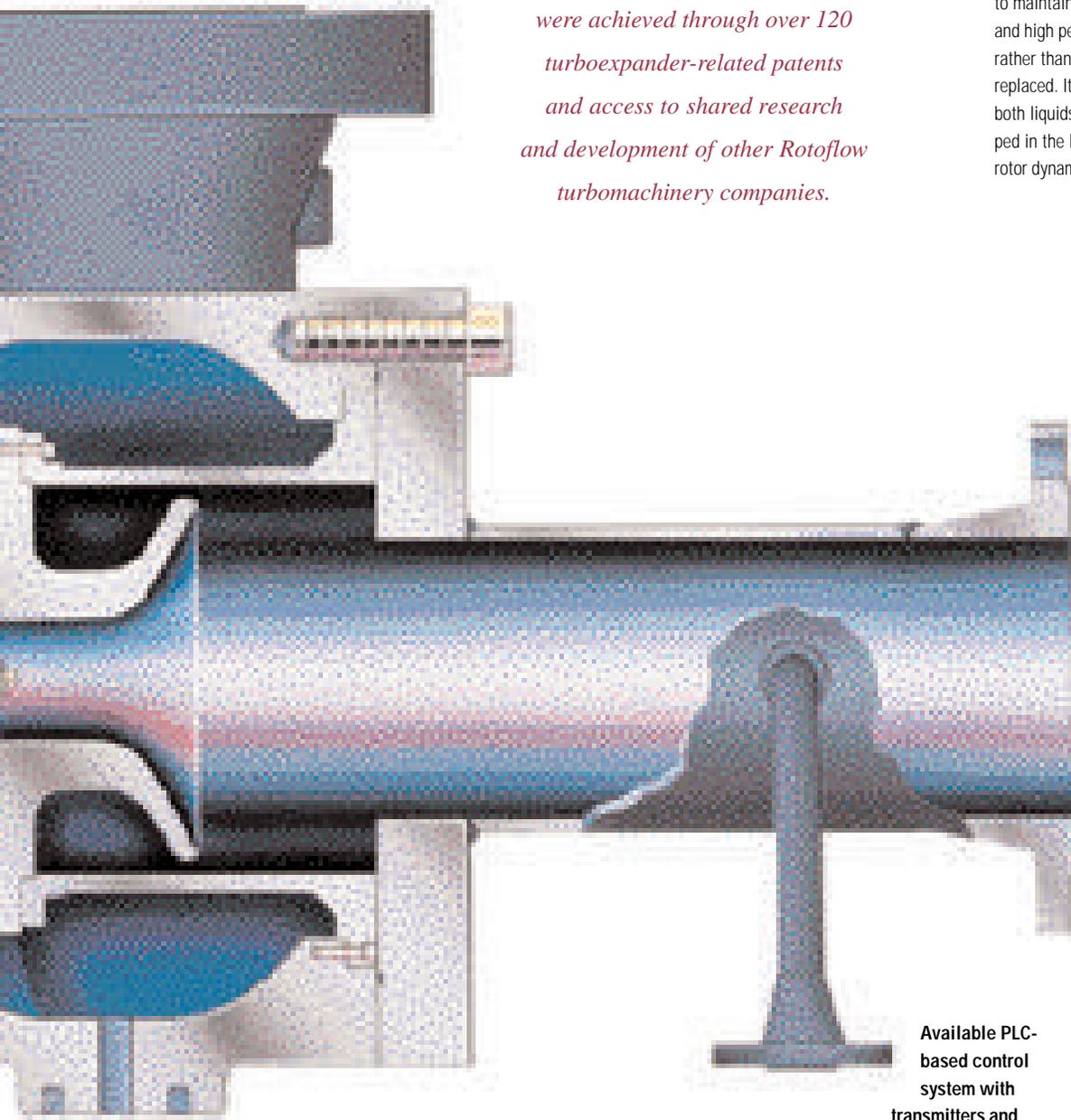
Our standard spiral-groove thrust loads are designed to take full thrust loads under any conditions (start-up to upset) for the utmost reliability.

Available patented drainer system for pre-boost applications

These minimize the process and seal losses by recovering gas at a high pressures. Dry gas seals are also available.

High compressor turn-down ratio

The compressor minimizes wasted energy by providing the highest pressure ratio at turn-down conditions with reduced need for recycling.



We did not come by our award-winning designs lightly. Our high quality designs were achieved through over 120 turboexpander-related patents and access to shared research and development of other Rotoflow turbomachinery companies.

4 Patented conical shaft seal design
This design allows for seals to be simply shim-adjusted to maintain low seal losses and high performance, rather than be immediately replaced. It also prevents both liquids from being trapped in the labyrinth and any rotor dynamic disturbances.

5 Patented dust-free seal design
This design reduces the probability of wear from dust particles entering the back-wheel seal area.

6 Patented inlet nozzle design with no blow-by and optimal clamping force
This ensures higher unit operating efficiency and smooth flow control throughout the turboexpander operating range.

Available PLC-based control system with transmitters and RTD inputs
This feature provides for remote monitoring through a serial link with the customer's DCS as well as off-site monitoring through a modem.

Total turboexpander range of flows, gases, pressures, power, temperatures
Turboexpanders can be designed to operate within an extremely wide range to meet virtually any practical application requirement. Turboexpanders have been built to deliver up to 1,200 kW.

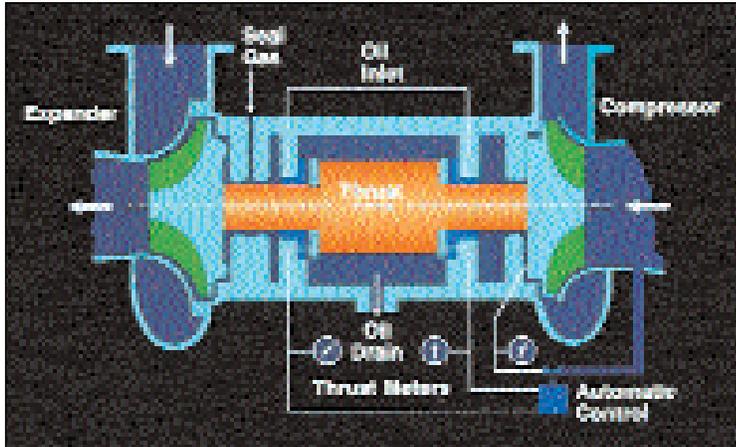
Pressures up to 200 bar
Turboexpanders can be designed to operate at pressures up to 200 bar (3,000 psi).

Temperatures
Rotoflow turboexpanders are routinely used to process gas streams ranging from +475°C (+900°F) to a few degrees above absolute zero.

Available patented oil viscosity monitoring system
This proprietary system monitors the rate of oil dilution without the need for frequent sampling.

Automatic thrust balancing system

The patented, Rotoflow system for automatic thrust load control is an active system which maintains the thrust loads well below the thrust



bearing capacity. Each thrust bearing is equipped with a special pressure tap that senses thrust-face hydrodynamic oil pressure, which is directly proportional to thrust load. The thrust-face pressures from these two opposing thrust bearings are applied to opposite sides of a hydraulic piston, which activates a quick-acting, compensating valve that adjusts the pressure behind the compressor wheel so that the front and back thrust bearing pressures are approximately equal and hence the rotor system is

in axial center position. A small bias is built into the system to prevent “hunting”.

A unique stiff-shaft design

Rotoflow turboexpanders can be built to incorporate a “stiff-shaft” design which ensures that there are no critical speeds through the entire operating range (minimum 20% above the highest operating speed). The shaft is machined from one solid piece of 17-4 PH stainless steel. Each shaft is individually balanced and includes a “shaft runout test”.

*The Rotoflow turboexpanders
run continuously,
24 hours a day at our refinery.
There's never a problem.*

Doug Bird, BP/Amoco

Instrumentation and control

Instrumentation systems are designed, fabricated and tested to meet our high quality standards. Solid state controls and annunciators are combined in a reliable, replaceable printed circuit board.

Rotoflow turboexpanders can also be configured with customized control systems, using solid state electronic circuitry to ensure safe, reliable machine control.

A full choice of sealing systems

(atmospheric and pressurized reservoir)

Adjustable seals employ a tapered-shaft conical labyrinth seal design. Seal clearance can be maintained by adjusting the axial position of the seal, a procedure not possible with other types of seals.

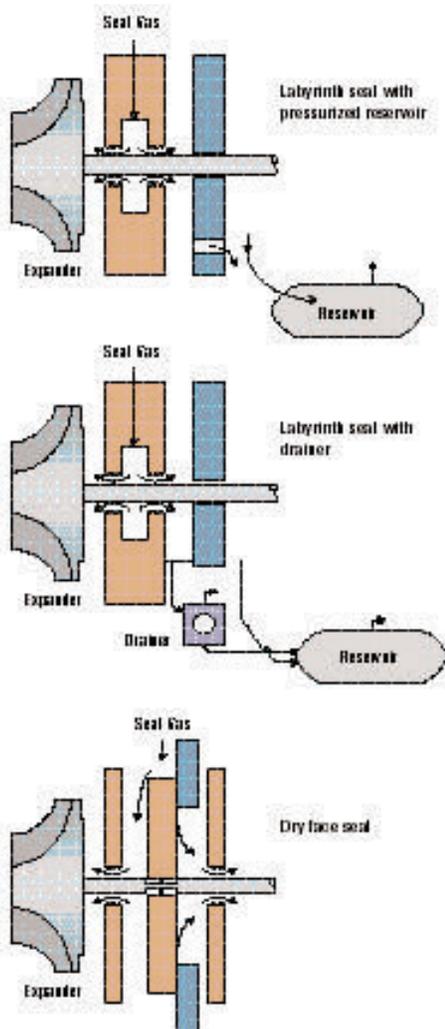
The turboexpander and compressor process gas pressures are sealed at the shaft by close-fitting, adjustable clearance, conical type labyrinth seals. A stream of compatible, warm, dry, pressurized seal gas is injected into the middle of the labyrinth seal at a pressure slightly higher than the process pressure behind the wheel. It is the flowing seal gas which retains the cold process gas within the cases and lube oil within the bearing housing.

Approximately half the seal gas will flow into the process and half the gas will flow into the bearing housing.

- Rotoflow’s patented “dust-free” seal which virtually eliminates erosion of the back-rotor and shaft seals. Without this special provision, such erosion is a common and serious problem.
- Rotoflow’s “drainer” seal which mixes seal gas and a small amount of bearing oil in a cavity behind the labyrinth seal. The oil/gas mixture is separated in a drainer to minimize dilution and eliminate the need for external oil degassing tanks. Seal gas is vented from the top of the drainer and can be recovered in a recovery system. Oil is returned to the lubrication system.
- Rotoflow’s “dry gas” seal minimizes leakage. The dry-gas seal can be applied in single or dual configurations. It is highly recommended when leakage can be hazardous and/or costly.

Lubrication systems

Rotoflow lubrication systems are an integral part of the turboexpander package. They ensure proper lubrication of all bearings at all times. Most systems are enclosed



and include pressurized reservoirs for gas conservation and safety. A patented continuous actual lubricant viscosity monitor at the bearing inlet is an optional feature.

Energy cost-saving applications

There are literally hundreds of applications where turboexpander can save you energy and recover electricity. For example, a combined service expander/compressor is ideal for any chemical plant which takes gas streams up to a certain pressure and brings those gas streams down to a lower pressure. By using a combined service expander/compressor (instead of a valve) to reduce pressure, you’ll recover much of the money you have already invested in that gas stream. Waste heat is another energy source that can be converted to useful energy

by using turboexpanders in organic Rankine cycle (ORC) systems. Potential heat sources include: tail gas from industrial furnaces or combustion engines, waste vapor from chemical and petro-chemical processes and solar heat from flat or parabolic collectors. Extraction of energy from geothermal resources offers a promising alternative to fossil fuels.

CONFIGURATIONS

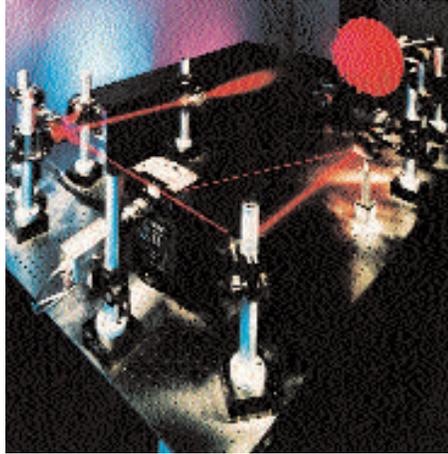
Turboexpander — Compressor
Turboexpander — Gear — Generator
Gear can be integral or separate.
Up to four stages of expansion can be mounted on a single gearbox.
Turboexpander — Dynamometer

Top engineering tools, testing and manufacturing equipment

Our state-of-the-art engineering and manufacturing processes result in optimal turboexpander design with high efficiency and reliability. Our rigorous testing procedures allow Rotoflow to maintain complete control over manufacturing of critical components, and provide short turn-around time in plant shut-down situations. Our unique test cell program tests for performance and our high-power overspeed tests each wheel at 115% of maximum continuous speed. In addition, state-of-the-art COMIG and MAX-5 software ensures that wheels are of the highest efficiency.



Laser holography machine



Service centers around the world

One of Rotoflow's main goals is to pro-

vide fully-equipped service centers accessible to our customers worldwide. Each service center handles all Rotoflow equipment. There you can find experts to handle such disparate services as:

- Dissassembly and reassembly of machinery
- Repairing and replacing of rotating parts

To find out more information on your nearest service center, call your Rotoflow Applied Compressor and Expander Technique local representative.

All the advantages of the Rotoflow network

Rotoflow is the company of choice to create and manufacture turboexpanders because we are the leading experts in both the compressor

and turboexpander technologies.

Our compressor and turboexpander divisions are one company, working seamlessly together, to combine and design our products effectively for the optimum performance and reliability you need.

Our customers are able to rely on the company's strong corporate commitment to customer satisfaction, as well as the company's worldwide financial stability / from contract execution to warranty.

The [Rotoflow] turboexpander converts energy into useful work which would be lost if we were using a JT valve.

Carl Kinney
Exxon Mobil



**ROTOFLOW SERVICE
CENTERS AROUND
THE WORLD.
THERE IS ONE CLOSE
TO YOUR INSTALLATION**

Process Proven Applications

Rotoflow turboexpanders provide cost-effective solutions for a wide variety of applications in hydrocarbon industries. Photos and captions on these pages illustrate several typical applications.

Three magnetic bearing expander/compressor units are installed in an on-shore natural gas processing plant where they are used in the dew point control process. The units are designed for 6,000 kW (8046 hp) at 7,000 rpm.



Turboexpander used to produce a cryogenic effect in a carbon monoxide production plant recovers energy to drive a booster compressor.



Turboexpander recovers 2,200 kW of energy from the natural gas liquefaction process circuit of a peak shaving plant in the Netherlands. Inlet pressure is 41 bar (600 psi). Outlet pressure is 11 bar (160 psi). Flow is 124,000 m³/h (73,000 ACFM).

Two turboexpanders reliquefy isobutylene gas in a Texas MTBE plant. The units take 6 bar (90 psig) 52°C (125°F) isobutylene gas and expand the gas to a -89°C (-125°F) temperature, where the gas condenses.



Rotoflow offers the widest range of Turboexpanders and Compressors

In addition to Turboexpander-Compressor Rotoflow offers a wide selection of Expander-Generator or Compressors for your applications:

- PL series: Turboexpander-integrally geared generator from 50-15,000 Kw to recover energy from pressure reduction;
- Boil-off compressors: Integrally geared Electric Motor (or other drivers) Driver Compressor for LNG loading/unloading facilities and LNG tankers;
- FB series: Integrally geared Compressors to boost fuel gas to gas turbines.



Two turboexpanders in this Hazira, India, LPG processing plant handle flows of 108,600 m³/h (64,000 ACFM) at inlet temperatures of -31°C (-24°F). A third turboexpander provides incremental chilling of feed gas at flows of 35,400 m³/h (20,890 ACFM).

*Please contact your GE Power Systems, Oil & Gas representative for detailed information
on turboexpanders and compressors for your applications.*

GE ROTOFLOW Inc.

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