

Engineering and Technical Services

Engineering Support • Technical Assessments
Equipment Performance Improvements



SERVICES AND SOLUTIONS

For the Global Infrastructure Markets

Flowserve Services and Solutions focuses on providing customers with uncompromising technical service and engineering support, wherever and whenever needed. Dedicated to delivering the highest quality support, Flowserve Services and Solutions integrates hydraulic, mechanical and materials engineering knowledge with creative equipment, system and business solutions.

A worldwide network of Quick Response Centers staffed by highly skilled engineers and technicians is available around the clock, seven days a week to respond to customer queries, to evaluate and troubleshoot problems and to provide reliable solutions with quantifiable business results.

INTEGRATED SOLUTIONS THAT SUPPORT THE COMPLETE LIFE CYCLE

Typically, 90% of the total life cycle cost (LCC) of a flow management system is accumulated after the equipment is purchased and installed. Flowserve offers a comprehensive suite of services and solutions designed to provide customers with unprecedented value and cost savings throughout the life span of the system.

- **Aftermarket Parts and Services**
 - Repair and maintenance
 - Replacement parts and components
- **Engineering and Technical Services**
 - Engineering support
 - Technical assessments
 - Equipment performance improvements
- **Education and Training**
 - Customer site
 - Learning Resource Center
 - Online
- **Asset Management and Optimization**
 - Business assessments
 - Asset data management
 - Asset optimization solutions





ENGINEERING AND TECHNICAL SERVICES FOR THE ENTIRE PROCESS SYSTEM

With an unrivaled stable of engineering and technical resources, Flowserve is uniquely positioned to deliver value-added solutions with the goal of improving operational performance and increasing revenues for its customers. The collective global resources of Flowserve offer customers a 360-degree view of the flow management system, from consulting during initial system design to ensuring safe, reliable and efficient operation of equipment over time.



Engineering Support..... **Page 6**

It's more than just equipment. It's a highly engineered system of machines and components. Flowserve engineers have the training and experience to consult on the most complex system issues. Whether in the early stages of construction or during system redesign, Flowserve engineers can be available on-site or remotely to ensure the proper sizing and application of equipment while also ensuring optimized system design. Services include:

- Front-end engineering
- On-site engineering



Technical Assessments **Page 8**

The performance of a flow management system can be measured in many ways, including throughput, energy consumption, uptime, environmental compliance and safety, all of which are components of the system's life cycle cost. Ensuring optimum performance against these interconnected parameters requires expertise. With a dedicated team of more than 150 solutions engineers, Flowserve can perform comprehensive assessments aimed at continuously improving all aspects of the process system. Technical assessments include:

- System
- Energy
- Bad actor
- Safety, health and environmental



Equipment Performance Improvements **Page 12**

In any plant environment, conditions can change very quickly or over extended periods of time. From a sudden increase in production requirements to gradual system degradation caused by wear and corrosion, Flowserve engineers wrote the book on equipment improvement, with an unprecedented track record of solutions with impressive economic paybacks. Flowserve routinely delivers tailored solutions such as:

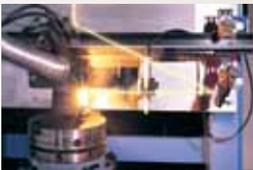
- Component or assembly exchange programs
- Mechanical and metallurgical upgrades
- Hydraulic re-rates and upgrades
- Dry gas seal retrofits

FOCUSED on Technology and Problem Solving



The Flowserve focus on the complete process system starts with an unparalleled commitment to building the industry's best engineering and technology organization. Flowserve boasts more than 1500 engineers trained and organized to address every aspect of the pumping system, with emphasis on either aftermarket or new equipment competencies. Experienced specialists from both aftermarket and new equipment engineering are hand-picked to join Virtual Centers of Excellence (VCOE). As a VCOE member, an engineer is responsible for maintaining and building Flowserve competencies in one of five technology areas:

Flowserve Technology Focus

<p>Hydraulic Engineering</p> 	<p>Flowserve engineers use computational fluid dynamics (CFD), flow visualization and cutting edge numerical techniques to study cavitation, optimize hydraulic designs and maximize pump performance.</p>
<p>Mechanical Design</p> 	<p>Computerized models help predict stresses and vibrations in existing and new designs to ensure reliable operation in severe applications and extended design envelopes.</p>
<p>Mechatronics</p> 	<p>The integration of electronics, mechanical engineering, sensors, actuation and computer technology allows data gathering, diagnostics, prognostics and intelligent equipment control.</p>
<p>Materials</p> 	<p>An unparalleled legacy of materials science capabilities continues with the development of advanced materials, laser-applied coatings, plasma coatings and weld overlays to increase wear and corrosion resistance.</p>
<p>Mechanical Analysis</p> 	<p>The use of rotor dynamics and finite element analysis mitigates equipment operation issues caused by mechanical stress, deflection, vibration and natural frequencies.</p>

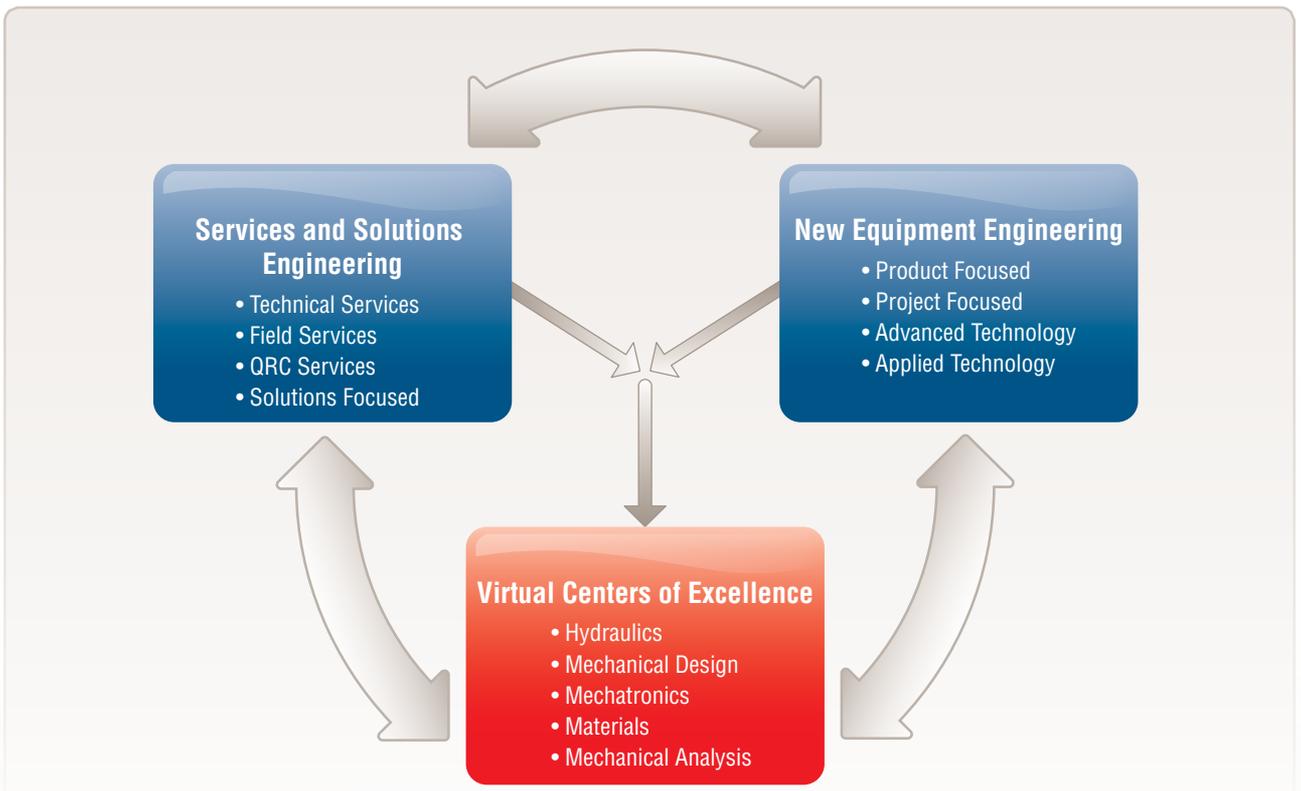


A DYNAMIC TEAM FOR ANY TECHNICAL CHALLENGE



No two system challenges are the same. And oftentimes, system issues can arise unexpectedly, requiring quick response and resolution to mitigate production losses or environmental risks. The Flowserve engineering organization is built for quick and efficient assignment of the most appropriate resources, whether deployed from a Quick Response Center (QRC) or an engineering center. Resources from aftermarket, new equipment and technology groups can remotely synchronize with the customer to analyze and resolve issues or can be deployed on-site for extended periods if necessary.

Flowserve Engineering Organization



ENGINEERING Support



Customers are under increasing pressure to complete projects cheaper, smarter and faster. Flowserve can provide the resources to manage even the most complex project from start to finish.

Globally deployed in more than 55 countries, Flowserve engineers can engage remotely or on-site to support grass roots project planning, system design or project management requirements.

The Flowserve Engineering Advantage



Resources and Qualifications

- More than 500 Services and Solutions engineers
- More than 1000 new equipment engineers
- Globally deployed in over 55 countries
- Formal recruiting program to obtain talent with advanced degrees
- Six Sigma training option
- More than 140 Quick Response Centers
- Eight global engineering hubs



Key Technologies

- Computational fluid dynamics (CFD)
- Flow visualization
- Erosion modeling
- Rotor dynamics analysis
- Pipe flow analysis
- Thermodynamic modeling
- Computer-aided mechanical design
- State-of-the-art test loops
- Process and system simulations
- State-of-the-art data acquisition systems
- Special field performance tools



ENGINEERING SUPPORT OFFERINGS



Front-End Engineering

Whether in the pre-procurement phase of new construction or in the midst of a process change implementation, Flowserve can provide front-end services to maximize long-term performance and reliability. Typical front-end services include:

- Systems analysis and optimization
- Material selection and testing
- Debottlenecking
- Energy efficiency optimization
- System design
- Predictive modeling and simulation
- Carrying inventory optimization



On-site Engineering

Large scale projects such as plant commissioning, critical equipment overhauls or energy improvement initiatives require resource planning, timeline management and budgeting services. Also, specific expertise concerning equipment design and operation is often required. Flowserve on-site project managers and engineers help customers successfully see projects to completion.

Flowserve can provide experienced engineers to complement plant resources or to serve as project managers. Customers often contract with Flowserve to provide permanent on-site rotating equipment experts who serve as the go-to resource for complex pump and pumping system issues. This permanent on-site resource provides a direct conduit to the entire network of technology resources throughout Flowserve.



TECHNICAL Assessments



GETTING TO THE ROOT CAUSE

Flowserve engineers perform comprehensive pump system audits to identify design weaknesses, reliability-availability and other operational issues. Operating and historical data are analyzed. Modeling and technology-aided tools pinpoint problems. Solutions, recommendations and economic justifications are offered based upon life cycle cost calculations. Once Flowserve and the customer agree upon the best course of action, a wide array of equipment or system improvement solutions can be implemented (see pages 12 to 15).

Five-Step Assessment Process

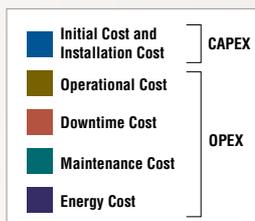
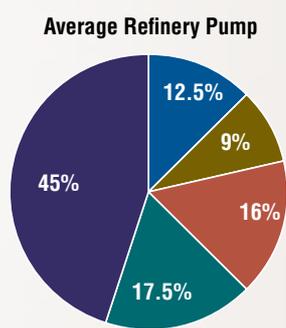
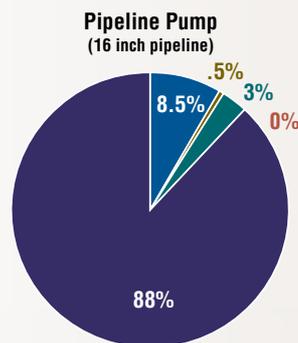
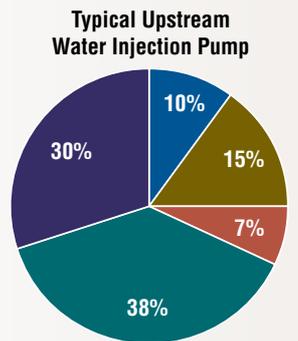


Aftermarket Disciplines Applied to Technical Assessments

Hydraulic Design	Vibro-elastics	Mechanical Design	Materials and Welding	Application and Process Knowledge
<ul style="list-style-type: none"> • Energy • Overall efficiency • Cavitation • Recirculation 	<ul style="list-style-type: none"> • Noise • Vibrations • Pulsations 	<ul style="list-style-type: none"> • General design • Reliability • Bearings • Seals • Seal systems • Warm-up • Internal alignments 	<ul style="list-style-type: none"> • Erosion • Corrosion • New materials • Repair welding • Boron diffusion surface treatment • PTA welding • HVOF overlay 	<ul style="list-style-type: none"> • Energy reviews • Systems analysis • Transients • Foundations • Driver technology



Numerous factors impact the life cycle cost makeup of a given pump system. A thorough evaluation is required to determine the relative impact of the various components of CAPEX and OPEX. The proportions of these components can vary greatly, as illustrated by the examples below.



THE LIFE CYCLE COST (LCC) PRINCIPLE

At the heart of any technical assessment is a thorough life cycle cost analysis. The initial purchase and installation cost (CAPEX) of a new pumping system is typically a small part of the total cost to operate the system (OPEX) over its life, which can be more than 15 to 20 years or even 40 years in the case of many high-energy pump systems. It is the routine OPEX costs of energy, maintenance and other recurring expenses that are the largest components of total life cycle costs.

Flowserve has played a defining role in creating the LCC analysis model through the joint efforts of the Hydraulic Institute and Euro-pump. Quickly becoming the global procedure for evaluating pumps and determining effective courses of action to improve performance and reduce total costs, the LCC model is defined as follows:

Informed Decision Making

LCC analysis is a powerful tool to help key decision makers understand the components that make up the total cost of owning and operating a particular piece of equipment or an entire system. Every flow management system is unique in some way and its distinctive characteristics can impact its total life cycle costs. Recognition of the potential opportunities to reduce energy, operating and maintenance costs provide any improvement project a solid basis for success.

In applying the model, Flowserve engineers perform a thorough assessment of each application to establish the critical elements and ensure the most effective course of action is implemented.

LCC Makeup Variability

Numerous factors impact the life cycle cost makeup of a given system and the proportions of these components can vary greatly, as illustrated by the examples at left.

A thorough evaluation is required to determine the relative impact of the various components of CAPEX and OPEX.

TECHNICAL ASSESSMENT OFFERINGS



System Assessments

Flowserve is fully committed to maximizing plant profitability by reducing the total life cycle costs within a plant and increasing throughput. And while there are many components that are critical to a flow management system, Flowserve engineers recognize that no piece of equipment operates in isolation. A pump, for example, is merely part of a system with many other components, all with crucial roles in achieving optimal plant efficiency and availability. That's why Flowserve engineers take a systems-driven approach to ensure the most effective solution is ultimately recommended and implemented.



Energy Assessments

Pumps can consume up to 80% of a plant's energy usage. Flowserve engineers are specially trained to identify pump and related equipment inefficiencies that are literally pulling money from an operation's bottom line. An energy assessment includes evaluations of hydraulic and mechanical design, driver and operating controls, auxiliary services and sealing systems. The assessment provides an analysis of specific pump, equipment and system issues, how to correct them, budget estimates and return on investment analyses. An energy assessment is especially valuable in plants where process parameters have changed or where systems degradation has occurred.



Bad Actor Assessments

Regardless of plant size, empirical evidence reveals that 5% to 10% of the installed pump base will become what is known as "bad actors," i.e., chronically problematic. A disciplined, methodical program to eliminate bad acting pumps will result in significant and rapid savings. Flowserve engineers can conduct an assessment to identify those pumps most negatively affecting LCC and plant availability.

Upon approval of recommendations, remedial actions are implemented to remove the bad actor from the list. Once improved performance is confirmed, the next bad actor asset is addressed and so on, until all are restored to expected performance. Customers report a 15% to 20% reduction in life cycle costs per bad actor pump.

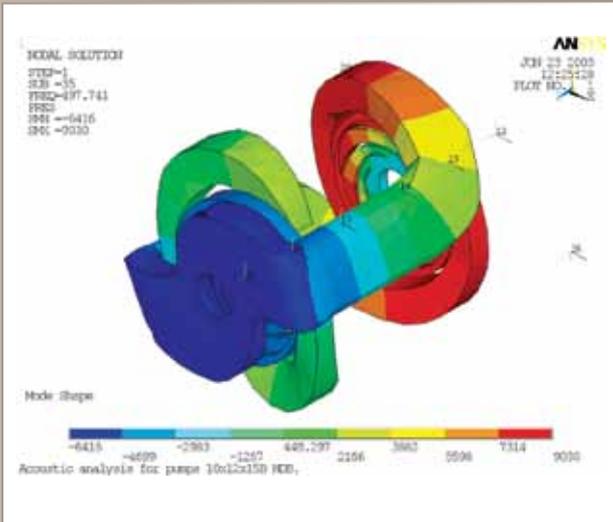


Safety, Health and Environmental Assessments

Flowserve offers numerous capabilities for customers to address SH&E obligations. Flowserve engineers routinely help customers turn SH&E expenses into positive life cycle cost investments using energy and environmental assessments, emissions monitoring and corrective control, and safety audits.



The Right Tools for the Job



Flowserve engineers use numerous analytical tools for technical assessments, including:

- Hydraulic and thermodynamic modeling validated with [real-time field data](#)
- Water-steam cycle thermodynamic modeling
- A multi-channel vibro-elastic data acquisition system to allow signature analysis, ODS, field model analysis, etc.
- Acoustic analysis of pump systems to handle pressure pulsation problems
- Erosion and corrosion materials analyses
- Software to model steady state and transient hydraulics in complex systems
- Hydraulic design, CFD analysis, flow visualization, energy optimization, erosion modeling, etc.
- Rotor dynamic analysis including all fluid force effects to calculate eigenvalues, responses to force, etc.

System Assessment Identifies \$3.51 Million in Savings

The Challenge: A South American pipeline company which moves over 42 000 m³/day (264 000 bpd) of crude oil was burdened with high operating expenses. Flowserve was engaged to identify opportunities to reduce operating expenses and to provide LCC justification for each.

The Assessment: Flowserve engineers performed comprehensive field testing of the entire system, consisting of 16 pump stations. Highly accurate torque meters were used to obtain operating efficiencies of pumps and gas turbines. In-depth mechanical and vibro-elastic reviews were also performed on two pumps known to be “bad actors.”

Using actual performance data and interactive software for designing and analyzing pipelines, Flowserve created a highly accurate model of the entire pipeline system. The model and LCC methodologies were used to identify and evaluate opportunities to improve system performance and reduce operating costs.

Upon completion of the analysis, Flowserve found:

- Several pumps were oversized, operating at $\leq 60\%$ BEP due to reductions in original hydraulic requirements
- Low-efficiency gas turbines were limiting pump availability and driving up operating costs due to increasing fuel prices

- Valve throttling to compensate for reduced flow requirements was amplifying vibration which in turn decreased mean time between repair (MTBR) and increased the related maintenance costs
- Improperly sized suction filters increased friction losses and reduced efficiency while escalating maintenance costs

The Solution: Flowserve recommended:

- Hydraulically re-rating the two bad actors as well as eight other pumps to restore BEP performance and improve energy efficiency
- Replacing inefficient gas turbine drivers with high-efficiency electric motors equipped with VFDs to eliminate fuel-related problems and improve net efficiency
- Eliminating valve throttling and vibration issues with VFDs for more efficient flow control, resulting in lower energy usage and maintenance costs while extending MTBR
- Upgrading suction strainers to reduce friction losses, energy use and maintenance costs

The recommendations represent an estimated annual savings of \$3.51 million – \$3.06 million in energy and \$450 000 in maintenance costs – on an investment of \$2.58 million, \$2.44 million of which is capital.

EQUIPMENT PERFORMANCE Improvements

TRUSTED EXPERIENCE

With more than two centuries of pump and mechanical seal innovation, an installed base exceeding one million units and a global footprint, Flowserve stands alone in process knowledge, applications experience and technical resources. Flowserve engineers have successfully implemented the most complex performance improvement upgrades in virtually every industry in every corner of the world. They have collaborated with plant operators, process licensors and architectural and engineering firms to solve virtually every conceivable equipment reliability, performance and availability problem.

Solving the Most Complex Equipment Problems

Examples of the challenges and the solutions Flowserve provides to the global infrastructure, broad process and general industrial markets include:

- Re-rating oil production and pipeline pumps
- Upgrading refinery charge pumps
- Designing new pump hydraulics for advanced hydrocracking process technology
- Upgrading boiler feed, condensate, cooling and auxiliary pumps and systems to satisfy new turbine generating capacity
- Modifying potable water treatment and distribution pumps for a growing population
- Recommissioning complete units of idle hydrocarbon process pumps
- Dry gas seal retrofits





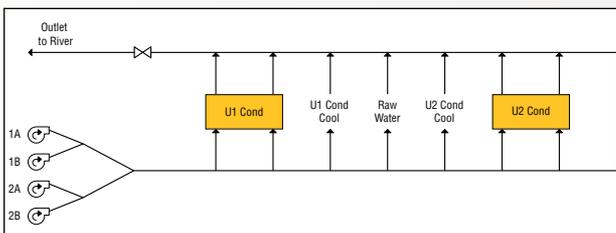
Computational Fluid Dynamics

A powerful means of determining improvements to pump geometry and configuration is through computational fluid dynamics, or CFD. A branch of fluid mechanics, CFD uses numerical methods and algorithms to analyze and solve fluid flow problems. Computers are used to perform the millions of calculations required to simulate the interaction of fluids, gases and particles with the complex surfaces found in pumping equipment. The objective is to optimize hydraulics for a specific application. CFD tools include programs to study potential flow and those providing full Navier-Stokes solutions for turbulent flow.

Flowserve Determines Cause of Circulating Water System Deficiency

The Challenge: A multi-unit power station located on a large river suspected the circulating water system supplying Units 1 and 2 was operating inefficiently, resulting in derated performance. Consequently, the station's profitability was negatively impacted.

The Assessment: Flowserve engineers conducted a thorough assessment of the system which consisted of four vertical pumps operating in parallel. These pumps provide water to the Unit 1 and 2 condensers, condensate coolers, jacket water coolers and raw water pumps.



Using non-invasive flow monitoring instrumentation and state-of-the-art wireless technology, Flowserve engineers collected high-resolution data under various operational scenarios. A hydraulic study was performed from which

a highly accurate model was developed. Validated with actual field data, this model was used to evaluate the system's response to multiple variables.

Flowserve Technical Services engineers determined:

- Unequal flow distribution existed throughout the system. Flow to the Unit 1 condenser was greater than design in all field test scenarios. Flow to the Unit 2 condenser only reached design level when four pumps were in operation.
- A significant reduction of flow to both condensers occurred during periods of low river elevation.
- Low flow caused increased condenser backpressure in both units, compromising unit power generation during low river level conditions.

The Solution: To correct the flow imbalance, Flowserve recommended two circulating water pump trains be retrofitted with higher speed motors to provide greater capacity when the river is low. The hydraulic model was used to verify that two higher speed motors the client already owned would provide the necessary increase in pump capacity. The resulting increase in flow would also reduce the condenser backpressure and improve steam cycle efficiency, increasing station profitability.



EQUIPMENT PERFORMANCE IMPROVEMENT OFFERINGS



Mechanical and Metallurgical Upgrades

Flowserve engineers are industry leaders in the fields of vibro-elastics and mechanical design and analysis. These engineers focus on converting mechanical root-cause failure problems into practical solutions that will reduce maintenance, repair and inventory costs, eliminate bad actor pumps and increase operating uptime.

Vibration, Pressure and Noise

As an industry leader in the field of vibro-elastics engineering, Flowserve has conducted research that has resulted in the development of numerous computer analysis tools and field acquisition systems that rapidly and accurately identify the root causes of equipment failure. These tools include:

- Pump and rotor dynamic analysis, including all fluid force effects to calculate eigenvalues, responses to forces, etc.
- Structural dynamic analysis to verify rotor-structure interactions and foundation and pump structure dynamics
- Acoustic analysis of pumps and systems to identify pressure pulsation problems

With its field data acquisition system that offers up to 48 channels, Flowserve has developed a powerful elimination scheme to determine root causes of equipment issues related to vibration and pressure pulsation. Root causes are identified in weeks rather than months, allowing prompt delivery of solutions.

Design and Component Issues

Mechanical engineers from Flowserve utilize the most sophisticated technology available, including: laser-assisted component technology; CAD-3D solid modeling coupled to rapid prototyping; finite element analysis (FEA) software; and tribology to study metallic and non-metallic surfaces in relative motion. Much of their work to improve MTBR and reliability is focused on upgrading and retrofitting components pertaining to:

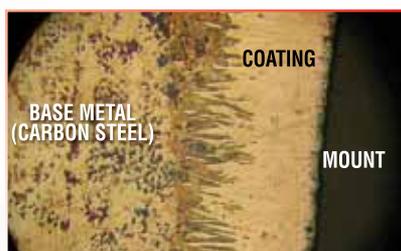
- Mechanical seals
- Axial and radial bearings and bearing housings
- Seal chambers
- Leakage of pressure containment components
- Running clearances
- Axial balancing devices
- Increased rotor stiffness
- Emissions reduction

Metallurgical Upgrades

Flowserve engineers apply materials and welding engineering to address a wide variety of wear, erosion and corrosion problems which may impact pump, seal and system performance. Materials engineers focus upon these issues:

- Increasing corrosion and erosion resistance
- Improving resistance to wear and galling
- Maintaining critical pump clearances

Flowserve may also apply advanced coatings, claddings and surface conversions to extend the life of equipment by increasing resistance to wear, corrosion and erosion.





Hydraulic Re-rates and Upgrades

Flowserve has extensive experience in implementing solutions to increase pump efficiency, lower NPSH requirements or adapt equipment operating performance. Whether system requirements have changed or plant output needs debottlenecking, Flowserve can execute solutions that enhance performance, improve reliability and reduce energy costs. Common hydraulic field issues addressed by Flowserve engineers include:

- Efficiency upgrades
- Hydraulic re-rating for changed duty conditions
- Suction eye and impeller discharge recirculation problems
- Rotating and stationary stall effects
- Diffuser/casing flow-induced erosion
- Minimum flow rate problems
- Two-phase flow problems
- Vertical pump intake flow problems
- Particle flow erosion problems
- Cavitation problems

After implementing a re-rate, Flowserve engineers work with customers to assess the performance of equipment in the field. This is done to confirm the intended hydraulic results have been achieved and to establish a new performance baseline.



Dry Gas Seal Retrofits

Flowserve has extensive experience in dry gas seal retrofits, including many of the world's first applications. Our expertise has been developed by retrofitting many compressors and turbo expanders in a full range of processes with an impressive, successful track record. Reliability is maximized and total life cycle costs are reduced by eliminating the need for unit and shaft modifications while still designing to customer requirements. Services include:

- Application design, rotordynamic analysis and machine design
- Finite element analysis
- Project management, installation and commissioning
- Training and technology transfer packs



Exchange Programs

Unreliable and leaking pumps can be refurbished to as-new condition through various, formalized exchange programs. The goal of these programs is to improve reliability and availability by updating pumps to the industry's contemporary performance standards while simultaneously reducing spare parts inventory complexity and cost. Among the programs offered are:

- API latest edition upgrade program which converts old process pumps to current API standards. Includes new power end, ISO 21049/API 682 seal chamber and cartridge mechanical seals.
- ANSI and ISO power end exchange for quick, cost-effective replacement of worn power ends.



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To find your local Flowserve representative:

For more information about Flowserve Corporation, visit www.flowserve.com or call +1 937 890 5839.

USA and Canada

Flowserve Corporation
5215 North O'Connor Blvd.
Suite 2300
Irving, Texas 75039-5421 USA
Telephone: +1 937 890 5839

Europe, Middle East, Africa

Flowserve Corporation
Parallelweg 13
4878 AH Etten-Leur
The Netherlands
Telephone: +31 76 502 8100

Latin America

Flowserve Corporation
Martín Rodríguez 4460
B1644CGN-Victoria-San Fernando
Buenos Aires, Argentina
Telephone: +54 11 4006 8700
Telefax: +54 11 4714 1610

Asia Pacific

Flowserve Pte. Ltd.
10 Tuas Loop
Singapore 637345
Telephone: +65 6771 0600
Telefax: +65 6862 2329