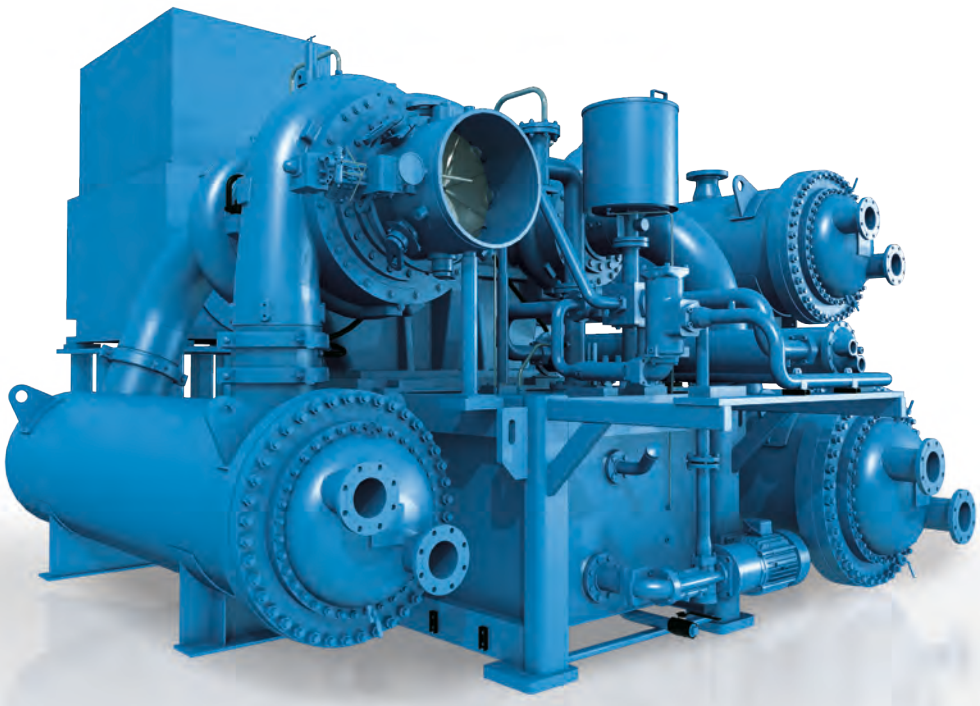
FS ELLIOTT

PAP PLUS

ENGINEERED AIR COMPRESSORS



Meeting Critical Needs

Air compression plays a vital role for processes across a range of industries and is particularly critical in oil and gas, refining, and chemical/petrochemical applications. Compressor designs must meet exacting specifications—from API 672 standards to end users' own complex needs.

PAP Plus® centrifugal compressors have been the first choice of plant owners and operators for more than 50 years. Building on a groundbreaking package design (the first in the industry), PAP Plus compressors are both ruggedly simple and highly advanced. Their simplicity means exceptional reliability. Advanced aerodynamics mean stellar performance. And their uniquely accessible components mean inspection, maintenance, and service have never been more efficient or less disruptive, making them easy and economical to own.

Engineered to spec and built to last, thousands of custom-designed PAP Plus compressors are on the job worldwide providing continuous, oil-free air. From providing process air and powering instruments to cleaning pipes to driving pneumatic tools to dozens of other applications, you can count on them to meet critical needs, including the most critical of all—yours.

1. Ambient air enters the first stage through the inlet control device.

2. The first-stage impeller accelerates the air. A radial diffuser converts the air's velocity into pressure before the air enters the scroll casing.

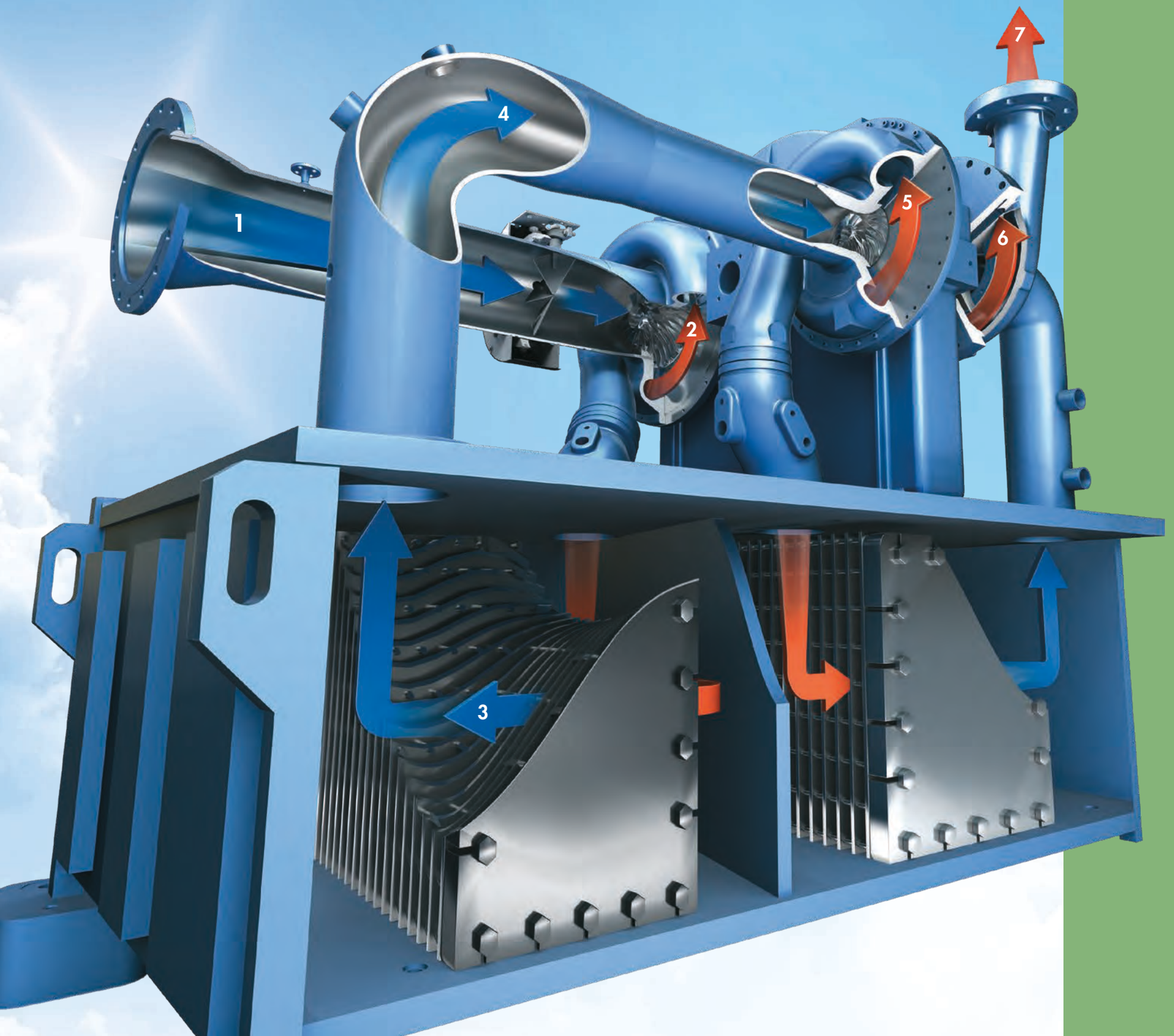
3. The air is conducted through interstage piping into the first intercooler.

4. The cooled air then flows into the second-stage inlet piping.

5. The compression process is repeated as the air passes through the second stage impeller, diffuser, and scroll casing and then into the second intercooler.

6. Air from the second intercooler moves through a third impeller, diffuser, and scroll casing.

7. Air is discharged into the aftercooler and air system.



Simply Superior

Machinery doesn't have to be complex to be effective. PAP Plus compressors are built on a simple, centrifugal design that delivers superior reliability and performance. The only moving parts are the bull gear and the rotors. With no lubricated parts in the air passages, the airstream is oil-free.

Intercoolers Minimize Power Loss

Effective intercoolers are a key to compressor operating performance and energy efficiency. All FS-Elliott packaged air compressors feature compact, highly efficient heat exchangers that provide minimum pressure loss, high heat-transfer efficiency, and fast and simple cleaning of the straight-through tube bundles. Phenolic (fluoropolymer) coatings are also available for extreme duty applications.

High Performance

PAP Plus compressors are known to be the most robustly built and reliable compressors in the industry. At their core: a state-of-the-art, backward-leaning impeller design that provides a broad range of superior aerodynamic performance characteristics.

High Base-load and Part-load Efficiencies

The highly efficient impeller design is the major component within the compressor stage that produces the required pressure rise with minimal loss in energy conversion from input torque to discharge pressure. Power consumption can also be reduced in low-demand situations by the efficient modulation of the adjustable inlet guide vanes.

Energy Savings

The impeller provides highly efficient air compression that can be precisely controlled for optimum air flow. Aerodynamic stage matching and intercooler efficiencies also minimize power requirements.

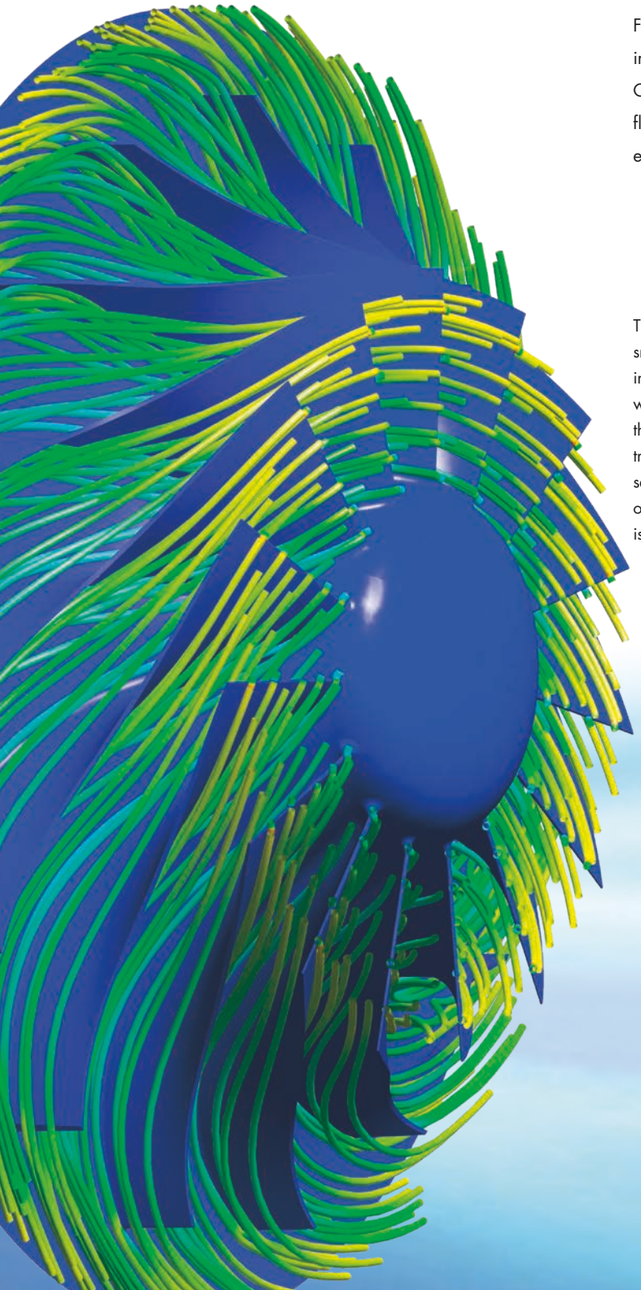
Corrosion Resistance

Constructed from high-strength, precipitation-hardened stainless steel, the impeller resists the corrosive and erosive action of atmospheric contaminants and water vapor that may pass through the inlet air filter.

Overall, our impeller designs provide optimum levels of performance in all facets of operation.

Impeller, diffuser, and scroll designs are uniquely sized to meet your specific needs in order to provide peak efficiency and large operating ranges. Superior impeller designs feature optimum blade loading and shroud profiling for your required performance level, which minimizes skin friction, incidence, recirculation, and other loss mechanisms inherent in impeller performance.

FS-Elliott engineers use the latest engineering design software to improve aerodynamic performance and enhance product design. Computational Fluid Dynamics (CFD) is used to perform complex flow analysis of aerodynamic components to increase stage efficiencies and optimize compressor performance.



This flow analysis shows smooth velocity streamlines in a rotating reference frame, with air paths moving from the impeller's inducer to the trailing edge. No disruptive secondary flow (recirculation) or blade-to-blade crossover is present.

Analysis of the pressure distribution of the impeller shows the increasing pressure generated by the impeller blades as they add energy to the air.

Adjustable inlet guide vanes control inlet flow to save energy. The guide vanes are automatically positioned in response to ambient air and system demand changes. They reduce the flow through the compressor by imparting a pre-swirl to the incoming airstream. This pre-swirl controls the work of the first stage impeller, adjusting the power and throughput to match system demand. By controlling the amount of air being compressed (and consequently the power consumed), the inlet guide vane efficiently adjusts to plant conditions and load variations to conserve energy.

A detailed view of the streamlines with velocity vectors between two impeller blades, also in a rotating reference frame, indicates efficient flow from the inducer to the trailing edge, which minimizes parasitic losses and maximizes impeller performance.

Carbon Ring Shaft Seal technology is the result of years of operational experience. The horizontally split design assures ease of maintenance and oil-free operation.

Pinion and Impeller Assemblies are composed of a rotor supported by two self-centering tilt or flex pad journal bearings. A shaft seal located at each impeller seals oil in the gearbox and out of the compression chamber. The rotor's extremely short shaft lengths mean that centrifugal forces are not amplified through a long lever arm.

Bull Gear Bearings are horizontally split for easy inspection and maintenance. The combination flat-land thrust bearings and sleeve journal bearings are made of steel with babbitt lining.

Helical Bull Gear is a high-precision AGMA Quality 13/ISO 1328.2 Grade 4 to minimize noise and vibration. The bull gear drives pinions with mounted impellers. The pinion shafts are designed to operate at the optimal rotational speed for best efficiency.

Self-centering, Horizontally split Tilt or Flex Pad Journal Bearings support rotors for the best stability through the entire operating range of loads and temperatures.

Exceptional Reliability

FS-Elliott is as committed to keeping your facility up and running as you and your employees. Our design philosophy is simple and consistent: We combine unyielding reliability with leading-edge technology to ensure that your vital operations will never be interrupted or compromised. Every component is designed with your need for trouble-free operation in mind, and is based on current codes and industry standards as well as state-of-the-art technology.

Gearing

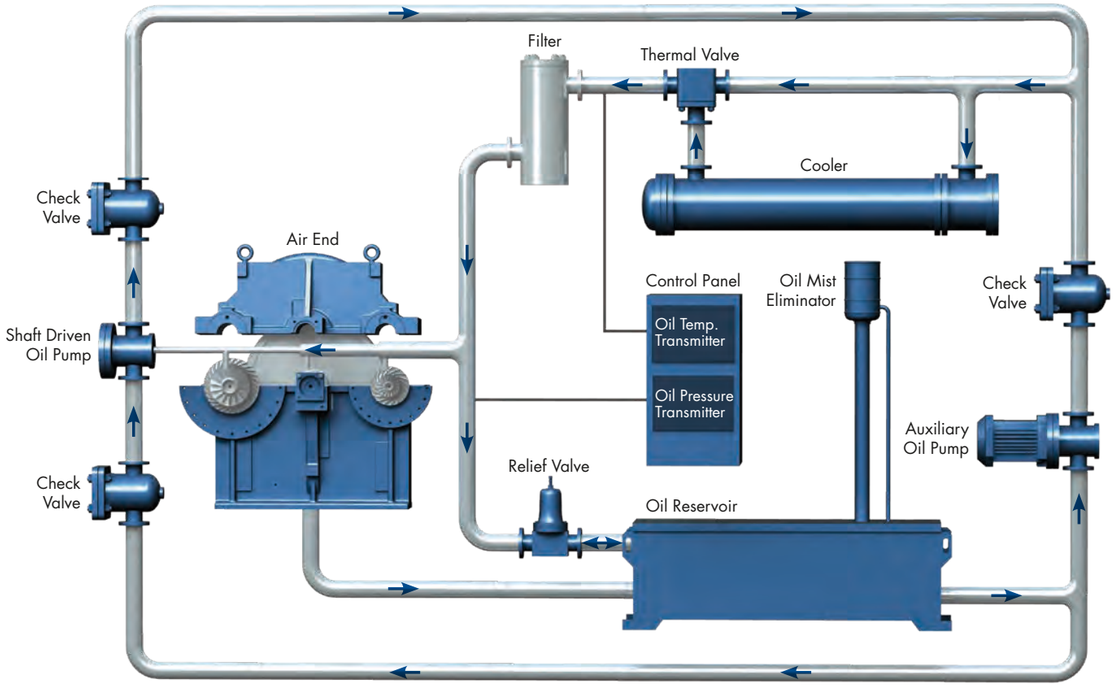
Helical gearing provides greater tooth strength, increased contact ratio, smoother operation, and reduced noise. During running periods, the helical gear thrust force remains relatively constant, while the pressure forces on the impeller can vary with operating conditions.

Journal and Thrust Bearings

For added reliability, each PAP Plus rotor has its own thrust bearing system to absorb thrust where it is created, rather than transmitting the thrust forces through the bull gear to a single bearing. Bearings are designed to withstand aerodynamic and gearing loads for the lifetime operation of the compressor.

Rotordynamics

PAP Plus rotordynamic characteristics have been meticulously analyzed using the latest analytical tools to assure smooth, reliable, and lasting compressor operation. Superior rotor assembly configurations and precision component and assembly balance procedures ensure the lowest level of vibration, the main cause of equipment wear and tear.



Pressure Lubrication System

The PAP Plus oil lubrication system has proven its reliability through many years of successful operating experience. Designed for ease of inspection and maintenance, the system is self-contained within the compressor package. All of the oil connections are positioned in the lower half of the gearcase for quick and simple access to the bearings, gears, and pinions. The system includes a full-flow auxiliary oil pump that operates automatically during start-up, shutdown, and emergency situations to provide additional protection to the overall package.

Our exclusive Corona™ lubricants are offered with every new FS-Elliott compressor for superior protection, optimum performance, and maximum service life. These premium lubricants offer:

- Extended lubricant life
- Less build-up of lacquer, varnish, and resins
- Excellent wear protection
- Superior resistance to foaming
- Reduced downtime
- Free lubricant analysis program to simplify preventive maintenance

Thrust Bearing Fundamentals

PAP Plus Double Acting

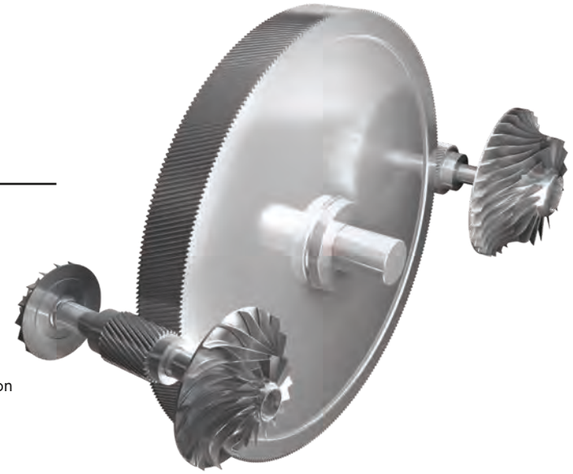
Thrust absorbed at each rotor

Bearings absorb thrust in both axial directions

Lightly loaded

Babbitt to metal construction

Can operate safely under all conditions



Journal Bearing Fundamentals

Optimum Performance Features	PAP Plus Tilt or Flex Pad	Fixed Lobe Type	Hydrodynamic Squeeze Film
Load-carrying Capacity	Superior	Good	Superior
Stability and Low Vibration	Good	Modest	Good
Self-centering	Yes	No	Yes
Low Oil Supply Pressure	Yes	Yes	No
Accommodates Shaft Radial Movement/Eccentricity	Yes	Moderately	Low
Friction Losses	Low	Low	Low
Sensitivity to Damage by Foreign Matter	Low	Moderately	High
Inspection Time/Costs	Low	High	High
Replacement Costs	Low	Low	High

Ease of Ownership

No matter how well a compressor performs, if it's difficult to install, commission, and maintain, why own it? Each PAP Plus compressor is custom-built to be easy to own and operate over years of demanding use.

Installation Ease

The PAP Plus compact, unitized package design minimizes the number of external connections as well as foundation and floor space requirements.

Operation Ease

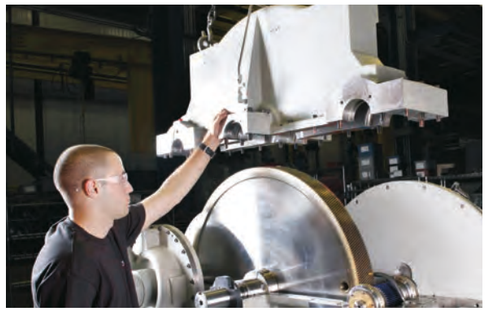
A variety of touch-screen displays and an array of standard features and options accommodate any site and compressor system application. Tailoring the control system to your specifications allows for precise system control that maximizes energy savings while providing outstanding operational benefits.

Maintenance Ease

Centrifugal compressors are inherently reliable over long periods with minimal maintenance. What sets PAP Plus compressors apart is the package design that allows easy access to critical components for fast, efficient inspection and maintenance during off hours and at scheduled intervals. This feature virtually eliminates unexpected shutdowns and production interruptions. All scheduled maintenance can be performed by your plant personnel, or FS-Elliott can provide a maintenance plan to fit your specific needs.

The gearing, intercoolers, aerodynamic parts, lubrication system, and control system are all independently accessible. Maintenance of any one of these items does not require disassembling other components or exchanging large assemblies. Unlike other compressors, the unique PAP Plus horizontally split design was meticulously designed to provide quick and easy local maintenance. Components do not need to be sent back to the factory. Compare this time-efficient procedure with other compressor designs that require days to perform the same tasks.

In fact, a complete maintenance operation, including removing the gearcase cover, inspecting gears, bearings, and seals, and reassembly, can be accomplished within 3 to 8 hours, depending on the specific site situation. This procedure can be done without disturbing impellers, diffusers, air or water piping, or other components. Simply lift the cover to expose these components.



Bolts are easily accessible to remove the gearcase cover. The cover lifts off easily, exposing gears, bearings and seals without removing any other components. The top half of the bearing comes off by removing two screws. The bottom half can be rolled out and removed from the casing for inspection. The two-piece seal assembly can be removed by sliding it into the bearing cavity area, allowing the bearing to be removed following the above procedure.

Seal and Bearing Inspection Time Comparison

Overall, PAP Plus owners spend significantly less time and effort on maintenance.

	Horizontally Split Centrifugal Compressor		Vertically Split Centrifugal Compressor	Screw Compressor
Inspection Procedure	PAP Plus	Brand "X"		
Remove Inlet Piping, Valve & Filter	Not Required	¾ hour	1 hour	Not Permitted Voids Warranty
Remove Interstage Piping	Not Required	½ hour	Not Required	
Remove Oil Piping to Bearings	Not Required	¼ hour	Not Required	
Remove Main Oil Pump	Not Required	¼ hour	Not Required	
Disconnect Main Drive Coupling	Not Required	¼ hour	Not Required	
Open Intercooler Casing	Not Required	Not Required	3 hours	
Remove Intercooler Bundles	Not Required	Not Required	4 hours	
Remove Impellers	Not Required	Not Possible	4 hours	
Remove Gearcase Cover	½ hour	½ hour	Not Required	
Pull Bullgear	Not Required	½ hour	Not Required	
Remove Bearing Assemblies	½ hour	Not Possible	2 hours	
Remove Shaft Seal Assemblies	½ hour	Not Possible	1 hour	
Remove Casing & Diffusers	Not Required	1½ hours	Not Required	
Remove Complete Rotor Assemblies with Bearing Attached	Not Required	1 hour, Return Rotor Assemblies with Bearings Attached to OEM to Maintain Warranty	Not Required	
Reverse Above Operations	1½ hours	5½ hours	15 hours	
Total	3 hours	11 hours + Weeks for OEM to Return Rotor Assemblies and New Bearings	30 hours	

FS-Elliott's engineering staff has the depth and know-how to meet any requirement—from the simplest to the most complex. Our base designs have the reputation as the most rugged, reliable packages for API 672 applications. These packages can be customized to accommodate rigid customer specifications and special operating parameters. Here are a few examples of the custom work we're known for around the world.

Installed in an Asian oil refinery, this engineered air system is used in the production of clean fuels. The compressor package inlet air flow is 2,585 cfm (4,390 m^3/hr). The end product for this refinery upgrade project is unleaded gasoline.

This engineered air, 2,670 cfm (4,540 m^3/hr) system was designed for a Middle East oil refinery. This air package design was based on API 672 plus comprehensive EPC and end user specifications. This compression unit is applied for the production of unleaded/ low-sulfur gasoline.

This engineered air compressor package is part of a major petrochemical plant capacity expansion project in eastern Canada. The 2,760 cfm (4,690 m^3/hr) compressor package provides instrument air for critical processes in an ethylene production plant.

BASIC PACKAGES

PAP Plus compressors combine more than 50 years of operational and design experience in an extremely rugged and reliable package. These quality-built packages are routinely required to operate uninterrupted for up to three years while maximizing efficiencies and minimizing unplanned downtime.

Electric Motors or Steam Turbines are selected to meet operating conditions and specified area classifications.

Coupling Guard encloses the coupling and shafts to protect personnel from contacting rotating parts during operation.

Spacer Type Coupling (forged steel, non-lubricated, flexible-element), in accordance with API 672 requirements, is included with every PAP Plus compressor.

Full-capacity Oil Filter eliminates contaminants 10 microns or larger. Twin filters in parallel arrangement with an integral three-port positive shutoff, zero leakage transfer valve are also available for maximum protection and for maintenance switchover during operation.

Single or Twin Heat Exchangers provide oil cooling for all conditions. Twin air coolers are piped in parallel arrangement with zero leakage tandem transfer valves. These valves enable switching from one cooler to the other for routine maintenance while the compressor continues operating.

Custom Instrumentation, including control panels, transmitter racks, junction boxes, and more, is configurable to meet specific requirements. RTDs, vibration monitoring, and customized controls provide maximum machinery protection.

Sound Attenuation Options, from soft sound wraps to custom-designed enclosures, are available to meet a wide range of requirements.

Oil Reservoir can be fabricated from stainless or carbon steel. Carbon steel reservoirs include an oil-compatible, corrosion-resistant internal coating.

Axial, Lateral, and Vertical Alignment Blocks and Positioning Bolts are provided for equipment alignment in accordance with API 672 and API 541 requirements.

Water-in-tube Intercoolers are easily cleanable to maintain optimum performance. Intercoolers provide maximum heat transfer efficiency with minimum pressure loss.

Fabricated Sub-skid Packages can be provided when a complete, pre-piped and pre-wired package is desired for minimal installation time on site.

Fabricated Steel Baseplate includes a continuous drip rim with conveniently positioned drains.

Painting Systems can be customized to suit the most inhospitable environments.

At the heart of every PAP Plus compressor is the Regulus® Control System. A touch of the screen lets you control and manage the performance of one or multiple compressors, at the unit or remotely, to meet air demands while maximizing energy savings. An extensive array of optional features is available to accommodate any site.

Energy Savings

- Multiple compressor unit energy management capabilities
- Precise air system pressure control maximizes turndown capability and energy savings
- Advanced adaptive controller saves energy by permitting protected operation closer to actual surge
- Innovative adjustable inlet guide vane design maximizes efficiency at off-design operations
- Suction Throttle and Auto-Dual control modes add operational flexibility and efficiency

Operating Simplicity

- All control set points are accessible from one interface
- Numerous language display capabilities
- Multiple choices of communication protocols with interfacing systems
- Supervisory capabilities include monitoring the entire air system from one location
- One-touch, instantaneous data storage and historical trend viewing enables detailed operating analysis and the ability to identify and avert potential problems
- Compressor can run virtually unattended at optimum efficiency through various plant air demand conditions

Sirius™ Integrator is an advanced software package that lets you monitor and control the entire compressed air system—even different types and brands of compressors—from a single location. By increasing overall system efficiency and energy savings, the Sirius Integrator has a very short payback period, typically within one year of installation.

REGULUS R200 CONTROL SYSTEM

The R200 model includes an enhanced PLC and is packaged with control and monitoring features that are considered optional on comparable systems. Its larger memory provides for advanced trending and diagnostics while still maintaining the cost benefits of a standardized design.

REGULUS R300 CONTROL SYSTEM

The R300 model is packaged with many standard features and available options that make it easily adaptable to a wide variety of applications. It is ideal for situations that call for increased analog and digital input and output requirements.

REGULUS CONTROL SYSTEMS

Superior pressure control capability and the flexibility to meet even the most complex system requirements set Regulus Control Systems apart. By eliminating excessive air blow-offs to the atmosphere while efficiently responding to the facility's changing air demands, Regulus empowers operators to master one of their plant's highest operating expenses—energy costs. And because the Regulus product line and customization options are the broadest in the centrifugal compressor marketplace, FS-Elliott engineers can assist you in designing a solution tailor-made for your needs.

REGULUS R400 CONTROL SYSTEM

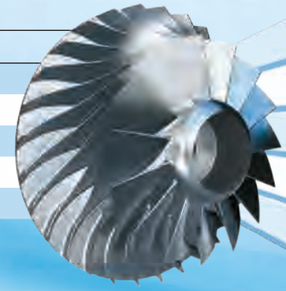
The R400 model is the control system of choice for those applications requiring the highest level of customization. Tailor the enclosure, hardware, control mode, communication package, and more than a dozen indication, alarm, and trip functions to fit your needs.

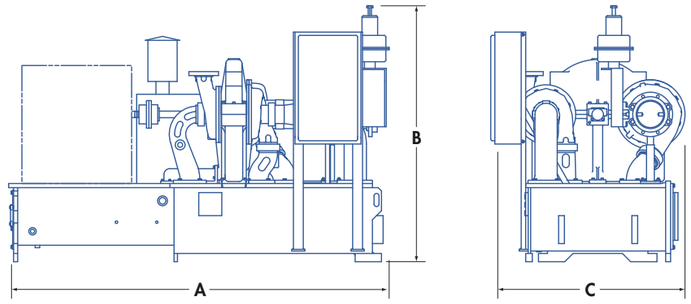
WEIGHTS AND DIMENSIONS

PAP Plus compressors combine more than 50 years of operational and design experience in a highly robust, uniquely easy-to-maintain package. Our customers enjoy lower cost of ownership and absolute reliability from PAP Plus models ranging from 900 to 18,000 cfm (1,530 to 30,600 m³/hr); and 250 to 4,000 HP (185 to 2,980 kW).

PAP Plus Compressor Frame	Overall Dimensions						Approximate Weight*	
	A*		B*		C*			
	in.	mm	in.	mm	in.	mm	lb.	kg
S1	124	3150	61	1549	81	2057	9500	4309
A1	124	3150	61	1549	81	2057	14000	6350
BH	174	4420	75	1905	96	2438	27000	12245
CH	195	4953	152	3861	120	3048	38000	17235
D	252	6401	134	3404	153	3886	70000	31750

* Value may vary with motor rating and type





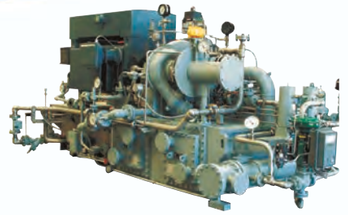
Discharge Pressure:
45 to 150 psig/3.1 to 10.3 bar g

Performance may vary based on actual site conditions. Consult your authorized FS-Elliott distributor for more information.

S1

900 ICFM / 1530 m³/hr
250 HP / 185 kW

2200 ICFM / 3740 m³/hr
450 HP / 335 kW



A1

1500 ICFM / 2550 m³/hr
350 HP / 260 kW

3400 ICFM / 5780 m³/hr
700 HP / 520 kW

BH

3500 ICFM / 5950 m³/hr
800 HP / 597 kW

5700 ICFM / 9700 m³/hr
1250 HP / 932 kW

CH

5500 ICFM / 9350 m³/hr
1000 HP / 746 kW

11000 ICFM / 18700 m³/hr
2000 HP / 1492 kW

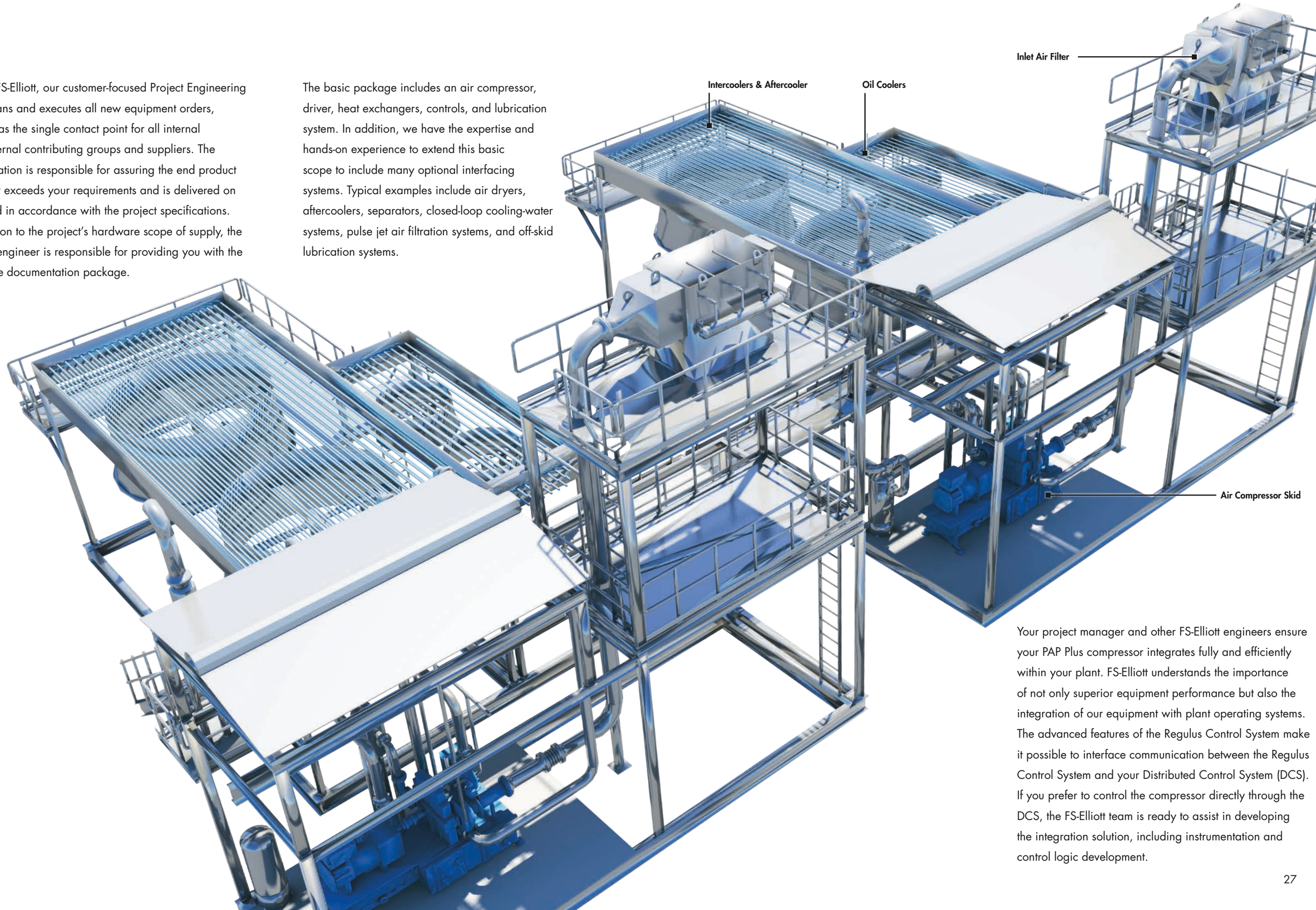
10000 ICFM / 17000 m³/hr
2000 HP / 1492 kW

D

18000 ICFM / 30600 m³/hr
4000 HP / 2980 kW

Within FS-Elliott, our customer-focused Project Engineering team plans and executes all new equipment orders, serving as the single contact point for all internal and external contributing groups and suppliers. The organization is responsible for assuring the end product meets or exceeds your requirements and is delivered on time and in accordance with the project specifications. In addition to the project's hardware scope of supply, the project engineer is responsible for providing you with the complete documentation package.

The basic package includes an air compressor, driver, heat exchangers, controls, and lubrication system. In addition, we have the expertise and hands-on experience to extend this basic scope to include many optional interfacing systems. Typical examples include air dryers, aftercoolers, separators, closed-loop cooling-water systems, pulse jet air filtration systems, and off-skid lubrication systems.



Your project manager and other FS-Elliott engineers ensure your PAP Plus compressor integrates fully and efficiently within your plant. FS-Elliott understands the importance of not only superior equipment performance but also the integration of our equipment with plant operating systems. The advanced features of the Regulus Control System make it possible to interface communication between the Regulus Control System and your Distributed Control System (DCS). If you prefer to control the compressor directly through the DCS, the FS-Elliott team is ready to assist in developing the integration solution, including instrumentation and control logic development.

Quality Systems

We take nothing for granted at our manufacturing facility and headquarters located in Export, PA. Every PAP Plus compressor is carefully crafted under our stringent quality program and accompanying standards. By the time your compressor arrives at your site for installation, it has undergone a rigorous execution process encompassing marketing, sales, engineering, manufacturing, inspection, and testing. The entire process is governed by our ISO 9001:2008 Certified Quality Management System. This quality process also assures that our suppliers are qualified and continuously monitored to the same high standards we demand of ourselves.

Testing

To ensure our compressors stand up to your requirements, we make sure they stand up to ours. Every FS-Elliott compressor is rigorously tested in our ultra-modern test facility equipped with the most progressive test equipment, instrumentation, and control systems available. This 16,000 ft^2/1,490 m^2 facility allows us to test three complete compressor units at once, using variable speed drives that provide 50 and 60 hertz capabilities up to 4,000 HP/2,980 kW and 6,600 volts. Wide-ranging resources allow us to accommodate project-specific testing requirements as well as mechanical testing in compliance with API 672 standards and performance testing in accordance with the ASME Power Test Code.

Technical Manual

Every FS-Elliott technical manual meticulously describes the installation, operation, and maintenance of our air compressor system. The information is the culmination of years of design and operational experience. Following the recommended procedures and guidelines will result in years of reliable operation. The manual includes:

- Technical drawings specific to each equipment package
- Drawings and literature of the major accessories
- Normal maintenance parts listings and spare parts interchangeability records
- Instructions for ordering replacement parts and obtaining service assistance and training for operators and maintenance personnel

Installation and Start-up

Our services range from qualified direction and assistance for your own installing and commissioning team to providing a total turnkey installation, including project management, supervision, and all of the craft labor and tools to complete the job.

Maintenance

Maintenance programs can be customized to your specific needs. You can design them to coincide with and support your scheduled outages, or to provide comprehensive, long-term maintenance for your air compressor, including scheduled visits by local, qualified service personnel.

Parts

Having the correct replacements parts available and easily accessible is a critical issue for compressed air users. FS-Elliott can provide these parts to exacting dimensions, material specifications, and quality standards. We maintain a large inventory of quality-made parts to assure quick delivery. Many high-usage components, such as bearings, seals, gaskets, and o-rings, can be shipped within 24 hours.

Repairs

ISO-certified authorized shops are fully capable of performing repairs. The experienced FS-Elliott service team is dedicated to ensuring that emergency situations are handled with urgency 24/7/365.

Rerates

Rerating an existing compressor to a new set of operating conditions is often the most economical way to meet a system's changed compressed air demands. We can also provide new design modifications and upgrades that enhance an air system's reliability and reduce life cycle cost. Given today's rising energy costs, rerates can generate very fast returns.

As the Original Equipment Manufacturer (OEM), FS-Elliott has direct access to the authentic manufacturing drawings, material specifications, and assembly clearances. Our customers can have total confidence and peace of mind that by using genuine OEM parts for rerates and upgrades, their equipment will perform as intended—the first time and every time.

Training

We offer a wide range of operator and maintenance training programs, including standard, self-contained packages and customized sessions to fit your needs. Programs feature an effective mix of cut-away models, hardware components, and textbooks to develop and train individuals in a wide range of oil- free compressor system subjects. Training can be delivered at your facility or one of ours.

Headquarters—Export, Pennsylvania, USA

Basingstoke, United Kingdom
Houston, Texas, USA
Jubail, Kingdom of Saudi Arabia
Köngen, Germany
Kuala Lumpur, Malaysia
Los Angeles, California, USA
Pune, India
Shanghai, China
Taipei, Taiwan
Tangerang, Indonesia

Building on a 50-year tradition of excellence in compressor design and manufacturing, FS-Elliott brings our customers the resources of a global industry leader along with the convenience and responsiveness of local sales and service. Thousands of reliable, hard-working FS-Elliott compressors are installed worldwide.

FS-Elliott Co., LLC

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Represented by:

ISO 9001- certified for the design and manufacture of centrifugal compressors.

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