



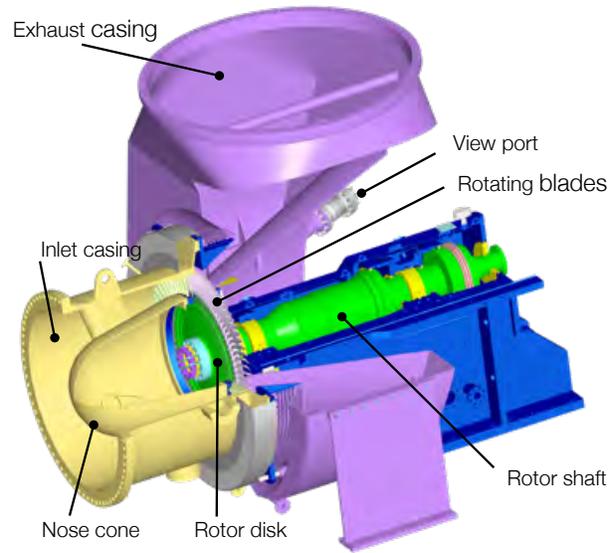
ei ELLIOTT GROUP
EBARA CORPORATION

Power Recovery Systems

THE LEADER IN POWER RECOVERY EXPANDERS

In 1963 Elliott designed and manufactured the first hot gas expander for capturing waste flue gas energy from the fluid catalytic cracking (FCC) process. Elliott's technological innovation enabled refiners for the first time to recover the heat energy from a waste flue gas stream that was previously lost through pressure reducing valves.

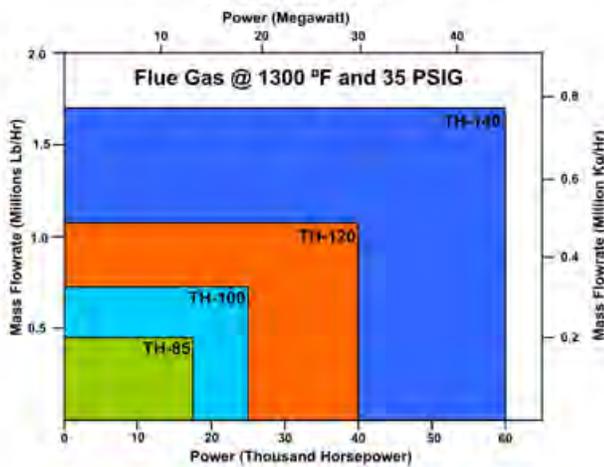
In the decades since this engineering breakthrough, Elliott has continued to enhance its expander design to reflect operating experience and FCC process innovations. Elliott's development of new alloys and metallurgical treatments has resulted in expanders that match the reliability and availability of other equipment in less arduous FCC services, despite the high operating temperatures and the corrosive effect of the catalyst in the flue gas stream. Superalloys used for rotor disks and blades offer an excellent combination of strength, toughness,



creep, and fatigue resistance for high temperature applications. Several Elliott expanders have remained in operation for more than seven years with the original set of blades. Elliott power recovery expanders lead the industry in efficiency, reliability, low maintenance costs and easy maintenance leading to shorter turnaround times.

Today, as environmental concerns grow, the efficiency and reliability of Elliott's power recovery expanders enable operators to reduce their carbon footprint (see diagram on page 4). The power recovered by the expander is often sufficient to drive both an air compressor for the FCC process as well as a generator. The efficient conversion of waste heat to rotational power reduces a facility's steam requirements as well the power it draws from the grid. Elliott expander strings deliver up to 60,000 horsepower (45 MW) of useful power from waste gas streams (see left chart for frame sizes).

ELLIOTT TH EXPANDER FRAME APPLICATION



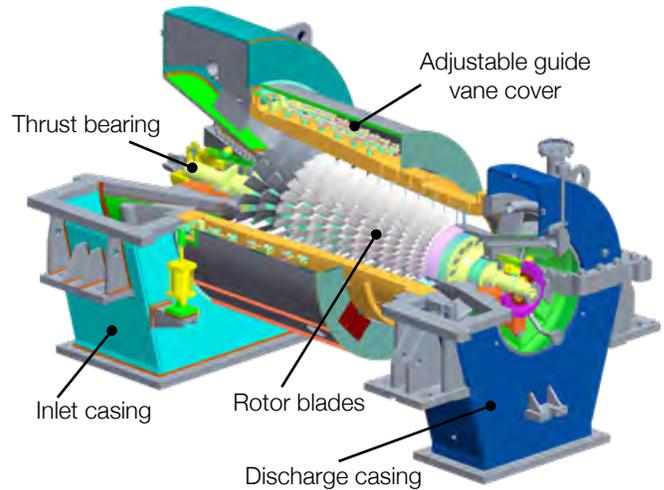
Hot mechanical test of TH expander.



Site installation of an expander power recovery unit.

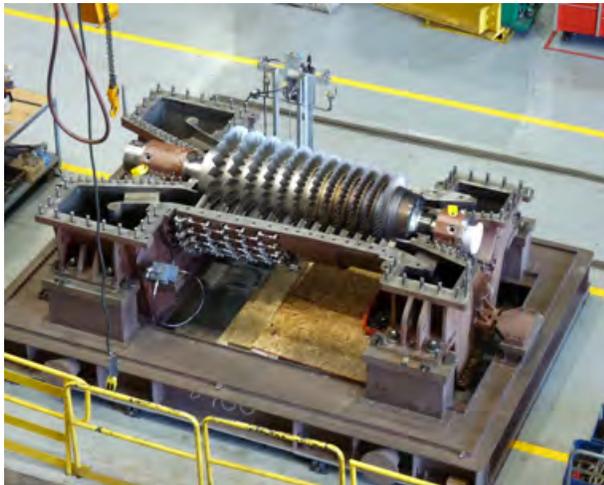
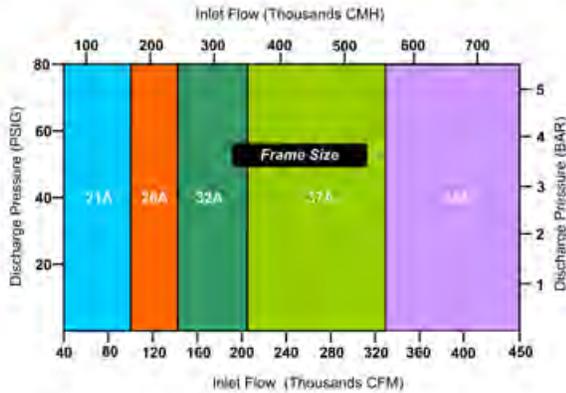
■ HIGH EFFICIENCY, HIGH FLOW AXIAL COMPRESSORS

Elliott's axial compressors are often paired with power recovery expanders to supply combustion air to the FCC process. These highly efficient machines are well suited for high flow, medium pressure applications beyond the flow capacity of centrifugal compressor designs. Elliott designs the aerodynamic components to maintain high efficiency levels over broad operating ranges, resulting in significant energy savings. Efficient, reliable axial compressors from Elliott are also used in air separation plants, blast furnace blowers, nitric acid plants, synthetic fuel processing and aerodynamic testing.



To ensure high reliability and ease of maintenance, Elliott axials have a dedicated adjustable guide stator vane cover for routine inspections. Elliott axial compressors offer direct access to bearings and seals with individual covers for reduced field service time. Axial compressors also provide weight and size advantages which translate into savings on foundation and support structures as well as floor space requirements. Elliott's high efficiency robust blading for reduced plant emissions is the result of many years of engineering and experience in both steam turbines and axial compressors.

ELLIOTT AXIAL COMPRESSORS



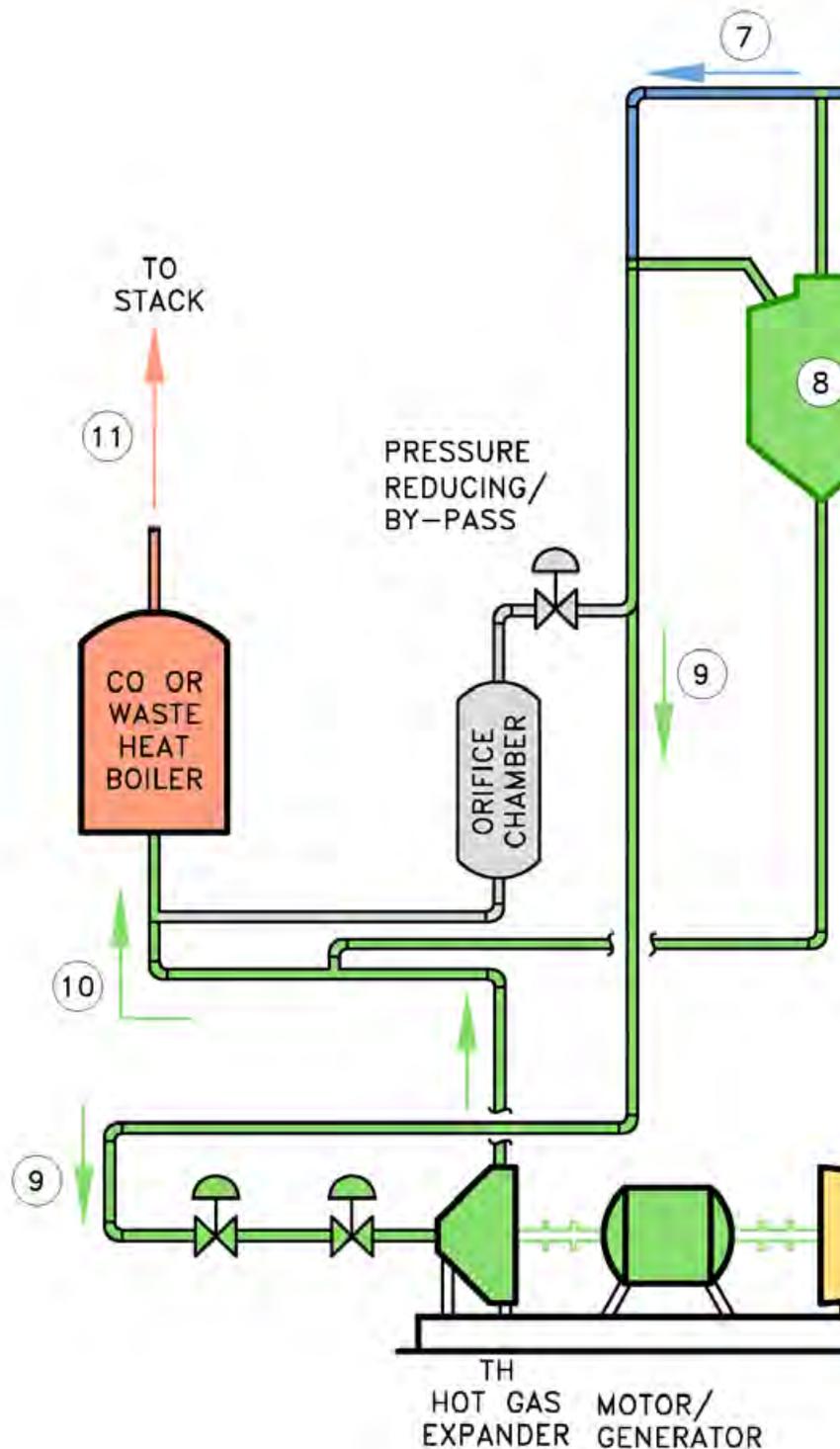
Axial compressor assembly shown with bearing covers.



Testing an axial compressor.

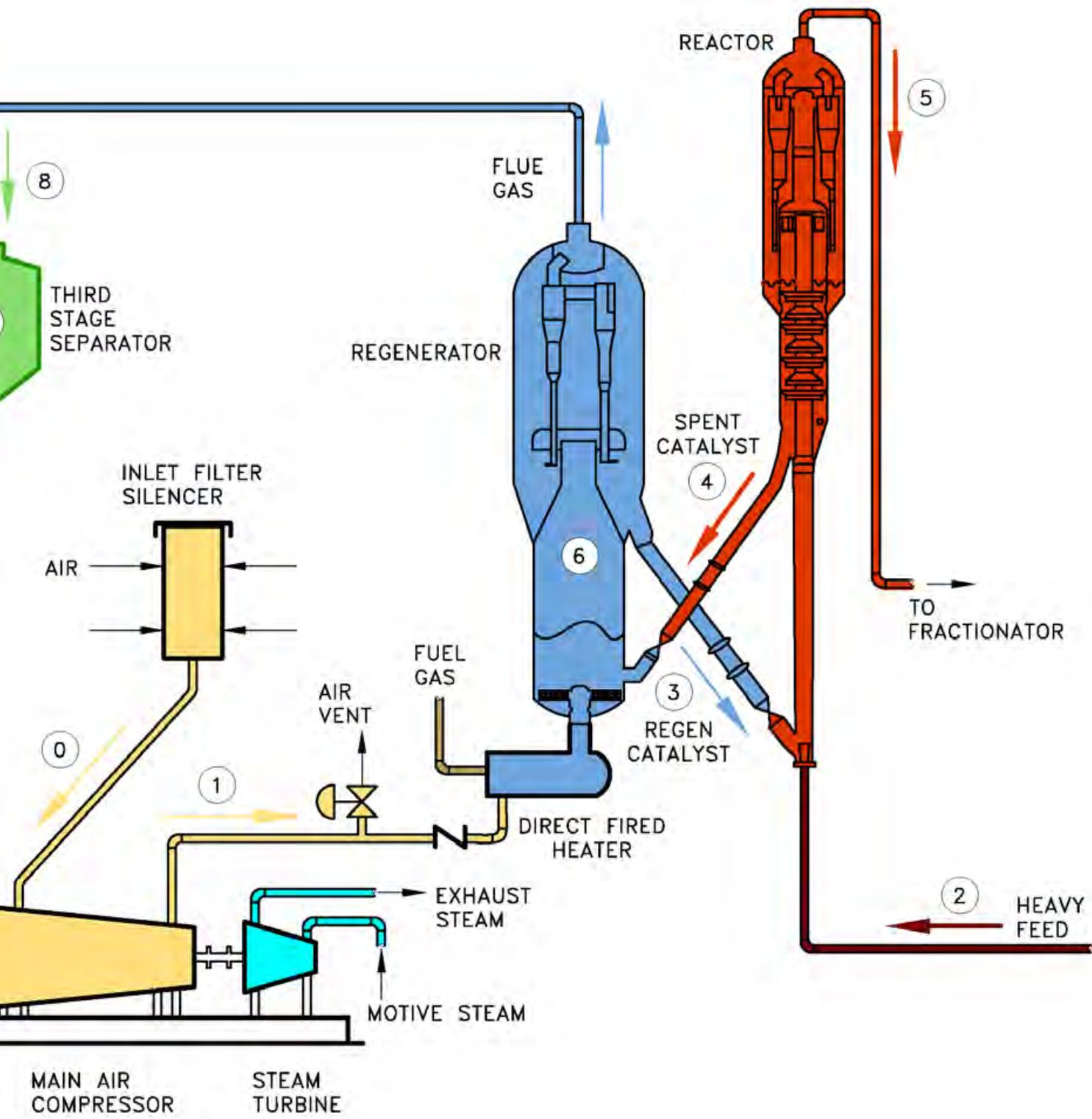
■ HOW TO IMPROVE PLANT EFFICIENCY

0. Air enters the inlet filter and flows through the main air compressor
1. Pressurized air is injected into the regenerator for combustion reaction.
2. Feed (heavy gas oils) is pumped to the reactor.
3. Catalyst is combined with the feed and cracking reaction takes place.
4. Spent catalyst with coke build-up is returned to the regenerator for recovery.
5. Cracked gaseous products are separated from the catalyst in cyclones and flow overhead to the fractionator.
6. Coke build-up on the catalyst combusts, producing hot flue gas.
7. Without the expander, flue gas flows into the pressure reducing valve, an orifice chamber, and leads to the waste heat boiler.
8. When an Elliott power recovery system is installed, flue gas flows to the third stage separator (TSS) for fine catalyst particles removal.
9. TSS overhead stream flows to the expander for power recovery.
10. Power is generated, and low pressure flue gas enters the waste heat boilers for thermal energy recovery.
11. Exhaust gas discharged in the stack.

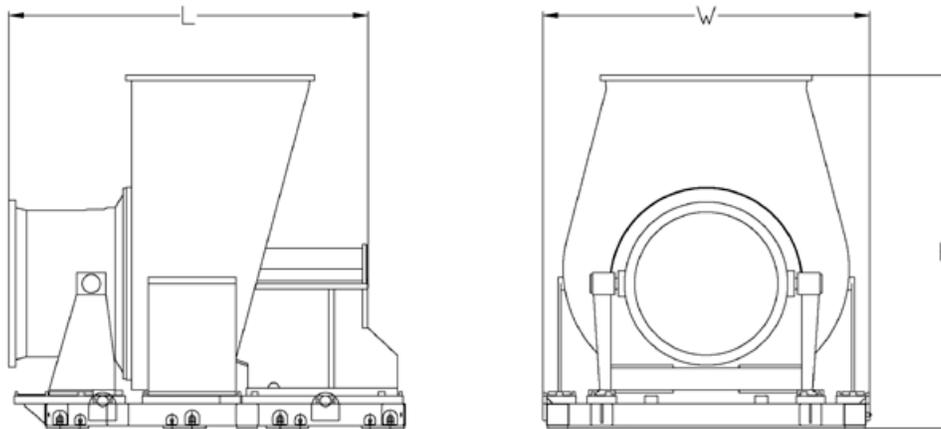


Typical FCC process with and without Elliott power recovery system

In a typical FCC process without a power recovery expander, a large amount of valuable kinetic energy is lost by passing the flue gas through a pressure reducing valve. Because coke is burned from the catalyst, enough thermal energy is generated from the combustion reaction to run the expander and generate additional electrical power. Based on 5¢ per kWh energy cost, an Elliott 30 MW expander can save refiners over \$13 million in one year. In this configuration, the high pressure steam used to drive the compressor, can now be converted in to more desirable low pressure steam by passing it through the same steam turbine to generate additional power from the generator. Overall, Elliott's power recovery process reduces the facility's carbon footprint and energy consumption.



■ ELLIOTT HOT GAS EXPANDERS

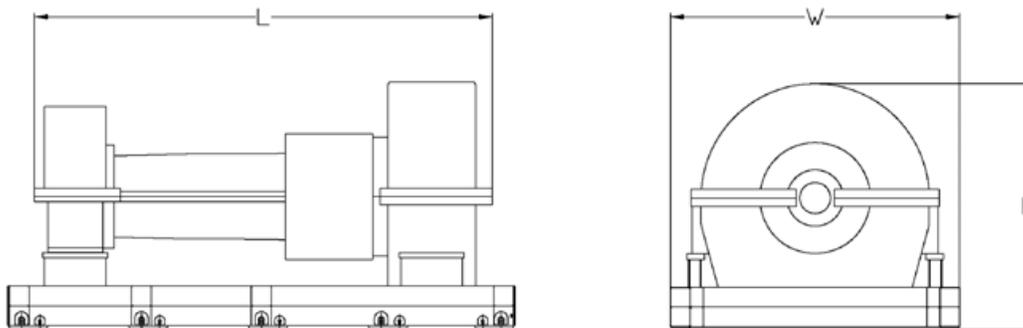


Approximate Dimensions and Weights

TH-Model	Inlet Nozzle inch (mm)	Exhaust Nozzle inch (mm)	Length inch (mm)	Width inch (mm)	Height inch (mm)	Weight lb (kg)
TH-85-1	48 (1 220)	66 (1 680)	118 (2 990)	106 (2 700)	109 (2 770)	26,500 (12 000)
TH-100-1	56 (1 420)	78 (1 980)	134 (3 400)	138 (3 505)	127 (3 240)	34,000 (15 400)
TH-120-1	66 (1 676)	84 (2 134)	156 (3 960)	128 (3 245)	145 (3 683)	78,700 (35 700)
TH-140-1	77 (1 956)	108 (2 743)	175 (4 450)	178 (4 520)	175 (4 450)	91,000 (41 300)

Information is of general nature; it is intended to allow preliminary estimates only, actual sizes and weights will vary depending on specific application requirements.

■ ELLIOTT AXIAL COMPRESSORS



Approximate Dimensions and Weights

A-Model	Inlet Nozzle inch (mm)	Exhaust Nozzle inch (mm)	Weight for 13 stage unit lb (kg)	Weight/ additional stage lb (kg)	Length 13 Stage inch (mm)	Diff length/ stage inches (mm)	Width inch (mm)	Height inch (mm)
21A	48 (1 220)	30 (760)	36,000 (16 330)	500 (230)	132 (3 360)	4.4 (112)	96 (2 430)	80 (2 020)
26A	54 (1 370)	36 (920)	59,000 (26 760)	910 (410)	175 (4 450)	4.9 (124)	110 (2 800)	99 (2 520)
32A	72 (1 829)	42 (1 067)	87,960 (39 900)	1,480 (671)	182 (4 623)	5.9 (150)	130 (3 300)	119 (3 030)
37A	84 (2 134)	54 (1 372)	156,000 (70 760)	2,140 (970)	237 (6 030)	6.5 (165)	148 (3 760)	142 (3 610)
44A	100 (2 540)	66 (1 680)	237,000 (107 500)	3,500 (1 590)	276 (7 010)	7.9 (201)	180 (4 570)	169 (4 300)

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■ GLOBAL SERVICE AND SUPPORT

Elliott offers comprehensive service and support for all types of turbomachinery regardless of the original manufacturer. Our experienced engineers, metallurgists, technicians, welders and mechanics have the expertise and experience to keep equipment performance high and maintenance costs low.

Elliott's global network of service centers, which are registered to ISO 9001 or have structured quality management systems, provide installation, maintenance, repair, overhauls, parts, rerates, modifications and training, 24 hours a day, 7 days a week. Supported by our service centers throughout the world, Elliott's field service teams are recognized for their hands-on experience with comprehensive overhauls, project management, resource planning, subcontractor control, installation and commissioning, and on-site repair. Elliott Technical Services provides practical, timely and cost-effective solutions for complex turbomachinery problems. Rerates and modifications by Elliott Engineered Solutions enhance operating efficiency and extend the life of rotating equipment from any manufacturer.

Elliott is accredited by the American Society of Mechanical Engineers (ASME), holding both U and R boiler and pressure vessel certifications. Nondestructive Examination (NDE) and welder qualifications are important parts of our quality control system. Elliott qualifies its NDE personnel

in accordance with American Society of Nondestructive Testing (ASNT) Recommended Practice SNT-TC-1A or country-specific equivalent based on ISO 9712. Elliott qualifies its welders in accordance with ASME Boiler and Pressure Vessel Code Section IX. Project-specific compliance with other industry standards includes: ANSI, API, CRN, CSA and CE/PED.





Elliott Group is a global leader in the design, manufacture, and service of technically advanced centrifugal compressors, steam turbines, power recovery expanders, cryogenic pumps and expanders, and axial compressors used in the petrochemical, refining, oil & gas, liquefied gas, and process industries, as well as in power applications.

Elliott Group is a wholly owned subsidiary of Ebara Corporation, a major industrial conglomerate headquartered in Tokyo, Japan.



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T H E W O R L D T U R N S T O E L L I O T T



C O M P R E S S O R S ■ T U R B I N E S ■ C R Y O D Y N A M I C S ■ G L O B A L S E R V I C E