ELLIOTT GROUP
EBARA CORPORATION

Elliott Compression Solutions for LNG

A Pioneer in LNG Refrigeration Compression

From the beginning of the commercial market for liquified natural gas (LNG) in 1964, Elliott Group has been a premier supplier of refrigeration compressors for baseload LNG plants. Our heritage in refrigeration compressor technology evolved from our association with Carrier Corporation beginning in the 1950s. Today, Elliott is a key partner for some of the largest LNG projects throughout the world.

Elliott's refrigeration experience includes over 100 compressor casing installations in base-load LNG plants around the world. These compressors contribute over 70 million tons per annum (MTPA) of LNG capacity. Elliott's list of installed compressors totals over 3,200,000 hp (2,390 MW) and continues to grow. Through its engineering experience and highly reliable equipment designs, Elliott enjoys a well-deserved reputation as a leading supplier to the LNG industry.

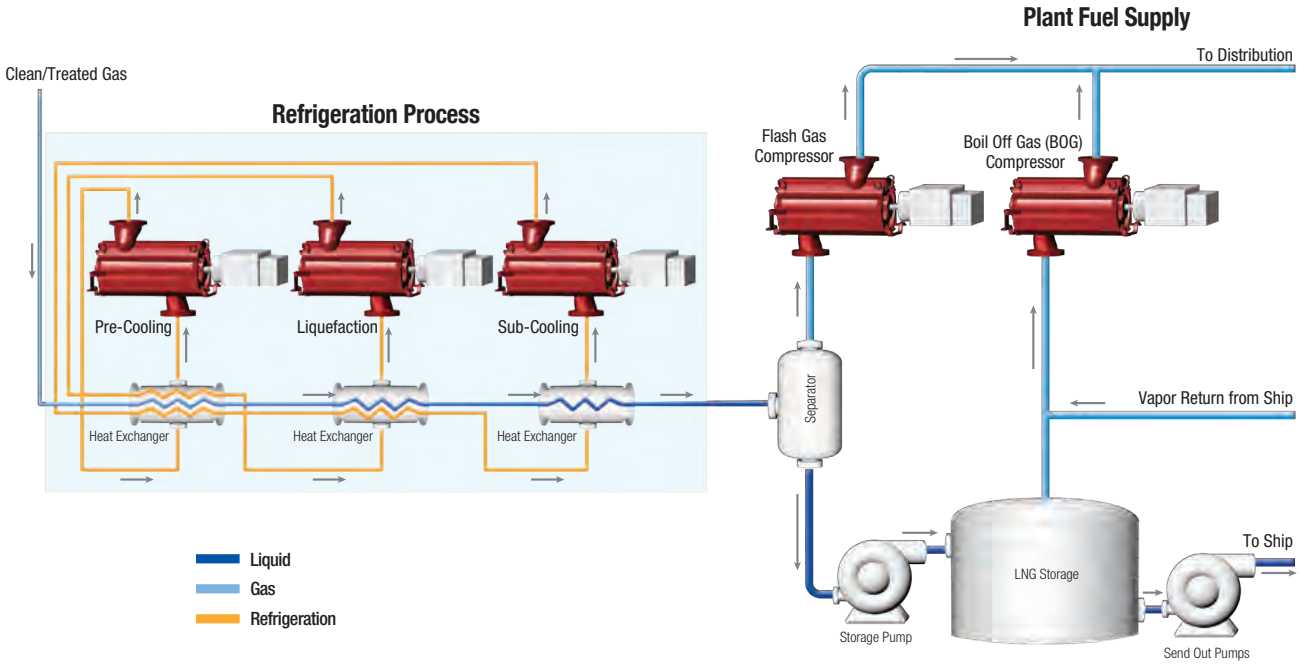
Our LNG compression solutions include:

- Boil off gas (BOG)
- Mixed refrigerant
- Dual refrigerant
- End flash gas
- Propane refrigeration
- Booster

Over the years, Elliott has contributed to many industry-leading innovations in LNG service:

- The world's first base-load LNG plant refrigeration compressors.
- The world's first gas turbine-driven compressors in an LNG plant.
- The world's first mixed refrigerant process LNG plant.
- The world's first use of a large frame, horizontally split, centrifugal compressor in propane refrigeration service.
- The world's first use of variable frequency synchronous motor starters for large frame gas turbines driving main refrigeration compressors.
- The world's first dual mixed refrigerant compressor service.
- A patented adjustable inlet guide vane (AIGV) system to efficiently control inlet flow and pressure in boil off gas (BOG) applications.

Elliott in LNG



Experience with Large Frame Compressors

Elliott has over 50 years of proven experience in large frame compressor applications, including propane and mixed refrigeration services for LNG, propane/propylene services for petrochemical applications, and many other gas processing applications. Elliott's reliable, large frame compressors are engineered to meet the demanding temperature extremes encountered in LNG refrigeration applications. These compressors are available in both horizontally and vertically split designs.

Elliott's largest horizontally split compressor designs are capable of up to 320,000 icfm (544,000 m^3/h) with casing ratings of up to 400 psig (27.6 barg).

Elliott's vertically split barrel compressors are designed for maximum flows of 154,000 icfm (261,650 m^3/h). Elliott has installations in Russia for dual mixed refrigerant, high-pressure applications rated over 600 psig (41.4 barg).

88MB6-5 LNG mixed refrigerant compressor.

110M6 compressor casing.

Experience in World-Scale LNG System Integration

LNG customers can draw upon the proven system integration experience of Elliott's project managers, project engineers, design engineers, and field service engineers. Our LNG project experience includes the integration of compressors, motors, and large frame gas turbines with plant DCS platforms, and fire and gas detection systems.

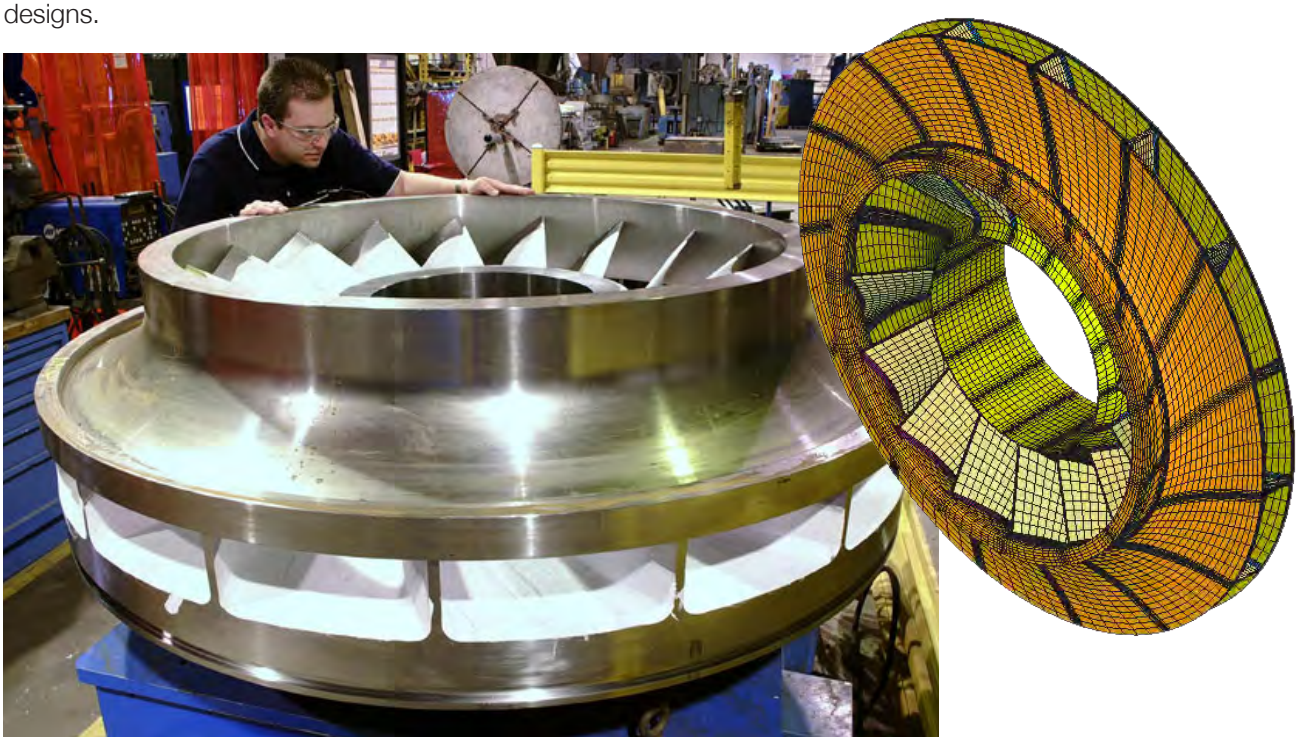
Elliott coordinates supply logistics among major suppliers such as the gas turbine and variable frequency drive manufacturers. By carefully managing delivery and start-up schedules, Elliott project managers help to reduce commissioning time. Elliott's alliance with Tri-Sen Systems simplifies the selection and coordination of multiple control systems in LNG facilities. Tri-Sen's TSx compressor controls feature configurable redundancy, advanced diagnostic capabilities, a built-in human machine interface, and real time and historical trending.

60MB6I LNG mixed refrigerant compressor.

Advanced Design Tools

Elliott employs the latest engineering design technologies, including computational fluid dynamic (CFD) analysis, finite element analysis (FEA), and solids modeling.

CFD and FEA provide a full 3-dimensional analysis of both the aerodynamic flow path and the structural mechanics of compressor designs. State-of-the-art rotor dynamics, compressor performance and dynamic simulation programs are used for developing compressor selections. These tools optimize a wide range of compressor configurations including those with side-stream, double flow, back-to-back, and inter-cooled designs.



Impeller inspection for a 103M3 high flow compressor.

Compressor Selection

Elliott's proprietary compressor selection program is used in all compressor performance simulations. The program incorporates data from single-stage design verification tests and actual factory performance tests. This powerful tool accurately models and predicts stage performance including induction and extraction side-streams.

Performance enhancements include higher aerodynamic efficiencies and longer performance life to handle the demanding LNG service applications. Elliott's patented AIGV design enables a wide performance range for fixed-speed compressors.

Elliott's long term relationships with major LNG process designers are invaluable for matching the process to the compressor performance characteristics and optimizing plant output.

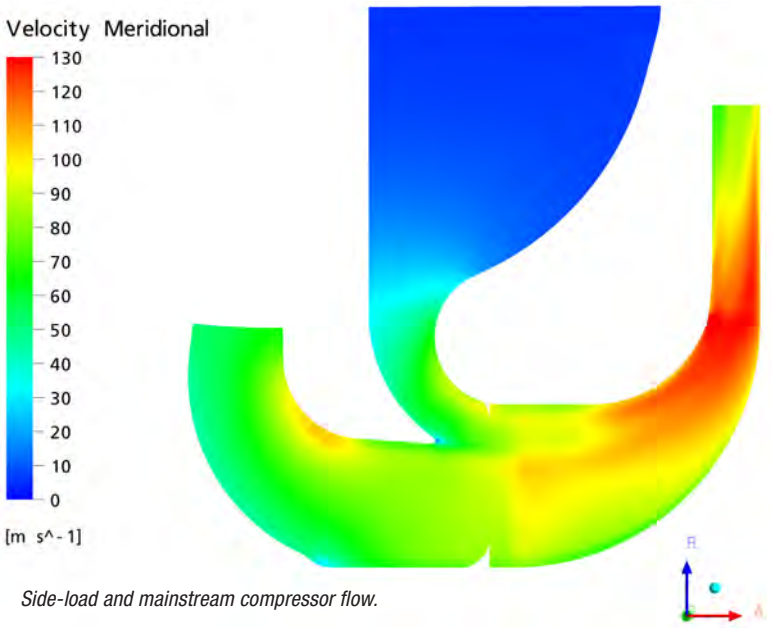
Modeling an 88MB5 compressor.

Supporting Production Requirements

In LNG service, the most extreme process demands are in the propane refrigeration applications. These applications involve high molecular weights combined with low temperatures and variations in volumetric flow requirements. Large volume side-streams are common in the liquefaction process.

Elliott's experience in the design of compressors for these challenging conditions ensures an accurate fluid dynamic design with high performance, a broad operating range, and reliable mechanical characteristics. Modeling confirms the proper design of the merging flow streams at similar velocity levels for minimum pressure loss and maximum efficiency.

- Design scalability ensures performance across the range of all possible applications.
- Expertise in metallurgy, weld repair, and specialty coatings ensures performance in extreme duty applications.



Side-load and mainstream compressor flow.

EDSCAN – Analytical Simulation

Elliott's proprietary EDSCAN simulation program is used to confirm the sizing of the starter or helper motor for a compressor/gas turbine train by analyzing the compressor string performance under various customer and factory process conditions. Elliott has simulated a variety of operating conditions, including:

- Start-up
- Controlled & emergency shutdowns
- Anti-surge valve selection confirmation
- Alternate gas operations such as nitrogen purge and defrosting operations
- Process upset conditions
- Simulation of site start-up conditions for factory testing

Simulations fully model the performance of the LNG train, which enables Elliott to predict the start-up and running performance of the compressor, motor, and gas turbine under site conditions.

88M4 & 60M4 mixed refrigerant compressors.

Manufacturing Capabilities

Elliott manufactures some of the largest centrifugal compressors in the industry. These large frame technologies are directly applicable to the production requirements of large-scale LNG plants. The maximum inlet flows for these large compressors are up to 320,000 icfm (544,000 m^3/h) in a single flow configuration.

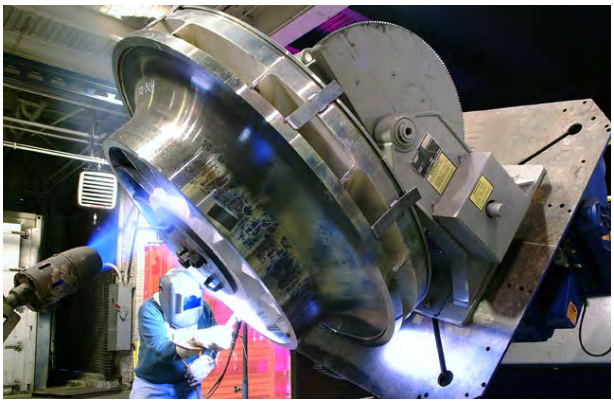
In Elliott's manufacturing facilities, large and powerful weldment positioners allow continuous welding of compressor casings by moving the mounted casing around the welder.

The Mastercenter Mill Turning Machine was the first of its kind to be installed in the United States and is used to manufacture diaphragms and seal housings.

The Masterhead Milling Center is a powerful machine which is like a factory within a factory. This machine's 5-axis capabilities allow layout, milling, drilling, boring, and inspection operations.

These machining centers, along with Six Sigma and Lean Manufacturing principles, enable Elliott to reduce cycle times for large compressors.

103M3 compressor casing on the masterhead.



103M impeller on a 5-axis weldment positioner.

Testing Capabilities

Few compressor manufacturers have capabilities that match the extent and versatility of Elliott's testing facilities.

- Testing to API 617 and ASME Power Test Code (PTC-10) requirements.
- A permanent gas turbine test pad incorporating all required utilities and necessary auxiliary equipment.
- Full-load string testing capabilities with a gas turbine driver over 100,000 hp (74.6 MW).
- A permanent motor test pad for full-load string testing over 16,000 hp (12 MW).
- Full variable frequency drive (VFD) capabilities including compressor drive and gas turbine start-up.
- Customer-specific testing capabilities for LNG process applications.
- Global testing availability with comprehensive testing facilities in the United States and Japan.

Elliott maintains a state-of-the-art metallurgy and materials engineering lab with a dedicated team of experts focused on optimizing the performance of Elliott rotating equipment in caustic, corrosive, and extreme temperature conditions.

Elliott's facilities, which are registered to ISO 9001 or have structured quality management systems, adhere to strict quality assurance practices throughout the design, manufacture, and testing of Elliott rotating equipment and auxiliary units.

Full load LNG gas turbine/compressor test set-up.

Elliott's Global Services

Service Parts Organization

Elliott's ISO 9001 registered Service Parts organization works with customers to ensure optimal performance and reliability of all Elliott equipment. Service Parts engineers are qualified to address the varying needs of each customer, including parts identification, upgrade recommendations, and customized parts kits design.

Elliott's Service Parts organization has extensive machining centers and finished parts inventories that allow quick manufacturing and shipment of parts. Emergency customer support is offered seven days a week and same day shipment is available on most in-stock items.

Elliott's service shops are strategically located worldwide to service and repair Elliott and non-Elliott turbomachinery. The service shops have extensive experience ranging from inspections and overhauls to specialty machining and weld repair.

Customer training classes for operations and maintenance personnel are offered several times a year at Elliott's U.S. headquarters. Arrangements may also be made for customized training at customer sites or at any Elliott facility or service center.

Field Support

Retrofitting and rerating compressors in the field can achieve capacity increases, de-bottlenecking and process optimization. Elliott offers a comprehensive range of support services for all types of turbomachinery from any manufacturer. Elliott's global service network provides experienced on-site project management, supervision and skilled labor to perform installation, commissioning, and start-up activities. Elliott offers maintenance programs that range from preventative, routine, and emergency services, to long-term service agreements.

88M4 low-pressure mixed refrigerant pressure compressor casing.

88M6I LP/MP mixed refrigerant compressor.

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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