ELLIOTT GROUP
EBARA CORPORATION

Elliott Boil Off Gas Compression Solutions

Optimizing Efficiency in Elliott Boil Off Gas Compressors

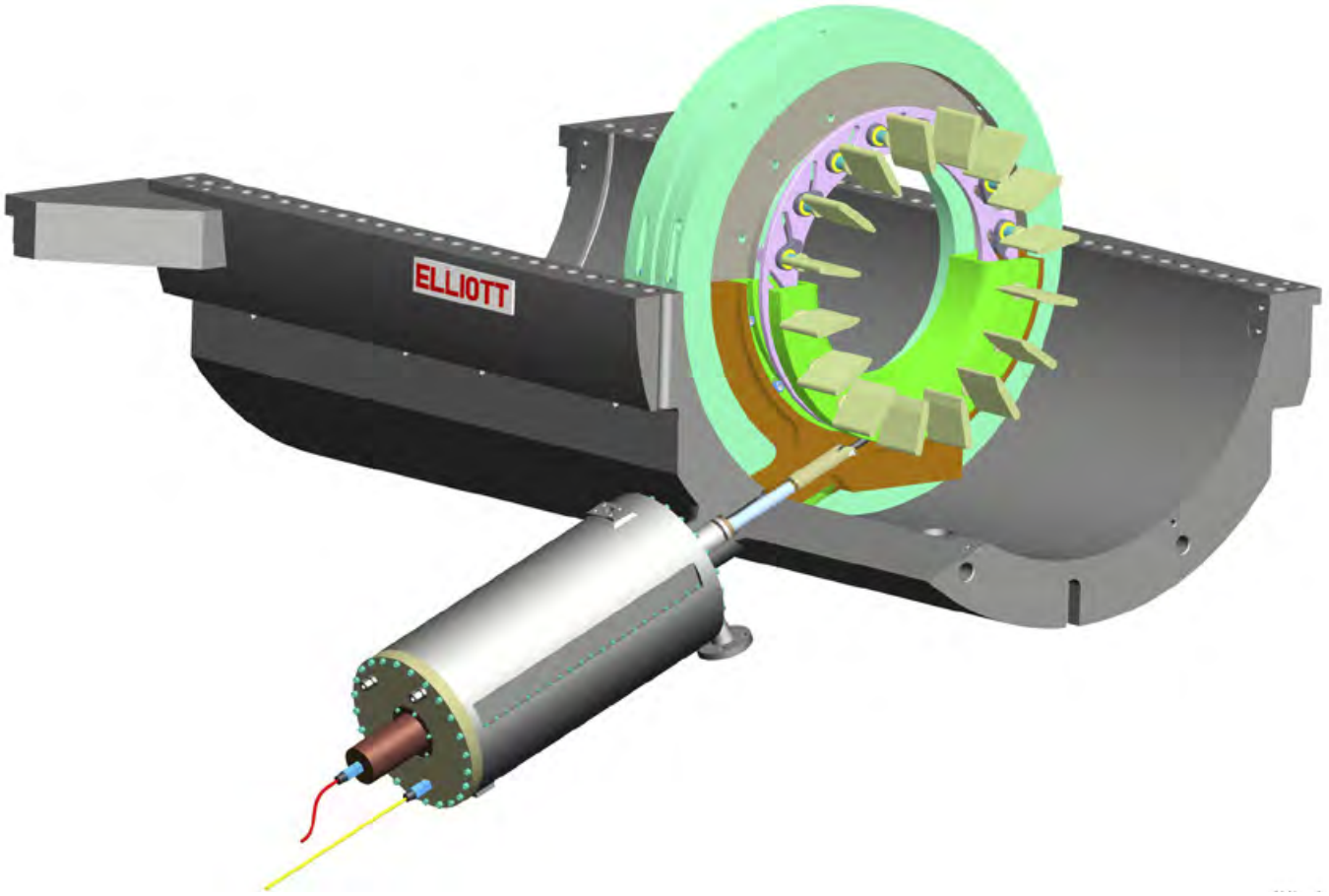
The accessibility of huge global reservoirs of natural gas has pushed natural gas into a prominent position as an abundant, low-cost, and low-carbon fuel. As natural gas becomes a bigger player in global energy production, better, more efficient methods are needed for storing and transporting liquefied natural gas (LNG).

Maintaining LNG in its liquid form at low pressure requires extremely low temperatures. Handling boil off gas (BOG) is inherent to the process. During LNG storage and transportation, as surrounding temperatures cause the LNG temperature to slowly rise, the LNG begins to evaporate or "boil." The expanding vapor causes the pressure to rise, and must be removed to maintain safe pressure levels inside the tank. The "boil off" gas is routed through a boil off gas compressor.

Adjustable Inlet Guide Vanes (AIGVs)

There are two common methods for controlling the mass flow and discharge pressure in a BOG compressor running at a fixed speed: 1) suction throttling control vales; or 2) adjustable inlet guide vanes (AIGVs). A suction throttling control valve is installed at the inlet pipe to restrict mass flow and lower the pressure immediately upstream of the BOG compressor. Alternatively, AIGVs are installed inside the compressor, just ahead of the first compressor stage to control the flow direction into the first impeller. While AIGVs are moderately more complex than suction throttling control valves, they provide greater range of flow. Most importantly, AIGVs maximize off design efficiency by minimizing pressure loss compared to a suction throttle approach, resulting in lower power consumption.

To ensure the efficiency of Elliott BOG compressors, we've developed and tested a new type of AIGV system to accurately and efficiently control mass flow and pressure at extremely low temperatures (-300° F). Elliott AIGVs enable a wide performance range (-20° to +70°), with a patented control mechanism that maintains a consistent vane angle with no slippage, load transfer or gear backlash. A flexible configuration is adaptable for use on ships and in on-shore offloading facilities.



Design and Testing

Computational Fluid Dynamics (CFD) was used to determine the optimal flow path for Elliott AIGVs. A 16-vane configuration was developed and thoroughly analyzed to ensure that proper inlet flow is maintained under varying AIGV turndown angles (-20° to +70°). Mechanical and aerodynamic testing verified design integrity.

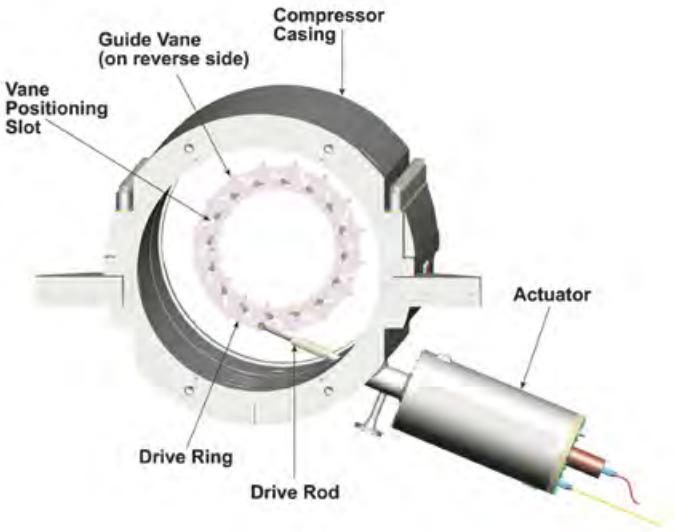
A busy LNG transport tanker unloading facility typically cycles the compressor from boil-off recovery mode to offloading mode twice a day, or 730 times per year. This cycle rate was factored into Elliott's AIGV design specifications to provide more than a decade of trouble-free operation.

Elliott's patented control mechanism is designed to maintain a consistent vane angle. The actuator is connected to a drive rod that directly controls the drive ring that positions the vanes. Tests were conducted to determine how the control and its individual components would perform under extreme cold. Cryogenic operating temperatures inside the compressor preclude the use of lubricants, so the control and its component surfaces were treated with a specialized low-friction coating and tested in liquid nitrogen at a temperature of -300° F. The control and all components outperformed the goal of 10,000 cycles, with no detectable increase in load due to component wear after 13,000 cycles.

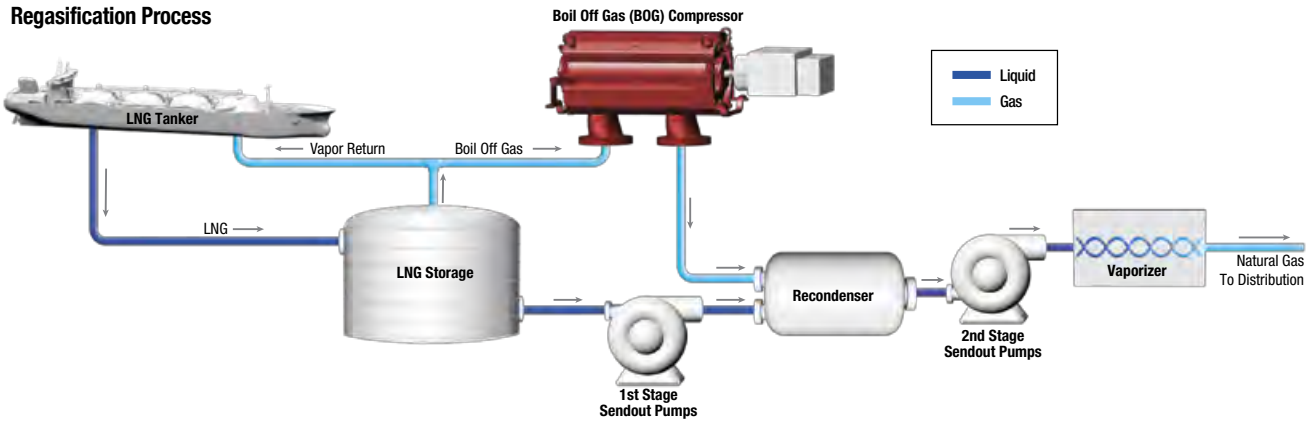
Elliott AIGV Features and Benefits

- Aerodynamic vane design ensures optimal flow path.
- Turndown angles enable a wide performance range (-20° to +70°).
- Patented control mechanism eliminates slippage, load transfer and gear backlash.
- Direct drive control maintains consistent vane angle.
- Specialized low-friction coating protects the control mechanism at cryogenic operating temperatures.
- Top half of casing can be removed without disassembly of AIGV hardware for easy maintenance.
- Typical cycle rate incorporated in design to provide 10 years of trouble-free operation.
- Flexible configuration easily adapts for use on ships and in on-shore offloading facilities.

Elliott's patented AIGV control



Elliott AIGVs are available for Elliott M-line centrifugal compressors, frame sizes 20M to 56M (~2,900 to 59,000 acfm).



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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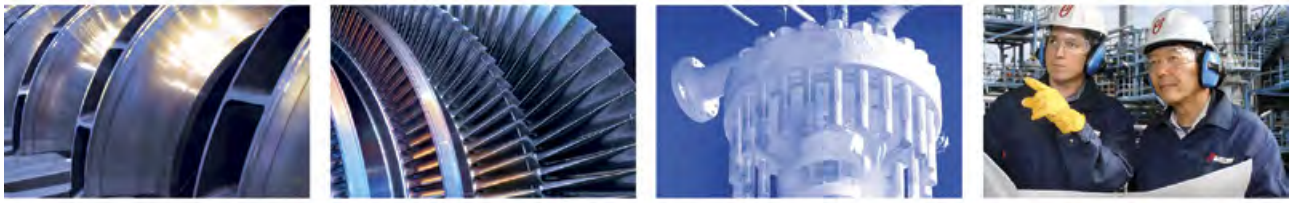
THE WORLD TURNS TO ELLIOTT



COMPRESSORS ■ TURBINES ■ CRYODYNAMICS ■ GLOBAL SERVICE

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