Klaus Brun, Director of Research & Development, Elliott Group, USA, discusses building new pipeline compression infrastructure to meet worldwide LNG demand.

REDESIGNING THE INDUSTRY

As one of the world's largest natural gas producers, the US is now the leading global exporter of LNG. US export capacity for LNG is approximately 12 billion ft^3/d, or about 15% of total natural gas production. Due to recent geopolitical turmoil, European demand for LNG has risen dramatically, requiring current suppliers to increase production and open new production facilities. There is significant political pressure and economic opportunity for the US to make up the shortfall of Russian-supplied natural gas with LNG. Given the commitments made to potential European recipients, US LNG production would have to increase by more than 20% (about 3 billion ft^3/d) over the next 12 months. This LNG will have to be converted from natural gas which must be produced and transported to the LNG plants.

An increase of 20% in US-exported LNG corresponds to an increase of 3% in US natural gas production. That may not sound like much, but becomes a staggering figure in the context of existing infrastructure and required new machinery.

In the US upstream sector – gas production and gathering – there are approximately 15 000 installed compressors, mostly smaller reciprocating compressors driven by engines or electric motors. In the midstream or gas transport sector, there are about 8000 mid-size and large installed compressors, made up of a mix of older low-speed integral reciprocating, high-speed separable reciprocating, and gas turbine or electric motor-driven centrifugal compressors. Finally, there are about 3000 mostly large compressors in downstream and LNG applications.

Ignoring downstream and LNG plants for now, there is an estimated 25 million hp in the upstream sector and 40 million hp in the midstream. Upping this by 3% requires another 2 million hp of new compression in the US alone, of which half will be for new pipeline compressors. It is critically important that this new compression infrastructure operates as efficiently as possible to reduce energy waste, preserve critically needed natural resources, and minimise greenhouse gas (GHG) emissions.

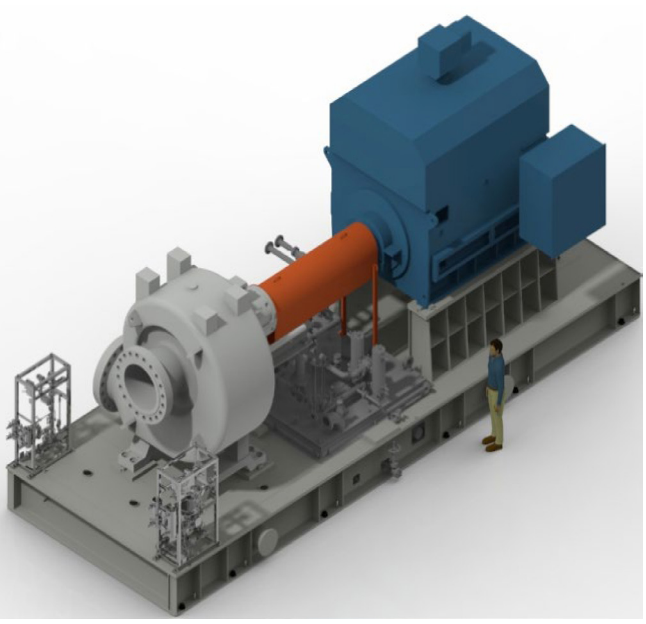

Figure 1. Elliott 140 TCH pipeline compressor on a baseplate.

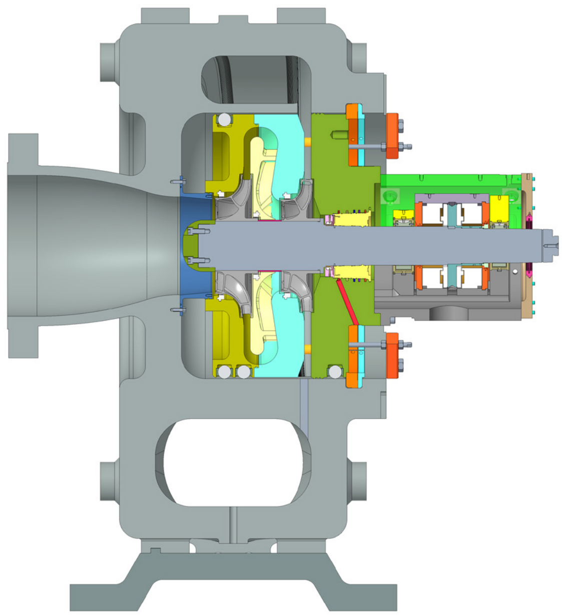

Figure 2. Elliott 140 TCH cross-section.

Demand background

In the oil and gas industry, compressors are used for natural gas gathering, transport, processing, storage, and distribution. The US has approximately 1700 midstream natural gas pipeline compressor stations. An estimate from the US Department of Energy indicates that 1 - 1.5% of US natural gas is utilised by oil and gas compressors for consumption and leakage. The average age of US pipeline compressors is 30 - 35 years, and industry estimates indicate that about 3 - 5 million hp of US compressors must be replaced within the next 10 years. To this we must add the new capacity requirements for LNG production and the expected typical growth demands. This results in a need for a total of 4 - 6 million hp of new pipeline compression over the next 10 years in the US alone. Clearly, with this huge quantity of new compression, there is significant potential to reduce energy usage in the gas transport sector through modernisation of the compression infrastructure.

Pipeline compression

Compressors are installed in natural gas pipelines to inject gas into the pipeline at its operating pressure, and then re-compress the gas at certain distances along the pipeline to compensate for its viscous pressure drop. Typical pipeline operating pressures range from several hundred psi to about 1500 psi for standard pipe diameters, which range from a few inches up to greater than 60 in. In the US alone, there are currently over 7000 compressors installed in natural gas pipeline compression service on over 2.6 million miles of pipelines. Approximately 25% of these compressors are old, low-speed, integral reciprocating machines that were originally installed between 1940 and 1970, making them technically outdated and mostly obsolete. This, in combination with additional natural gas demands driven by increasing LNG exports, new/refuelled fossil power plants, and increasing domestic consumption, has led to the need to rapidly increase the North American pipeline compression capacity, both by the installation of new units, and by replacing older, low-power units with modern, higher-power units. At the same time, environmental regulations require the reduction of carbon emissions and gas leakage from pipeline operations, which has resulted in the preferred installation of electric motors over gas engines or turbines as pipeline compressor drivers.

Most centrifugal compressors that are currently being installed in pipelines were originally derived from process gas barrel beam style compressors. For this design, a long, multi-stage impeller shaft is mounted on bearings and seals at both ends of the casing, and a balance piston and thrust bearing are used to limit axial movement of the shaft. This design evolved from classical refrigeration, refinery, and chemical process compressors that were originally intended for handling high-pressure ratios and a wide range of different gases at high pressures. However, this design style is sub-optimal for basic pipeline service where the pressure ratios are relatively low and the gas composition is fairly constant, but the operating conditions are highly variable. The design also must be reliable to operate for long periods without scheduled or forced outages. Furthermore, because of the traditional preference of pipeline operators to utilise gas turbine drivers, most current pipeline compressor designs are speed matched to provide optimal performance at high, gas turbine speeds, rather than the lower speeds of electrical motors. Driving

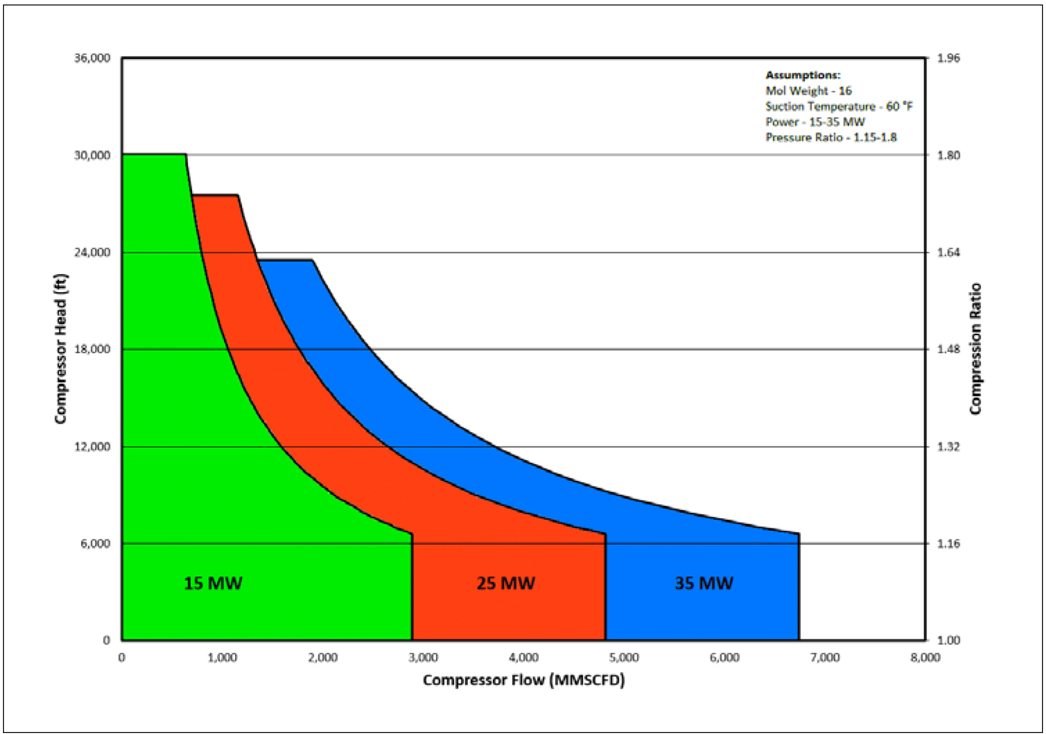

Figure 3. **Elliott 140 TCH pipeline compressor operating range.**

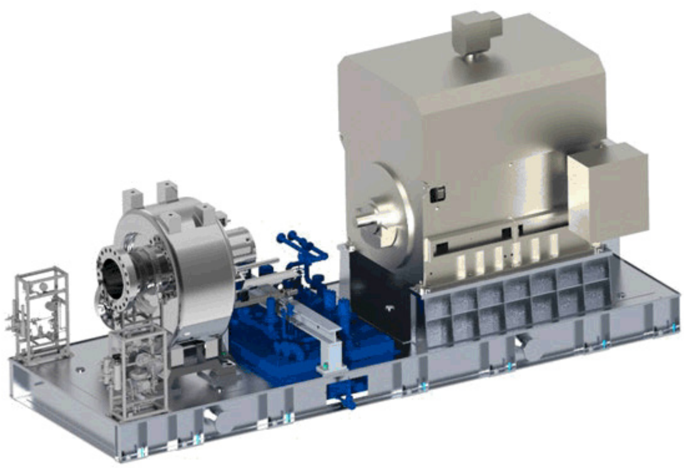

Figure 4. **Elliott 140 TCH package and maintenance access.**

centrifugal compressors with electric motors requires the use of a gearbox in most pipeline applications.

Electric, motor-driven centrifugal compressors have been available for pipeline compression since the 1960s, but they were originally neglected by the industry because of the need to install additional electrical infrastructure on the pipeline. However, due to stricter environmental compliance regulations, centrifugal compressors driven by electric motors have become more popular over the last 15 years and now represent approximately 50% of all new, installed mainline pipeline compression equipment. This trend is continuing with an increased focus by the pipeline industry to reduce GHGs, carbon dioxide, and methane emission point sources.

Electric, motor-driven centrifugal compressors are available from low, single-digit power to well above 100 000 hp applications. There are several technical options to electrically drive a centrifugal compressor for pipeline service. These include fixed speed, variable speed using a VFD, variable speed using a hydrodynamic coupling, direct drive, and indirect drive using a gearbox. Since pipeline service by nature is highly variable in throughput, variable-speed solutions are preferred over fixed-speed drivers to avoid the need to recycle gas, and to maintain a high efficiency over a wide operating range. Also, gearboxes add complexity and cost to the design while reducing reliability. However, since many centrifugal compressors designed for pipeline service were speed matched to be driven by gas turbines, they usually require a gearbox when driven by a conventional electric motor. It is important to note that this is a design decision that can be avoided if a centrifugal compressor is designed from its outset for a lower speed driver, such as a synchronous or induction electric motor.

To meet the demand of new compression for the replacement of old legacy compressors and the increased power demand for natural gas, the industry needs a simple, reliable, and highly efficient electric motor-driven compressor that is optimised for pipeline service.

The Elliott 140 TCH pipeline compressor addresses some of these shortcomings with features that were specifically designed for the natural gas pipeline service. This compressor uses a 1 - 2 stage impeller overhung design to reduce the number of bearings and seals. It does not require a balance piston, has an axial inlet for optimal aerodynamic performance and reduced leakage, and is speed matched to conventional, induction electric motors without the need for a gearbox.

Elliott 140 TCH pipeline compressor

Elliott has successfully provided centrifugal compressors for the oil and gas industry for over 80 years, including hundreds of machines in the pipeline or midstream service. The Elliott 140TCH (Figure 1) is derived from Elliott's many years of experience with overhung compressor designs, but it has features that are specifically designed for optimised, natural gas pipeline service.

The Elliott 140 TCH is a single or dual-stage, overhung design with an axial inlet that is electric motor-driven without a gearbox (Figure 1). This design approach results in higher efficiency, reduced leakage from a single, dry gas seal, and the avoidance of a balance piston. The 140 TCH comes with a direct connect, variable speed (VFD) motor and a standard footprint, in addition to custom aerodynamics for optimum efficiency and extended operating time between scheduled overhauls. The gearless configuration provides several advantages including a smaller footprint, reduced lube oil requirements, and higher net efficiency. The high-speed VFD-powered motor significantly reduces CO_2 and NO_X emissions as compared to a gas turbine driver. The VFD addresses starting issues and allows for adjustable operation to match load/capacity requirements. The pipeline compressor's single lift plug-and-play design includes auxiliaries such as lube oil, a buffer gas panel, and integrated, customised controls. Piping and wiring are included on the skid. The Elliott 140 TCH pipeline compressor is available from 10 000 - 42 000 hp to accommodate the full range of gas transport applications.

The 140 TCH is designed to handle most modern, mid-size and large pipeline compression applications. Its design is lean and simple, and focuses on making pipeline compression efficient, reliable, and cost-effective. The impeller aerodynamics are based on Elliott's advanced and proven EDGE technology. With the axial inlet and flexible or customisable aerodynamic design, efficiencies of greater than 85% can be obtained. The direct drive compressor, with a variable speed electric motor, provides a wide operating range, including efficient turndown operation. With three standard frame sizes, 15MW, 25MW, and 35MW, the centrifugal compressor is designed for applications up to 7000 million ft^3/d with a pressure ratio ranging from 1.15 - 1.8. The typical operating range for the 140 TCH is shown in Figure 3.

The machine design philosophy allows for simpler installation with a standardised package, an axial inlet, and selectable discharge for right or left piping configurations. The package includes an integral lube system for the compressor and motor, a simplified buffer or seal gas panel (the compressor only has one seal), an on-skid control system, and all compressor piping and wiring included on a single-lift skid for reduced footprint and weight. The compressor internals are contained in an inner-barrel design and can be removed from the driver side. This allows for easy maintenance and removal of the compressor internals without the need to move any piping. The removable barrel also allows for quick and easy, installable spare bundles or compressor restaging to change aero components, as needed (Figure 4).

The 140 TCH is designed to increase reliability by minimising component count. The compressor design allows for a direct drive electric motor, which does not require a gearbox, making the footprint small and light. The axial inlet and overhung design allow for a single seal. This results in a simpler, more reliable design with reduced emissions. The balance piston and balance piston line have been eliminated, further increasing reliability and reducing losses, which leads to increased efficiency.

With a clean and simple design and industry-proven components, the reliability, availability, and time between maintenance intervals has been increased. To meet modern pipeline compressor requirements for efficiency, reliability, and low emissions, Elliott has responded with a state-of-the-art pipeline compressor, incorporating years of experience and evolution into the design of the 140 TCH. This compressor is ideally suited to meet the increased capacity demands of modern pipelines efficiently with minimal GHG emissions.

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