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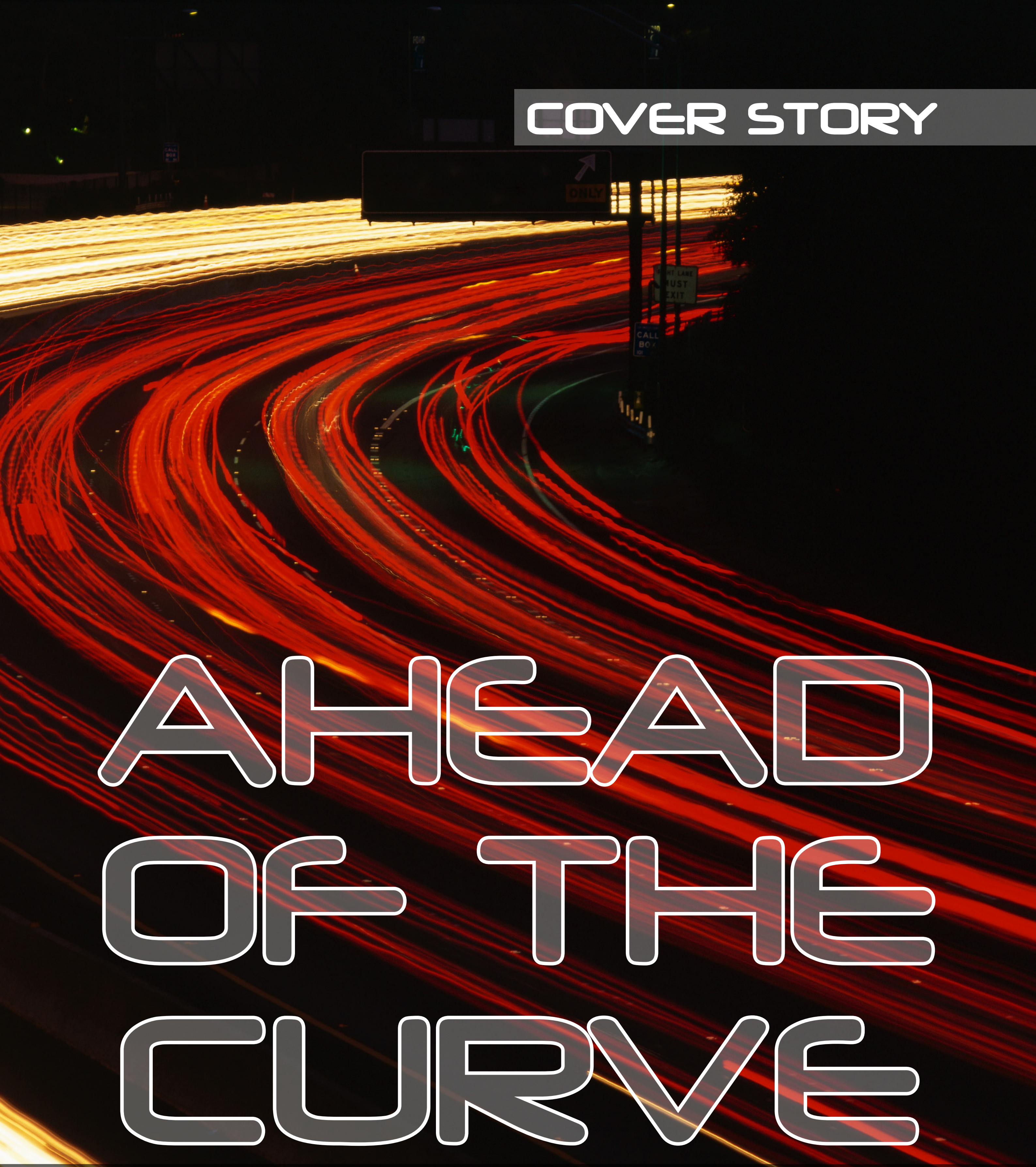

AHEAD OF THE CURVE

Nathan Brunell and Alessandro Bernardi, Baker Hughes, explore the latest trends and developments in the cryogenic valve sector.

LNG trade has increased more than 300% since the beginning of the century, and continues to expand at extraordinary rates with major new project developments taking off around the world. This liquefied form of natural gas comes with many advantages for accessing stranded gas without pipelines to market, including its highly dense characteristic that allows for maximum benefit during transportation. Demand continues to increase for this cleaner-burning fuel, resulting in LNG and regasification facilities rapidly being constructed all over the world. LNG growth continues its prominent expansion across all climates ranging from tropical to Arctic; from remote to heavily populated areas; from mega-capacities to local terminals. Each of these unique plant locations comes with a wide variation of design requirements, but all follow similar challenges and mega-trends, such as reduced emissions, alternative materials for cryogenic operation, integrated control with compressor equipment, and advanced diagnostics to monitor and predict trends before they occur.

Valve and equipment manufacturers see greater demand today than ever before, and partnerships to co-develop system enhancements are necessary to continue the acceleration of technology and advance performance. This article will explore these mega-trends and the developments around performance enhancement and advanced qualifications that are on the top of end-users' minds today.

Low emissions

Recent studies have tied valves and pumps to as much as 80% of total emissions from plants and pipelines today. These emissions are now policed around the world, with stiff penalties and consent decrees severely impacting offending customers. When specifying emission requirements for LNG valves, there are additional factors that must be considered to ensure operational results are in-line with specified expectations. This includes validating valve emissions certificates are qualified at not only ambient conditions, but also as low as the -196°C cryogenic test temperatures; and also understanding the valve qualifications should be evaluated at not only the number of mechanical cycles, but also the number of thermal cycles, as cryogenic temperature fluctuations can have a severe impact on performance.

Selecting the right specification that applies to the valve type is just as important. API 622 and 624 specifications (shown in Table 1) are applicable to on/off and isolation valves, while ISO-15848 and ANSI/FCI91-1 are more applicable to the control valves within the plant. The most significant variation between these specifications comes from the number of mechanical cycles that are required for the test. Control valves are required to throttle and control process variation, and hence are put through a more stringent task of mechanical cycle to ensure they do not lose their qualifications immediately after being in service. Ensuring the valves are qualified to the application requirements is a necessity for longer-term performance.

Furthermore, many standards set leakage requirements to either <500 ppm or <100 ppm rates, but in fact, products such as rotary valves can far surpass those performance expectations and offer differentiated benefits while in cryogenic service. For example, most valves are designed with extension bonnets to relocate the valve packing away from the cryogenic conditions. This feature improves the emissions leakage by removing key performing components away from extreme temperature conditions. However, the packing is only one of the potential leak paths that needs to be considered. Valves operating at -160°C or lower under cryogenic conditions directly expose the bonnet gasket joint to the low temperature conditions invoking thermal impact. Rotary valves can be beneficial for certain applications that are without high pressure drop, as they include an inherent design benefit of one less potential leak path with the

Table 1. Fugitive emission qualification standards

	Application	Mechanical cycles	Thermal cycles	Pressure	Fluid	Method	Packing leak rate
ISO-15848	Control and on-off valves	Control valves: CC1 (20 000 cycles) CC2 (60 000 cycles) CC3 (100 000 cycles)	Control valves: CC1 (2 cycles) CC2 (3 cycles) CC3 (4 cycles)	Mfg. Defined	Helium	Isolated vacuum atmosphere	A: 1,78 10^{-7} B: 1,78 10^{-6} C: 1,78 10^{-4} UOM mbar . L / s per mm stem dia.
		On-off valves: CO1 (205 cycles) CO2 (1500 cycles) CO3 (2500 cycles)	On-off valves: CO1 (2 cycles) CO2 (3 cycles) CO3 (4 cycles)		Methane	Sniffing	A:≤50 B:≤100 C:≤500 UOM ppmv of methane
ANSI/FCI 91-1	Control valves	A (100 000 cycles) B (25 000 cycles) C (100 000 cycles) D (25 000 cycles) E (5000 cycles)	A (3 cycles) B (3 cycles) C (0 cycles) D (0 cycles) E (1 cycle)	Mfg. Defined	Methane	Sniffing	CL 1: 100 ppm CL 2: 500 ppm
API 622	On-off valves	1510	5	600 psi (41.4 bar)	Methane	Sniffing	500 ppmv
API 624	On-off valves	310	3	600 psi (41.4 bar)	Methane	Sniffing	100 ppmv
VDI 2440	Not defined	Not defined (typ. 500 – 2000)	Not defined	Not defined (typ. 40 bar)	Helium	Isolated vacuum atmosphere	T≤250°C: 10^{-4} T≥250°C: 10^{-2} UOM mbar . L / (s . m)

absence of a bonnet gasket joint. Properly engineered rotary valves often are qualified to <50 ppm as they do not require this bonnet arrangement to access the trim, and they have less motion wear with only a quarter-turn rotary motion to operate compared to a longer linear (up/down) stroke motion of a globe valve. In many cases, rotary valves can be the right solution, but when conditions become severe, the reliable globe valve is still the most robust solution.

Cryogenic operating temperatures

Cryogenic operation is not a new topic for the valve industry, and one that can be proven by many examples of installed reference lists. The key design considerations for LNG control valves are to ensure proper material selection for continuous throttling that will avoid galling, and repeatable shutoff while these applications experience extreme thermal changes. Industry standards, such as BS-6364, document best practices for original equipment manufacturers (OEMs) to validate performance, but were developed with rigorous leakage requirements intended for isolation valves rather than control valves. Most valve OEMs today will follow similar practices as identified in the BS-6364 specification, with some level of deviation that is appropriate for the particular leakage need of the application.

Commonly, valve OEMs will fully test and document the valve performance at ambient temperature, prior to cooling the valve within a cryogenic bath. This allows the manufacturer to validate that the valve is meeting performance standards, as well as set a baseline for expectations under cryogenic temperatures. Valves are then cooled in the cryogenic conditions where they are pressurised with nitrogen or helium to perform seat leakage tests while under temperature. Most valves also require a helium sniff test on the shell of the valve to ensure the joints are tight and leak free to the environment. Control valves that cycle and need to withstand a wide range of conditions typically invoke a final test after the valve warms to ambient conditions to ensure the performance is repeatable under the thermal cycling. These cycles are essential to ensure the materials are properly selected in combination to withstand the wide swings of thermal expansion.

Integrated equipment control

Within the liquefaction train, the most critical equipment to liquefy the natural gas and compress to a 20:1 ratio are the compressors. Each compressor is equipped with an antisurge system composed of a series of control valves, sensing instruments and controls with the purpose to recycle the fluid within the system when the compressor is operating in an unstable performance area. The antisurge control valve must be completely aligned with high dynamic response characteristics required by the control system to perform their antisurge function.

This remains one of the most critical performance related topics with advanced research collaboration, along with extensive modelling and simulation. Close coordination between the compressor OEM, surge control system supplier and anti-surge valve manufacturer can result in overall improvement of the anti-surge system. At Baker Hughes, Nuovo Pignone API 617 compressors and Masoneilan™ valves have worked closely around

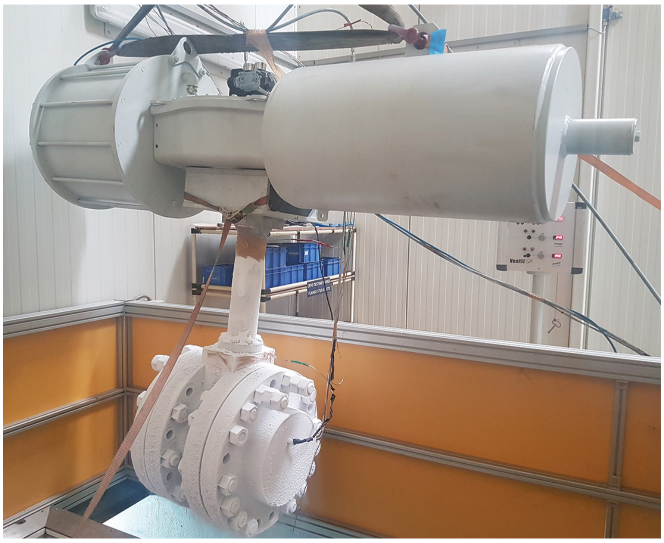

Figure 1. Triple eccentric butterfly valve performing leakage tests using nitrogen.

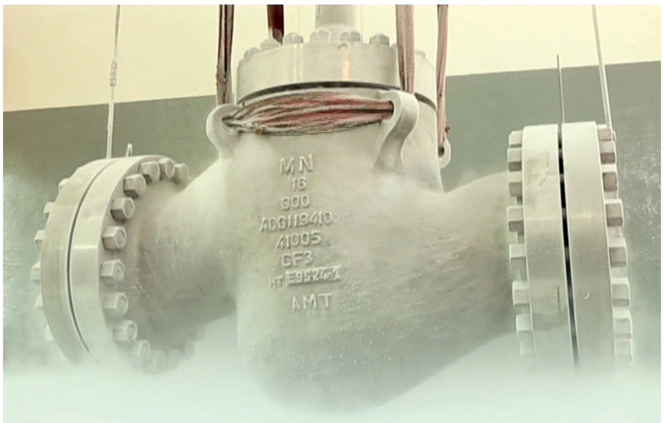

Figure 2. 16 in. cryogenic globe valve used for coldbox valve applications.

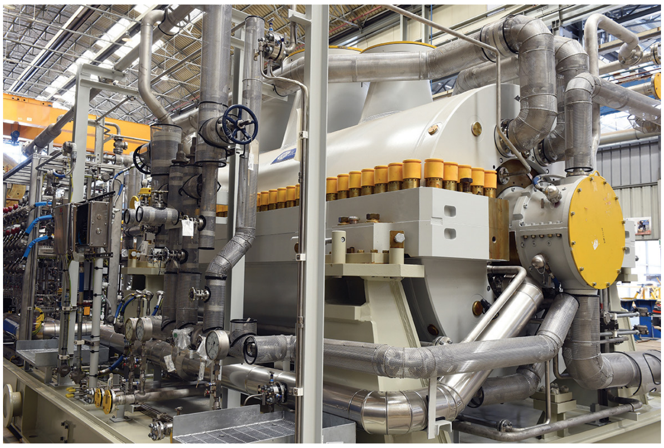

Figure 3. A Baker Hughes, Nuovo Pignone centrifugal compressor.

cooperative system design and dynamic simulation. Overall combined system optimisation can benefit users for best performance at a lower CAPEX by fine tuning the operation of each valve, including continuous research to fine tune high rangeability, control algorithms around events such as pre-opening and antisurge throttling.

Advanced diagnostics

With the right equipment and control systems in place, plant engineers can devote their attention to ensuring products are tuned and systems harmonised as intended. Leading valve OEM providers offer advanced diagnostic tools and services that can detect trends and potential failure variables well in advance of an actual hardware failure. For example, elevated levels of friction or sticking within the valve can be detected as a sign of materials that are not responding well to thermal cycling, or could be seeing control resistance from the effect of debris that are caught between components. A proper maintenance schedule, or valve diagnostic services contract, can identify these indicators early and monitor trends that are concerning in preparation for proactive maintenance at upcoming outages. If left unresolved, these high friction scenarios could potentially lead to a major disruption, such as preventing a rapid response anti-surge control system from protecting such a valuable asset such as a compressor and maintaining the liquefaction process uptime.

Diagnostic packages today are capable of looking much further into the future operation trends for early detection. Real-time valve control curves are constantly plotted and compared against optimal 'as-shipped' condition to track deviations that lead to excess process variation (inefficiency) that can result from blockage or wear induced leakage. Damage to actuator springs and diaphragms, or even damaged valve trim components potentially caused by vibration from surrounding equipment, can now all be detected. Loss of control air supply pressure, or failure of the valve positioner to maintain its proper calibration range, can be monitored in real-time. Changes in application conditions that are causing cavitation, vibration, excessive noise or even erosion can be seen and proactively modified in advance all while the valve is operating according to the daily process demands. Ideally today, end-user maintenance teams can now focus on proactively continuous improvement as opposed to costly and sometimes dangerous emergency repair and recovery.

Conclusion

Mega-trends, coupled with mega-growth, are driving the LNG valve business to levels never expected decades ago. Continuous improvements in hardware have turned previous specialty applications into normal course of business. Diagnostic technology and advancements in control systems are opening new doors for research into potential full integration of the valve and compressor controls. Major equipment and valves are becoming harmonised with technology, and the future is bright for the businesses that can lead the way forward with the most reliable systems. LNG