Managing the risk of component failure in cryogenic valves

Industry standards and specifications must always be followed when designing cryogenic valves, but it is important that manufacturers understand the effects these standards have on valve components and the way they perform in-service.

By G. Ravindran, Head Global Technical Services, After Market, L&T Valves & Maswood Ahmed, Manager, New Products

Cryogenic valves are easily identified by their extended column or extended valve stem arrangement. The purpose of the extended column is to provide a gas column that acts as insulation to prevent an influx of heat from the outside environment. The extended column also keeps the gland packing system from influencing the cryogenic temperature. It is important that the packing system is kept at ambient temperatures so that sealing performance is not affected due to low temperatures.

Designing valve components like stems, extension columns, and sizing of either a manual or powered operator is as equally important as designing the valve sealing elements for cryogenic temperatures. There are instances that cryogenic valves performed well at cryogenic temperature in terms of sealing but suffered mechanical damage to the stem or stem train due to wrong or oversizing of the operators.

Cryogenic valves can be opened or closed either manually (hand wheel or gear unit) or automatically (actuator), and in a typical plant 60% of the valves are manual valves while automated and control valves constitute 40%. As it is not feasible to actuate all manual valves, there's a high degree of focus on the operating effort to open and close manual valves. Operating effort is the force an operator exerts by pushing or pulling on a lever or turning a hand wheel.

The main considerations during selection of manual operators are the effort and the number of turns required to operate the valve. In addition, there a host of other factors that determine the ability of operators to apply the required force such as space available, position of the hand wheel or lever, operator's physical strength, the nature of force (such as momentary or uniform), environmental conditions, and finally the frequency and urgency of operations.

Industry specifications

It is commonplace in the valve industry for end users to specify the operating effort requirements for a specific project based on local statutory laws or incorporate specifications/standards which provide guidelines for valve operation. Figure 1 lists the operating effort requirements of end users around the world and the trend is conspicuously leaning towards alleviating the burden of operators.

A typical project specification often includes these requirements:

The maximum force applied at the hand wheel, for operation of the valve during the maximum differential test pressure, shall not exceed the lowest value as per the applicable design standard/specification at ambient temperature or 350 N at subzero temperatures.

While the intent of the standard is to reduce operator effort while closing and opening the valve complying to the 350N limit, it is a well-known fact that valve seating and unseating requires momentarily higher effort and can exceed the 350N. The standards like MSS SP91 and EN 12570:2000 have recognized this and permitted a momentary force up to 1000N.

While few customers have accepted this and incorporated the momentary feature in their specification, many still insist on 350N compliance. A valve manufacturer can design their cryogenic valve to meet this requirement by adopting the following methods.

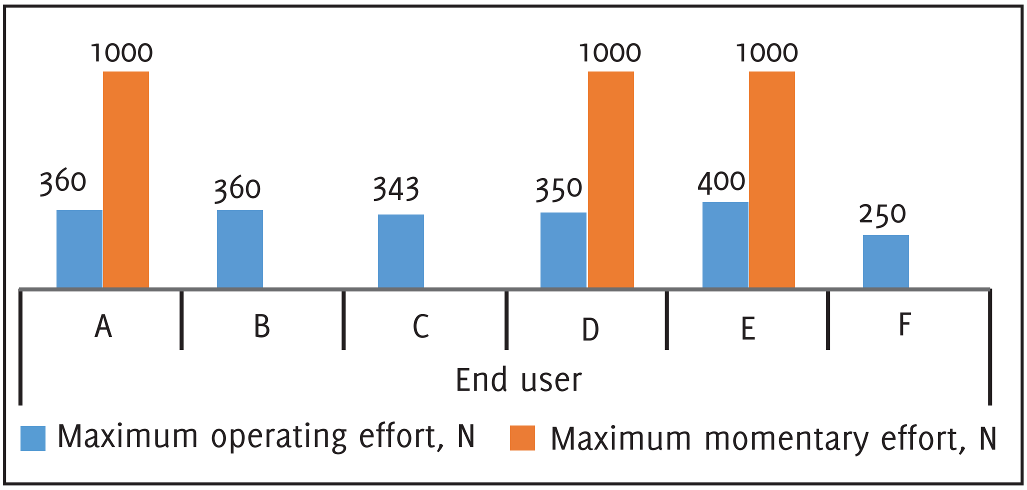

Figure 1.

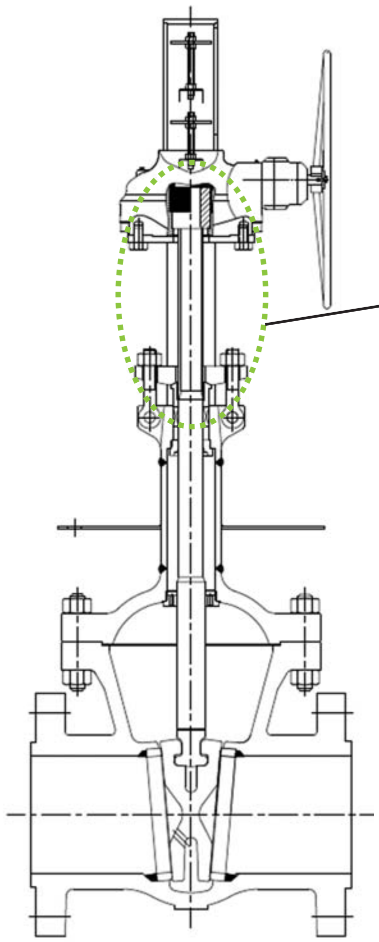

Figure 2.

Using larger diameter hand wheels

By increasing the hand wheel diameter or lever lengths, the operating effort can be reduced as F = 2 x T/D (where F is the operating effort, T is the torque and D is the diameter). However, there is a limitation to the maximum hand wheel diameter that can be specified as an over-sized hand wheel can hinder other equipment in a plant lay-out. Certain end-users restrict the maximum hand wheel diameter to 800 mm or the face-to-face dimension of the valve.

Using high efficiency gear units

Gear units with a high mechanical advantage can be used to reduce the operating effort to acceptable limits. For a linear valve, bevel gear units are commonly used, and in special cases, double stage reduction gear units or gear units with spur attachments are used when the valve torque is high or the operating effort has to be restricted below a certain value. Thus to meet the 350N effort, the designer is left with no choice but to choose either a hand wheel with a larger diameter or a gear unit with a higher mechanical advantage and higher potential danger for causing damage to the stem train in service.
Let us look at a typical cryogenic valve gear unit selection for a multi-turn valve with valve toque of 1079 Nm. It is not possible to operate with a hand wheel as the effort required will be enormous. If the designer selects a gear unit model from the gear unit manufacturer meeting the torque and thrust requirements of the valve, the mechanical advantage (MA) becomes 4.5. The operating effort comes to 599N which is more than the allowable limit. Thus the designer has to select a gear unit from the same manufacturer with a higher mechanical advantage of 10.9, which brings down the operating effort under 250 N. While this sounds like an easy fix, there is more behind this decision than meets the eye. The mechanical advantage of the gear unit selected reduced the maximum acceptable effort based on the MAST (Maximum Allowable Stem Torque) of the stem material from figure of 853N to 350N. Despite the valve operating effort being less than 250 N, the failure of the stem is imminent as the torque applied would exceed the MAST if the operator applied a force › 350 N. It is common knowledge that an operator can, in most cases, apply an effort exceeding 350 N in real life conditions and MSS SP-91 specifies that a typical operator is one who is capable of exerting approximately 670 N on a lever with an effective length of 12 inches at waist level.

Parameters	Direct hand wheel 800mm	Gear unit with hand wheel 800	Gear unit with spur attachment hand wheel 800
Valve torque, Nm	1079	1079	1079
Mechanical advantage of GU	NA	4.5	10.9
Operating effort for the valve torque, N	2697	599	247
Maximum allowable stem torque or MAST (Yield: 30,000 psi), Nm	1535	1535	1535
Maximum allowable torque at the gear unit shaft, Nm	NA	341	141
Maximum allowable operating effort based on MAST, N	3838	853	350

Stem damage

A typically a cryogenic valve has a stem material of stainless steel 316, as specified in the data sheet, and will thus have a fixed MAST value that when exceeded can cause damage to the stem. A cryogenic valve has another challenge of extended stems, and in case of multi-turn valves where the torque is getting converted into the stem thrust, there is a danger of stem bend due to lengthier stem. Figure 2 shows a cryogenic valve designed to meet the 350 N effort requirement. The data sheet for the stem material showed it was SS316, and it was found to have stem bend in service. A root cause analysis found that due to compliance with the 350N standard, the manufacturer chose a gear unit with higher MA, and when the in-service operator exerted more force on the hand wheel, it caused the stem to bend.
Managing the risk of this sort of stem failure is possible by influencing the customer specification to allow the momentary force to align with the MSS SP91 standard. API 600, 13th edition addresses the momentary force. Alternatively, if it is not feasible to incorporate this in the customer specification, then the specifications should allow the use of high-strength materials like XM19 for valve stems, in place of SS 316. Finally, the use of a torque-limiting device on the gear unit can also reduce the risk of stem train failure, but it adds cost to the valve. Though this solution is known to the industry it has not become very popular.