Purchase a Qualified Valve for Your Operation

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Qualification testing benefits both the valve purchaser and manufacturer, as it ensures valves meet certain standards and functionality expectations.

Many products are qualified — *i.e.,* tested and certified to meet an industrial standard — before they are available for sale. This qualification process may be as simple as testing and analysis carried out by a manufacturer to show that the product meets a minimum level of functionality and safety. Or, it could be as complicated as medical trials that take years, cost millions of dollars, and require government approvals to verify that a device or medication performs as advertised.

Proper valve operation is necessary to prevent hazardous fluid releases, equipment damage, and unstable plant control, all of which can be dangerous and costly. Qualification testing or certification of valves gives the user some sense of assurance when purchasing a valve, although this may be a false sense of security unless a variety of other factors are considered in the purchasing decision. This article describes the most common valve qualification tests and standards, and explains how the results of these tests can be factored in with other considerations to choose the most appropriate valve for an application.

Qualification testing

The qualification process depends on the standard to which the valve is qualified. In certain cases, testing can be done at the manufacturing facility (Figure 1), although most specifications require that a third-party witness attend, observe, and document the tests.

Only a few globally recognized independent facilities specialize in valve testing, and finding third-party facilities can be challenging. The test facilities must have valve-specific equipment and test fixtures to perform the required testing. Specific equipment includes bunker and hydrostatic pumps, heat tape and insulation, thermocouples, torque and force meters, fluid leak meters, and mass spectrometers for evaluating fugitive emissions.

The valve manufacturer submits the required documentation to the test facility, which is responsible for checking the documentation. Required documentation includes general assembly drawings, calculations, material certificates, parts lists, supplier lists, references, and other miscellaneous information related to internal equipment and processes. The test facility then performs a series of tests (or subcontracts and monitors the testing), and writes a report that summarizes success criteria and product performance.

Typical tests include hydrostatic shell tests, and mechanical and thermal cycling of the valve while an operator measures seat leakage, fugitive emissions, and required actuator output. Pressure-retaining components may undergo nondestructive evaluation and sectioning to ensure that material strength and chemistry are acceptable.

The test report is given to the manufacturer for distribution to customers as requested or as required by purchase orders. If the valve supplier's quality management system is acceptable, the user/purchaser may issue a certificate, or add the supplier to the approved manufacturer's list (AML) for that product category. Depending on the specification, recertification may be required on a regular basis, such as every five years.

Valve classification

Valves can be sorted into three main categories: rising-stem (*e.g.,* gate and globe valves), quarter-turn (*e.g.,* ball, butterfly, and plug valves), and other designs (*e.g.,* pinch and axial valves). In a rising-stem valve, the action of the stem is linear, whereas quarter-turn valves have a stem that rotates up to 90 deg. In all valves, the motion of the closure element (*e.g.,* ball, disk, or plug) modifies the area through which the fluid can flow.

Valves subject to qualification testing fall into two basic categories: control valves and on/off (*i.e.,* isolation) valves.

Control valves

Control valves are used to maintain a process variable setpoint, such as flow, pressure, temperature, or level, by modulating between the open and closed positions as required. Their construction aims to minimize friction and eliminate backlash in the drivetrain, which reduces hysteresis. Rarely will a control valve be in the fully open or fully closed positions. Pneumatic or smart valve positioners ensure constant correct positioning. Control valves typically operate at 20–80% open. Characterized flow trims may be used to optimize specific applications.

Isolation valves

Isolation valves are used to shut off flow or allow it to pass unimpeded. They spend most of their time in either the fully open or fully closed position. Higher friction due to packing and seat contact in an isolation valve creates a larger stick-slip phenomenon (spontaneous jerking) than in control valves. Isolation valves can perform rough modulating service where control accuracy is not a concern. In modulating service, the isolation valve is positioned at rough positions between open and closed. This positioning is not very accurate and the position is not based on the control of a process variable (flow, temperature, pressure, level, etc.) like it is in a control valve. Isolation valves are required to have good shutoff with near zero leakage and may spend more than one year in one position, so a larger actuation force may be required to move the drivetrain from a static state.

The number of full-stroke mechanical cycles experienced over the product life depends on the application, but it is normally in the hundreds. However, there are exceptions, such as emergency shutdown valves (ESD), which may only be used a few times, and sootblower and catalyst lockhopper services, which can experience more than 100,000 mechanical cycles.

Valve specifications

Valve specifications establish a minimum set of performance criteria. Valves that meet the specifications are more likely to be accepted by the customer, industry, or application in which they are used. This common measure of suitability typically references industry standards, allowing the valve to interface seamlessly with other related components. This way, the customer can substitute products without experiencing a change in product performance or the need for expensive changes in infrastructure.

Common form-and-fit industry standards include the American Society of Mechanical Engineers (ASME) B16.5 and B16.10, which guarantee that valves of the same pressure class and size will have the same mating connection and end-to-end dimension, allowing a user to source and install equivalent replacements without converting mating piping and fittings. Table 1 lists many relevant valve standards in the U.S.

Standardization also benefits valve suppliers, as it minimizes the number of products required to satisfy market needs. However, overly stringent specifications may make it difficult for suppliers to differentiate and innovate. Any

▲ **Figure 1.** Qualification testing can be done at the valve manufacturer's facility.

product changes require requalification, which can discourage improvements to materials, designs, or manufacturing methods.

Qualification testing concerns

Despite the benefits of qualification testing, a valve purchaser should consider the possible oversights of a test or standard.

Limited sample size. Qualification testing is conducted on just a few valves, but it is used to qualify an entire platform of products, assuming relatively consistent design. Criteria used to extrapolate the certification include valve or stem size, operating pressure, and material. Most testing is done on only one device or a small batch, using tolerances and material strengths within a narrow band that is not necessarily reflective of the variability in production.

For example, material strength can have a relatively large acceptable range, on the order of ±10% of the nominal strength. For this reason, testing multiple samples is not critical if they are all from the same batch, but it is important to verify that tested valves are consistent with the batch supplied to the users.

Similarly, valve manufacturers or suppliers may test multiple units of the same construction, hoping at least one sample passes. Any new construction that needs to pass a qualification test usually has to go through multiple iterations before it passes. Suppliers do not report how often units failed a test, only that one passed. This practice is less common when a third-party test facility is used, but it is still possible.

Limited material options. Another qualification concern is that testing may be limited to materials from only one manufacturing location and casting or forging vendor, which may not be a representative sample. Differences in tools and manufacturing methods may also affect the performance of valves of the same design. Some standards invalidate past qualifications due to changes in ownership, tooling, or manufacturing methods, although these may not directly change the quality of the product or its performance. Valves that undergo such changes will need to be requalified.

Limited testing conditions. When testing is not performed under field conditions, tests may not examine the

Table 1. Valve standards are set by organizations such as the American Society of Mechanical Engineers (ASME), the American Petroleum Institute (API), and the International Organization for Standardization (ISO).

Standard	Description
API RP 591	Process Valve Qualification Procedure
API 598	Valve Inspection and Testing
API 599	Metal Plug Valves — Flanged, Threaded, and Welding Ends
API 600	Steel Gate Valves — Flanged and Butt-Welding Ends, Bolted Bonnets
API 602	Gate, Globe, and Check Valves for Sizes DN 100 (NPS 4) and Smaller for the Petroleum and Natural Gas Industries
API 603	Corrosion-Resistant, Bolted Bonnet Gate Valves — Flanged and Butt-Welding Ends
API 608	Metal Ball Valves — Flanged, Threaded, and Welding Ends
API 609	Butterfly Valves: Double-Flanged, Lug- and Wafer-Type
API 623	Steel Globe Valves — Flanged and Butt-Welding Ends, Bolted Bonnets
API 624	Type Testing of Rising-Stem Valves Equipped with Graphite Packing for Fugitive Emissions
API 641	Type Testing of Quarter-Turn Valves for Fugitive Emissions
ASME B16.5	Pipe Flanges and Flanged Fittings
ASME B16.10	Face-to-Face and End-to-End Dimensions of Valves
ASME B16.34	Valves – Flanged, Threaded, and Welding Ends
ANSI/FCI 91-1	Standard for Qualification of Control Valve Stem Seals
ISO 15848	Industrial Valves — Measurement, Test, and Qualification Procedures for Fugitive Emissions
Shell MESC 77/300	Procedure and Technical Specification for Design Validation Testing of Industrial Valves
Shell MESC 77/312	Fugitive Emission Production Testing

▲ **Figure 2.** Valves can fail where erosive or corrosive fluids are present. In this example, erosion damage occurred on the outlet of a separator inlet control valve in a coal seam gas application. Erosion was caused by the valve being oversized and operated barely open, coupled with poor material selection unable to withstand erosion from entrained particles.

most likely failure modes of a valve. Even though pressure and temperature extremes are explored, it is impossible to test for every combination of these extremes. Valves are rarely tested under flow conditions, where fluid dynamics may severely affect the torques or forces required to close a valve. For example, even if performance is confirmed at ambient conditions in a clean environment, the valve could fail where erosive or corrosive fluids are present (Figure 2).

Table 2 lists many of the severe service applications for which valves cannot be adequately tested and qualified, as well as some suggested selection criteria. In some cases, a user may have to rely on the valve manufacturer for guidance on valve selection.

Although the valve manufacturer may be able to provide some guidance, the user should evaluate the given valve materials to ensure they will work with their process fluids. Field trials and proven-in-use information can also be valuable, because valves experience a wide variety of normal and upset conditions that cannot be replicated in typical qualification testing.

Subjectivity. Subjective tests are of little value in assessing product suitability. Qualitative conditions and acceptance criteria should be clear with little room for interpretation. It is not useful to evaluate the strength of a component using an unspecified or nominal force. Similarly, objective criteria for visually inspecting valve stems for surface finish degradation do not exist. These requirements are open to interpretation, and photos provided with the qualification report communicate the part's condition better than an individual inspector's impression.

Variation and consistency. Seemingly minor variables can impact the valve capabilities. Where possible, controls should be put in place to vet any valve changes. Periodic qualification testing can account for changes in people, processes, and tools over time, although this risk can also be mitigated by testing each order. The people, process, and tools referenced here relate to valve manufacturing. Different people (machinists, assemblers, inspectors, etc.), processes (heat treating, coating, machining steps, etc.), and tools (machining equipment, test fixtures, casting molds, etc.) all may have a small impact on the final product. These small impacts may compound over time and a requalification may be beneficial to ensure the product still operates correctly even though the core design did not change.

This is the premise of the Shell Material and Equipment Standards and Code (MESC) 77/300 and 77/312 standards: Shell 77/300 is the qualification testing performed on a design, and Shell 77/312 is the production testing done on a sample of each order.

Changing standards. Updated standards can cause confusion regarding a valve's qualification status. A valve that was qualified to a standard may become obsolete and

Table 2. It is difficult to adequately test and qualify valves in certain severe-service applications. Use extra caution when sizing and selecting a valve for these situations.

Application	Issue	Solution
Lean amine control valves	Cavitation damage at high differential pressures	Hardened multistage cavitation or dirty service trims
Compressor antisurge and discharge valves	Fast and accurate throttling; noise control	Actuators with smart positioners and volume boosters; vibration-resistant mountings; noise-attenuating trim; valve diagnostics
Coking drum isolation valves	Buildup of coke on valve components; high torque; erosion	Steam purge ports; oversized actuation; hardened trim
Fractionator bottoms and heavy gas oil product valves	Erosive and corrosive viscous slurry at high temperatures approaching 1,000°F	Eccentric plug valves with hardened Alloy 6 or ceramic trim
Fluid catalytic cracking unit (FCCU) catalyst valves	High cycling; erosive media	Flow ring with set clearances or Alloy 6 metal seat
Rich amine letdown valves	Body and trim erosion; excessive vibration; multiphase flow	Nose attenuating trim made of Alloy 6; out-gassing and multi-stage dirty service trim
Gasifier black and gray water valves	Erosive media	Hardened Tungsten carbide or Alloy 6 trim
Furnace feed gas control valves	Maintaining tight control; high ambient temperatures; fugitive emissions	Hardened trim with noise-attenuating trim for noise and wear; low-emission packing; high-temperature actuator and accessories
Ammonia synthesis valves	High pressure drops	Noise-attenuating trim; high-strength stem materials and valve stem connections
Urea letdown line valves	High-pressure-drop flashing	Angle valve made of Type 316L stainless steel, duplex or Ultimet body; replaceable outlet liner

not meet the current needs of the industry if the standard is revised but the valve design is not adapted. Standards are revised frequently (typically every 3–6 years); some revisions are minor or administrative, whereas others are major and involve changes in the functionality of the valve. Before purchasing a valve, understand your needs and which standards are relevant to your operation.

Production testing

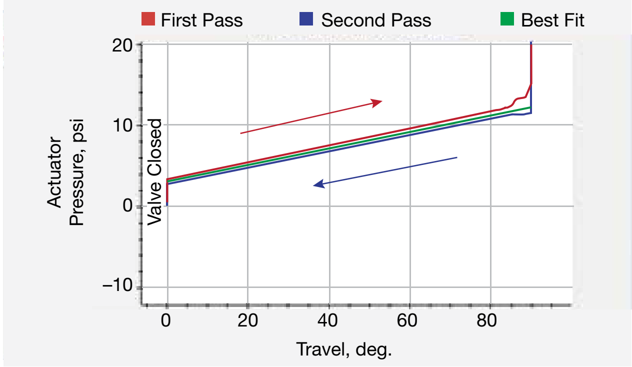
Consider other criteria to complement a qualification certificate. Testing valves as they are produced provides insight into their performance. This may include nondestructive performance testing, such as detecting seat leakage, measuring stroke times, hydrostatic pressure testing, or obtaining a valve signature plot (Figure 3) to ensure operation is as expected. Alternatively, destructive testing can help determine the drivetrain failure force. Mechanical or metallurgical testing can determine the pressure and material strength limits.

A valve signature is a calibration curve for a valve that plots the output of the valve (travel) versus the input (actuator pressure). The signature is used to diagnose the health of the valve. A baseline plot is produced during manufacturing and changes in this plot can be used to detect problems with the air supply or valve operation, such as excessive friction from packing or trim parts.

In Figure 3, the arrows show in what direction the data was acquired. The test started on the left side of the curve at zero travel and zero pressure. Actuator pressure was increased and data progressed along the red line until the valve was fully open and actuator pressure was at its maximum. The actuator pressure was then decreased and data was acquired as the valve closed, as shown by the blue line.

These possible evaluations have limitations, as testing takes time and destructive testing on all units is not possible. Testing samples provides a reasonable assurance that other units will operate within acceptable limits, assuming the materials and manufacturing methods are the same. A valve manufacturer can use statistical process control limits to monitor real-time variances in the production process.

Although measurements of key part characteristics (such as stem surface finish) may be important, it is more telling to measure performance characteristics — such as valve torques, seat leak rates, and fugitive emissions — to identify variations in the assembly before they become a problem.



▲ **Figure 3.** Valve signature plots are used to ensure that a valve is operating properly. This valve signature shows the course of the valve's movement from fully closed to fully open, and from fully open to fully closed.

Seat leakage

Preventing leakage when the valve is in the closed position is critical, as leaks have negative process and/or financial implications and may be a safety concern. Isolation valves commonly provide tight shutoff, although new control valve designs have better capabilities.

Multiple specifications — including Manufacturers Standardization Society (MSS) SP 61, American National Standards Institute (ANSI)/Fluid Controls Institute (FCI) 70-2, American Petroleum Institute (API) 598, and International Organization for Standardization (ISO) 5208 — specify test parameters, such as pressure, fluid leak rate, and test duration, to characterize the quality of shutoff. In most cases, the allowed leakage is a function of valve size or capacity — standards allow larger valves to have a higher leakage rate because the flowrate through the valve is higher.

Mechanical cycles or flow erosion/corrosion can wear down seals and increase leakage. A valve specification's leakage rates are only valid at the time of production testing, and users account for this through process design and maintenance planning.

Stem packing

Live-loaded packing uses springs to compensate for packing consolidation, extrusion, and oxidation. These springs are either on each gland packing stud or on springs surrounding the stem. As a rule of thumb, the larger the springs used for live loading, the more consistent the packing performance will be over time. The valve manufacturer chooses a packing to work with the valve design, considering the stem surface finish, type of travel, and length of travel (Figure 4).

▲ **Figure 4.** Packing selection is critical for leakfree valve operation. This image depicts the cross section of a live-loaded, low-fugitive-emission packing in an eccentric-plug quarter-turn valve.

The user should be cautious when servicing the valve to ensure replacement packing is compatible with the design and will meet original equipment manufacturer (OEM) performance standards.

Fugitive emissions

Fugitive emissions are a growing concern in the chemical process industries (CPI), and much work is being done in the refining and chemical industries to set acceptable limits and test criteria. Standards committees, made up of users, valve manufacturers, distributors and component suppliers, are regularly updating the standards and criteria. The number of standards, variety of qualification levels, and frequency of changes have caused confusion for valve manufacturers and end users alike.

The API 624 and API 641 standards for fugitive emissions on rising-stem and quarter-turn valves, respectively, use methane as the test medium. These standards focus primarily on isolation valves in hydrocarbon applications and are based on the U.S. Environmental Protection Agency (EPA) Method 21. They produce unambiguous results — the valve either passes or fails. The performance of valves qualified to these two API specifications cannot be compared to each other due to the difference in required mechanical cycles. API 624 requires 310 mechanical cycles whereas API 641 requires 610 mechanical cycles.

Although quarter-turn and rising-stem are different kinds of valves, the method of operation is insignificant to the user. The user cares about the quantity of fugitive emissions coming out of the valve stem.

The ANSI/FCI 91-1 standard is specific to fugitive emissions from control valves and it also employs methane and is tied to EPA Method 21. Different classes of qualification are available up to 100,000 mechanical cycles. Pressures and temperatures are not specified in this standard and must be defined prior to the test.

▲ **Figure 5.** A technician measures the leakage of helium from the packing of a rising-stem valve.

Fugitive emissions standard ISO 15848 is more complicated, as it allows for different levels of fugitive emissions, mechanical cycles, and associated stem seal adjustments, temperature classes, and the choice of methane or helium as the test medium (Figure 5). Endurance classes are listed for isolation and control valves, although test results and certifications across manufacturers are difficult to compare. Endurance class refers to the number of thermal and mechanical cycles that the valve must endure as part of the test. There are three endurance classes for control valves and three endurance classes for isolation valves.

Do not compare valve fugitive emissions performance testing under two different industry specifications. Nor should you compare the performance of two valves tested to different criteria within the same specification. A user should specify the minimum acceptance criteria and ensure the certifications received meet that need.

Shell MESC SPE 77/300 has influenced all the previously mentioned API, ANSI, and ISO fugitive emission specifications, and is referenced globally. This specification requires fugitive emission testing and expands qualification testing to the operation of the valve, including seat leakage and operating torque or thrust, with all tests executed at both ambient and extreme temperatures. The sister specification Shell MESC SPE 77/312 specifies fugitive emission testing of production samples.

Pressure testing

The ASME B16.34 standard includes requirements and guidelines for valve pressure-testing and seat-leakage testing. However, pressure tests under this standard and others only verify that the valve does not fail during the testing — they do not assure the valve will be safe in operation. Factors such as high-temperature creep, mechanical fatigue, and pipe stresses go beyond this test and are only accounted for in the design process.

Cavitation, flashing, and noise control

Cavitation, flashing, and noise control are important in applications with large pressure drops. Cavitation and flashing occur when the pressure of a liquid dips below the vapor pressure, creating gas bubbles that may damage valve components (Figure 6) and cause excessive noise. Noise may negatively affect surrounding personnel or the community. In extreme cases, the vibration associated with cavitation and flashing can damage the valve. Special valve trims can be used to control cavitation by breaking up the flow into smaller flow streams and reducing the

▲ **Figure 6.** Cavitation and flashing can damage valve components, but may be controlled by using special valve trims.

pressure over multiple stages.

Testing and prediction of control valve noise is governed by the International Electrotechnical Commission (IEC) 60534-8 series of standards. Aerodynamic noise testing is performed with air on a valve installed in a pipeline with upstream and downstream silencers. Inlet pressure is maintained while the pressure drop across the valve is modulated. Fluid pressures, temperature, and flow are recorded in addition to the sound pressure level in a sound chamber one meter downstream and one meter radially from the pipe. This testing is performed at multiple increments of valve travel.

Hydrodynamic noise is normally a result of cavitation and is tested similarly to aerodynamic noise. Water is used as the fluid, and inlet pressures are controlled while the pressure drop across the valve is varied. At the pressure drop where cavitation begins, the amount of sound produced increases significantly.

Design

Valve users should be aware of normal manufacturing variations and account for them during the design process. A valve's design is analyzed at its theoretical weakest state where the part geometries and material strengths are diminished and the load is maximized. Users should ensure that design codes are specified that require a factor of safety to account for the severity of failure and the scale of unknowns.

For valves, the minimum factor of safety of two should be used for ductile pressure boundary parts, depending on tested wall thickness and material strength. To ensure this safety factor, a prototype valve is pressurized or analyzed to twice its cold working pressure and the material should not yield. Acceptable part tolerances are analyzed in an assembly, where total assembly of parts is reviewed to ensure all combinations of parts will work as needed. A good qualification test program verifies that the analysis method is correct and that failure occurs where and when expected (Figure 7).

Good valve designs evaluate the range of part tolerances allowed by the drawings, to ensure that any change in processing of these parts will not adversely affect the performance of the valve assembly. Parts may be machined near nominal dimensions early in the production of the valve. As time goes on, these part dimensions may vary as tooling changes. Even though the parts may still be within drawing tolerances, it is possible that the valve assembly will not work correctly unless the valve designer evaluated all possible part combinations. Reputable valve manufacturers have done this analysis and have an installed base to show that their products will operate correctly. A valve user should ask to see these results.

ASME B16.34, considered the grandfather of valve design specifications, includes pressure and temperature ratings for common materials and dimensions, with specific emphasis on the calculation of wall thickness in different areas of the valve body. Determining the

◀ **Figure 7.** This valve body, installed in a proof-of-design hydrostatic test fixture, is coated so that digital image correlation can be used to pinpoint high-strain areas and later attach strain gauges. The strain gauges are small and adhere to the valve at the end of the black, white, and red wires. This way, valve manufacturers can determine where the valve is most likely to fail.

correct diameter based on bore and end connection dimensions and calculating the minimum required wall thickness can be confusing. The B16.34 standard can be ambiguous, requiring the designer to interpret the wall thickness allowed in different parts of the valve. And, numerous rules within the standard must be accounted for collectively. This can be especially confusing for the valve designer whose native language is not English.

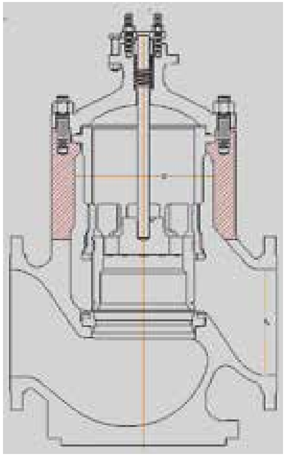
It is important for valve designers to account for ligament dimensions and localized areas in the neck and around connecting valve body sections where bolting holes penetrate the pressure boundary (Figure 8).

Reputable valve suppliers provide valves with thicker walls than the B16.34 calculations require. Additional wall thickness prevents malfunction due to bolt loads, pipe stresses, corrosion, irregular geometries, and high temperature creep or fatigue. Finite element analysis (FEA) is commonly performed to determine where additional material is needed. An experienced valve designer and software user can set boundary conditions, meshing, and material properties to obtain results that correlate well with testing (Figure 9).

Valve warranty and maintenance

A valve purchaser should consider whether the supplier will provide a total valve assembly and take responsibility for the overall performance of the unit. When a valve assembly is composed of a valve body, an actuator, mounting hardware, and various accessories cobbled together from different suppliers, responsibility for resolving any problems becomes murky. Sometimes vendors blame another vendor if the valve performs poorly, delaying determination of the root cause and the necessary fix. Valve purchasers should ensure that the supplier will stand behind the entire product.

Valves can remain in service for a few months or decades, depending on the application. All valves wear over time from mechanical cycling, particularly at the bearings, packing, and seal rings. In addition, flow erosion, atmospheric corrosion, or fluid fouling may cause degradation. A regularly maintained valve will last longer and users should consider the availability of replacement parts and locality of qualified service personnel when purchasing a valve.



◀ **Figure 8.** The wall thickness area of concern on this globe valve schematic is shaded in red. This, along with neck diameter and end-connection diameter, is used to determine the minimum wall thickness.

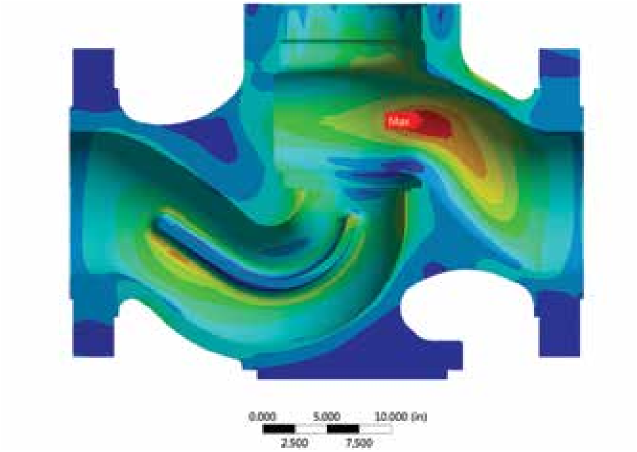
Application-specific requirements

Valve users with additional requirements beyond industry standards can cause problems for valve manufacturers, increase the price, and limit the number of qualified suppliers. It becomes burdensome for suppliers when the standard test is negated by additional requirements, such as performing the same test at different operating conditions, thus requiring a test to be repeated specifically for that customer.

These tests can be expensive for valve suppliers and can make it difficult for the purchaser to find qualified products quickly and at a competitive price. Qualification testing can also be overly burdensome to the point where few vendors are qualified, resulting in few available options and the need for purchasers to compromise their requirements and/or testing.

Final remarks

Qualification testing benefits the purchaser and manufacturer but should never be the sole basis for a purchasing decision. It is only part of the information to consider, and must be evaluated in conjunction with other factors. The valve manufacturer's reputation, design details, boundary conditions analysis, quality management system, experience, production testing, and product support should all be considered together with qualification testing when making a purchasing decision. CEP



▲ **Figure 9.** Finite element analysis (FEA) is commonly performed to determine where additional material is needed on a valve body. This FEA image shows stress amplitudes due to pressure and bolt loads in a globe valve body, where blue corresponds to the lowest stress and red corresponds to the highest.

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