How Codes, Standards and Specifications Influence Valve Design in the Power Industry

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Date: 2013-03-08
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This presentation is from the perspective of a North American valve manufacturer, supplying to the North American power industry. It doesn`t cover all international valve industry codes and standards (DIN, RCC-M etc.).
Overview - Specifications

Specifications:

• What the purchaser/user requires
  • reference to Codes, Standards and Specific requirements.
• Size, class, type of valve.
• Materials of construction.
• Flow conditions.
• Testing requirements.
• Quality assurance requirements.
• Painting/coating requirements.
• Packaging/crating.
• Shipping.
• Other.
Standards:

• Set of rules used by the designer, manufacturer and end user to define a product.
• Developed by an organization or committee usually involving all the affected parties: manufacturers, contractors and users.
• Used to ensure interchangeability of components (eg. valves, flanges).
• Used to ensure adherence to minimum requirements for construction and design.
• Used to satisfy certain code and regulatory requirements.
• Only products that fully conform can be identified as such.
• Used by all parties by agreement or voluntarily.
• Reviewed and revised every few years (depending on standard).
Overview - Standards

- API – 594, 598, 600, 602, 603, 607, 608, 609.
- MSS -SP-61, 67, 117.
- ISO-5208, 5752, 6002.
- NACE MR0175
- Others.
Overview - Codes

Codes:
- A code is a standard that has been adopted by one or more governmental bodies.
- Enforceable by law.
- Minimum requirements to ensure the safety of the public.
- May invoke other codes and standards.
- Examples:
  - ASME Boiler and Pressure Vessel Code.
  - ASME B31.1 Power Piping.
  - ASME B31.3 Process Piping
Codes

ASME Boiler and Pressure Vessel Code

- ASME formed 1880 in response to widespread steam boiler explosions in the 19th century.
- First started working on standards for interchangeability.
- First ASME code issued in 1884 for the testing of boilers.
- First version of what was to become the ASME Boiler and Pressure Vessel Code was published in 1915 and was 114 pages long.
- Now law in Canada, the United States and more than 60 countries.
ASME Boiler and Pressure Vessel Code

- Rules for the material, design, examination, fabrication, inspection and testing of boilers and pressure vessels.
- Divided into many sections covering different areas.
- For valve design and construction the following sections are used:
  - Section II – Materials
  - Section III – Nuclear Facilities Construction
  - Section V – Non-destructive examination
  - Section VIII – Rules for construction of pressure vessels
  - Section IX – Welding and brazing qualifications
  - Code Cases (BPVC and Nuclear)
Codes

ASME Boiler and Pressure Vessel Code

• Section II – Materials
  • Divided into 4 parts.
    • 2 parts for material specifications.
      • Part A for ferrous materials and Part B for non-ferrous.
      • Gives the physical and chemical properties for all materials approved for use as pressure containing components.
    • Part C for welding rods, electrodes, and filler metals.
    • Part D gives the properties of the materials.
      • Allowable stresses / stress intensities.
      • Yield strength / tensile strength.
      • Modulus of elasticity, thermal coefficients of expansion.
Codes

ASME Boiler and Pressure Vessel Code

- Material properties in Part D are used to obtain allowable stresses or stress intensity for design analysis.
  - Allowables changed in 1999 addenda. Factor for determining the allowable stresses changed from 4.0 to 3.5.
  - SA105 allowable increased from 17,500 psi to 20,000 psi.
  - Allows for smaller sections.
- Section VIII specifically does not apply to valves or components.
  - Originally had all the allowable stress values. These were moved to Section II as they were referenced by many of the sections of the BPVC (1992 Edition).
  - Has rules for various areas which we apply to valves including bolting and flanges.
Codes

ASME Boiler and Pressure Vessel Code

- Section III has 3 divisions and 8 sub-sections covering a variety of areas related to nuclear power plants.
- Included pressure/temperature ratings and wall thicknesses.
- Became part of 1971 version of BPVC Section III.
- The appendices have sections related to design analysis methods.
- Sections NB, NC, ND for Class 1, 2 and 3 components respectively, each has a specific section related to valves (NX-3500).
- Section NX-3100 and NX-3200 contain design loading and acceptable stress limits.
- Later referred to ASME/ANSI B16.5 and then to ASME/ANSI B16.34.
Codes

ASME Boiler and Pressure Vessel Code

- Section III Subsection NB (Class 1 components) has requirements for body crotch area:
  - fluid/metal area relations.
  - Thermal analysis.
  - Cyclic/fatigue analysis.
- Design by analysis.
- Design margins are reduced due to increased material control.
- Sections NC, ND call up ASME B16.34.
- Design by rule.
Codes

ASME Boiler and Pressure Vessel Code

• Code case 1621, which became N-62, was first introduced in 1974
• Describes requirements for valve components other than pressure retaining parts:
  • Stems.
  • Seats.
  • Discs.
  • Springs.
  • Yokes.
• Code case gave increased allowable stresses for use in these components for certain materials.
ASME B31.1 Power Piping

• The original ASME B31 Code for Pressure Piping was tentatively introduced in 1935 as a single all inclusive document for piping design.

• Beginning in 1955, various sections were "spun-off" to address the designs of specific piping systems.

• B31.1 Power Piping is intended for piping associated with power plants and district heating systems. It also covers geothermal heating systems.

• Materials to be BPVC listed. Not to be used above listed temperatures. No rules below -20° F.

• Gives allowable stresses which may be different from BPVC Section IID due to casting quality factors or welding efficiency factors.
Codes

ASME B31.1 Power Piping

• Design basis of allowable stresses Tensile/3.5, Tensile at temp/3.5, 2/3 yield, 2/3 yield at temp, austenitic 90% yield, creep.

• For Class 2 and 3 piping, the divisor was 4, until 1999, when it was reduced to 3.5. The same reduction occurred in ASME B31.1, first as a Code Case in 2000, then in the Code itself in the 2005 addendum.

• SA106 Grade B carbon steel pipe, allowable stress at 100°F increased from 15,000 psi (1/4 of the minimum ultimate strength of 60 ksi) to 17,100 psi (1/3.5 of the minimum ultimate strength of 60 ksi).
Although there are requirements for valves in various sections of the codes, they do not drive the design of the valves.

The codes refer to other standards for valve design and construction requirements.

There have not been any significant changes over the years that have forced large changes to design of a given valve.
Standards

Fasteners

- ASME B1.1- Unified Inch Screw Threads -1924
- ASME B1.5 - ACME Screw Threads - 1941
- ASME B18.2.1 Square and Hex Bolts and Screws - 1933
- ASME B18.2.2 Square and Hex Nuts - 1933
Standards

ASME B36.10 Welded and Seamless Wrought Steel Pipe

• In March 1927, the American Standards Association authorized a committee to standardize the dimensions of wrought steel and wrought iron pipe and tubing.

• Only standard weight (STD), extra-strong (XS), and double extra-strong (XXS) existed.

• The committee surveyed the industry and created a system of schedule numbers that designated wall thicknesses based on smaller step sizes.

• Original intent was that each schedule would relate to a given pressure rating, however the numbers deviated so far from wall thicknesses in common use that this original intent could not be accomplished.
Standards

ASME B16.5 Pipe Flanges and Flanged Fittings

- 1894 - A standard flange template was adopted by ASME for low pressure applications.
- Eventually became B16.1 Cast Iron Pipe Flanges.
- 1927 B16.e, Steel flanged fittings released.
- 1939 size/pressure range increase, pressure/temperature ratings for alloy steel flanges and fittings included.
- 1949 First edition of B16.5 was issued. Included requirements for wall thickness for weld-end valves.
- 1973 another subcommittee was assigned responsibility for valves so the 1977 edition of B16.5 eliminated all reference to valves.
- Continues to add more materials.
- Once dimensions were decided, any changes have had little effect on valve design.
Standards

ASME B16.34 Valves, Flanged, Threaded and Welding End

• First released in 1973.
• Included pressure/temperature ratings based on B16.5 and MSS-SP-66.
• Certain sections were based on BPVC which covered nuclear valves
• Testing requirements added.
• Included requirements for bolting and wall thickness.
• Over the years, clarifications added for rotary valves, ball and butterfly valves, wafer valves. More materials added.
• 2004 all pressure/temperature ratings revised due to changes in ASME BPVC. Some materials changed groups.
• Changes have been minor and have not been driving the design of valves.
Standards

Summary

• Most standards are based on existing requirements and construction.
• Usually written by a committee which includes manufacturers, contractors and users.
• None of these parties want radical changes.
• New requirements or changes to standards can have a significant impact on current product availability, production, inventory and design. Examples:
  • API-600 – extending sizes which may affect existing wall thickness and stem diameters.
  • API-623-Steel Globe Valves – New Standard.
  • MSS –SP-XXX Pressure Seal Bonnet Connection – with stress limits for various components – New Standard.
Specifications

User/Purchaser Requirements

• Most valve specifications have ASME B16.34 near the top of the list.
• If the valve is flanged, ASME B16.5 is listed.
• API 598 is usually invoked for testing.
• Valve is fairly well defined by these and the referenced standards.
• The same valve may have been supplied for decades and would meet all the requirements with very little modification.
• Additional requirements are often added which require minor changes, often to add accessories.
How Valve Design is Affected: A Nuclear Case

Nuclear Industry

• For North American valve manufacturers, most new requirements which require core design changes, come from the nuclear industry, specifically driven through the NRC.

• NRC requirements are sent to the nuclear plant owners/operators who must comply with the regulations to keep their licences.

• What causes new requirements?
  • Operating experience at nuclear power plants in the 1980s and 1990s revealed weaknesses in many activities, in particular, those associated with MOV performance.
New Requirements

Testing

- Idaho National Engineering Laboratory (INEL), multi-utility-sponsored projects, individual U.S. nuclear utilities, and valve manufacturers tested many valves, including blow-down conditions.
- Showed potential common-cause failure mechanisms as a result of which multiple safety-related MOVs could become incapable of performing their safety functions under design basis conditions.
- NRC issues GL89-10.
New Requirements

GL89-10 - GL96-05

- Largest changes to present came as a result of these generic letters.
- Require nuclear licensees develop and maintain a performance based test and analysis program that demonstrates MOV design basis function capability over the life of the plant.
- Included in these programs are design basis reviews, valve and actuator sizing, switch setting criteria and periodic diagnostic performance testing and performance trending.
- On first glance, did not appear to affect design.
New Requirements

**EPRI TR-106563-V1**

- Two volumes.
- One for gate and globe valves, another for butterfly valves.
- Came as a result EPRI Performance Prediction Program.
- This was based on the development of analytical models based on first principles, flow loop testing and other testing.
- Resulted in a validated and computerized performance prediction methodologies for gate, globe, and butterfly valves.
- Provides methods for evaluating valve design and functional requirements.
- Provides conservative methods for sizing actuators.
EPRI Requirements

**Disc Tipping**

- Caused by the clearances between the wedge slots and the wedge guides on the body.
- When the disc tips, the lower leading edge of the wedge may come into contact with the inner edge of the seat.
- The leading edge of the wedge slot may dig into the wedge guide.
- A typical specification would ask for a maximum tip of 4°.

**Solution**

- Reduce clearance between wedge and wedge guides.

**Problem**

- This may lead to galling between components.
EPRI Requirements

Radii on Sliding Surfaces

- EPRI recommends a minimum radius of .10” on the leading edge of sliding surface.
- EPRI recommends a minimum radius of .06” on the leading edge of the wedge slot.

Problem

- The width of the seat and wedge overlay must be increased to allow for the larger radii.
- Leads to larger, heavier components.
EPRI Requirements

Guide Clearance and Welding

- For carbon steel guides, galling is possible if the temperature is above 120°F and the flows are greater than 15 ft/s.
- EPRI recommends a minimum clearance of .06” and a full weld along the length of the guide to reduce or eliminate bending.

Problem

- Enlarging clearance leads to disc tipping.

Solution

- Hardface the wedge and wedge guide sliding surfaces to prevent galling.
- Optimize the clearances to reduce tipping.
- Weld the full length of the wedge guides.
EPRI Requirements

Coefficient of Friction/Valve Factor

- Stellite® on Stellite®, steam service COF = .55.
- Stellite® on Stellite®, water service COF = .61.
- This leads to valve factors of .580 and .647.
- Approximately doubles the thrust from previous generations of valves.

Problem

- Leads to larger valve components and a larger actuator.

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EPRI Requirements

Actuator Sizing

• Sizing is based on the mean seat diameter, not inside diameter.
• For sizing, stem nut coefficient of friction: 0.2, up from 0.15.
• Margins up to 45% added for uncertainties, repeatability and bias.
• Actuator sized with a reduced voltage (-10% to -30% of nominal).
• Utilities often ask for a minimum margin of 25%.

Problem

• Larger seat diameter, stem nut friction and additional margins increase the size of the actuator.
• For AC actuators, the reduction in voltage causes a reduction in actuator torque of between 19% and 51%, therefore larger actuators are required.
User/Purchaser Requirements

Stall Conditions

• Depending on the user and the function of the valve, there are different requirements for what happens in the event of an actuator stall:
  • As a minimum, the pressure boundary must remain intact.
  • There can be damage but no parts may leave the valve/actuator assembly (no “missiles”).
  • The valve must operate after the stall.

Problems

• The actuator torque is calculated at 110% of the nominal voltage. As actuators are usually AC, the torque is 121% of nominal ($1.10^2$).
• The stem nut coefficient of friction is reduced to 0.07.
Example

3”-1500 Bolted Bonnet Gate Valve

- Line Pressure = 2,735 psi.
- Differential Pressure = 2,735 psi.
- Stem coefficient = 0.15, negotiated down from .2 for 2012 valve.
- Stem coefficient Stall = 0.1, negotiated up from .07 for 2012 valve.
- Voltage drop for sizing = 10%, 20% for 2012.
- Mean seat diameter is used for thrust calculations for 2005 & 2012.
## Comparison

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Seat Bore</td>
<td>2.625”</td>
<td>2.25”</td>
<td>2.25”</td>
</tr>
<tr>
<td>Valve Factor</td>
<td>.3</td>
<td>.602</td>
<td>.65</td>
</tr>
<tr>
<td>Stem Diameter</td>
<td>1.125”</td>
<td>1.125”</td>
<td>1.5”</td>
</tr>
<tr>
<td>Valve thrust</td>
<td>8,926 lbs</td>
<td>13,369 lbs</td>
<td>23,745 lbs</td>
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<tr>
<td>Valve Torque</td>
<td>108 ft-lbs</td>
<td>163 ft-lbs</td>
<td>375 ft-lbs</td>
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<tr>
<td>Setting Torque</td>
<td>139 ft-lbs</td>
<td>252 ft-lbs</td>
<td>475 ft-lbs</td>
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<tr>
<td>Stall Torque</td>
<td>328 ft-lbs</td>
<td>782 ft-lbs</td>
<td>1621 ft-lbs</td>
</tr>
<tr>
<td>Stall Thrust</td>
<td>26,979 lbs</td>
<td>64,380 lbs</td>
<td>127,626 lbs</td>
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</tbody>
</table>
## Material Changes

<table>
<thead>
<tr>
<th>Component</th>
<th>1970’s</th>
<th>2005</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studs</td>
<td>660</td>
<td>630</td>
<td>Inconel 718</td>
</tr>
<tr>
<td>Allowable Stress (@500° F)</td>
<td>20,200 psi</td>
<td>28,000 psi</td>
<td>34,200 psi</td>
</tr>
<tr>
<td>Yield Stress</td>
<td>85,000 psi</td>
<td>115,000 psi</td>
<td>150,000 psi</td>
</tr>
<tr>
<td>Stem</td>
<td>630</td>
<td>Inconel 718</td>
<td>Inconel 718</td>
</tr>
<tr>
<td>Wedge</td>
<td>316</td>
<td>XM-19</td>
<td>Inconel 718</td>
</tr>
<tr>
<td>Allowable Stress (@500° F)</td>
<td>14,400 psi</td>
<td>25,500 psi</td>
<td>55,200 psi</td>
</tr>
<tr>
<td>Seats</td>
<td>316</td>
<td>316</td>
<td>XM-19</td>
</tr>
<tr>
<td>Body</td>
<td>3” Forging</td>
<td>3” Forging</td>
<td>4” Forging</td>
</tr>
<tr>
<td>Yoke</td>
<td>WCB casting</td>
<td>Barrel Style Fabricated</td>
<td>Barrel Style Fab.</td>
</tr>
<tr>
<td>Wedge Guides</td>
<td>No Stellite®</td>
<td>2 Faces Stellite®</td>
<td>3 Faces Stellite®</td>
</tr>
</tbody>
</table>

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Comparison

1970’s
427 lbs

2005
575 lbs

2012
1035 lbs
Comparison

How Codes, Standards and Specifications Influence Valve Design in the Power Industry
Comparison
Additional Requirements

ASME QME-1 Qualification of Active Mechanical Equipment Used in Nuclear Power Plants

• Requires extensive prototype and production testing.
• On design side - extensive FEA and CFD analysis to prove design and to provide evidence of the parent-child relationship which is used to extend qualification to other valves.

• For prototypes:
  • Digital Signature - requires instrumented stems.
  • Thermal binding, pressure locking tests.
  • Flow testing, Cv and blow-down.
  • Seismic testing.

• Production tests:
  • Digital signature - to be within 10% of prototype.
Conclusions

- Codes and standards do not have a large influence in changing valve design.
- Customer specifications are the driving change.
- For Velan, the nuclear industry has a significant influence on the evolution of our valves.
- Features from nuclear valves trickle down to other products for other industries.
Questions?