The Problem with Globe Valves, and Opportunities for Improvement

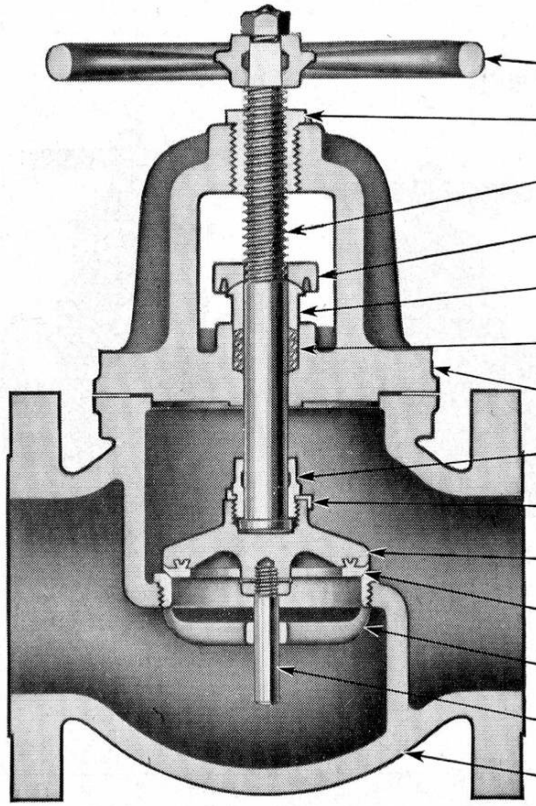
Ron Merrick & Claire Dwyer
Fluor Corporation

What happened?

- A major US refinery project was in startup
- We started getting calls about how the control station bypasses were vibrating, leaking and "the globe valves were breaking and catching fire"
- How do you break a valve?
  - The operators said "the stems were breaking"
- We thought this meant
  - Disc separating from stem
  - Disc dislodging
  - But:
  - Here's the evidence.

History

- **Why do we use globe valves in the first place?**
- Historical background –
  - First used for control of steam
  - By 1840s, various inventors had developed concepts similar to those in use now
  - The English name 'globe' came from the early bodies being more or less spherical in a pressure envelope with an internal wall containing the port



Globe Valve—Brass Trimmed
(Illustration shows No. 21E, 250-Pound, page 110)

Illustration courtesy Crane Co., 1953

History

- Globe valves use to be used as manual control valves but this use is extinct in modern plants
- High pressure systems use globes as block valves
- It was once possible to specify globe valves with a variety of different disc contours (ball type, plug type, v-port) for different flow characteristics
- So the control valve bypass is where most manually-operated globe valves find a home today.
- Globe valves are 9% of the gate/globe/check quantity

Why did it happen?

- Bad design or defects
- Globe valve sizing

Table 3. Fluor Daniel Typical Block and Bypass Valve Sizing Chart

Control Valve Size	Line Size 1		1-1/2		2		3		4		6		7		10		12	
	BLOCK	BYPASS	BLOCK	BYPASS	BLOCK	BYPASS	BLOCK	BYPASS	BLOCK	BYPASS	BLOCK	BYPASS	BLOCK	BYPASS	BLOCK	BYPASS	BLOCK	BYPASS
1	1	1	1	1	1-1/2	1	2	1	-	-	-	-	-	-	-	-	-	-
1-1/2	-	-	1-1/2	1-1/2	1-1/2	1-1/2	2	1-1/2	3	1-1/2	-	-	-	-	-	-	-	-
2	-	-	-	-	2	2	2	2	3	2	4	2	-	-	-	-	-	-
3	-	-	-	-	-	-	3	3	3	3	4	3	6	3	-	-	-	-
4	-	-	-	-	-	-	-	-	4	4	4	4	6	4	8	4	-	-
6	-	-	-	-	-	-	-	-	-	-	6	3	6	4	8	4	10	8
8	-	-	-	-	-	-	-	-	-	-	-	-	8	4	8	4	10	8
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	6	10	8
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	8

The crucial problem

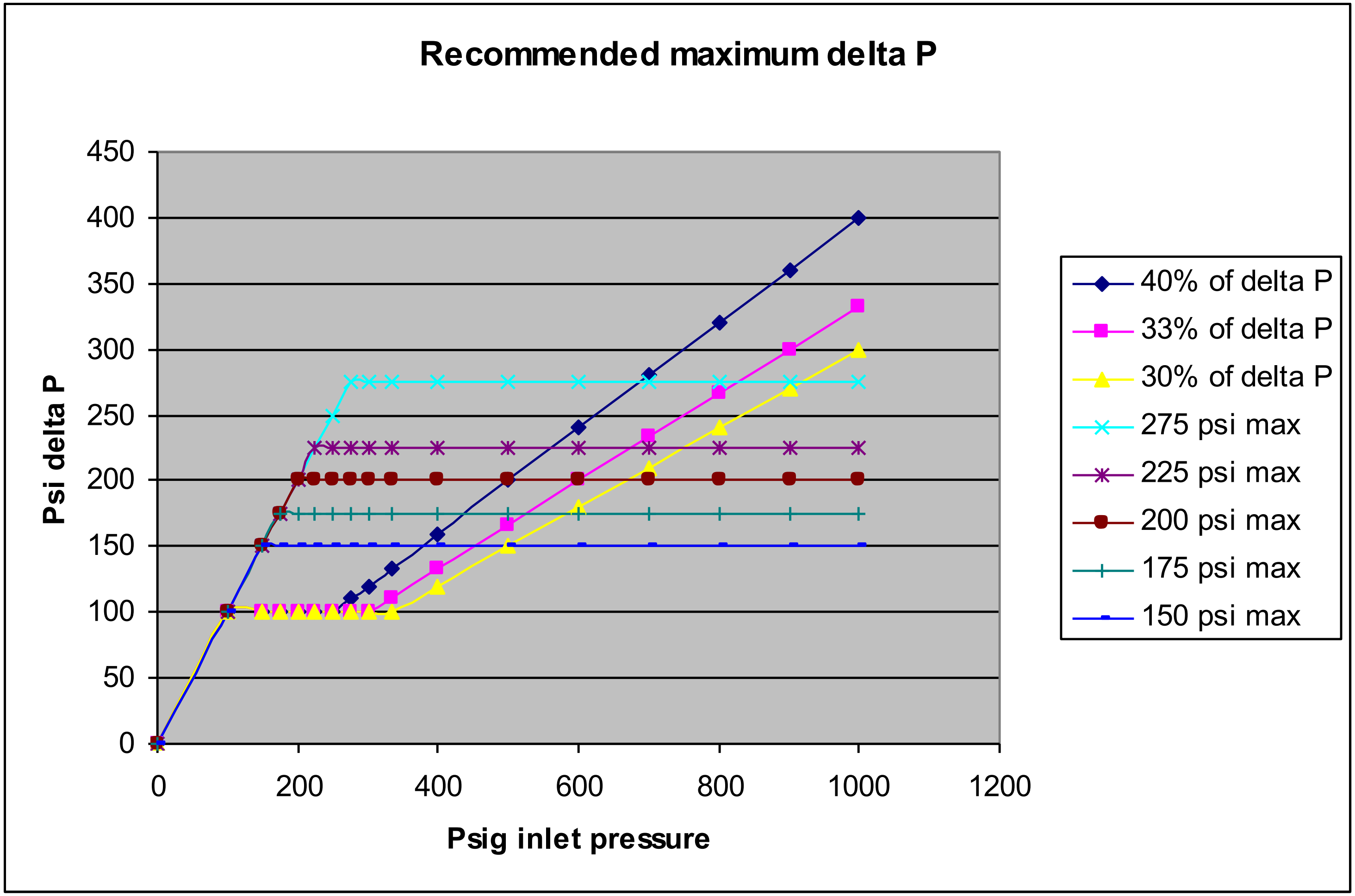
- Why have these issues been important?
- Although a globe valve can handle any **pressure** that's within its range, it doesn't like too much flow
- High **flowrate** equals high **velocity**, which can mean (or which comes from) too much **pressure drop** which means too much **vibration** which means too much **noise** and too much **damage** to the valve.
  - Vibration and flow can actually cause a **rotating-stem** globe valve to open on its own
  - Vibration and impact has been known to break yoke nuts on **non-rotating-stem** globe valves

Why did it happen?

- Further investigation revealed:
  - Considering every control valve station in the new units, the ones reporting problems all had fairly high pressure drops, from 200 psi / 15 bar up to over 1000 psi / close to 100 bar
  - The ones reporting problems were all in flashing service
  - In fact, numerous valves with high delta P but no potential for flashing operated with no problem.
  - Valves 1-1/2 and smaller had no problems
    - API 602 valves seem to be stiffer than larger valves
- The pervasiveness of this problem, and its obvious relation to flow characteristics, ruled out defective manufacturing pretty quickly
- Several manufacturers, and a couple of users were consulted, who each had a suggestion for the maximum delta P that a globe valve should be expected to take.

Why did it happen?

Here are these recommendations, combined:



Why did it happen?

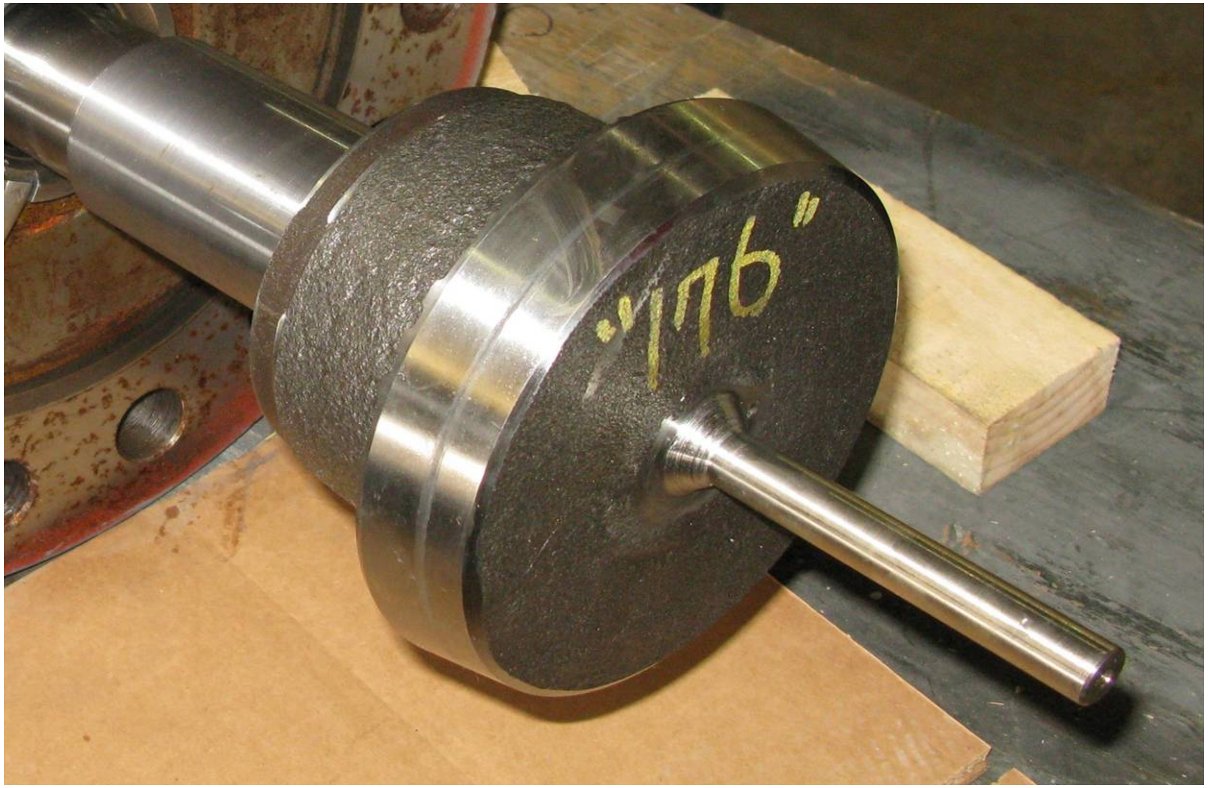
- What this shows is that the awareness of this problem is pretty widespread,
- But awareness of the limits of performance capability is very uncertain.
- We saw that services that had flashing potential, or were close to cavitation, were likely to cause vibration and noise, while non-flashing services were much less likely
    - This could explain why it's hard to pin down the boundaries of this problem.
- So how did we solve our problem?
    - We put more valves in.

Solution

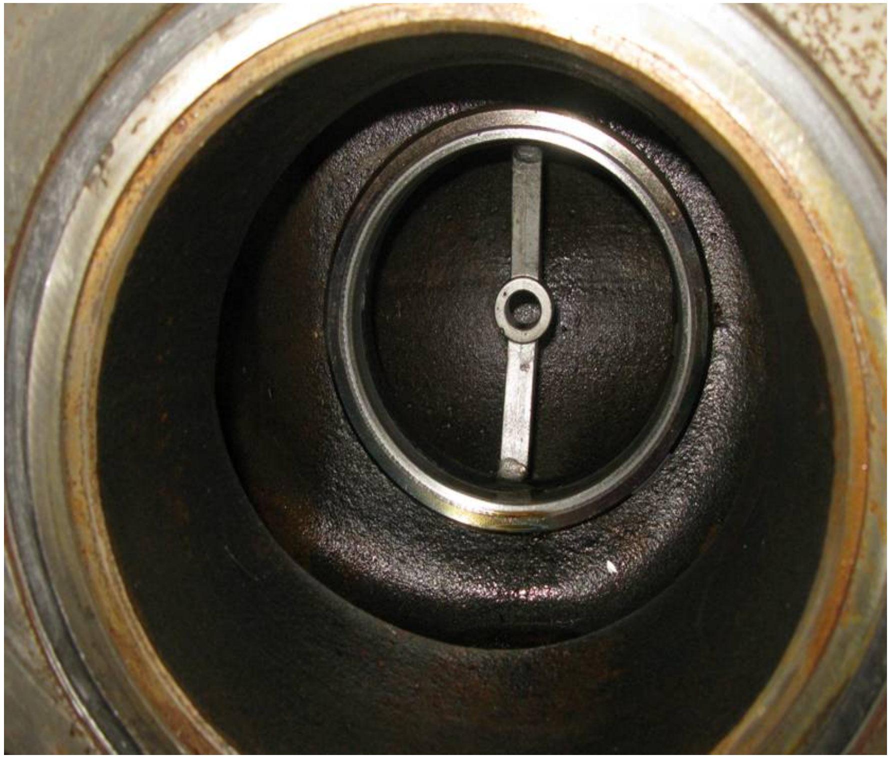
- Base the bypass valve size on *required* control valve Cv, not *furnished* control valve Cv,
- and especially not on line size or control valve flange size.
- And, for sure, don’t use a sizing chart.
- Remember 50% open on a manual globe valve is 80-90% of full open Cv
- Or, use a better globe valve.

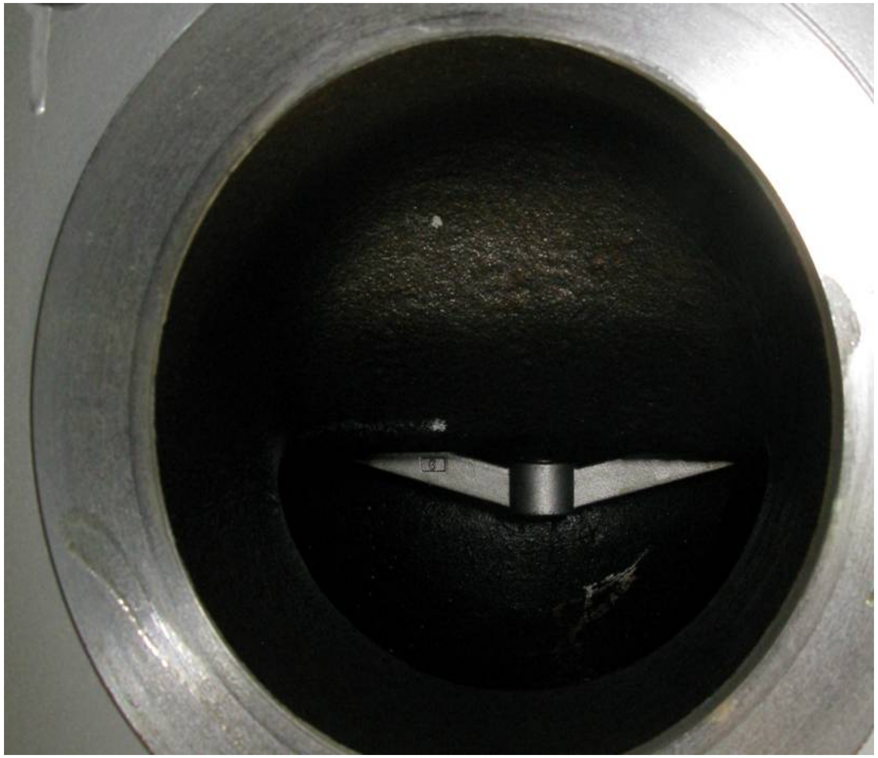
Examples of better globe valves

Guided disc - guide attached to bottom of disc

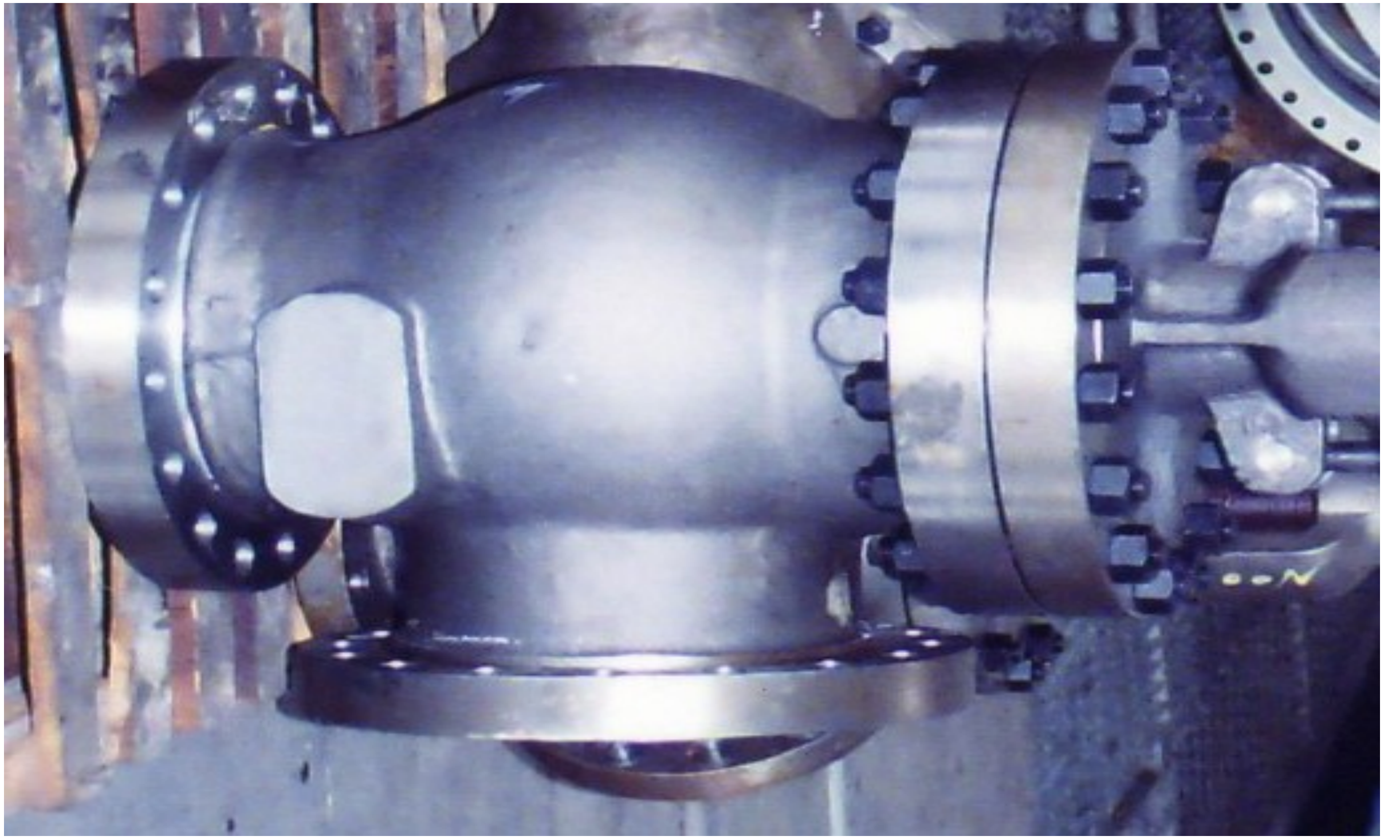


Modified – guides welded to seat ring





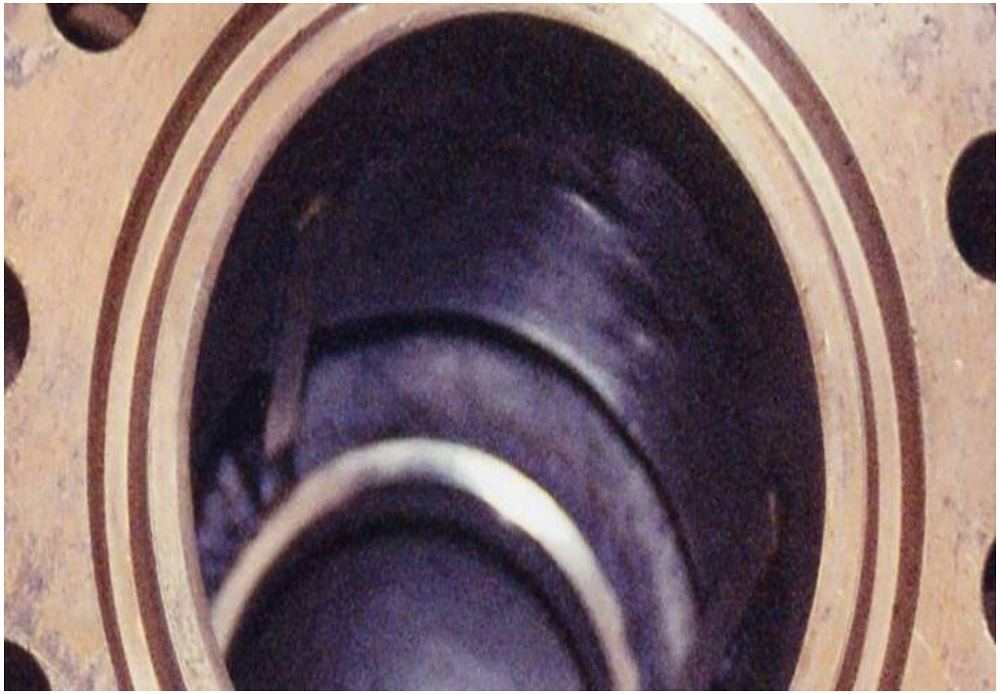
Angle valves



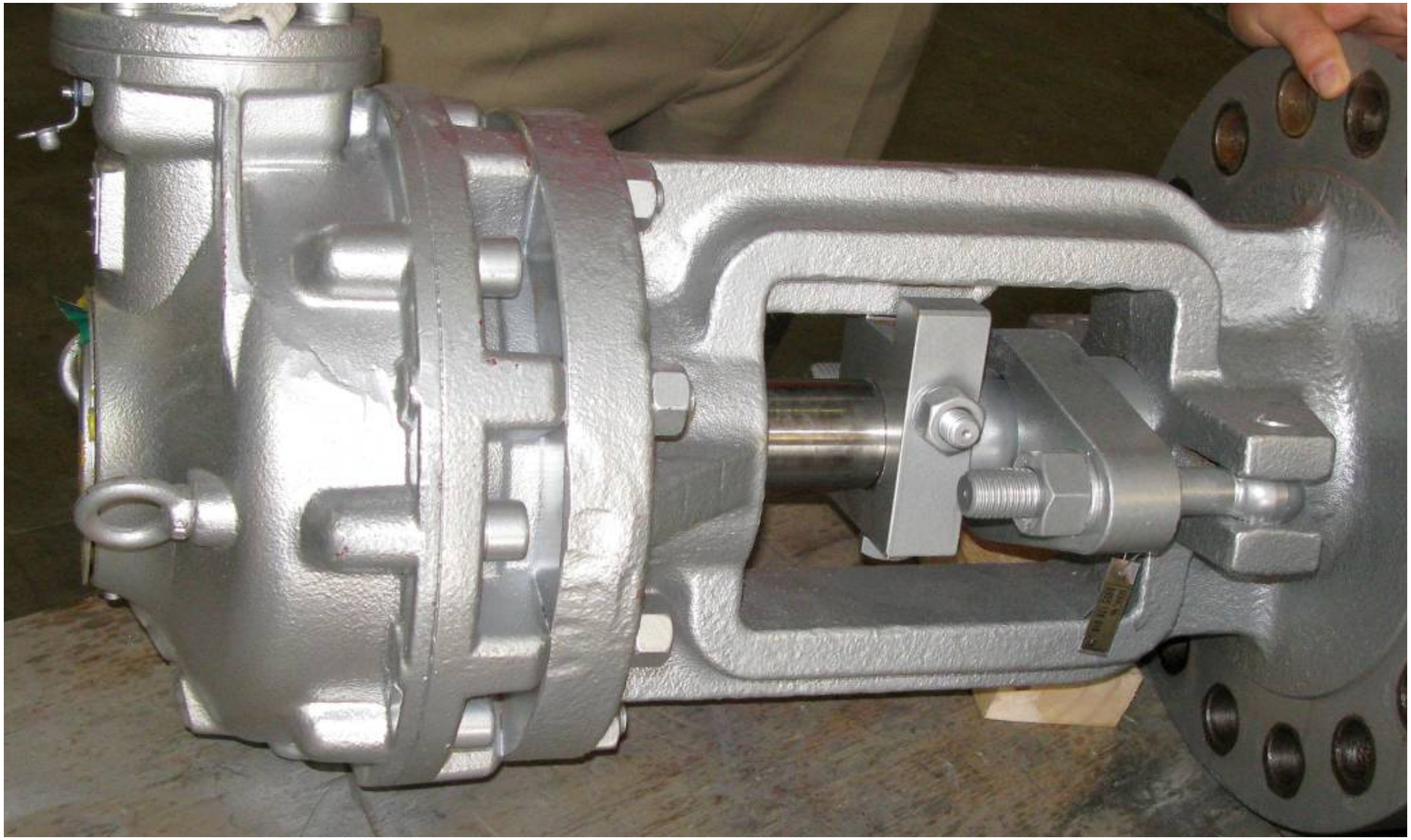
Y-Pattern Valves

INDUSTRIALVALVESUMMIT

Body Guided Globe Valve



Non-Rotating stem design



So now, back to the API standard

- There had never been an API downstream standard on globe valves
  - There are a number of possible reasons, but perhaps, there never seemed to be that great a need for it
- Because of ISO co-branding, API 602 expanded in scope to cover small forged globe and various check valves
  - Incorporating much information from BS 5352
- So the time was right for a cast steel globe valve standard.

- Here's how the API development process works:

Development of the API standard

- Authority to develop or discontinue an API standard originates as a project work item at the SCOPV (Sub-Committee On Piping and Valves) level
- The work item is then approved by the CRE (Committee on Refinery Equipment)
- The globe valve work item was approved in 2009, followed by appointment of a task group leader, who called for volunteers at the fall 2009 API meeting
- First task group meeting was in spring 2010, first draft produced in summer 2010.

Development of the API standard

- Criteria for an API task group
  - Task group leader and five to nine members
  - Balance of users and manufacturers
  - Task group expires when standard is issued
- Our goals in developing the API 623 standard were:
  - Parallel with API 600 wherever possible
  - Incorporate items addressed by BS 1873
  - Verify everything by original calculations *
  - Incorporate most existing designs and manufacturing practice,
    - Subject to the task group's judgment as to suitability
  - <u>Make the valve better than it would be without the standard</u>

* BS 1873 larger high pressure stem diameters appear to be undersized, are overstressed in column loading

Summary of API 623 details

1 **Scope** (calls out the features covered)

This API standard specifies the requirements for a heavy-duty series of bolted bonnet steel globe valves for petroleum refinery and related applications where corrosion, erosion and other service conditions would indicate a need for heavy wall sections and large stem diameters.

This standard sets forth the requirements for the following globe valve features:

- bolted bonnet,
- outside screw and yoke,
- rotating rising stems and nonrotating rising stems,
- rising handwheels and nonrising handwheels,
- conventional, y-pattern, right-angle,
- stop-check (nonreturn type globe valves in which the disc may be positioned against the seat by action of the stem, but is free to rise as a check valve due to flow from under the disc, when the stem is in a full or partially open position),
- plug, narrow, conical, ball, or guided disc,
- metallic seating surfaces,
- flanged or butt-welding ends.

What's in API 623

- Includes size range NPS 2-24, pressure Class 150-2500
  - Class 2500 NPS 2-12 only
- Specifies minimum wall thickness
- Specifies minimum stem diameters, minimum seat diameter, following the principles of API 600 but sometimes requires different values due to the calculation results
- Requires guided disc for Class 900 and higher
- Requires hardfacing on seat and disc Class 900 and higher
  - Alloy 21 hardfacing allowed, in addition to alloy 6
- Requires "Consider the effects of severe operating conditions"

API 623 details

5.3.5 Body Seats

5.3.5.1 The inside diameter of the seat opening shall not be less than that specified in Table 4 for the nominal pipe size and pressure class.

5.3.5.2 Integral seats with overlays per Table 8 are permitted. Integral body seats (without overlays) are permitted in austenitic stainless steel and other group 2 materials bodies. An austenitic stainless steel or a hardfacing material may be weld-deposited either directly on the valve body or on a separate body seat ring.

5.3.5.3 Finished thickness of any facing material shall be not less than 0.06 in. (1.6 mm). Where a separate seat ring is provided, it shall be shoulder or bottom seated, and either threaded and seal welded or inserted and seal welded in place.

5.3.5.4 Body seat rings shall have adequate seating area surface and shall have edges designed to prevent galling or any other damage. Body seat ring seal surface area shall be designed so that the contact stress of the disc against the seat shall be less than the yield strength of both seating materials, to prevent plastic deformation or any other damage to the seating surfaces.

5.3.5.5 Sealing compounds or greases shall not be used when assembling seat rings; however, a light lubricant having a viscosity no greater than kerosene may be used to prevent galling of mating threaded surfaces.

API 623 details

5.6 Disc

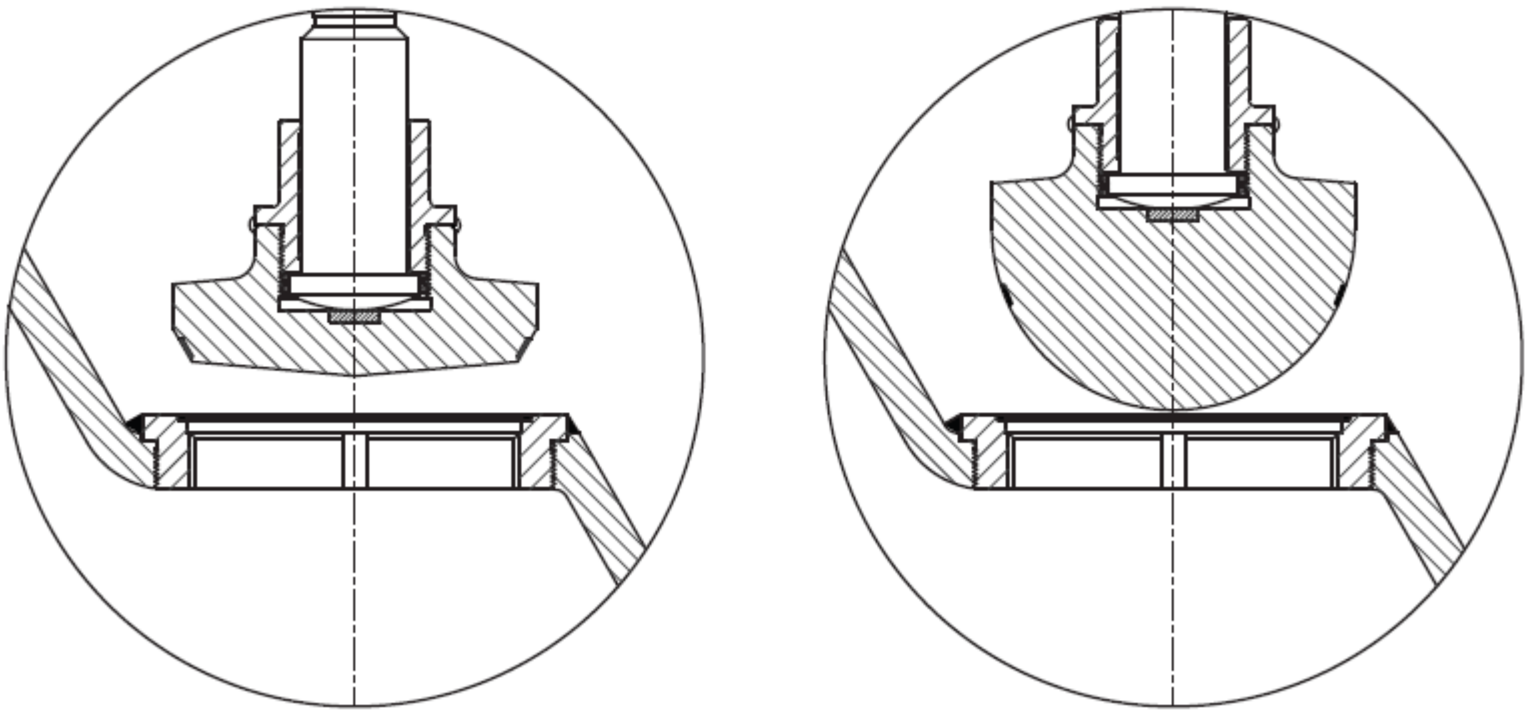


Figure 2—Typical Discs

API 623 details

5.6.3

The disc shall be guided throughout its full range of travel. Guiding may be provided by stem, body, or other means. For Class 900 and higher, the disc shall be guided by means other than the stem and shall be guided throughout its full range of travel. Guides need not be hard-faced unless specified in the purchase order or when required to allow for proper operation in required configuration.

API 623 details

5.8 Stem, Stem Nut, and Yoke Bushing

5.8.1 The minimum stem diameter, d_S, shall be as given in Table 5. The minimum stem diameter applies to the stem along the surface area that comes into contact with the packing and to the major diameter of the trapezoidal stem thread. However, the major diameter of the stem thread may be reduced, at the manufacturer's option, by no more than 0.06 in. (1.6 mm). The stem surface area in contact with the packing shall have a surface finish, *Ra*, of 32 µin. (0.80 µm) or smoother.

5.8.2 Stems shall have a disc attachment means at one end and an external trapezoidal style thread form at the other. A yoke bushing on rising and rotating stems or a stem nut on non-rotating rising stems shall be provided.

- API 623 minimum stem diameters specified are in excess of other international Industry standards for Globe Valves, such as BS 1873

API 623 details

Stem

(continued)

Stem diameters are based on 20 ksi max design stress

Table 5—Minimum Stem Diameter

Class Designation	150		300		600		900		1500		2500		
Nominal Size NPS	Minimum Stem Diameter d_s in. (mm)												Nominal Size DN
2	3/4	(19)	3/4	(19)	7/8	(22)	1	(25)	1 1/8	(29)	1 1/2	(38)	50
2 1/2	7/8	(22)	7/8	(22)	1	(25)	1 3/8	(35)	1 3/8	(35)	1 5/8	(41)	65
3	1	(25)	1	(25)	1 1/8	(29)	1 3/8	(35)	1 1/2	(38)	1 3/4	(44)	80
4	1 1/8	(29)	1 1/8	(29)	1 1/4	(32)	1 3/4	(44)	1 7/8	(48)	2	(51)	100
6	1 1/4	(32)	1 3/8	(35)	1 7/8	(48)	2 1/4	(57)	2 3/4	(70)	3 1/8	(79)	150
8	1 3/8	(35)	1 3/4	(44)	2 1/2	(64)	2 7/8	(73)	3 1/2	(89)	4	(102)	200
10	1 1/2	(38)	2 1/4	(57)	3 1/4	(83)	3 1/2	(89)	4 1/4	(108)	4 7/8	(124)	250
12	1 3/4	(44)	2 5/8	(67)	3 3/8	(86)	4 1/8	(105)	5	(127)	5 3/4	(146)	300
14	1 7/8	(48)	2 7/8	(73)	3 7/8	(98)	-		-		-		350
16	2 1/4	(57)	3 3/8	(86)	-		-		-		-		400
18	2 1/2	(64)	-		-		-		-		-		450
20	2 3/4	(70)	-		-		-		-		-		500
24	3 1/2	(89)	-		-		-		-		-		600

API 623 details

Stop check
(also known as non-return stop valve)

- This valve, also, is covered in scope of API 623.

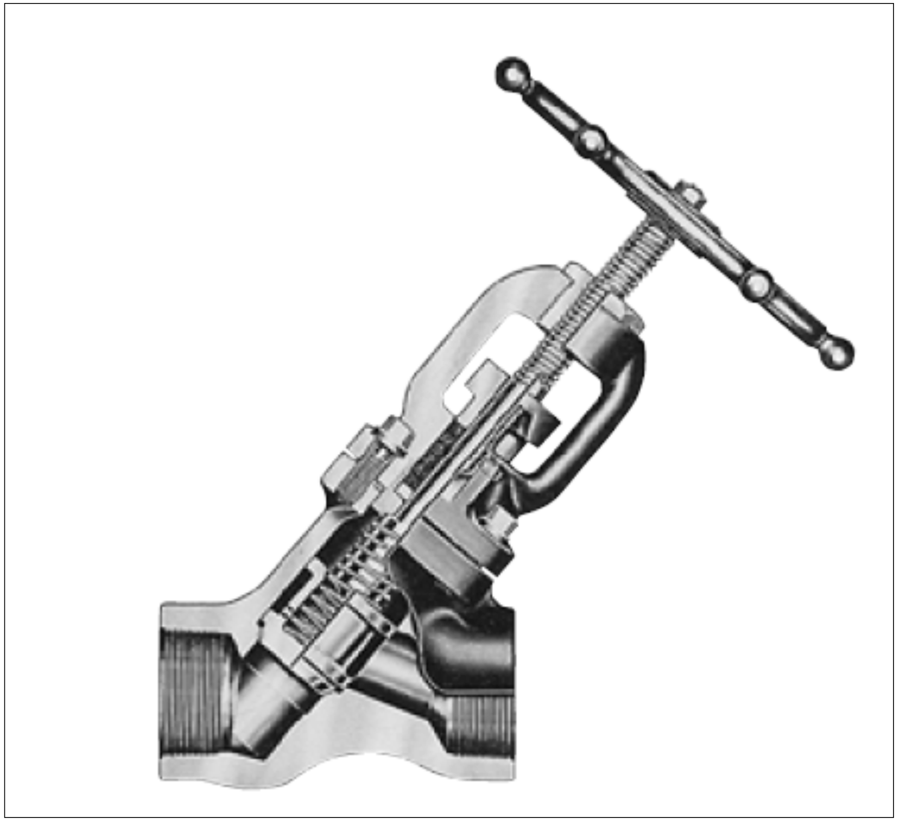


Illustration courtesy Flowserve

API 623 details

Stop-Check : nonreturn type globe valve in which the disc may be positioned against the seat by action of the stem, but is free to rise as a check valve due to flow from under the disc, when the stem is in a full or partially open position.

5.12 Stop-Check

5.12.1 Stop-check valves shall be provided with a means to equalize pressure in the bonnet above the disc to the downstream side.

5.12.2 Stop-check valves shall have suitable disc or bottom guiding to ensure the disc moves freely during check valve operation.

5.12.3 Stop-check valves shall be tested in accordance with the requirements of API 598 for both globe and check valves and shall meet the acceptance criteria of both types of tests.

5.12.4 Stop-check valves shall be suitable for installation with the stem in the vertical orientation or in an orientation where the stem is within 45 degrees of vertical orientation.

Stem Diameter
BS 1873 – API 623 comparison

Size-Class	BS 1873:1975 Min Stem Diameter	API 623
2-150	3/4	3/4
2.5-150	7/8	7/8
3-150	1	1
4-150	1 1/8	1 1/8
6-150	1 1/4	1 1/4
8-150	1 3/8	1 3/8
10-150	1 1/2	1 1/2
12-150	1 5/8	**1 3/4**
14-150	1 3/4	**1 7/8**
16-150	1 7/8	**2 1/4**
18-150		**2 1/2**
20-150		**2 3/4**
24-150		**3 1/2**

Size-Class	BS 1873:1975 Min Stem Diameter	API 623
2-300	3/4	3/4
2.5-300	7/8	7/8
3-300	1	1
4-300	1 1/8	1 1/8
6-300	1 3/8	1 3/8
8-300	1 1/2	**1 3/4**
10-300	1 5/8	**2 1/4**
12-300	1 3/4	**2 5/8**
14-300		**2 7/8**
16-300		**3 3/8**

Bold is data changed from BS 1873 to API, otherwise identical

BS 1873 – API 623 comparison

Size Class	BS 1873:1975 Min Stem Diameter	API 623
2-600	13/15	7/8
2.5-600	1	1
3-600	1 1/8	1 1/8
4-600	1 1/4	1 1/4
6-600	1 5/8	**1 7/8**
8-600	1 3/4	**2 1/2**
10-600	2	**3 1/4**
12-600	2 1/8	**3 3/8**
14-600		**3 7/8**

Size Class	BS 1873:1975 Min Stem Diameter	API 623
2-900		**1**
2.5-900		**1 3/8**
3-900	1 1/4	**1 3/8**
4-900	1 3/8	**1 3/4**
6-900	1 3/4	**2 1/4**
8-900	2	**2 7/8**
10-900	2 1/4	**3 1/2**
12-900	2 3/8	**4 1/8**
14-900	2 1/2	**4 1/2**

Bold is data changed from BS 1873 to API, otherwise identical

BS 1873 – API 623 comparison

Size Class	BS 1873:1975 Min Stem Diameter	API 623
2-1500	1 1/8	1 1/8
2.5-1500	1 1/4	**1 3/8**
3-1500	1 3/8	**1 1/2**
4-1500	1 1/2	**1 7/8**
6-1500	2	**2 3/4**
8-1500	2 1/4	**3 1/2**
10-1500	2 5/8	**4 1/4**
12-1500	2 7/8	**5**

Size Class	BS 1873:1975 Min Stem Diameter	API 623
2-2500	1 1/2	**1 1/2**
2.5-2500	1 5/8	**1 5/8**
3-2500	1 3/4	**1 3/4**
4-2500	2	**2**
6-2500	2 1/2	**3 1/8**
8-2500	3	**4**
10-2500	3 1/2	**4 7/8**
12-2500	3 3/4	**5 3/4**

Bold is data changed from BS 1873 to API, otherwise identical

API 623 will improve globe valve reliability

- Size range NPS 2-24, pressure Class 150-2500
  - Class 2500 NPS 2-12 only
- Minimum wall thickness
- Minimum stem diameters, minimum seat diameter, follows principles of API 600 but sometimes different values
- Requires guided disc Class 900 and higher
- Requires hardfacing on seat and disc Class 900 and higher
  - Alloy 21 hardfacing allowed

- "Consider the effects of severe operating conditions"

Questions / Comments?

- Thank you for your time.

- Photos by Ron Merrick unless otherwise credited.