Consider Gate Valve Specifications

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Gate valves are by far the most common valve used in a traditional water utility. Surprisingly, a review of modern municipal and commercial specifications reveals some confusion between current and previous standards. Many specifications reference the current ANSI (American National Standards Institute)/AWWA C515 standard (Reduced-Wall, Resilient-Seated Gate Valves for Water Supply Service), whereas others still use the older ANSI/AWWA C509 standard. Others publish requirements for valves complying with an even older ANSI/AWWA C500 metal-seated standard.

Sometimes, specifications are published that enlist contradictory features from multiple standards, requiring a valve that may not even exist. In these instances, the problem is usually based on a lack of knowledge or the use of older specifications that need to be updated. To understand the source of the confusion, one must first look at the evolution of gate valve standards in the water industry.

Evolving Standards

Metal-seated gate valves, constructed of gray cast iron, have been produced since the 1800s. Although the C500 standard (*Metal-Seated Gate Valves for Water Supply Service*) did not receive its current designation until 1952, its origins as the first US gate valve standard date back to 1913. Today, C500 is recognized as the standard for metal-seated gate valves.

The minimum wall thicknesses published in the C500 standard were based largely on experience, application, and the standard gray-iron casting methods employed at the time. These limitations made the wall thicknesses somewhat arbitrary. Inherent in the metal-seated design are two weaknesses: (1) metal-to-metal seats have allowable leakage from the manufacturer that worsens with time, and (2) metal-to-metal contact along the sealing surfaces results in friction and high operating torques.

The resilient-seated gate valve design addresses both of these primary issues by using a monolithic, rubber-faced wedge that is leak-tight and yields lower operating torques. The resilient-seated gate valve was used in Europe for many years before its introduction in the United States. With the emergence of resilient-seated gate valve development and its widespread acceptance in the US market, ANSI/AWWA C509, *Resilient*

Finite Element Analysis Image

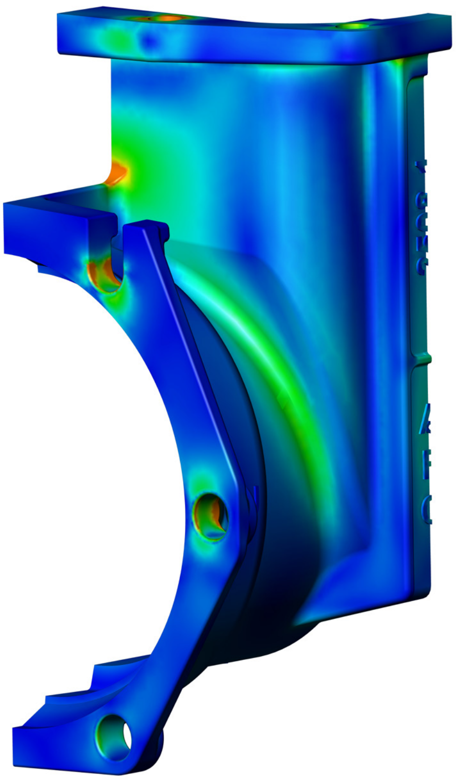

Figure 1

Seated Gate Valves for Water Supply Service, was published in 1980. Although C509 allows for the use of both cast-ductile and gray cast-iron pressure-containing materials, the wall thicknesses published in the standard were carried over from the C500 standard, making the C509 wall thicknesses arbitrary as well.

Following trends that saw the industry's migration from cast-iron pipe to ductile-iron pipe, and later from full-bodied cast-iron fittings to reduced-wall ductile-iron compact fittings, Waterous Company began field trials on a reduced-wall, ductile iron gate valve in 1985. In 1999, the C515 standard was published for gate valves constructed of ductile iron. In the past 24 years, a large majority of users have made C515 the standard of choice in their specifications. Different from C500 and C509, the thicknesses in the C515 standard are based on modern engineering techniques, such as finite element analysis (Figure 1), along with product verification through validation testing.

Examining the differences in strength and ductility of ASTM A536 Grade 65-45-12 and ASTM A126 Grade B (two commonly used irons in the waterworks industry) reveals that cast ductile iron has a tensile strength of at least 65,000 psi, which is more than twice the tensile strength of gray iron, at 31,000 psi. Just as important, ductile iron exhibits a 45,000-psi minimum yield strength and 12% minimum elongation, whereas gray iron has practically no ability to flex before fracture. Because of these superior material properties, after C515 was published, demand in the market for waterworks gate valves shifted significantly toward ductile-iron gate valves that met this standard.

Corrected Valve and Wall Thickness Comparison

	Minimum Wall Thickness Adjusted for Allowable Minus Tolerances	
Valve Size *inches*	**AWWA C500/ AWWA C509** *inches*	**AWWA C515** *inches*
4	0.35	0.31
6	0.38	0.32
8	0.44	0.34
10	0.55	0.36
12	0.60	0.38
14	0.66	0.45
16	0.74	0.50
18	0.82	0.56
20	0.85	0.56
24	0.95	0.62
30	1.22	1.06
36	1.35	1.31
42	1.38	1.42
48	1.51	1.44
54	1.93	1.44
60	2.14	1.68
66	2.35	1.88
72	2.56	1.94

C509 thicknesses above 36-inch size are pending publication of the newest edition.

Table 1

Failures Due to Simulated Corrosion of Valve Castings

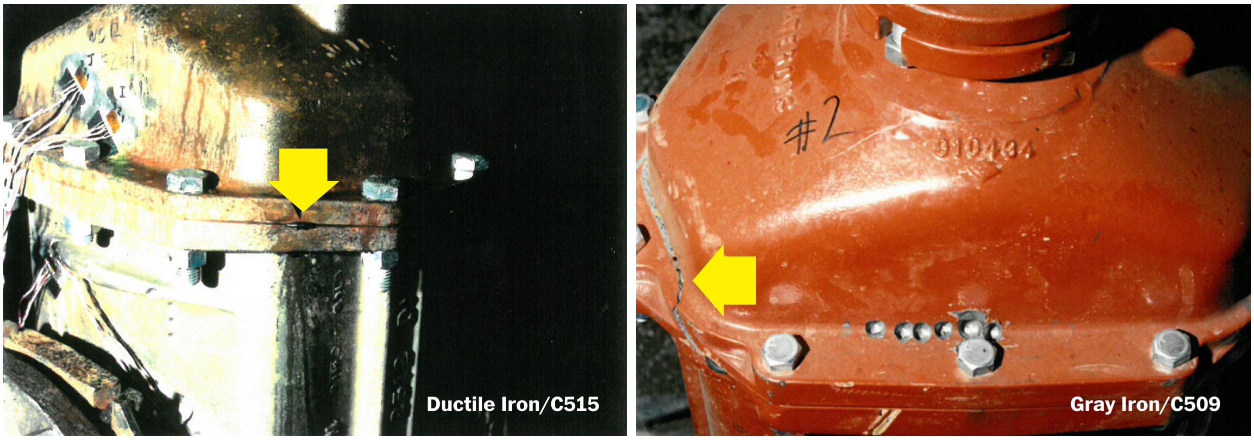

Figure 2

Review of C509 and C515 reveals significant harmonization, with only slight differences between the two standards. The primary differences are that C515 requires the valve body and bonnet to be constructed of ductile iron. Because of the increased strength and elasticity of ductile iron, the allowable minimum wall thickness requirements are reduced. However, a deeper dive into the standards reveals the differences in wall thickness to be minimal due to an allowable 12.5% reduction in the published C509 dimensions. This allowance is attributed to manufacturing tolerances. The C515 published thicknesses are minimums, with no under-tolerance. Table 1 shows the minimum wall thicknesses allowed by each standard.

The use of ductile iron has tremendous advantages, including valve strength, increased rated working pressures, and a reduction in product weight and installation times. The ductility of the body and bonnet material also make the valve more resistant to damage during handling or from forces exerted by settling of soil and attached piping after the valve's installation.

After the C515 standard was published in 1999, there was concern about any potential effects of corrosion due to the reduced wall thickness, particularly how any material loss might affect a valve's strength under pressure. Along with several other questions, the corrosion concerns were addressed during the validation process for the reduced-wall design, as described in the next section.

Both C509 and C515 valve castings are typically coated with a fusion-bonded epoxy before assembly to insulate the individual valve components and protect against corrosion. Metal-seated C500 valves, upon which C509 wall thicknesses were based, were not coated with epoxy.

Valve Testing

AMERICAN Flow Control was the first company to produce a reduced-wall C515 gate valve. As part of the validation process, the company conducted experiments on both the gray iron C509 and ductile-iron C515 designs to determine what effect the reduced wall had. To simulate advanced corrosion, numerous half-inch-diameter spots were drilled one-quarter inch deep into known high-stress concentration locations, determined using finite element analysis, on both valve models (Figure 2). It is generally accepted that gray iron and ductile iron exhibit similar corrosion properties.

These drilled spots simulated worst-case conditions of potential corrosion. Both valve models were then pressurized, with the gate (wedge) open until failure. Table 2 shows the results of repeat tests under these conditions.

Performance equal to or better than the established gray iron C509 valve was considered satisfactory validation of the ductile iron C515 design. As Table 2 shows, both valves failed well above their rated working pressures, even with the casting walls compromised to simulate a highly corroded condition.

The valve constructed from gray iron components failed at approximately 850 psig when its bonnet fractured along a row of drilled pit holes at the bonnet flange. Despite the

Pressure-Related Fracture Due to Simulated Corrosion

	Gate Valve Type	
Variable	12-inch gray iron valve	12-inch ductile-iron valve
Rated working pressure	200 psig	250 psig
Undrilled casting wall thickness (average)	0.70 inches	0.44 inches
Drilled casting wall thickness (average)	0.45 inches	0.19 inches
Pressure at failure	850 psig	1,200 psig
Method of failure	Fracture along drilled spots	Blown bonnet gasket

Table 2

drilled wall thickness of the ductile-iron valve being less than half of its original wall thickness and that of the compromised gray iron valve, the valve casting did not fail due to iron fracture. Instead, a temporary flexing of the bonnet casting allowed the bonnet gasket to slip out of position at approximately 1,200 psig. This flexing is attributed to ductile iron's ability to yield without breaking.

During the test, the ductile-iron castings experienced no permanent deformation or damage. In total, the results of the test validated the wall thicknesses used in the C515 standard and confirmed that its performance exceeded the older, established wall thicknesses and material requirements.

Unrelated to corrosion, the valve design was also subjected to beam load tests (Figure 3). Beam loads can develop from settling of structures, soil, pipe misalignment, and vibrations. A similar comparative analysis was performed to simulate beam loading on the valve. A

Beam Load Tests

Figure 3

pressurized system was configured using flanged pipe. Subsequently, a vertical load was applied to the top of a valve until fracture occurred.

With the gray iron C509 style valve, fracture occurred on the lower portion of the valve flange at 78,000 pounds, with a vertical displacement of less than an inch. The ductile-iron, C515-style valve withstood 135,000 pounds of vertical load with a displacement of approximately 2 inches. The ductile iron valve never failed. Instead, the piping system failed at the threaded-on flange location.

As with the simulated corrosion tests, the beam load test underscored the performance capabilities of gate valves complying with the C515 standard. The results of these simple validation tests should reinforce confidence in the newer standard and diffuse any notions that when it comes to gate valves, thicker walls are not always necessary.

Product Selection

Specifications are a critical component in the design of any project, and they can be the foundation of a high-performing utility. Product selection typically depends on user or designer preference. Such preferences are often based on successful experience; however, sometimes they come from inexperience or too much reliance on what was used last. Whichever products and standards are needed, specifiers should be aware of all available technologies and ultimately select reliable products that best meet the needs of the project engineer, owner, and end users.

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