# High-Temperature Boiler Steam Stop Valves — Beware of a Hidden Problem

## Be forewarned, hardface disbonding is something frightening to behold.

By Joseph Miller

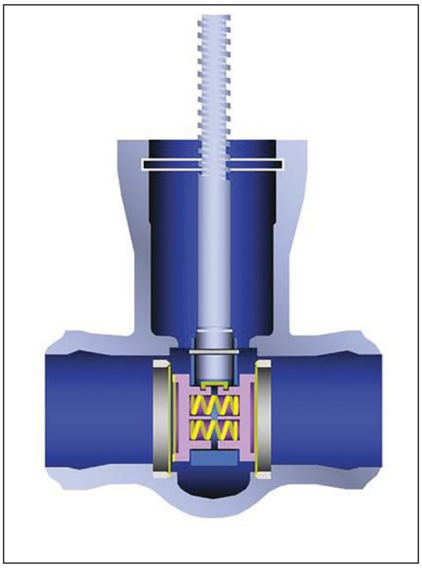

**Figure 1. A cross-sectional view of a parallel disc gate valve.**

**Figure 2. HP turbine first-stage damage due to liberated pieces of hardfacing.**

What lurks beneath the surface? What is underneath, where eyes cannot see? Is it something valuable? Is it something old? Is it some treasure or something frightening to behold? These are common questions for miners, deep-sea oceanographers, or even a young child staring into the murky water, but this is an article on boiler steam stop valves. What exactly do these questions have to do with the subject matter? Let's find out.

Located at the steam outlet of the boiler, the steam stop valve provides a means of isolation. For multiple boiler installations, two stop valves are required. Typically, one of the two valves is a gate valve, and the other is commonly a stop-check valve. In lower pressure/temperature applications, a solid wedge gate valve can be used, while a flexible wedge style is typically employed when ANSI CL600 – CL900 valve ratings are required. Above Class 900, the most common design chosen is the parallel disc or parallel slide gate valve.

At high steam temperatures, it is very common for valve trim to be hardfaced with a cobalt alloy. Hardfacing is applied to the seat and/or closing member (wedge, plug, or discs) to provide wear resistance and, in some cases, corrosion resistance. Hardfacing, when applied to both the seat and closing member, reduces the coefficient of friction, which aids in valve sealing and ac-

**Figure 3. Interfacial crack at base metal substrate and hardface boundary.**

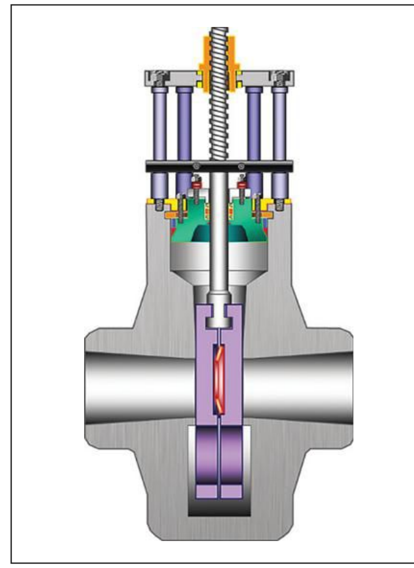

**Figure 4. ValvTechnologies' IsoTech® parallel slide gate valve (PSGV).**

| | RiTech 31 | Alloy 6 |
|---|---|---|
| 1,000°F | 68.5 Rc | 30 Rc |
| 1,200°F | 66 Rc | 22 Rc |
| 1,400°F | 62 Rc | 10 Rc |

**Figure 5. A Rockwell C hardness comparison.**

tuation. The hardfacing is applied by welding the harder and often tougher material to the metal substrate. For steam valves, Alloy 6 and Alloy 21 (developed under the Stellite brand) have been used extensively for decades. But then something started happening, something unexpected and hidden, that caused significant problems in the power industry. Over a dozen years ago, the first widespread occurrences of an unexpected issue with cobalt alloy hardfacing began surfacing. Numerous valves fabricated from F91 and A217-C12A, upon ultrasonic testing (UT) inspection of the seats and discs, revealed extensive subsurface cracking at the metal substrate/hardfacing boundary. The subsurface interfacial cracking, also known as "disbonding" or "delamination," can propagate to the point where sections of the hardfacing liberate and become entrained in the steam flow. Liberation of the hardfacing at a power plant may in fact have been the first clue that a heretofore hidden problem existed. Pieces of Alloy 6 hardfacing material were found in the perforated screen of the combined stop/control valve at the steam turbine. After cobalt alloy delamination became a known problem, multiple power plants that used UT reported finding the same issue. Why, after decades of successful use, was valve trim hardfacing disbonding/delaminating from the metal substrate and, in some cases, liberating from the valve and causing downstream damage? This is occurring not only in old valves but in valves operating for as few as 10,000 operating hours.

Disbonding of steam stop valve hardfacing has predominately been a power industry issue affecting mainly combined cycle power plants and, to a lesser degree, coal-fired power stations. Besides the loss of isolation integrity from disbonding, entrained pieces of hardfacing material can breach the steam turbine screens and cause blade path damage as evidenced in Figure 2. If a section of hardfacing is not visibly missing, the only means to determine if hardface disbonding is occurring is to perform UT inspection.

The issue became so prevalent and consequences so severe that the widely respected Electric Power Research Institute (EPRI) established a program to investigate the cobalt alloy disbonding problem. Findings from the investigation revealed that no one steam stop valve manufacturer solely had an issue; many, if not all, major valve manufacturers using cobalt alloy hardfacing experienced subsurface cracking. It was also found that disbonding was not solely a gate valve problem; disbonding was also occurring in stop-check valves. A common theme though was disbonding occurring in F91 and C12A valves. Since F91 and C12A valves are used in high-temperature/high-pressure steam applications, elevated steam temperature (1,050°F and higher) became a common denominator.

EPRI's investigations focused on the metallurgical structure of the base metal substrate/cobalt alloy interface boundary layers. These boundary layers were found to contain a brittle intermetallic Sigma phase that formed from the base metal and cobalt alloy weld pool. Circumferential, subsurface cracking propagates in the interface boundary possibly due to this brittle Sigma phase. Operating time at elevated temperature appears to be a factor, since hardface disbonding does not occur right away. Empirical evidence suggests that the cracking takes at least 10,000-80,000 hours to initiate.

What explains the seemingly sudden onset more than a decade ago of this problem after decades of successful cobalt alloy hardfacing use in steam stop valves? Also, why continue using cobalt alloy hardfacing when there is a time-proven high-temperature/high-pressure parallel slide gate valve available that does not use cobalt alloy hardfacing?

The answer to the first question is still not definitively known. Hypotheses include the production rate of the hardfacing application increased to the point that too much heat during welding was occurring, resulting in excessive iron dilution from the base metal into the cobalt alloy. Another theory is the operating regime of combined cycle power plants and some coal-fired power stations has become more cyclic in nature, potentially leading to more significant thermal transients from quenching events (attemperator overspray). It could also be a combination of separate and distinct issues, such as weld procedure, residual stresses, operating thermal stresses, and hardfacing material choice. Based on the EPRI investigations, several recommendations have been proffered, including keeping iron dilution below 10% and using an Inconel "butter" layer between the base metal and the cobalt alloy hardfacing. Time will tell if these recommendations solve the problem.

Consider the following: Several power industry veterans predict that more than 50% of all steam stop valves operating at 1,050°F and above will experience disbonding within 100,000 operating hours. Repairing hardface disbonding costs $250,000 per steam stop valve, on average. Additionally, if hardface material liberates and goes downstream, the financial consequences of a damaged steam turbine can run into the millions in repair and lost generation costs. The question remains: Why continue using cobalt alloy hardfacing in high-temperature/high-pressure applications when an alternative cobalt, alloy-free PSGV design exists?

**ValvTechnologies' IsoTech Valve.**

Figure 4 offers a cross-sectional view of ValvTechnologies' IsoTech® parallel slide gate valve (PSGV). Unique to this valve design is the coating applied to the guide rib, seats, and discs. ValvTechnologies' leading-edge team developed a proprietary compressive spray technique resulting in higher bond strengths. This proprietary process is called Robotically Integrated Technology (RiTech®) in which coating is 80% by weight chromium carbide and 20% nickel-chrome and allows for exceptional quality control and shortened lead times.

This coating is applied by a High Velocity Oxygen Fuel (HVOF) process that results in no intermetallic Sigma phase formation and provides a very strong bond to the base metal. RiTech 31 coating is harder than Alloy 6, especially at operating temperatures above 1,000°F as shown in Figure 5.

What lurks beneath the surface? What is underneath where eyes cannot see? Is it something valuable? Or is it something old? Is it some treasure or something frightening to behold? For steam stop valves with cobalt alloy hardfacing, the answers to these questions are, yes, a problem is hiding beneath the surface, one that can take your hard-earned treasure of time and money. Be forewarned, hardface disbonding is something frightening to behold. TB

***Joseph Miller is the power industry director for ValvTechnologies.***