The DSCV-SA valve: a modern solution to steam conditioning

Mark Wheat, Celeros Flow Technology, outlines how technical innovation and leading-edge valve design has improved the conditioning of superheated steam used in power generation and other essential industries.

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The pressures and temperatures involved in generating energy from steam continue to grow, making new demands of critical flow control equipment such as valves.

Many industrial activities rely on steam for their processes, including power generation plants, refineries, and paper mills. The means to generate energy using steam have been understood for centuries. The basic principles, using a boiler, steam turbine and generator, remain largely unchanged. However, the pressures and temperatures involved have increased considerably.

This article explains how Celeros FT brand Copes-Vulcan developed the critical steam conditioning valve technology that meets the rigours of modern steam energy generation.

A brief history of steam

Early coal-fired steam generators provided low-pressure saturated or slightly superheated steam for steam engines driving DC dynamos. The first steam turbine generator, built in 1884, had a thermal efficiency of just 1.6%. Six years later, General Electric delivered the world's first 5-MW steam turbine. The 1910s saw the introduction of turbines with steam extractions for feedwater heating and steam generators equipped with air preheaters—all of which boosted net efficiency to about 15%.

Main steam temperatures consistently increased through the 1940s (the decade that also saw the first attempts to clean flue gas using dust removal). The 1950s and 1960s were characterized by more technical achievements to improve efficiency—including construction of the first once-through steam generator with a supercritical main steam pressure.

Unit ratings of 1,300 MW were reached by the 1970s. In 1972, the world's first integrated coal gasification combined cycle power plant—a 183-MW power plant for the German generator STEAG—began operations. Vast improvements in component performance have continued from the mid-20th century to the present day.

Operational challenges

A steam power plant essentially uses a boiler to generate steam at high pressure and high temperature. A steam turbine converts the heat energy of steam into mechanical energy, and a generator then converts the mechanical energy into electric power.

Water boils at 100°C under normal atmospheric pressure [0.101 MPa]. As pressure increases, the boiling temperature of water also increases. When the pressure is increased to 22.12 MPa, and at a temperature of 374°C, water is directly converted into steam. This is called the critical point. Pressure above this critical point, with a temperature equal to or more than 593°C, is called ultra-supercritical pressure.

Handling superheated steam at these pressures and temperatures places enormous strain on flow control equipment. Inadequately specified valves could lead to inefficiencies through leakages and unplanned outages. What the 21st century required was a valve that could deliver operational reliability and withstand the extreme operating conditions within modern power plants – particularly during plant start-up, shutdown and turbine trips.

21st century solution

The DSCV-SA (Direct Steam Converting Valve – Steam Atomization), addresses the issues encountered by older, base load designed bypass valves when employed on modern high frequency, rapid ramp rate plants. Key to the DSCV-SA's performance are a number of unique technical innovations developed following extensive consultation with power generation customers.

Innovation #1: high-pressure balance

Unlike conventional turbine by-pass valves, the DSCV-SA is designed to use high-pressure balance rather than low-pressure balance. This eliminates risk of wear, damage or breakage relating to piston rings and balancing systems, which are a major problem with traditional valves.

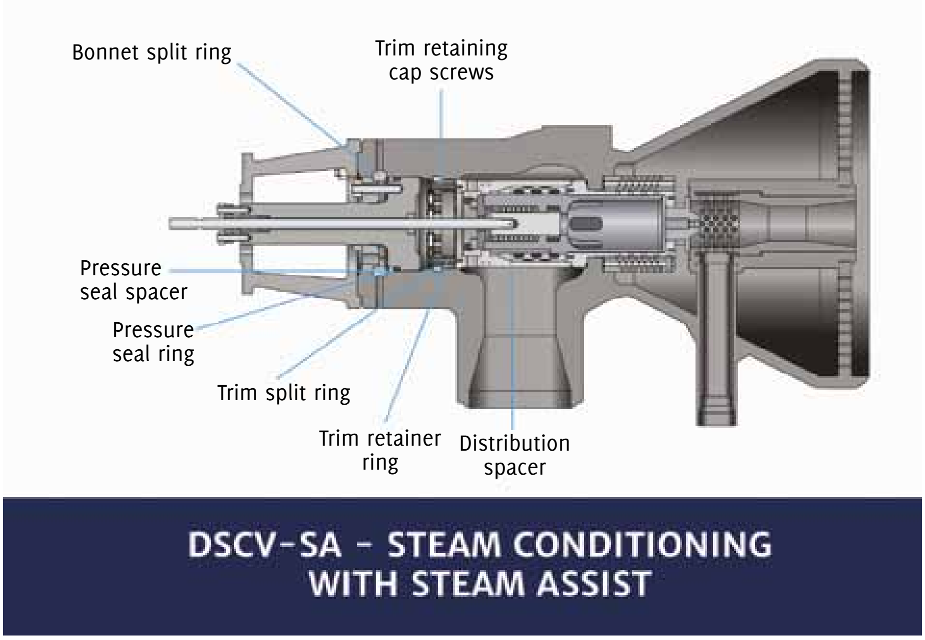
When an open command signal is received, the DSCV-SA actuator retracts, and the pilot plug is the first to open. This allows P1 steam to flood through the large pilot plug port to the underside of the main plug, which in turn balances it and reduces the actuation thrusts required.

In traditional low-pressure or P2 balancing designs, auxiliary balancing seals such as piston rings and close tolerance sealing surfaces are needed to prevent the high-pressure steam unbalancing the trim. If these seals or surfaces become worn or damaged, it can unbalance the trim and stem loads can fluctuate dramatically, causing the valve to oscillate violently or not open on command.

When the DSCV-SA pilot plug is open, high-pressure inlet steam floods the underside of the main plug and the steam atomizing unit (see Innovation #2 below) operates in preparation of the incoming cooling water from the water control valve. The pilot plug shoulder engages with the underside of the tandem cap of the main plug, which then starts to lift, and the main seat opens.

As the main plug opens, steam first enters the valve via a heavy-duty distribution spacer. The steam passes through the spacer by means of numerous holes evenly positioned around the circumference. This distribution spacer is specifically designed to negate any upstream pipework-induced flow disturbance being communicated to the main plug. This is important because long radius bends or isolation valves can be fitted directly to the valve inlet to minimize installation space. The main plug is fully guided by the cage and spacer to ensure complete plug stability through full travel.

After the inlet steam has passed through the distribution spacer, it then travels through the main seat area to the underside of the main plug via large feed ports. With the main plug lifted, the pressure reducing ports of the cage now open to allow the steam to be pressure reduced in a controlled manner. As the main plug opens further, more pressure reducing ports are exposed and the steam flow rate increases.



Key features of the DSCV-SA design, which facilitate high turndown in steam atomization applications.

The Copes Vulcan DSCV-SA turbine bypass valve has evolved to be at the forefront of today's thermodynamic engineering in steam conditioning.

Innovation #2: steam atomization

Steam atomization is a technology that has significant benefits over mechanically spraying the cooling water via nozzles. Traditional mechanical spray nozzles - even spring-loaded types - are limited in their turndown. This is because the water atomization and spray pattern degrade as the water flow rate and available pressure differential reduces. As the water demand reduces, the spray water control valve closes and the spray valve trim absorbs the water pressure differential, which leaves little pressure differential for the spray nozzles. This lack of pressure differential does not allow atomization of the spray water, which results in the water pouring into the steam rather than producing a fine atomizing mist. Mechanical spray nozzles rely on the surrounding steam velocity to provide adequate mixing. When the steam load reduces, so too does the steam velocity and the ability of the mechanical spray nozzles. This effect manifests itself with poor downstream steam temperature control and water 'drop-out', which can be very damaging as cold water can track along the bottom of the inside wall of the downstream pipe whilst un-cooled superheated steam travels along the top and sides. This produces high thermal shocks which can lead to steam header fracture.

With steam atomization however, cooling water is pre-heated; significantly accelerating the evaporation and desuperheating process. Equally important is the finely atomized incoming cooling water. Very fine atomization produces extremely small water droplet sizes with a vastly

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increased surface area to promote rapid heat transfer. The atomized, pre-heated water is introduced via a combining tube where it is atomized and then passed through a converging-diverging venturi throat section. The hot atomised water exits the atomising head and is rapidly evaporated, cooling the main steam flow. Because this method of water introduction does not rely on surrounding steam velocity or turbulence for effective mixing, it gives very high turndowns - generally in excess of 100:1.

Robust design

In terms of design, the DSCV-SA has a standard body-to-bonnet joint, up to ANSI 900#, which is bolted and incorporates a fully enclosed spiral wound gasket made from 300 stainless steel with graphite filler. For pressure ratings above ANSI 900#, a pressure seal bonnet closure is employed, which utilizes a graphite sealing ring. The DSCV-SA is available in an almost infinite range of sizes, materials and pressure ratings as each valve is tailored to suit particular customer requests and requirements.

The valve can be fully rated or split rated and is available in standard, special or intermediate classes. Standard classes are available up to and including ANSI 4500# and intermediate and special class designs can be accommodated where required. As the DSCV-SA is usually supplied as a split rated design, this provides the customer with a convenient point for pipe transition for size, rating and material. The DSCV-SA is of a two-part construction and therefore virtually any configuration can be met to satisfy client requirements.

Modern steam turbine bypass systems must be able to react and modulate very quickly under emergency conditions such as a turbine trip. Stroking speeds of less than one second may be required and as a result, the DSCV-SA can be supplied with either pneumatic or hydraulic actuation to meet this critical requirement.

Low maintenance

Importantly, the DSCV-SA is not a high maintenance valve. The complete trim is a 'Quick-Change' style with no welded-in components or large internal threaded parts. The whole trim assembly is held in compression by either a compression ring or the bonnet. Simply removing the compression ring or bonnet allows the whole trim to slide out the top of the valve. Therefore in-situ maintenance, if required, should be both expeditious and uncomplicated with no need for specialised tooling or training.

Conclusion

Superheated steam continues to play a pivotal role in electricity generation and other essential industries. Climate change and the need to use resources even more efficiently will no doubt bring new flow control challenges in the coming decades. Innovations such as the DSCV-SA will be essential in delivering the high performance and operational efficiencies that are the basis of a more sustainable future. ■

About the author

Mark Wheat is Copes-Vulcan Global Technical Sales Manager for Celeros Flow Technology. He is a qualified engineer with more than 35 years of experience and specializes in steam power distribution and thermodynamics. He joined Copes-Vulcan in 1995 as Export Sales Manager and has held positions of increasing seniority within the company, including Director GM UK Operations. Since 2001, Mark has applied his considerable expertise on steam turbine bypass applications and other critical valve applications around the boiler island.