Technical Paper

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High-temperature valves in modern high-performance power plants

In times of increasingly stringent requirements complying with environmental legislation and scarcity of raw materials the effective and environmentally responsible handling of the available resources becomes more and more important. This applies also to the area of power generation.

Because of the continuous technological development of power plants development researchers have succeeded in raising the efficiency from approx. 30% to 45 - 50%. This means cutting the CO2 emission roughly in half with the same amount of power produced. This remarkable increase in efficiency was essentially achieved by operating the power plant at higher pressures and temperatures.

Raising the steam parameters to temperatures up to 750°C and pressures up to 500bar at the same time requires the qualification and optimisation of suitable materials and power plant components to meet these demands. This applies also to the valves which must be able to withstand these extraordinary loads during the plant's lifespan of approx. 40-50 years.

Special requirements concerning valves

To ensure the reliable operation of the valves first off all the right materials must be selected. Normally steels with 9 to 12% of chromium are used for temperatures up to 630°C (example: material 1.4901 or ASTM A182 grade F92). Only nickel-based alloys such as 2.4663 (Alloy 617) are used for temperatures above 700°C. These alloys are very expensive, and their difficult machining requires extremely high production know-how.

To ensure top safety of the power plant components the material requirements must meet specific power plant specifications in addition to those of the EN and VdTÜV standards.

When a power plant is started up and shut down the piping components as well as the fittings are subjected to extremely high temperature differences. These temperature differences strain the materials and due to different thermal expansion of the components they may cause undesirable tensions. Another risk consists of the fact that the valve stem can expand less during the heating phase than the valve body and as a result the valve tip will slightly lift off the valve seat causing internal leaks.

Consequently, special attention must be given when selecting the materials for the valve components to ensure that the materials used have the same thermal expansion coefficients. To prevent the valve tip from lifting off during temperature changes the initiation of the closing force of the valve tip via a spring assembly, which compensates the thermal expansion differences, is recommended.

However, not only the metallic materials of a valve must withstand the extremely high pressures and temperatures but also the sealing elements, especially the packing, which seals the valve stem dynamically toward the atmosphere. Graphite packings are used here as a rule. However, graphite begins to oxidise in the presence of oxygen in the air from 550°C; moving the stem seal to an area where the temperatures are considerably lower and no more risk of oxidation is present at all is therefore advised. This can be achieved by extending the bonnet and using additional cooling ribs.

Last not least, the welding joints must be closely scrutinized. Especially high-temperature materials such as 1.4901 are very sensitive to the formation of heat cracks during welding. Even if the valve itself does not have any welds, it must be remembered that when welding the valve in the pipe assembly this weld must be subjected to subsequent heat treatment; this takes place over a period of at least half an hour (depending on the size of the seam) at approx. 750°C.

Particularly high requirements on the weld apply for so-called black-white connections which occur frequently at the process to instrument interface. To avoid having to make the welding joint on-site, this special connection is already made on the primary isolation valve, for example, by welding a short piece of pipe with the material 1.4952 to the valve body from 1.4901. The production of such welds requires comprehensive know-how of welding and also the subsequent heat treatment and must be evidenced by a welding procedure qualification record.

Research and development projects

To observe and test innovative high-strength boiler and piping materials under extreme conditions research and development projects were established already several years ago.
The insights gained shall be used in the development of components such as safety, control and needle type globe valves, seals or coating systems, which can be employed even at temperatures above 700°C in a reliable and economic manner.

Fig. 1: AS-Schneider dual shut-off valve installed in a test plant COMTES700 for a long-tern design test at 700 °C (insulation removed)

One of these projects is COMTES700 (acronym for "Component Test Facility for a 700°C Power Plant"). The project was started in July of 2004 and made possible through the close collaboration between European power plant operators and manufactures. After the successful manufacturing and installation of the components in the power plant Scholven, Gelsenkirchen/Germany, of the E.ON Kraftwerke GmbH, this test plant was operated from July 2005 to December 2011.

AS-Schneider A4 Series -
Development for the COMTES700 research project

Already in June 2004 AS-Schneider received the order by ALSTOM Power Boiler GmbH to develop an isolation valve which should be used in the COMTES700 test plant and is able to withstand temperatures up to 750°C at 400bar.

The high requirements on the valve design and the very difficult mechanical machinability of the material Alloy 617 presented a special challenge to our development team.

Material procurement also turned out to be complicated. For the research project there were special material specifications (Alloy 617mod) and as a result the material could no longer be procured through customary channels. Each component manufacturer had to register his material demand in advance at the performing steel forge. For the subsequent production of components not planned the individual component supplier had to help each other out with left-over material.

The performance specification for the AS-Schneider A4 Series was prepared based on the VGB directive R 107 L "Ordering and design of valves in thermal power plants".

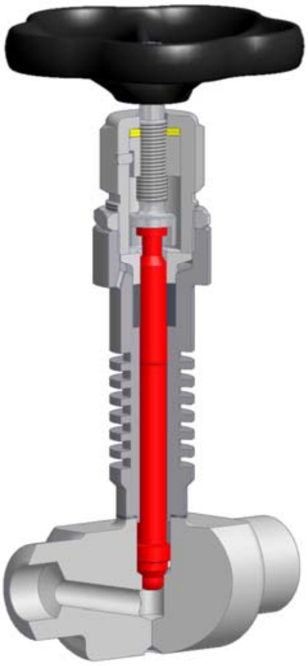

Fig. 2: AS-Schneider A4-Series

The essential points were:

- All materials used must be suitable for the high temperatures and exhibit the same thermal expansion coefficients to rule out material tensions and leaks on the valve seat during the temperature changes from room temperature to 750°C.
- The valve head units shall be solidly welded to the valve body to prevent leaks even from developing.
- The valve shall be equipped with a metal back seat which completely relieves the packing (stem seal toward the atmosphere) when the valve is fully opened.
- Packing and stem thread must have a sufficient distance to the valve body so that the temperature on these components is markedly lower and reliable operation is thereby guaranteed even at 750°C.
- The closing force of the valve tip must be introduced via a spring assembly which can compensate the thermal expansion differences to prevent the valve tip from lifting during temperature changes.
- A vent hole must be present above the packing through which the hot steam is directed away from the handwheel in the event of a leaking packing.

  (Note: Steam with a temperature of 750°C is not visible directly at the leakage point. It cools down only at some distance, condensing in the air and then becoming visible as steam.)

You can simply rely on the AS-Schneider development team!

When searching for the perfect solution, our engineers dared to chart unknown technical terrain. The specified requirements where harmonised with the latest technologies in close cooperation with ALSTOM and the resulting prototypes were successfully tested in the framework of a long-term design test at 700°C in the COMTES700 plant.

Meanwhile, the AS-Schneider A4 Series is available in different materials such as 1.4901 (P92) and Alloy 617 and has proven successful in many power plants of the new generation.

Would you like more information? Then just send us an e-mail to kontakt@as-schneider.com. We look forward to hearing from you.

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