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H.F. Lee combined-cycle plant, Wayne County, NC.

From Coal to Combined Cycle

BY STEVE BROWN

In the United States and around the world, industrial processers are striving to do more with less—to maximize efficiency, minimize costs and remain compliant with increasingly stringent regulations governing operations and output. The need for higher production at lower cost is especially pronounced within the power market. Producers must balance the growing demand for energy with the changing regulatory environment, while the traditional methods of power production, such as coal-fired power, face challenges that threaten their future viability.

To keep pace with market trends, power providers must remain ahead of legislation, anticipate the evolution of the industry and implement the necessary adaptations. One significant illustration of this reality is the increasing trend to construct new power plants that use alternative fossil fuels. This article explores the cause for the conversion and explains how this change and the demand for increased efficiency has influenced the selection of valve equipment used in power generation.

Executive Summary

SUBJECT: Because of increasing regulatory restrictions and other factors, power generation is evolving in the United States from coal-fueled platforms to alternative fuels and renewable types of plants. The tougher regulatory environment, as well as stiff competition in the industry, have created an increased need to balance cost savings with greater efficiency.

KEY CONCEPTS:

- The transition of new build power plants from coal to combined cycle
- Changing fuel sources and plant types
- What these changes could mean for valve selection
- Forged versus cast products

TAKE-AWAY: Both cast and forged valves are important for the power industry with forged valves becoming more preferred in the most demanding applications and cast valves still comprising the balance of power plant valve installations.

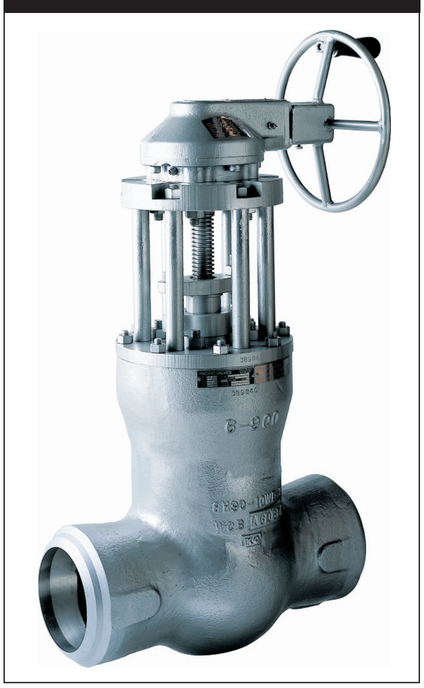
THE ORIGINS OF COAL

Coal use in the U.S. has a history that predates the nation itself. Coal was used as early as the 1300s by the Hopi Indians for cooking, heating and pottery production, then rediscovered as a good source of energy by explorers in 1673. During the first half of the 1800s, the Industrial Revolution was instrumental in expanding coal's use, and the various applications used then became the basis for the modern proliferation of coal as an energy source in the United States.[1]

Because of its applicability for a number of private, commercial and industrial processes, the consumption of coal is also driven by the fact that we simply have a good supply in this nation—we know where and how it can be readily mined. As a result, coal, which has nearly tripled in use since 1960, provides roughly half the nation's electricity today—far more than any other source of power. While proponents of coal maintain it is a low-cost energy source, both the mining and power generation processes can be costly and damaging to the environment.

Almost all coal plants operating today use pulverized coal technology, which involves grinding the coal, burning it to make steam and channeling the steam through a turbine to generate electricity. A relatively newer technology known as Integrated Gasification Combined Cycle converts coal into gas that powers a combustion turbine to generate electricity. The method then uses the excess heat from the process to generate additional electricity via a steam turbine.[2]

Typical cast valve for a power plant



Typical forged valve for a power plant

The challenge, even with this technology, is that, when it burns, pulverized coal emits enormous quantities of carbon dioxide (CO_2) and other pollutants such as sulfur dioxide, nitrogen oxide, mercury and microscopic particulate matter, making coal-fired power plants the largest single source of CO_2 emissions in the U.S.

As a consequence, anticipated CO_2 regulations and other policy and market changes have already made an impact on the long-term viability of coal-burning electricity. Power companies are starting to integrate the future price of carbon emissions into their cost estimates for new plants, which may greatly compromise how practical investing in new coal projects will be. Although coal continues to be a significant domestic energy source and economic driver, producers are seeking cleaner, more viable solutions with a less-expensive regulatory footprint.

THE RISE OF COMBINED-CYCLE

According to the U.S. Energy Information Administration, many coal-fired generators in the United States are at risk for retirement from the impact of lower natural gas prices, higher coal prices, slower economic growth and intensification of environmental regulations. The Annual Energy Outlook 2014 Report states that, "of the total installed 310 gigawatts (GW) of coal-fired generating capacity available at the end of 2012, 50 GW, or 16%, is projected to be retired by 2020."[3]

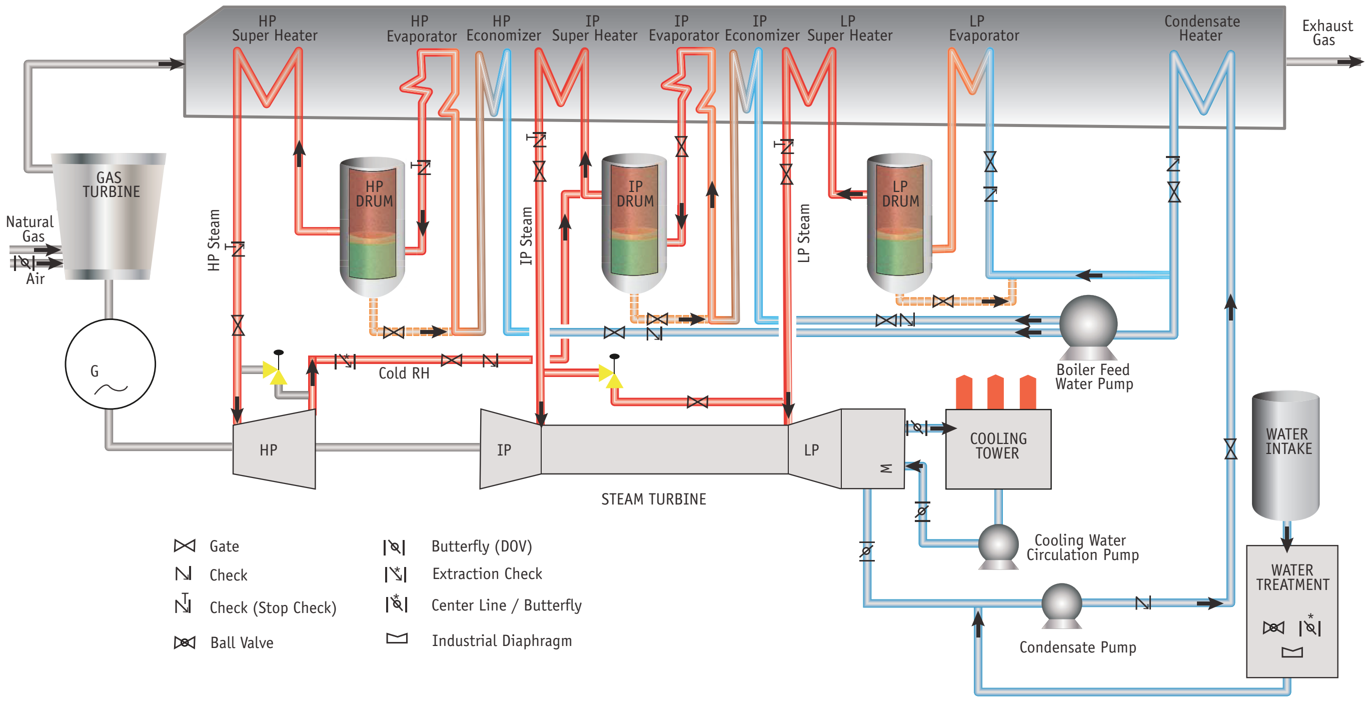
As coal-fired power plants gradually become less sustainable, combined-cycle power plants offer an alternative for domestic power generation that is both cleaner and more efficient. Advances in hydraulic fracturing technology and the resulting shale gas boom have made natural gas the fuel of choice for an increasing number of private investors and consumers. Natural gas is more versatile than coal or oil, and can be used in 90% of energy applications. Also, power plants fueled by natural gas run at higher efficiencies than coal-fired power plants, operating with an average gain of nearly 10% when compared to coal.[4]

With these higher efficiencies, however, higher demands are placed on process equipment that must withstand increasing temperatures and pressures throughout the power cycle. The primary process steps in combined-cycle power plants are:

- ***Air Inlet:*** Air is drawn though the large air inlet section to be cleaned, cooled and controlled in order to reduce noise.
- ***Gas Turbines:*** The air then enters the gas turbine, where it is compressed, mixed with natural gas and ignited, causing it to expand. The resulting pressure spins turbine blades attached to a shaft and a generator to create electricity.
- ***Heat Recovery Steam Generator (HRSG):*** The hot exhaust gas exits the turbine at about 1,100°F (593°C) and passes through the HRSG, where layers of tall tube bundles are filled with high-purity water. The hot exhaust gas coming from the turbines passes through these tube bundles, which act as heat exchangers to boil the water inside the tubes and convert it to steam. The gas then exits the power plant through the exhaust stack at a much cooler 180°F (82°C), after having used most of its heat during the steam process. The steam is sent to the steam turbine through overhead piping.
- ***Steam Turbine:*** Steam enters the turbine with temperatures as high as 1,000°F (538°C) and pressure as high as 2,200 psi. The pressure of the steam spins turbine blades attached to a rotor and a generator, producing additional electricity

COMBINED CYCLE POWER PLANT

HEAT RECOVERY STEAM GENERATOR



(about 100 megawatts per HRSG unit). This is the origin of the term “combined cycle” power plant.

- ***Cooling Tower and Boiler Feed Water Pumps:*** After the steam is consumed in the turbine process, the residual steam leaves the turbine at low pressure and low heat at about 100°F (38°C). The exhaust steam passes into a condenser, where it is cooled back into water and pumped back to the system using feed water pumps.

VALVE SELECTION CONSIDERATIONS

The transition of the power industry from coal-fired power plants to combined-cycle power plants has compelled, in part, a conversion from cast-steel valves to forged equipment. Combined-cycle power plants seek higher efficiencies to maximize returns; as a result, operating temperatures and pressures have increased, necessitating superior valve solutions that can withstand the conditions without suffering the impact of the harsher environment.

Market conditions also demand faster start-up times, increasing the severity of gas turbine starts. This in turn increases the thermal transients, with higher gas turbine acceleration and higher gas flows at increased temperatures, feeding the HRSG. Every time the plant is turned on, then turned off (cycling), the gas turbine, HRSG unit, steam lines, steam turbines and auxiliary components undergo drastic thermal and pressure stress. This can quickly damage the equipment and dramatically accelerate the wear and tear on valves. As a result, non-cast valve solutions are becoming increasingly sought by both supercritical coal and combined-cycle power producers.

Because process equipment in these conditions is subject to a lifetime of thermal cycling (hot, warm and cold start), load changes and trip scenarios, valves can become susceptible to material creep and fatigue damage, which may dramatically limit service life. By being inherently free of the internal discontinuities typically found in cast products, forged valves are less prone to defects like blow holes and shrinkage. As a result, they are becoming increasingly popular in some power generation applications.

Despite the growing popularity of large forged valves, there are still hundreds of applications throughout a power plant where castings are also well suited, including high-pressure steam. Cast technology is proven and has been used in the majority of power projects for over a century. Without the additional expense of forging dies and machining, cast valves are generally more cost-effective than their forged counterparts. They are successfully used in continuously-run modern plants, where many of the problems originally attributed to cast valves have been eliminated. Furthermore, cast valves are often easier and more practical in terms of design modification, fabrication and upgrade.

While both types of valves have distinct advantages in the proper applications, neither is completely impervious to the potential for defects. Forged valves are susceptible to laps, seams, poor grain structure and bursts—internal tears that can result in valve cracking. Castings are vulnerable to surface discontinuity, sand inclusions, porosity, hot tears and shrinkage cavities.[5] Despite these possibilities, however, good forging and casting processes can eliminate the risk of defects, which underscores the importance of selecting a reliable valve supplier.

Castings remain appropriate for a wide range of applications, especially in cases where a unique metal composition is required, the part is relatively large or complex, or weight and cost are prohibitive factors. However, the inherent ability of forgings to provide longer life in today's demanding applications is attractive for the volatile environment of a frequently cycling, combined-cycle power plant. To truly understand the best valve solution for a particular application, valve users and manufacturers must work together to evaluate product design, quality and cost, and select the most appropriate product for their needs.

CONCLUSION

With coal use facing gradual reduction in the U.S. and natural gas fueling the next generation of power production, valves and other process equipment must be designed to address specific conditions of the changing environment.

Power professionals worldwide seek to assure their operations are increasingly efficient. But productivity gains come at a cost because increases in plant cycling, temperatures and pressures place additional burdens and stress on the equipment. Consequently, valve users seek solutions that are reliable, safe and, above all, efficient to meet the energy needs of an increasingly-demanding nation. Forged and cast valve solutions alike meet this need in the harsh environment, while offering users the quality and dependability commanded by the ever-dynamic industry. VM

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