

STEAM GENERATORS

THE BENSON BOILER TURNS 75

The success story of a steam generator

by JOACHIM FRANKE

SIEMENS

Power for generations

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Mark Benson's invention of a boiler that could be used at supercritical steam pressures and temperatures broke new ground. Siemens further refined his invention for commercial use in the 1920s, and has continued its development to this day.

by Dr. JOACHIM FRANKE, specialist for Benson boiler technology and responsible for licensing and further development of this steam generator type, Siemens Power Generation

When Mark Benson applied for a patent in 1922 for a "process for the generation of working steam ready for use at any desired pressure," he really had no idea that his name would one day be associated with the most popular type of once-through steam generator manufactured worldwide.

Safety was the Main Concern Behind Benson's Concept

Earlier steam generators were designed for relatively low pressures of up to about 100 bar, corresponding to the state of the art in steam turbine development at the time. One of their distinguishing technical characteristics was the riveted

drum. These drums were used to separate water and steam, and were often the source of boiler explosions, usually with catastrophic consequences.

However, the drum can be completely eliminated if the evaporation process is avoided altogether. This happens when water is heated at a pressure above the critical pressure and then expanded to dry steam at subcritical pressure. A throttle valve located downstream of the evaporator can be used for this purpose.

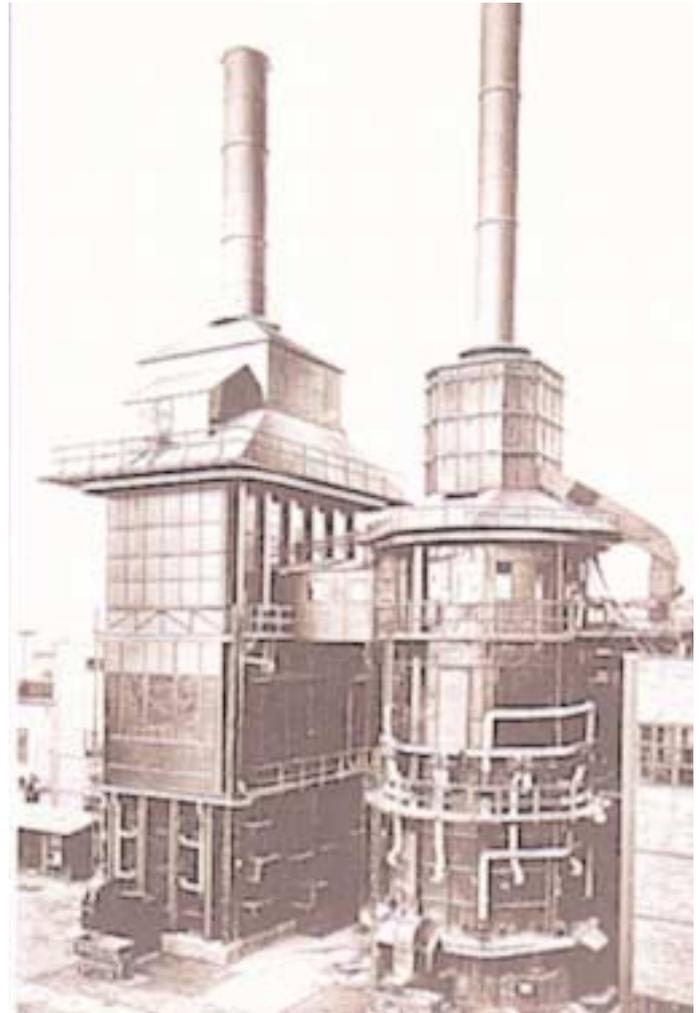
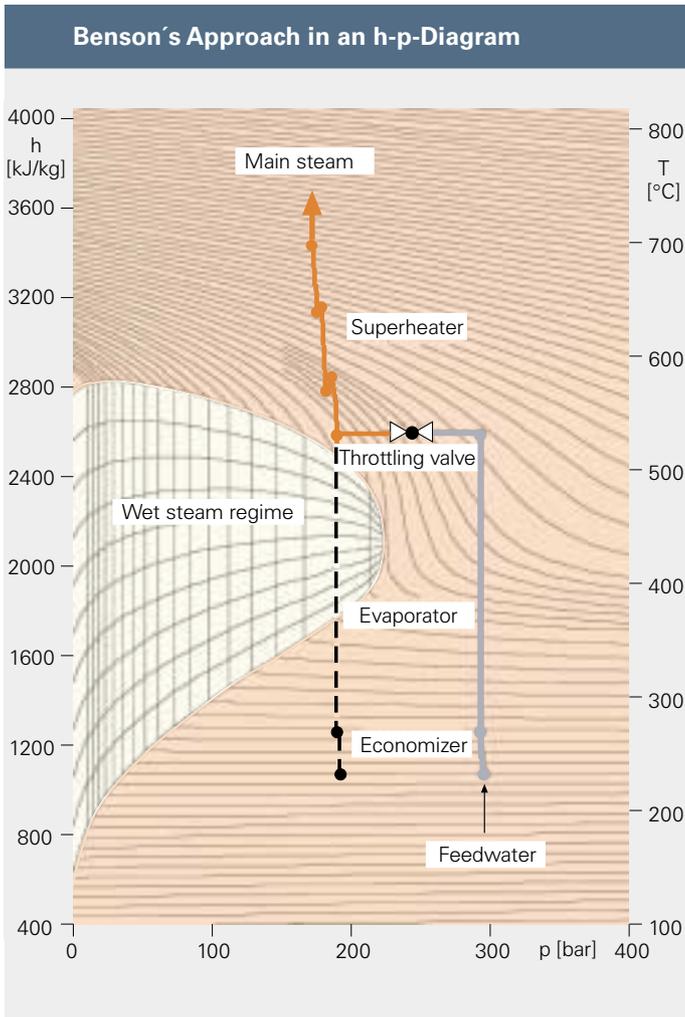
State-of-the-art Benson technology is used in the two 936-MW units of the Lippendorf power plant in Germany.

Milestones in Benson Technology

The advantages of the Benson boiler can be seen in the numerous milestones achieved by Siemens in its continued development of Benson technology. The market success of the Benson boiler is reflected in the approximately 1,000 boilers built to date with a combined steam output of more than 700,000 t/h, making it the world's most popular type of once-through boiler.

1924	Siemens acquires the rights to Mark Benson's patent
1926/27	The first Benson boiler is built, producing 30 t/h
1933	Siemens discontinues its own production, awarding licenses instead, and introduces the variable-pressure operating mode
1949	World's first once-through boiler designed to operate at high steam pressure and temperature (175 bar/610°C)
1954	First Benson boiler built for supercritical steam pressure (300 bar/605°C)
1963	World's first once-through boiler with spiral-wound tubes in membrane wall design
1982	World's first once-through boiler built for circulating fluidized-bed combustion
1987	First coal-fired steam generator with spiral evaporator tube configuration built for a unit output of over 900 MW (Heyden, Germany)
1994	Large-scale testing of an advanced Benson boiler with vertical tubing and natural-circulation flow characteristic
1999	First once-through heat-recovery steam generator with natural-circulation flow characteristic (Cottam, England)
2001	Construction begins on first coal-fired once-through boiler with natural-circulation flow characteristic (Yaomeng, China)





The evaporation process is eliminated when the water is heated at a pressure above the critical pressure and then expanded to dry steam at subcritical pressure. This was the basic concept proposed by Mark Benson that obviated the drum, at that time an explosion risk.

This concept led to the development of the first once-through boiler. In 1924, Siemens acquired the rights to the patent and, expanding on the concept proposed by Mark Benson, developed a once-through boiler for commercial use. The world's first industrial once-through steam generator was built in 1926/27 at the Siemens-Schuckert cable factory in Berlin.

The Name "Benson Boiler" is Trademarked

As development of Benson technology continued, Siemens soon moved away from the original concept introduced by Mark Benson and began taking out patents on significant technical advances. In 1929, a test boiler that had been built in 1927 began operating for the first time in subcritical mode with a fully open throttle valve. The second Benson boiler began operation in 1930 without a pressurizing valve at pressures between 40 and 180 bar, depending on load, at the Berlin cable factory. This application represented the birth of the modern variable-pressure Benson boiler. After that development, the original patent was no longer used. The Benson boiler name, however, was re-

With the once-through steam generator produced at the Siemens-Schuckert cable factory in 1926/27, Siemens applied the patent rights it had acquired from Mark Benson, and for the first time developed a Benson boiler for industrial use.

tained and had started to become synonymous with efficient steam generation.

Siemens manufactured several boilers—the last of which was one of the largest of its time with a steam output of 125 t/h and with reheating. In 1933, Siemens decided that it would no longer manufacture steam generators in its facilities, but would instead award licenses based on its

own patents and expertise. A predecessor of the current Siemens Westinghouse Power Corp., known at the time as the Westinghouse Electric & Manufacturing Company, became the first Benson boiler licensee. Thereafter, many other boiler manufacturers followed in rapid succession, most of them from Germany or neighboring countries.

As a licensor, Siemens has enjoyed great success in continuing the development of Benson boiler technology, and many of its achievements have become milestones in international boiler manufacturing. One such milestone, for example, was the gas-tight welding of the membrane wall, first used for the vertical tubing (Philo, USA, 1954) and later for the spiral evaporator tube configuration (industrial boiler near Freiburg, Germany, 1963).

Benson Technology Makes a Name for Itself

By 1945, 109 Benson boilers and a large number of marine boilers with steam outputs of up to 160 t/h had been produced for the German navy and merchant marine. A period of stagnation followed, as the future of the licensing agreements was uncertain due to the postwar political situation. Most of the patents had expired, and the capital needed to build new power plants was not available.

The rapid economic growth that began in the 1950s led to renewed and increasing interest in Benson boiler technology in Germany. This interest was also driven by the boiler's suitability for high pressures and for flexible operating modes at a constant steam temperature over the entire load range, which favored the transition to greater unit outputs and to unit operation of boiler and turbine.

Starting in 1950, boiler manufacturers once again began applying for Benson licenses. This trend was stimulated by Siemens' experience in building power plants within and outside Germany, as well as by new patents that were granted as the result of renewed development activities.

The Goals of Research: Design Safety and Innovation

Reliable use of Benson technology in different boiler designs made it necessary to conduct basic theoretical and experimental studies of the flow behavior of once-through systems. In particular, efforts to ensure that the design of the evaporator would enable sufficient cooling of the combustion chamber walls led to the decision to build a high-pressure test rig in order to perform experiments on heat transfer and pressure drop.

This system has been operating as a Benson testing facility in Erlangen, Germany since 1975, and has continually undergone modernization to reflect the latest advances in technology. Today it is still the only facility in the world where the entire range of parameters for sub- and supercritical steam generator operation is accessible for measurement. The results of this research are the basis both for verifying design programs and for resolving issues related to power plant operation.

Two current innovations have an excellent chance of winning acceptance in the competitive market for once-through steam generators:

- A new type of heat-recovery steam generator based on the Benson boiler, which has operated successfully at the Cottam combined-cycle power plant in the central part of England for over two years,
- The vertical tubing in the combustion chamber walls of coal-fired steam generators which combines the operating advantages of the Benson system with the design advantages of the drum-type boiler. Construction of a first reference plant, the Yaomeng power plant in China, commenced in 2001. ■