1800	1900	1939	1946	2011
10 sq. ft. of boiler heating surface originates based on “physical” size of boiler.	“Double Rated” 5 sq. ft. of heating surface boilers are built.	The Navy begins building 2–3 sq. ft. of heating surface boilers. Trend of smaller boilers begins, but boilers have a shortened lifespan.	ABMA recommends 5 sq. ft. of heating surface for firetube boilers as the standard to prevent shortened boiler life.	Cleaver-Brooks designs firetube boiler utilizing advanced heat transfer tubes and optimized furnace with less than 5 sq. ft. of heating surface. Superior performance proves firetube boilers can be properly designed with lower heating surface requirements.

The technology behind the CBEX:

EXPLORING THE MYTH OF BOILER HEATING SQUARE FOOTAGE

In 1800, the number of boiler horsepower denoted the actual “physical” size of the boiler. One rated horsepower was defined as 10 sq. ft. of boiler heating surface. This was based on a “standard” coal-fired steam piston engine that required 30 lb/hr of water evaporated from 100ºF to steam at 70 psi saturated to generate one net horsepower of shaft power. This equated to a performance of less than 8% efficiency (one horsepower or 2,546 BTU/hr output when divided by one boiler horsepower or 33,475 BTU/hr input equals 7.6%). This inefficient 10 sq. ft. rule stayed in effect until a century later, when oil combustion boilers began to be built as “double rated,” or 5 sq. ft. per boiler horsepower. During World War II, the U.S. Navy had requirements for firetube boilers smaller than the “double rated” boilers being built utilizing the 5 sq. ft. standard, and the trend towards smaller boilers and less heating surface began.

The Navy commissioned boilers designed utilizing 2–3 sq. ft. of heating surface per boiler horsepower. These boilers had a limited life due to the overheating of the rear tube sheets—for the Navy this was fine, as the space constraints were more important than the life cycle of the boiler. However, conventional users would not accept such a short life. After the war ended, several boiler manufacturers, including Cleaver-Brooks, worked with the American Boiler Manufacturers Association (ABMA) to study the failures of boilers and recommend a standard for heating surface area per boiler horsepower. With only experience from the field to rely on, they recommended 5 sq. ft. of heating surface per boiler horsepower. This is where the 5 sq. ft. engineering rule originated.

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BOILER HEATING SQUARE FOOTAGE

Cleaver Brooks®

In 2011, Cleaver-Brooks R&D engineers set out to design a revolutionary firetube boiler from the ground up, not letting any "rules of thumb" go unchallenged. Utilizing the latest in Computational Fluid Dynamics (CFD) modeling and finite element analysis, they studied two key areas of boiler heat transfer: the boiler tube design and the furnace geometry.

They focused on addressing the issue of traditional plain tubes utilizing a fraction of their heat transfer surface because of boundary layers caused by the laminar, or straight, flow of the gases through the tube. The boundary layers create a barrier for heat transfer, requiring more tube length, or square footage of heating surface, to accomplish the required heat transfer. By designing a tube with a proprietary rib system inside, engineers were able to develop a tube that utilizes 100% of its heating surface and transfers 85% more heat through the tube than a traditional bare firetube. Thus, fewer tubes, or less square footage of heating surface, are required to accomplish the required amount of heat transfer.

With the tubes now transferring more heat with less heating surface, space was afforded to the engineers to evaluate the size and geometry of the furnace, where 60%–70% of the boiler's heat transfer takes place. With advanced CFD modeling and finite element analysis, engineers were able to optimize the geometry of the furnace to maximize the heat transfer while achieving the ideal balance of high heat transfer with the lowest pressure drop.

Balancing the heat transfer with the pressure drop was important because of the lessons that had been learned in the field with boilers with less heating surface per square foot overheating, specifically the rear tube sheet attachment. The optimized furnace has a heat release rate of 125,000 BTU/hr/cubic foot compared to a boiler industry average of 150,000. The low heat release rate keeps flue gas temperature lower and reduces thermal expansion. A lower flue gas turnaround temperature at the end of the furnace reduces temperature gradient of the tubesheet. This, combined with the reduced thermal expansion of the furnace, increases the tubesheet and tube attachment's life, leading to longer pressure vessel life. The engineers had created a boiler that has a longer pressure vessel life than boilers that maintain at least 5 sq. ft. of heating surface per horsepower, with a boiler design that defies the century-old "rule of thumb." In addition to the extended life, the boiler has a smaller footprint and lower shipping cost.

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