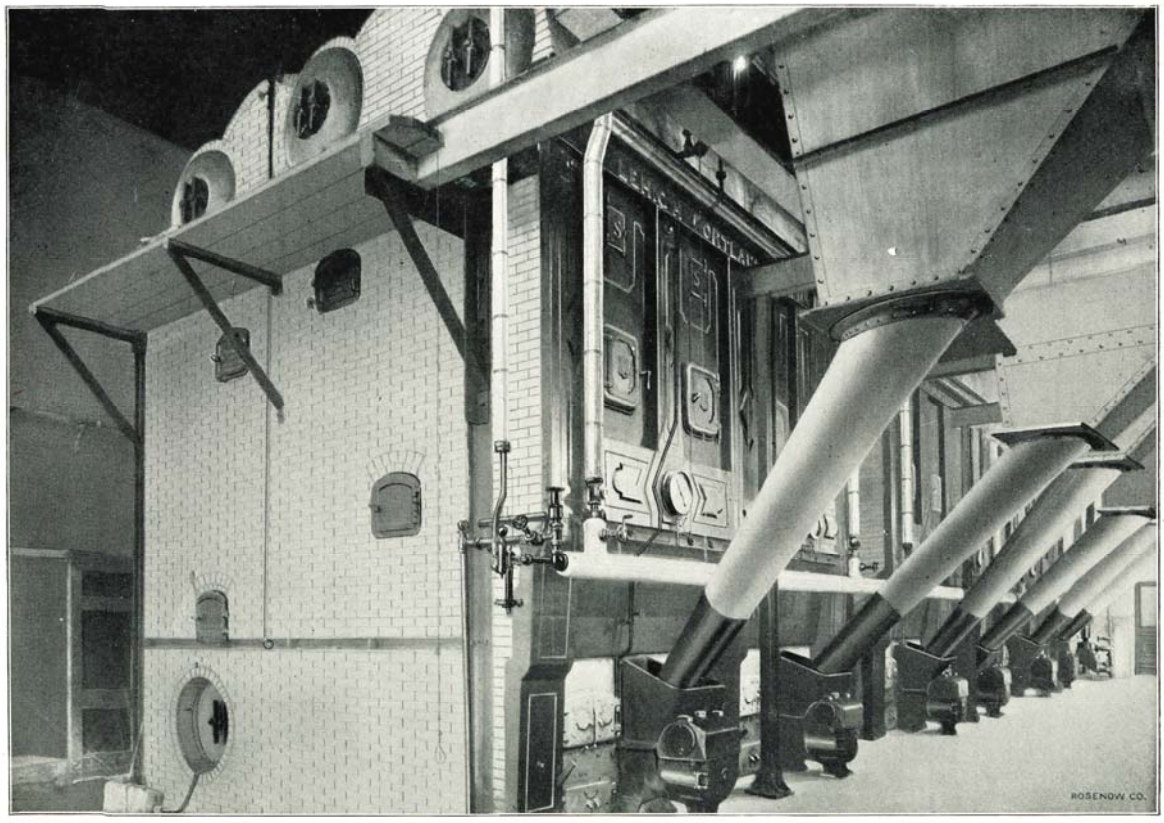
THE STIRLING BOILER



This article titled, The Stirling Boiler is Not for Resale. The article is intended for training of our profession. The article was developed with permission, by Larry Tarvin the owner of the material and The American Society of Power Engineers, Inc (ASOPE®).

Today when we read about a Stirling boiler it is a paragraph or maybe two. In yester-year it was a giant work horse in its field. Alan Stirling (1844-1927) designed his first boiler in 1883, and in 1888 established the Stirling Boiler Company in New York City. He patented the Stirling four-drum boiler in 1892 and then the bent-tube steam boiler in 1893. The original Stirling boiler was placed on the market in 1888 by the International Boiler Company, Limited, of New York. It consisted of two upper drums and one lower or mud drum, all connected together by means of tubes which were bent slightly so as to allow them to enter the drums normal to the periphery. The boilers were crudely constructed and but little attention was paid to minor details of design and called the Stirling Three Drum Boiler.

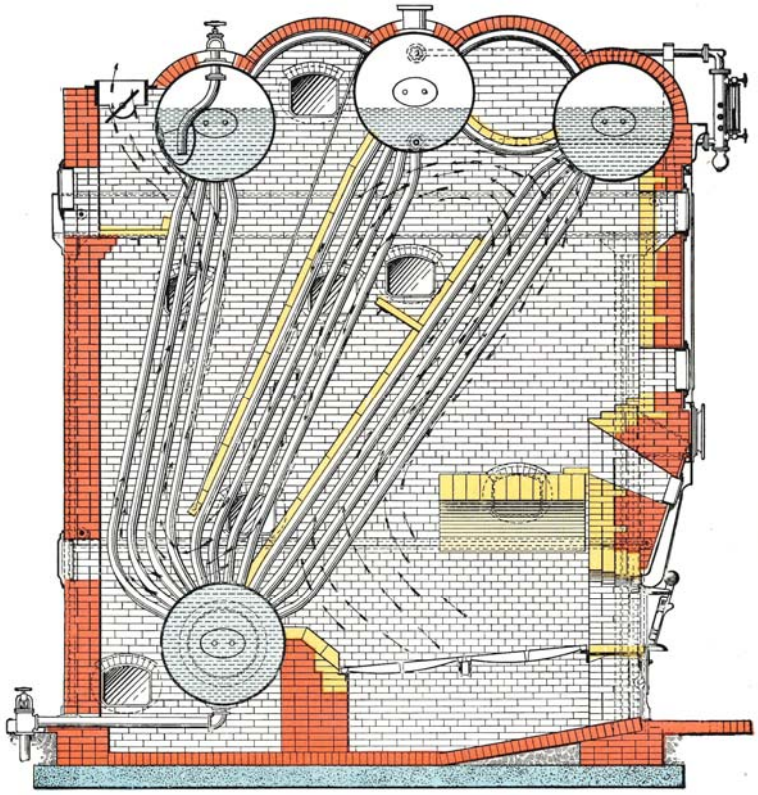


FIG. 1. SECTIONAL SIDE ELEVATION
THE RED, YELLOW AND BLUE SECTIONS RESPECTIVELY INDICATE
RED BRICK, FIRE BRICK. AND CONCRETE

In 1890, The Stirling Company was formed and its energies were concentrated upon improving the construction and details of the boiler. A third upper drum and an additional bank of tubes connecting with the mud drum were added, the plan of the setting modified, and one improvement followed another until a design was adopted essentially that of the boiler called a Four Drum Stirling Boiler.

In 1906 The Babcock & Wilcox Company purchased the plant and interests of The Stirling Company.

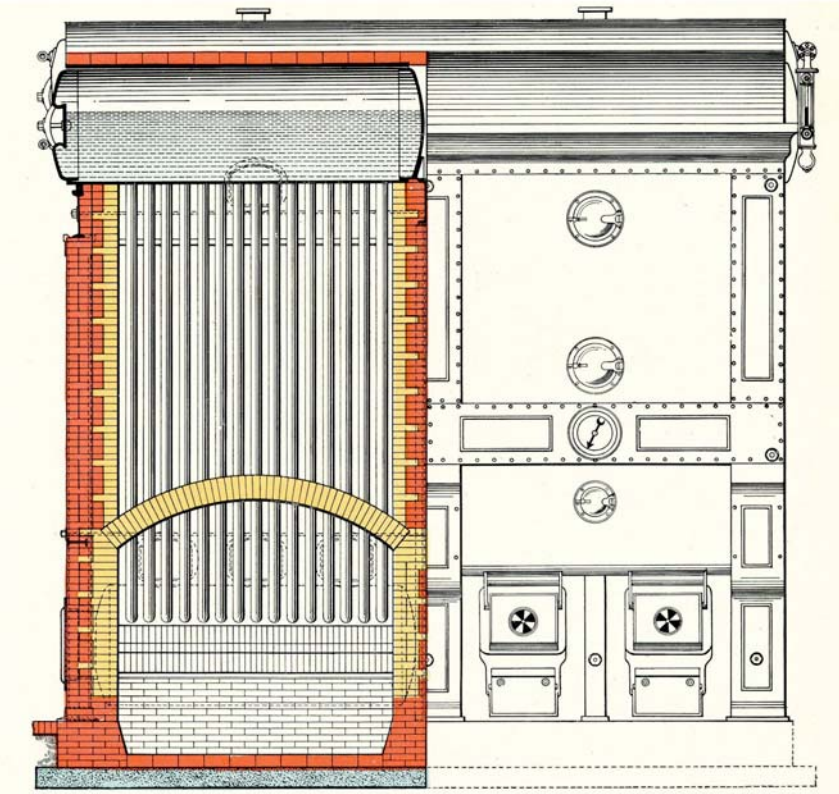


FIG. 2. SECTIONAL FRONT ELEVATION
THE RED, YELLOW, AND BLUE SECTIONS RESPECTIVELY INDICATE
RED BRICK, FIRE BRICK, AND CONCRETE

Description

As now constructed the Stirling boiler consists, as illustrated in Figs. 1 and 2, of three transverse steam and water drums set parallel and connected to one mud drum by water tubes so curved that their ends enter the tube sheets at right angles to the surface. The disposition of the steam and water drums provides ample space for a furnace and combustion chamber under the front portion of the heating surface. The front and middle steam drums are connected by curved equalizing tubes above the water line and curved circulating tubes below the water line, while the rear and middle drums are connected by curved equalizing tubes above the water line only.

The steam generated in the three banks of tubes passes into the middle drum, which is set higher than the other two to give additional steam space, thence it passes through the main steam outlet, which may be located anywhere along the top of the drum to suit piping conditions.

The safety valves are located on the top of the middle steam drum. The feed pipe connection passes through the top of the rear drum into a trough by which the water is distributed along the whole length of the drum, as shown in Fig. 1. The blow-off connection is attached to the bottom of the mud drum at the center and passes out through

a sleeve in the rear wall, just outside of which the blow-off valve is located. The water column, located at one side of the front of the boiler, is connected to one head of the center steam and water drum.

Drum Construction

Each steam and mud drum is made up of a single tube sheet riveted by properly proportioned lap or butt and strap longitudinal seams to a drum sheet. In each end of the drum is riveted a forged steel drum head, one end being fitted with a manhole. All rivet holes are drilled.

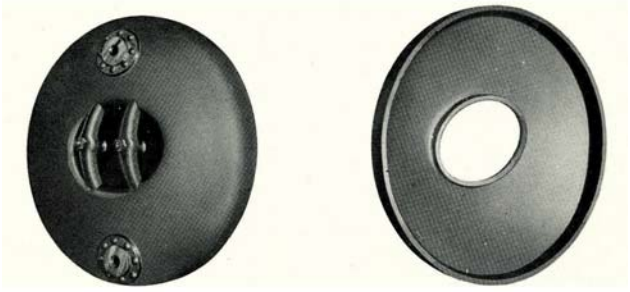


FIG 3. FORGED STEEL DRUM HEADS AND PADS FOR WATER COLUMN CONNECTIONS

In the construction of the drums of the Stirling boilers there are no circular drum seams exposed to the action of the hot gases. Before they are rolled into a semi-circular shape, the tube-sheets are punched with properly located holes for the tubes. After the tube sheets, the drum sheets and drum heads have been assembled and all joints riveted, the holes for the tubes arc reamed to proper size and neatly finished, ready for insertion and expansion of the tube ends.

DRUM LUG **MANHOLE AND ARCH BARS** **STEAM NOZZLE PAD**

FIG 4. FORGED STEEL DETAILS OF BOILER DRUM

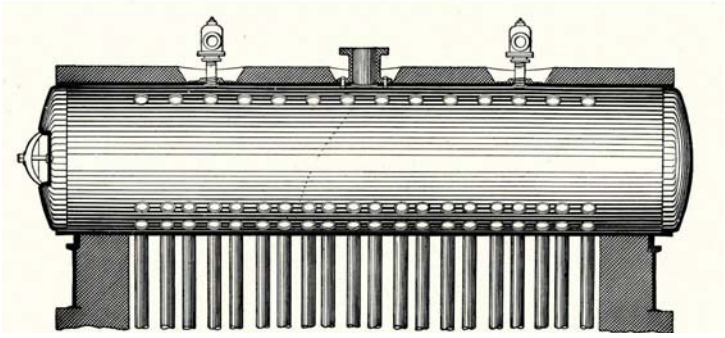


FIG. 5. SECTION THROUGH STEAM DRUM

Freedom to Expand and Contract

The mud drum is suspended from all of the steam and water drums by the tubes, the curvature of which, to insure their entering the tube sheets at right angles, gives ample and efficient provision for expansion and contraction.

This design ensures thorough equalization and proper distribution of all strains incident to the service of steam generation. The pressure parts of the boiler are supported on saddles under each steam and water drum by a rectangular structure of rolled steel sections.

Circulation

Stirling boilers may be made in very large sizes. It is usual for a standard design to be used, but in varying widths, according to need rapid circulation in a boiler is essential and it can readily be seen that the design of the Stirling boiler is favorable for securing good results in this direction, while at the same time there is an abundant supply of water to the tubes, no matter how hard the boiler may be forced. The feedwater enters the upper rear drum and passes downward through the rear bank of tubes to the lower drum, thence upward through the front bank to the forward steam and water drum. The steam formed during the passage upward through the front bank of tubes becomes separated from the water in the front drum, and passes through the upper row of cross tubes into the middle drum, from which point it enters the steam main. The water from the front drum passes through the lower cross tubes into the middle drum, and thence downward through the middle bank of tubes to the lower drum, from which it is again drawn up the front bank to retrace its former course. The steam generated in the rear bank of tubes passes through the cross tubes to the center drum. In its passage down the rear bank of tubes the feed water is heated so that much of the scale-forming matter is precipitated and gathers in the rear bank of tubes and in the mud drum, where it is protected from high temperatures and can be washed and blown out as frequently as the case demands.

Stirling boilers are one of the larger arrangements for a water-tube boiler: acceptable for stationary use, but impractical for mobile use, except for large ships with modest power requirements. They consist of a large brick-built chamber with a sinuous gas path through it, passing over near-vertical water-tubes that zig-zag between multiple steam drums and water drums.

They are amongst the older, "large-tube" designs of water-tube boilers, having water-tubes that are around 3¼ inches (83 mm) in diameter. The tubes are arranged in near-vertical banks between a number of cylindrical, horizontal steam and water drums. The number of drums varies, and the Stirling designs are categorized into 3, 4 and 5-drum called the W design boilers. The number of tube banks is one less than this, i.e. 2, 3 or 4 banks.

Manholes

There is a manhole in one end of each of the four drums and by the removal of the manhole plates the drums may be entered. This arrangement makes the boiler very easy to enter for examination, cleaning or repairs, as it is only necessary to remove the four manhole plates to get at all of the interior parts.

Accessories

The boiler accessories consist of the feed water connection and valves which are attached to the upper rear drum, the blow-off connection and valve which are attached to the bottom of the mud drum, and the steam connections, safety valves, water columns and steam gauges which are attached to the central upper drum. All of these are made in a most substantial way and are in keeping with the high class workmanship of the other parts of the boiler.

Boiler Front

The boiler front is of cast iron and pressed steel designed for the convenient location of the fire doors and cleaning doors. It presents a substantial and work-man like as well as an ornamental appearance suitable for such a structure.

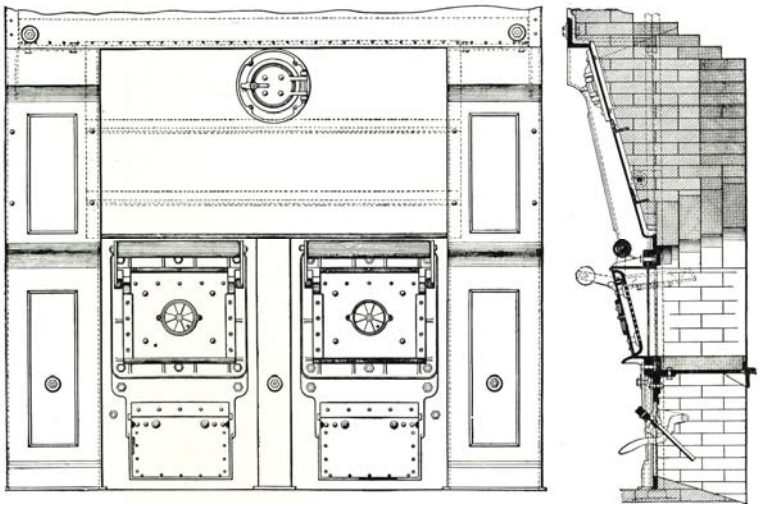
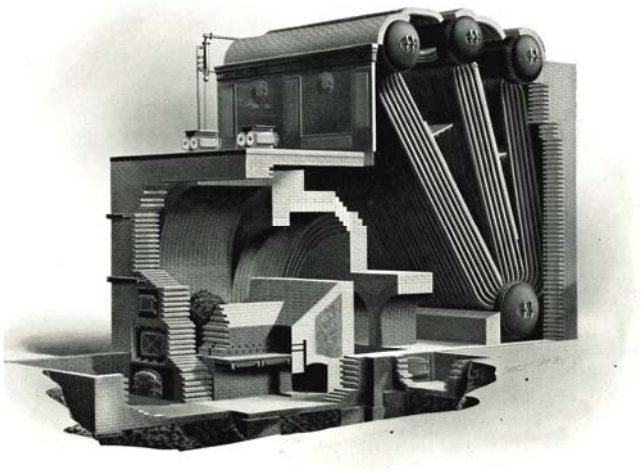


FIG. 6. BOILER FRONT SHOWING STEEL FIRING AND ASH-PIT DOORS

Furnace

A distinguishing feature of the Stirling boiler is the combustion chamber with an arched roof from which the products of combustion pass into the lower portion of the front bank of tubes. The space available under the arch is adaptable to nearly all fuel conditions, whether with hand or stoker firing, without any extension of the front beyond the standard setting walls.



The reverberatory action, characteristic of the arched roof construction, lends itself to high furnace efficiency at varying rates of fuel combustion, and a considerable reduction of smoke where bituminous or other volatile fuels are burned.

Baffling

The baffle walls guide the gases up the front bank of tubes, down the middle bank, and up the rear bank, thus bringing them in intimate contact with the heating surfaces.

The baffle bricks are plain tiles resting against the rear tubes of the first and second banks, and extending in the first case from the mud drum nearly to the top of the first bank, and in the second case from the central upper drum nearly to the bottom of the second bank of tubes. A covering of fire bricks resting on the water tubes connecting the front and center drums prevents the gases from passing above these tubes. A shelf placed near the top of the front baffle deflects the gases into the second bank.

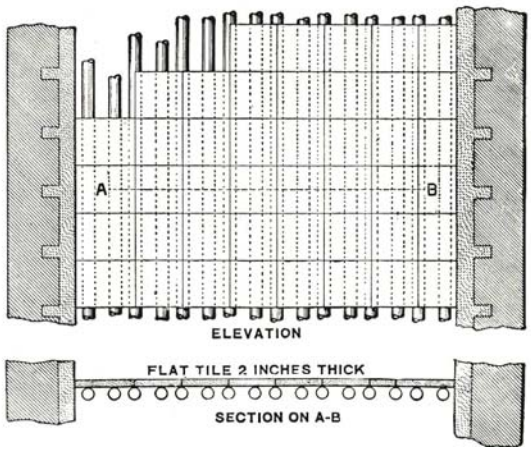


FIG. 7. ELEVATION AND SECTION OF FIRE-TILE BAFFLES

Brick Work

The brick work in outline forms a simple rectangular enclosure for the pressure parts. In the interior it is adapted to a suitable furnace outline and a proper distribution of the products of combustion. It is all plain work which can be done by any good brick mason familiar with furnace work. No special shapes not to be found on the open market are needed in its construction. All necessary repairs to the brick work can be done without disturbing the boiler connections.

Access Doors

Doors for cleaning, etc., are provided in the front, side, and rear walls of the setting sufficient in number to give easy access to all of the interior chambers and heating surface of the boiler. These doors are made tight by means of asbestos packing so as to avoid air leakage.

FIG. 8. CLEANING DOORS WITH ASBESTOS PACKING WASHERS

Facility for Making Repairs

Replacing a defective tube in a Stirling boiler is an exceedingly simple matter. The tubes are spaced as represented in Fig. 9, and each alternate space is one-half inch wider than the tube diameter, so that to remove an inner tube it is only necessary to cut the tube as near to the tube sheet as possible, and pass it out between the rows of tubes in front of it, as indicated by the arrows in Fig. 9. After a tube is removed from the bank, it may be taken from the setting through either the side or front doors provided for the purpose. Any tube in the Stirling boiler may be replaced without disturbing any other tube, distorting the tube sheet, or damaging the fire tile baffles.

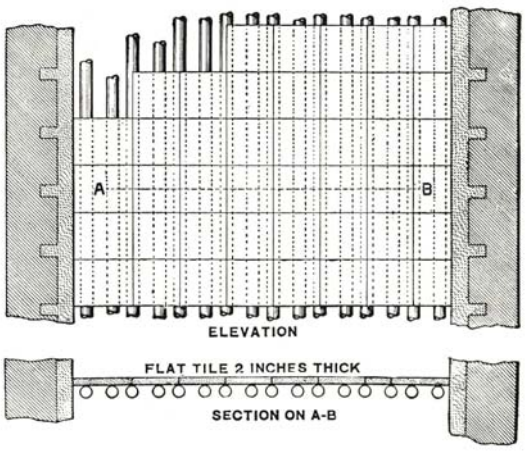


FIG. 9. TUBE SPACING

All Parts Accessible for Cleaning

The entire interior of the boiler is accessible for cleaning by removing a manhole plate from each of the drums.

The scale may be removed by a “turbine cleaner” of any of the many designs on the market. The hose, to which the cleaner is attached, is passed into the drum and the operator moves the turbine through the tubes by means of the hose. With the arrangement described, a curved tube can be readily cleaned. So much progress has been made in the development of tube cleaners that the removal of scale is merely a question of selecting a tool or device best adapted for the work to be done.

Cleaning doors are provided in the setting so that the exterior of the heating surfaces may be kept clean with a steam lance which is used for blowing off the accumulation of soot, ashes, etc. The tubes are in parallel rows and so arranged that it is possible to pass the hand, and indeed the whole arm, between two rows, and the steam lance can be readily made to bear on any point of their surface.

Flexibility Regarding Space Conditions

Another distinguishing feature of the Stirling boiler is its adaptability to variations of space conditions and of ratio of heating to grate surface, by variation of length of tubes and depth of grate. A 200 h.p. boiler may be built in a number of sizes ranging from 12 ft. high, 15 ft. wide and 16 ft. deep, to 24½ ft. high, 7 feet wide and 21 ft. deep. This feature allows the boiler to be used where certain dimensions cannot be exceeded such as, for instance, a limited height, or a limited width. In such cases one or two of the above dimensions may be adjusted to meet the particular limitations. Basements often have low ceilings, but large floor areas are available; again, it is sometimes desired to place a boiler under a pavement where the width is small, but the length or height is ample. The Stirling boiler is well adapted to meet such variable requirements.

Superheaters

Where a superheaters is fitted, it is installed as straight or hairpin tubes in the upper part of the boiler between the first two steam drums. The baffles direct the gas-flow through this area first, so it may reach the highest temperature.

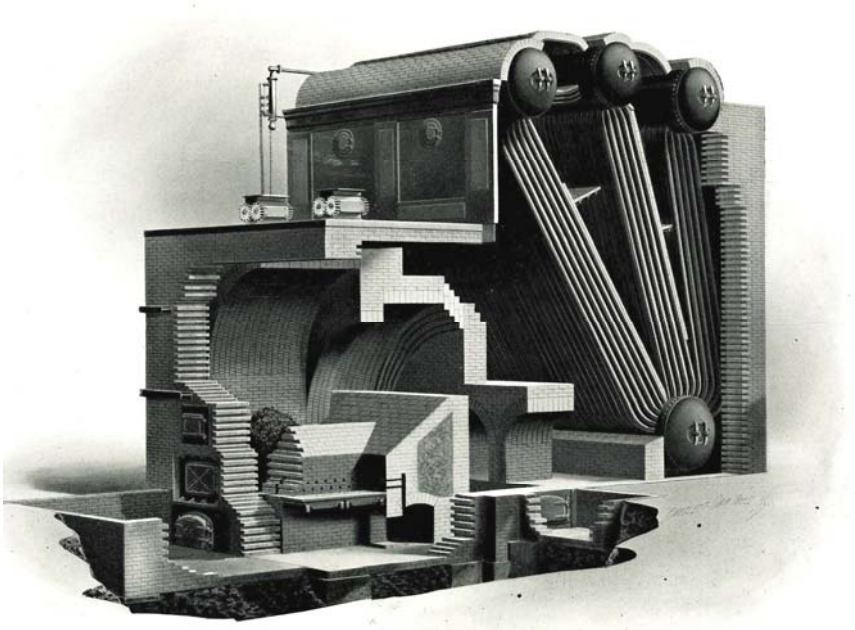
Ample Steam and Water Spaces

It is essential in a steam boiler that there shall be a sufficient surface from which to liberate the steam from the water, It is also essential that there shall be enough water in the boiler to store sufficient heat to prevent sudden fluctuations of pressure when the steam is drawn from the boiler in an irregular way or when there are irregularities in the firing. The Stirling boiler provides a steam and water space fully equal to that required

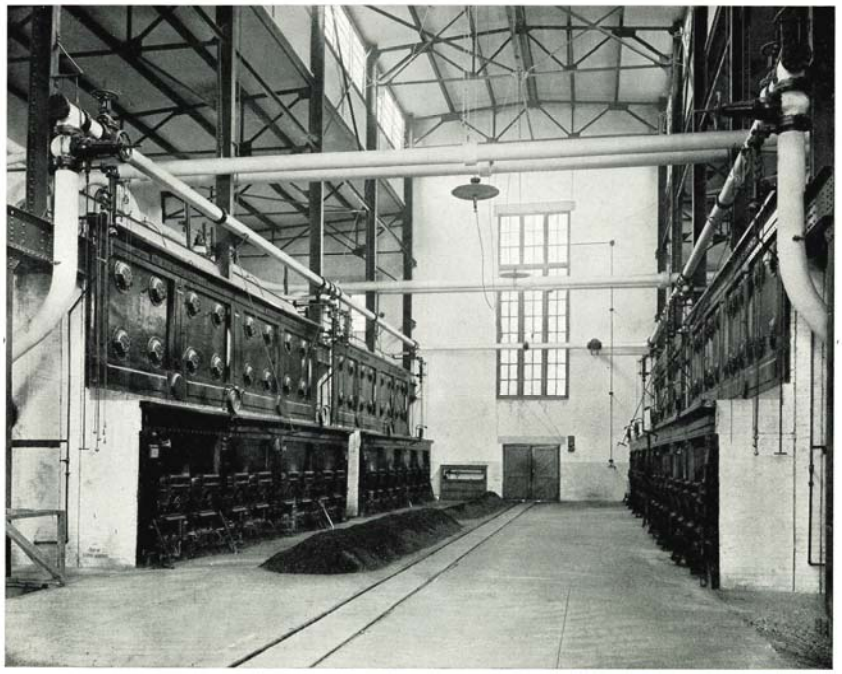
for any set of conditions. To produce dry steam there must be a proper amount of disengaging surface. In the Stirling boiler, in addition to the surface provided in the front drum where the greatest amount of steam is liberated, there is a separation in the second or middle drum of any moisture which may possibly be carried over from the first drum. In many cases the feed water contains impurities which tend to produce foaming, and in such instances the large disengaging surface of the Stirling boiler is a point in its favor.

Ability to Handle Impure Feed Water

When the feed water passes from the rear upper drum to the lower, or mud, drum, any precipitate formed through the elevation in temperature is deposited in the mud drum which, as it is protected from the heat of the furnace, acts as a settling chamber. The scale-forming matter which is deposited on the heating surface due to the elevation of temperature will collect mainly in the tubes of the rear bank which are subjected to the lowest external temperature, and where it will do the least harm. The precipitate deposited in the mud drum is removed by blowing off, and is thus prevented from being carried through the tubes by the circulation of the water, and from being thereby deposited on the inner surfaces along with other scale-forming matter.

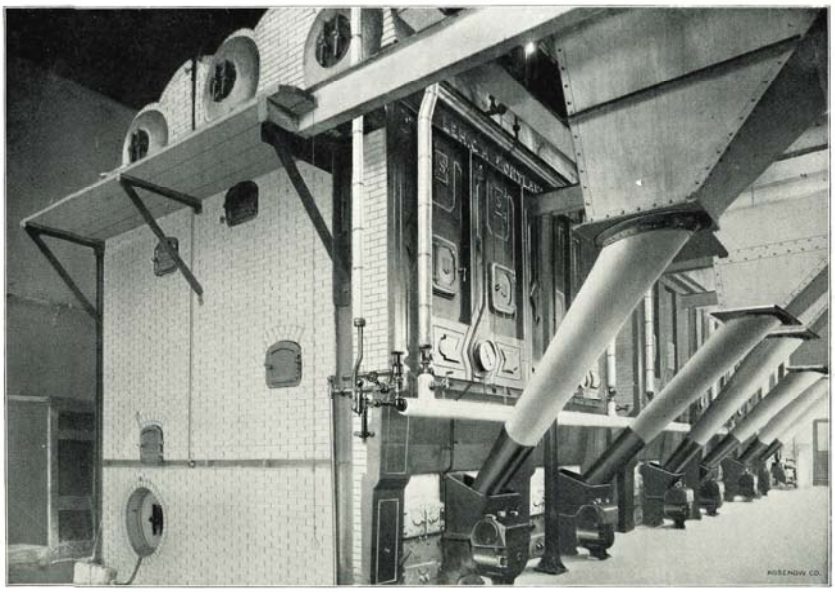


STIRLING BOILER SET WITH FURNACE FOR BURNING GREEN BAGASSE

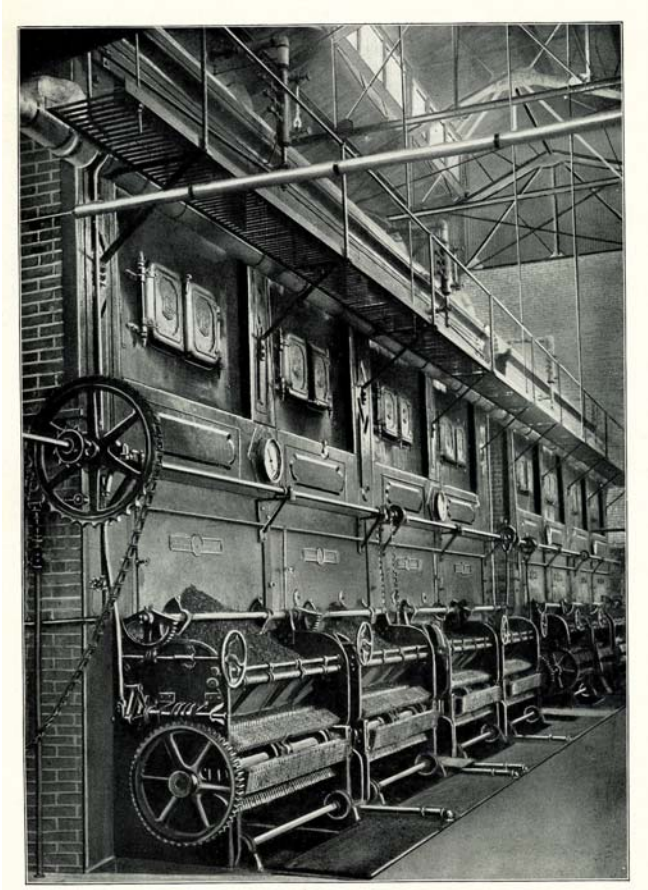


STIRLING BOILERS WITH HAND-FIRED EXTENSION FURNACES

STIRLING BOILERS ARRANGED FOR BURNING OIL

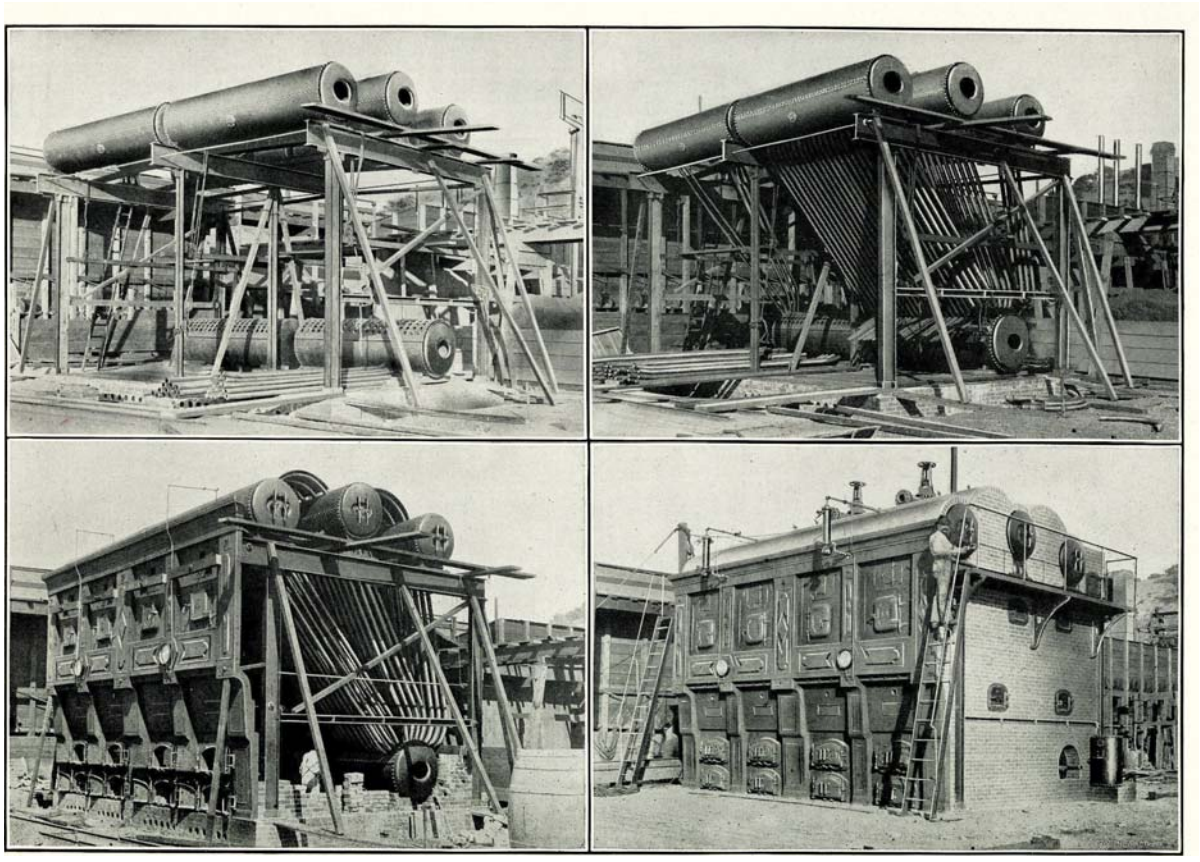


STIRLING BOILERS SET WITH UNDERFEED STOKERS

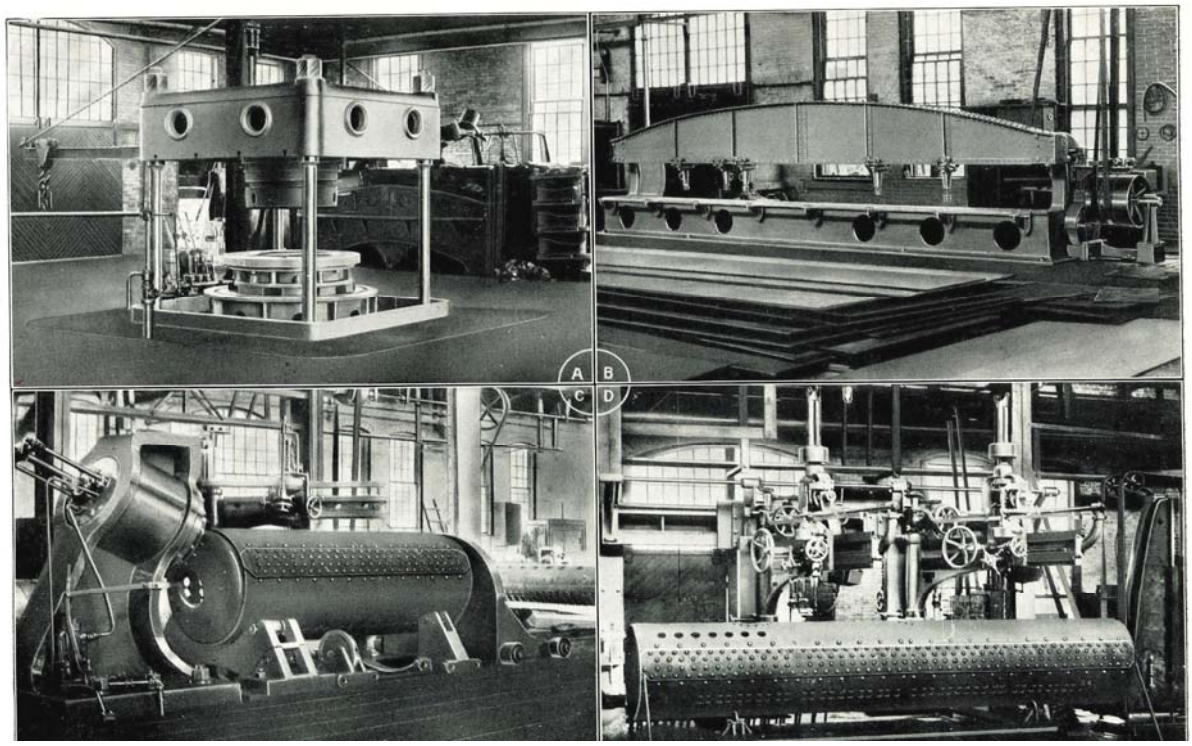


STIRLING BOILERS WITH CHAIN-GRATE STOKERS

STIRLING BOILERS ARRANGED FOR BURNING BLAST-FURNACE GAS



STIRLING BOILERS IN PROCESS OF ERECTION



**VIEWS FROM DRUM SHOP OF THE BABCOCK & WILCOX COMPANY'S WORKS AT BARBERTON, OHIO
A. HYDRAULIC HEAD-FLANGING MACHINE. B. A PLATE PLANER. C. HYDRAULIC PRESS FOR INSERTING DRUM HEADS. D. DOUBLE ARM RADIAL DRILL**

Advantages of water-tube boilers:

- They have a small water content, and therefore respond rapidly to load change and heat input.
- The small diameter tubes and steam drum mean that much higher steam pressures can be tolerated, and up to 160 bar may be used in power stations.
- The design may include many burners in any of the walls, giving horizontal, or vertical firing options, and the facility of control of temperature in various parts of the boiler. This is particularly important if the boiler has an integral superheater, and the temperature of the superheated steam needs to be controlled.

Disadvantages of water-tube boilers:

- They are not as simple to make in the packaged form as shell boilers, which means that more work is required on site.
- The option of multiple burners may give flexibility, but the 30 or more burners used in power stations means that complex control systems are necessary.

Information and research used in developed used in this write up was obtained by Larry G. Tarvin. The copyright was 1909 and was approved by B&W to use in this article. For more information please contact Larry Tarvin @ lgtarvin@aol.com