

April 14, 1942.

E. G. BAILEY

2,279,548

LIQUID VAPORIZING TUBE

Filed June 11, 1938

3 Sheets-Sheet 1

Fig. 2

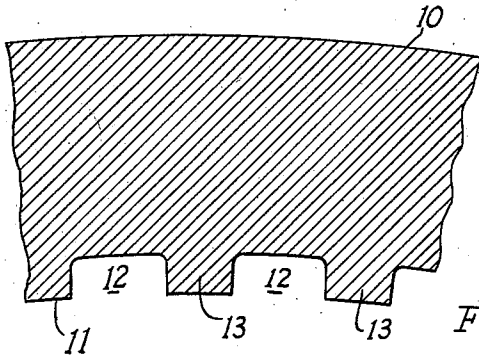


Fig. 1

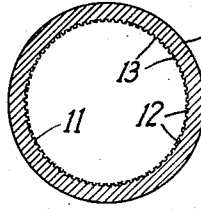
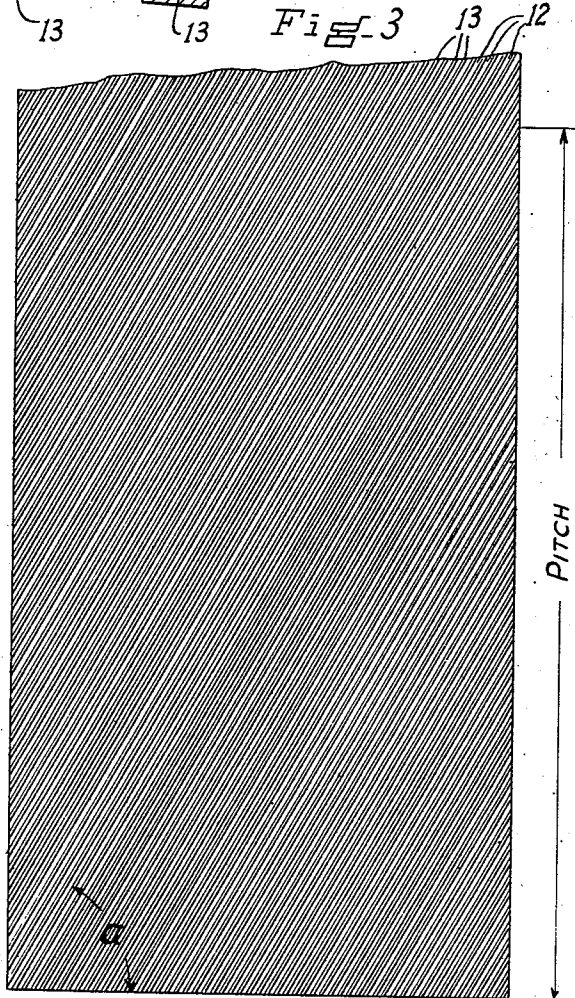


Fig. 3



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Fig 4

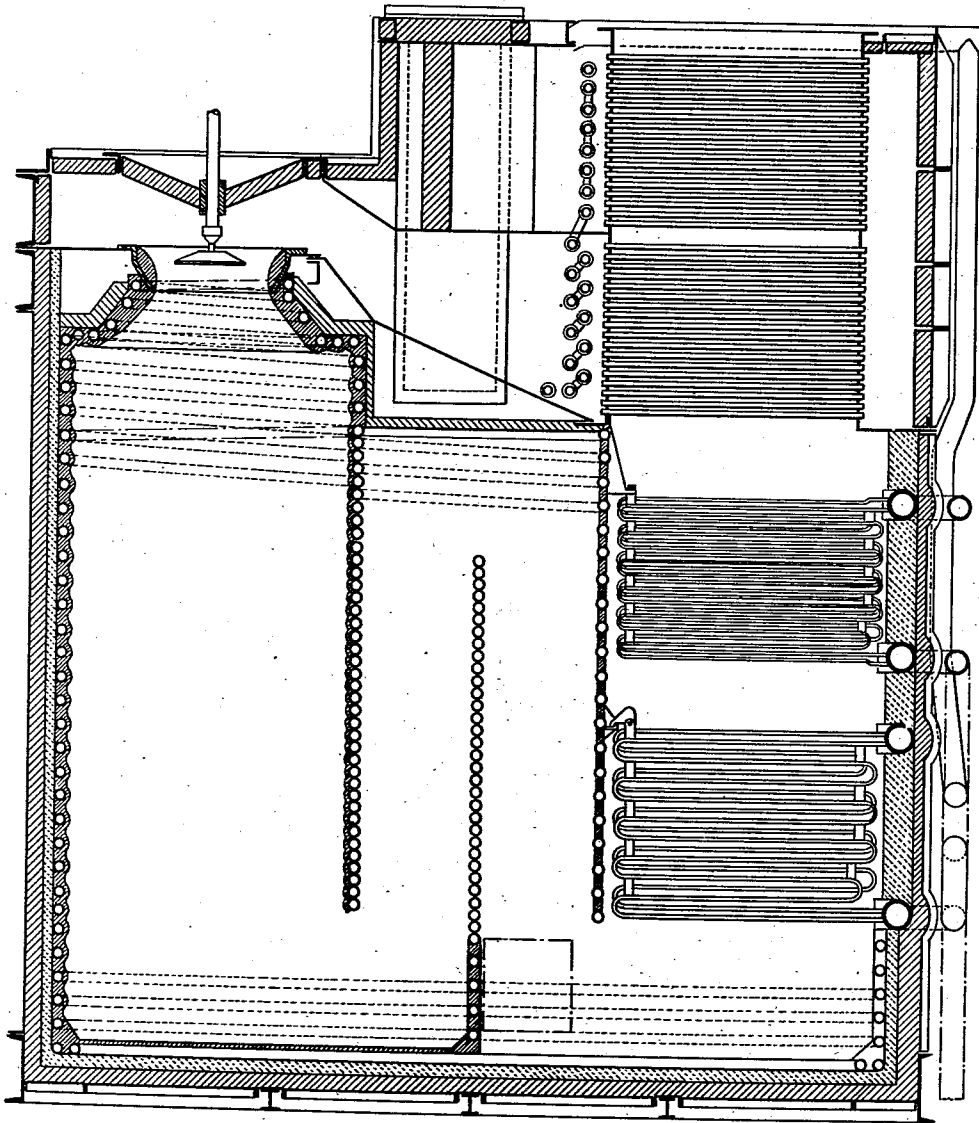
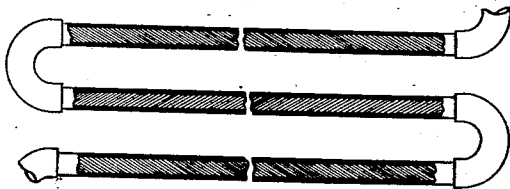


Fig 6



BY

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3 Sheets-Sheet 3

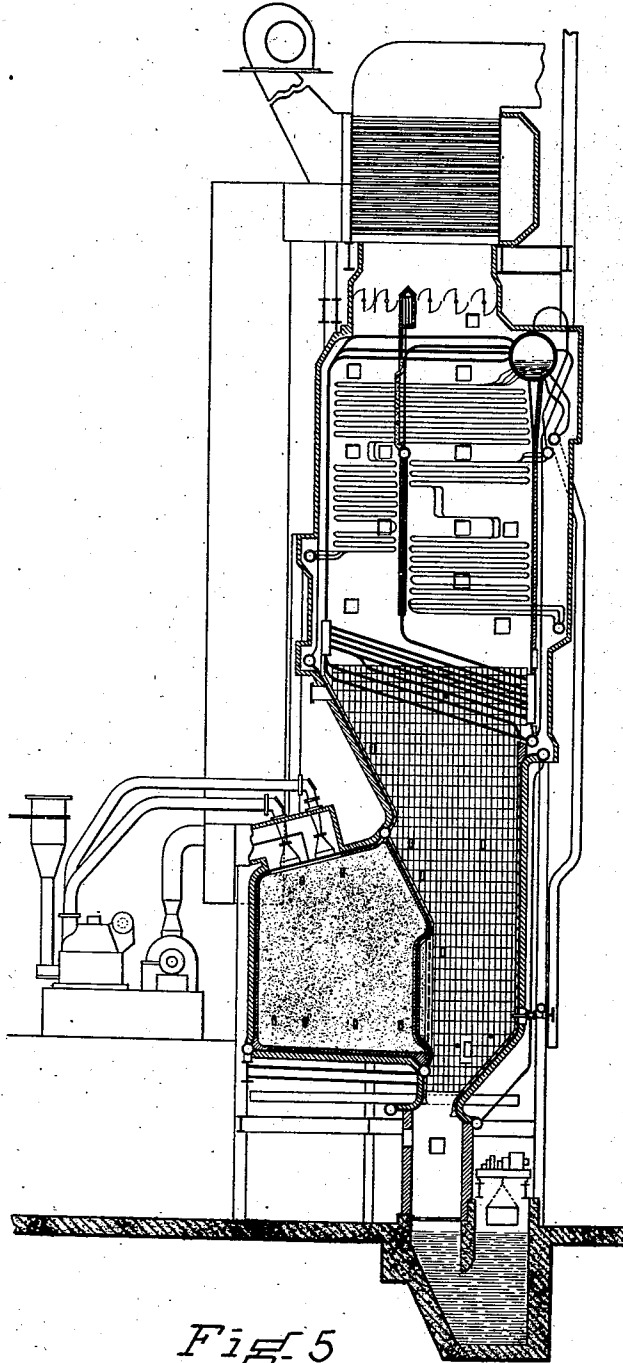


Fig. 5

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UNITED STATES PATENT OFFICE

2,279,548

LIQUID VAPORIZING TUBE

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Application June 11, 1938, Serial No. 213,130

9 Claims. (Cl. 122—235)

The present invention relates to the construction and operation of tubular vapor generating elements, and more particularly to tubular vapor generating elements of circular cross-section of the type adapted in operation to contain a fluid stream having one part liquid and the other part vapor of the liquid with a high ratio of vapor to liquid by volume in all or a portion of the tube length. My invention is particularly designed and especially useful in the construction of the steam generating tubes of a steam generator which in view of their location relative to the furnace normally absorb heat at relatively high rates.

In the operation of a water tube steam boiler, for example, it is essential to operation that water flow through the inside of each steam generating tube while heat is being received by the tube on its outer face. Steam is formed in the water inside of the tube, and at successively greater distances along its length there will be an increasing fraction of the flowing fluid in the form of steam and a decreasing fraction in the form of water, depending upon the rate of heat absorption. When steam flows with water inside of a tube it may have any one of several different physical relations with the water. The steam may be uniformly distributed in the form of small bubbles in the flowing water, the bubbles originating on the tube inner wall surface and being detached therefrom by various local forces, or in the form of large bubbles more or less uniformly distributed, or in the form of segregated steam and water masses alternating along the tube length or in other forms. When the volumetric ratio of steam to water is quite large the water may be more or less uniformly distributed through the steam as a fog or mist, or as a film on the inside of the tube wall, or as a more or less segregated parallel stream. Such a film or layer of water may be uniformly distributed around the tube circumference at any given cross-section of the tube, or over only a part of the tube inner wall surface. Under the latter condition the part of the inner wall surface not in contact with the water will be dry, while the part that is in contact will be wet.

It is well known that the wall metal temperature of a steam boiler water tube will not rise above the temperature of the contained fluid enough to weaken or otherwise damage the tube so long as the tube is wet with water on the inner wall surface opposite the heat receiving outer surface even with high heat transfer rates through the metal of the tube wall due to the

contact of hot gases or radiation from the furnace. It is also well known that when any part of the inner wall surface of a tube is dry that portion of the tube wall will tend to overheat and be damaged even with moderate heat transfer rates, in spite of the fact that other wall parts adjacent to it, either circumferentially or longitudinally, may be at safe temperatures with even higher heat transfer rates because of local wetness of those wall parts. This fact limits the average heat transfer rate and the generating capacity of the whole tube. This limitation becomes most severe if the heat transfer rate varies circumferentially of a tube that is not internally wet over its whole circumference and the more intense heating is applied to the dry portion of the tube wall.

The main object of my invention is the provision of an improved construction of a tubular vapor generating element which is characterized by simple and effective means for insuring substantially uniform circumferential distribution of the liquid in a liquid-vapor stream flowing therethrough over the inner wall surface of the vapor generating element irrespective of the position of the tube and without requiring any distortion of the tube or substantial weakening of the tube wall and without materially increasing its cost of manufacture or installation. A further and more specific object is an improved wall construction of a steam generating tube of circular cross-section of the character described which is adapted for use in parts of the steam generator where the enclosed fluid has a high ratio of steam to water by volume and the tube is mainly heated over only part of its circumferential area.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described a preferred embodiment of my invention.

Of the drawings:

Fig. 1 is a transverse section of a vapor generating tube constructed in accordance with my invention;

Fig. 2 is a view of a portion of the wall of the tube shown in Fig. 1 magnified twenty times;

Fig. 3 is a developed view of the inner wall surface of the tube shown in Fig. 1;

Fig. 4 is a sectional elevation of a forced flow steam generator in which the invention is adapted for use;

Fig. 5 is a view similar to Fig. 4 of a natural circulation steam generator adapted to incorporate the invention, and

Fig. 6 is a somewhat diagrammatic view of a tube coil constructed in accordance with the invention.

In accordance with my invention, the tubular vapor generating element is formed of suitable carbon or alloy steel tubing of circular cross-section having a smooth outer wall surface 10, although studs or other forms of extended surface may be applied thereto if desired provided that the inner wall surface is not distorted in consequence. The inner wall surface 11 of the tube is formed throughout its length, or a predetermined portion thereof, with a circumferentially arranged series of slightly separated parallel continuous grooves 12 of helical form, preferably formed by rifling the tube with relatively shallow grooves of approximately rectangular cross-section having a relatively high pitch. With this formation the grooves will be separated by lands 13, the sides of which define the adjacent sides of the adjoining grooves.

By way of example and not of limitation, the tube shown is of $1\frac{1}{2}$ " O. D. with a wall thickness of .125" and the rifling having helical grooves .0375" in width and .015" depth, adjacent grooves being separated by lands .025" in width. The rifling consists of 53 grooves and lands arranged with a pitch of $7\frac{1}{4}$ ", which when developed as shown in Fig. 3, will have a base angle α of approximately 60° .

The tube specifically described is especially designed for use as a wall tube in the upper wall portion and burner throat of the furnace of a forced flow high pressure steam generator having small liquid and heat storage capacity, such as illustrated in Fig. 4 and disclosed in my pending application Serial No. 113,060, filed November 27, 1936.

The rifled tubes of my invention are also adapted for effective use in natural circulation steam generators, such as shown in Fig. 5 and disclosed in a pending application of R. Shellenberger, Serial No. 137,158, filed April 16, 1937, and other forms of vapor generators, where the vapor generating tube conditions render the use of rifled tubes desirable in all or a portion of the vapor generating section thereof.

In the installation of rifled steam generating tubes of the character described in a water tube steam boiler, such tubes will be located in the part or parts of the circulation system where the fluid stream has a high ratio of steam to water by volume. By a "high" volumetric ratio of steam to water, I have in mind a steam fraction of at least 75% of the fluid stream and usually substantially greater. My invention will be found highly effective even when the volume of water flowing through a rifled tube is only sufficient to partly fill the wall grooves 12.

In the operation of a water tube boiler with rifled tubes, the outer layer of the flowing fluid is deflected by the rifling in such a way as to cause a circumferential motion in at least part of it. When the ratio of steam to water by volume has become high enough the water that might otherwise fail to be uniformly distributed circumferentially and flow along the bottom of a horizontal tube or the outside of a bend in a tube, for example, will be caught by the rifling

and caused to move circumferentially. The combined effects of surface friction of the steam and the rifled internal surface tends to distribute the water uniformly over the circumference of the grooved inner wall surface of the tube as the steam and water flow longitudinally through it, until all or substantially all of the water has been evaporated. With such rifled tubes, the tube wall metal temperature can be maintained at a safely low value with heat transfer rates that would cause damage by overheating if plain tubes were substituted.

In cases where the unevaporized water is small in amount and would tend to flow along the bottom of a horizontally arranged plain tube, one side of which is subjected to more intense heating, in a rifled tube similarly arranged the rifling would cause the bottom stream of water to be lifted and to sweep the highly heated side. In such cases it is desirable that the rifling be left or right-handed according to in which direction the lifting of the water from the bottom would be least, i. e., the rifling should be arranged so that the rotary movement of the water will be in the direction from the bottom toward the heated side. Where tubes are arranged in coils consisting of parallel tube legs with opposite reverse bends at opposite ends, the tube legs can be advantageously formed, as shown in Fig. 6, by tubes rifled alternately left and right-handed to secure proper distribution of the liquid after flowing through the reverse bends.

The use of the tube wall construction described for the high temperature generating section of a vapor generator will substantially increase its operating capacity in cases where the use of plain tubes in this location necessitated operation at reduced capacity for high availability and economic maintenance. It has also been found that rifling of the character described effects a decrease in the pressure drop through the tube at high mass flow rates of the fluid stream, as compared to that in plain tubes. The character of rifling particularly adapted for the most effective use of the invention does not decrease the flow area of the tube, or materially weaken the tube wall.

While in accordance with the provisions of the statutes I have illustrated and described herein the best form of the invention now known to me, those skilled in the art will understand that changes may be made in the form of the tube disclosed without departing from the spirit of the invention covered by my claims, and that my invention may sometimes be used to advantage over only a portion of the tube wall area.

I claim:

1. A vapor generating tube coil consisting of a series of side-by-side tubes of circular cross-section serially connected at their opposite ends by reverse bends, adjacent tubes having their inner wall surfaces alternately rifled in opposite directions.

2. As a new article of manufacture, a vapor generating tube for conducting a vaporizable liquid and its vapor having a circular cross-section and a series of shallow helical grooves formed in its internal wall surface and uniformly spaced circumferentially of the tube, said grooves being constructed of a size and shape providing an unobstructed flow area at least 90% of the total flow area of the tube and a tube internal surface area not more than twice the internal surface area of an ungrooved tube of the same maximum internal diameter.

3. As a new article of manufacture, a vapor generating tube for conducting a vaporizable liquid and its vapor having a circular cross-section and a multiplicity of continuous helical grooves of uniform pitch formed in its internal wall surface and uniformly spaced circumferentially of the tube, said grooves being constructed of a size and shape providing an unobstructed tube flow area at least 90% of its total flow area, and a tube internal surface area not more than twice the internal surface area of an ungrooved tube of the same maximum internal diameter.

4. As a new article of manufacture, a vapor generating tube for normally conducting a vaporizable liquid and its vapor in a high vapor-liquid volumetric ratio having a circular cross-section and its internal wall surface formed in a multiplicity of alternating continuous helical grooves and lands of a relatively high uniform pitch and uniformly spaced circumferentially of the tube, said grooves and lands being constructed of a size and shape providing an unobstructed tube flow area at least 90% of its total flow area, a groove depth not more than 10% of the maximum internal tube radius, and a tube internal surface area not more than twice the internal surface area of an ungrooved tube of the same maximum internal diameter.

5. In a vapor generator, a substantially horizontal vapor generating tube of circular cross-section arranged to receive heat mainly on one side thereof and normally conducting a vaporizable liquid and its vapor, said vapor generating tube having its internal wall surface formed in a series of shallow helical grooves pitched in a direction tending to cause liquid in the bottom of the tube to be lifted along the highly heated side of the tube and uniformly spaced circumferentially of the tube, and said grooves being constructed of a size and shape providing an unobstructed flow area of the tube at least 90% of its total flow area.

6. In a vapor generator, a furnace, a substantially horizontal vapor generating furnace wall tube of circular cross-section arranged to receive heat mainly on one side thereof at relatively high rates of heat absorption and normally conducting a vaporizable liquid and its vapor in a high vapor-liquid volumetric ratio, said furnace wall tube having its internal wall surface formed in a multiplicity of shallow helical grooves of uniform pitch in a direction tending to cause liquid in the bottom of the tube to be lifted along the highly heated side of the tube and uniformly spaced circumferentially of the tube, said grooves being

constructed of a size and shape providing an unobstructed tube flow area at least 90% of its total flow area, a groove depth not more than 10% of the maximum internal tube radius, and a tube internal surface area not more than twice the internal surface area of an ungrooved tube of the same maximum internal diameter.

7. In a vapor generator, a vapor generating tube of circular cross-section arranged to receive heat at relatively high rates of heat absorption and normally conducting a vaporizable liquid and its vapor in a high vapor-liquid volumetric ratio, said vapor generating tube having its internal wall surface formed in a multiplicity of shallow helical grooves of uniform pitch and uniformly spaced circumferentially of the tube, said grooves providing an unobstructed tube flow area at least 90% of the total flow area, and a tube internal surface area not more than twice the internal surface area of an ungrooved tube of the same maximum internal diameter.

8. In a vapor generator, a furnace, a vapor generating furnace wall tube of circular cross-section arranged to receive heat from said furnace at relatively high rates of heat absorption and normally conducting a high velocity stream of a vaporizable liquid and its vapor in a high vapor-liquid volumetric ratio, said vapor generating furnace wall tube having its internal wall surface formed in a multiplicity of alternating continuous helical grooves and lands of relatively high uniform pitch and uniformly spaced circumferentially of the tube, said grooves and lands providing an unobstructed tube flow area at least 90% of its total flow area, and a tube internal surface area not more than twice the internal surface area of an ungrooved tube of the same maximum internal diameter.

9. In a vapor generator, a vapor generating tube of circular cross-section arranged to receive heat mainly on one side thereof and normally conducting a high velocity stream of a vaporizable liquid and its vapor in a high vapor-liquid volumetric ratio, the internal wall surface of said tube having a multiplicity of continuous shallow helical grooves of relatively high pitch formed therein, said grooves being constructed of a size and shape providing an unobstructed tube flow area at least 90% of the total flow area of the tube and a tube internal surface area not more than twice the internal surface area of an ungrooved tube of the same maximum internal diameter.

ERVIN G. BAILEY.