Feb. 25, 1941. E. G. BAILEY 2,232,935

FLUID HEATER

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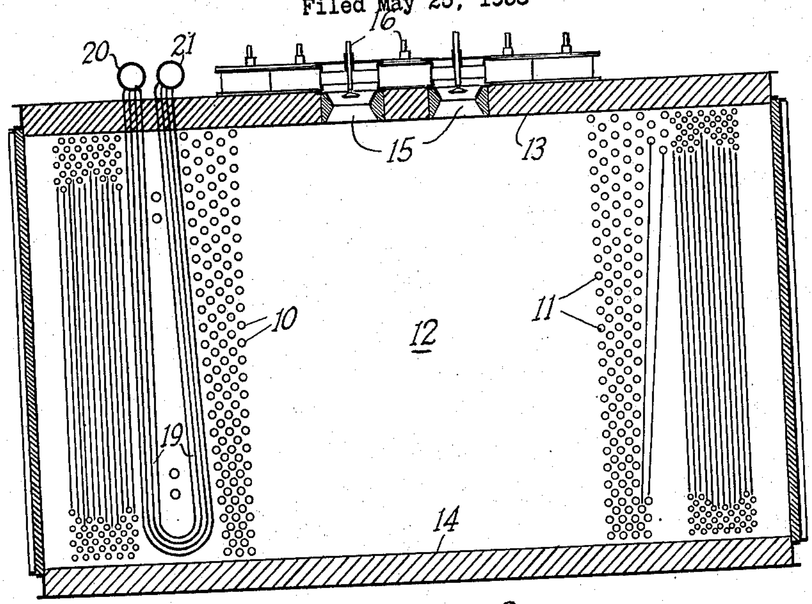


Fig. 2

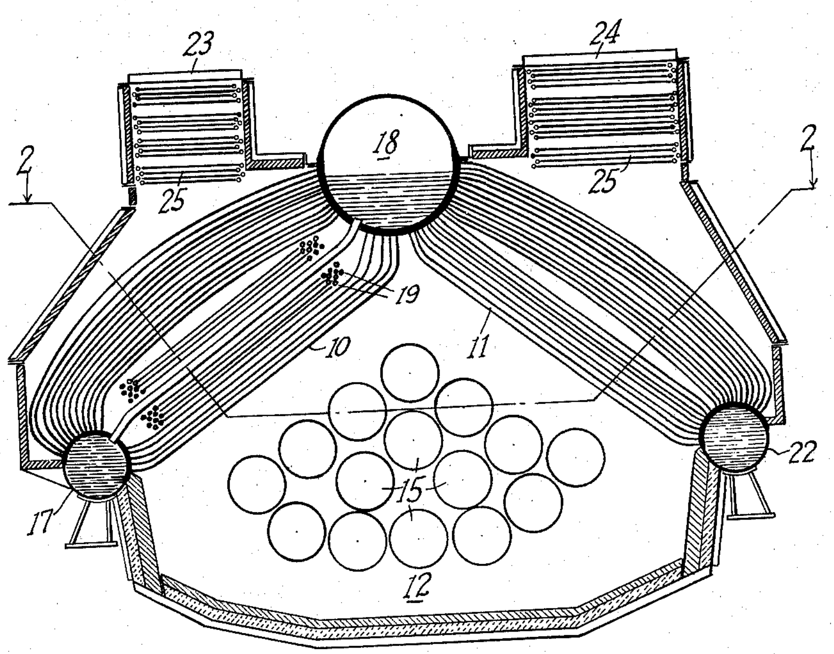


Fig. 1

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Fig. 4

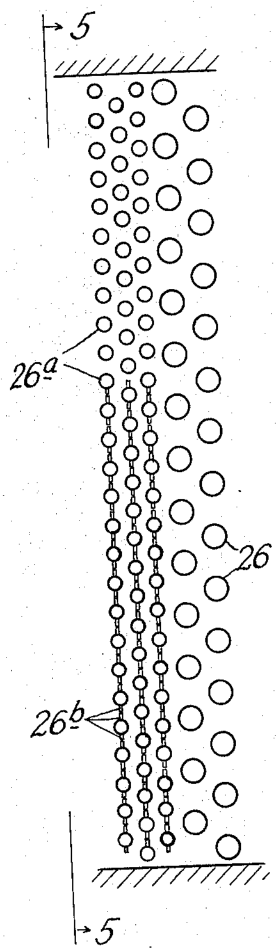


Fig. 3

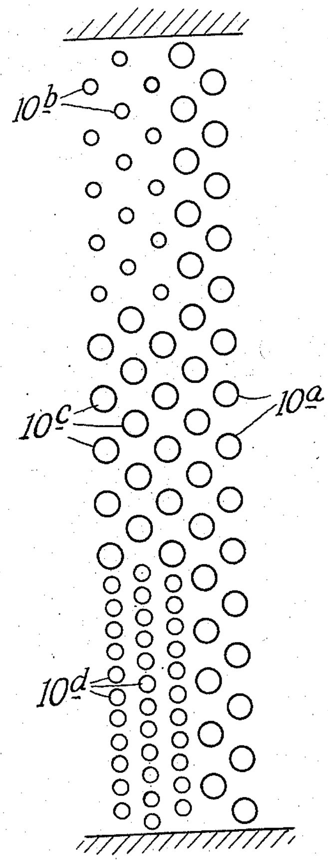


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Fig. 6

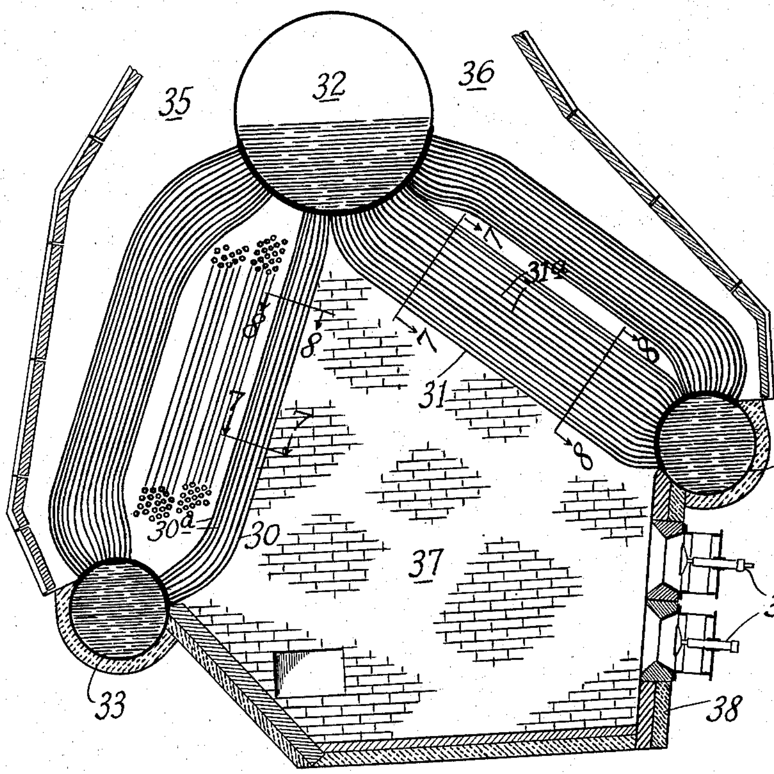



Fig. 7

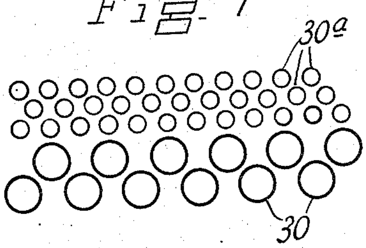



Fig. 8

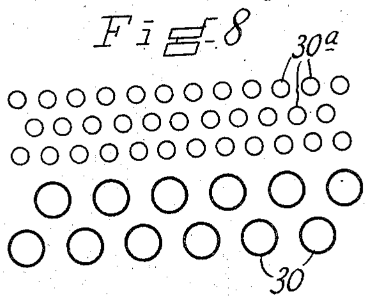
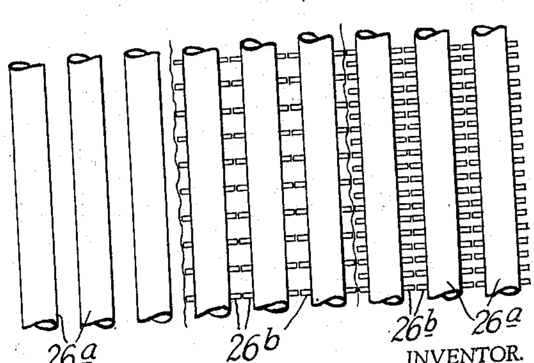



Fig. 5

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2,232,935

# UNITED STATES PATENT OFFICE

2,232,935

## FLUID HEATER

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Application May 25, 1938, Serial No. 209,921

12 Claims. (Cl. 122—328)

My invention relates in general to the construction and arrangement of a bank of fluid heating tubes arranged to receive a flow of heating gases transversely thereof from an associated furnace or other source of heating gases. While my invention may be embodied in various types of heat transfer apparatus, it is particularly designed and especially useful in the construction of water tube steam boilers.

In the operation of water tube boilers having a bank of water tubes extending across a gas pass opening to a furnace, experience has shown that some of the tubes may rupture from overheating even when clean internally. This experience has resulted in practices limiting the permissible operating capacity of a steam boiler to a capacity below the point at which tube failures of this type are likely to occur.

When clean tubes fail through overheating of the metal, it is usually found that the damaged tubes are localized as to position in a tube bank. Certain tubes appear to always fail before others, and in many cases in the tubes that fail, the failure is localized at a certain position along their lengths and does not extend over the full length. In most of such cases, the tubes that fail are only a small part of the total number of tubes in the bank, so it is apparent that most of the tubes had not reached their limit of capacity at the time when the first tube to fail exceeded its safe limit.

The tubes in the front row of the tube bank are more likely to fail by overheating than others. These front row tubes not only receive more heat by radiation from the furnace than the other tubes, but in addition receive heat by convection more intensely than the others because the gases contacting therewith will have the highest temperature. It often happens however, that the tube internal conditions are not the same throughout the bank, and that they are less favorable to tube maintenance within the more intensely heated tubes in the front row than in the remaining part of the bank, in which case the tendency for the front row tubes to fail is increased.

Not only do the tubes in the front row tend to fail more quickly for the same internal conditions in all of the tubes, but it commonly occurs that only a few of the tubes of the front row fail, indicating an inequality in the rate of heating of the tubes in the front row, either by excessive radiation or convection heat transfer, or both. I have found that this localization of the zone of tube failure to certain tubes lying in the front row of a tube bank is materially affected by the method of fuel firing and is greatest when the heating gases have a velocity of approach, i. e., a velocity component normal to the tube bank, which is not uniform over the entire tube bank area. For example, in one well known type of marine boiler, two oppositely inclined steam generating tube banks are symmetrically arranged relative to an A-shaped furnace therebetween fired by liquid fuel burners located in one of the end walls of the furnace. With this arrangement the heating gases tend to travel longitudinally of the furnace with a velocity dependent upon the combustion rate. The gases must make a 90° change of direction to enter either tube bank. Under these conditions there appears to be a tendency for the heating gases to concentrate in the opposite end of the furnace and the high velocity of approach of the gases in this section makes the convection heating rate greater for the tube bank portion near the wall opposite the fuel burners than in the tube bank portions nearer the burner wall. In addition the most intense combustion conditions in the furnace usually occur nearer to the rear wall, so that the front row tubes near this wall tend to receive a greater amount of heat by radiation than the other tubes of the front rows.

In accordance with my invention the gas flow areas between the tubes of the tube bank are relatively proportioned to eliminate any inequalities in the heating of corresponding tubes in different portions of the tube bank by regulating the distribution of the heating gases over the tube bank. By my invention the convection heating of any tubes in danger of overheating can be reduced to a safe operating rate while the convection heating of other tubes that were previously heated far below their safe operating limits can be substantially increased. This will result in a greater margin of safety for a rate of fuel burning and some increase in steam generating capacity of the tube bank as a whole, because there will be a substantially greater number of tubes receiving an increased amount of heating than the number of tubes that receive a decreased amount of heating. Conversely it will permit of a higher rate of fuel burning and a substantial increase in steam generating capacity without exceeding the factor of safety previously used.

The various features of novelty which characterize my 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 several embodiments of my invention.

Of the drawings:

Fig. 1 is a sectional elevation of a marine type steam boiler constructed in accordance with my invention;

Fig. 2 is a section taken on the line 2—2 of Fig. 1;

Figs. 3 and 4 are sectional views illustrating modified tube bank constructions;

Fig. 5 is a fragmentary longitudinal section taken on the line 5—5 of Fig. 4;

Fig. 6 is a view similar to Fig. 1 illustrating a modified steam boiler construction;

Fig. 7 is a transverse section illustrating the tube arrangement on the lines 7—7 of Fig. 6; and

Fig. 8 is a transverse section illustrating the tube arrangement on the lines 8—8 of Fig. 6.

The general steam boiler design illustrated in Figs. 1 and 2 is of a well known marine type, comprising a pair of oppositely inclined banks of steam generating tubes 10 and 11 defining therebetween an A-shaped furnace chamber 12. The furnace chamber is closed at its front and rear ends by walls 13 and 14 respectively, the front wall 13 being formed with a plurality of burner ports 15 through which liquid fuel burners 16 discharge parallel streams of atomized liquid fuel and air horizontally toward the rear wall 14. The tube bank 10 is divided into transversely spaced inner and outer sections extending between a lower water drum 17 along one side of the furnace chamber and an upper steam and water drum 18 extending along the apex of the furnace chamber. A bank of U-shaped superheater tubes 19 are horizontally arranged between the sections of the tube bank 10 with the ends of the U-tubes connected to external inlet and outlet headers 20 and 21 respectively. The opposite tube bank 11 extends between the steam and water drum 18 and a lower water drum 22 arranged along the opposite side of the furnace chamber. The tube banks 10 and 11 are constructed for a single pass gas flow transversely thereof to heating gas outlets 23 and 24 respectively, in which suitable economizer sections 25 are located.

As previously described, in steam boilers of this type the burning fuel streams tend to travel longitudinally in the furnace chamber at a velocity dependent upon the combustion rate. The heating gases generated must therefore make a 90° change of direction to enter either tube bank. The velocity head or inertia of the heating gases will cause the gases to concentrate in the rear portion of the furnace chamber, and consequently with a uniform tube arrangement longitudinally of the bank and thus a uniform pressure drop transversely of each tube bank, the heating gases would tend to distribute non-uniformly along the tube bank, and more particularly, a major portion of the gases will tend to flow transversely of the rear half of the tube bank. With this burner and tube bank arrangement it is also found that combustion conditions in the furnace chamber are non-uniform and usually more intense in the rear portion thereof. Under these conditions the water tubes in the rear portion of the tube banks, and particularly those in the front rows of that section, may be in danger of overheating, while most of the remaining tubes in the bank are not being heated up to their safe operating limits.

In accordance with my invention, the inner sections of the tube banks 10 and 11 are constructed with a tube pattern to provide a distribution of the heating gases relative to each tube bank of such a character that a substantially uniform heating of all of the tubes in the same longitudinal row of each tube bank will result. In Fig. 2 I have illustrated the tube arrangement for the inner sections of the tube banks 10 and 11. As shown, the inner section of the tube bank 10 is formed by five longitudinal rows of staggered tubes of uniform diameter. All of the tubes in each longitudinal row have the same spacing, but the transverse spacing of the tube rows is progressively decreased from the front to the rear end of the unit, so that the free gas flow area transversely of the bank will correspondingly decrease toward the rear end of the bank. This tube arrangement will provide a heating gas distribution effecting a more uniform heating of the tubes longitudinally of the tube bank. If desired, the same principle can be applied to the superheater by spacing the superheater tubes in groups with a progressively decreasing gas flow area across each group towards the rear end of the superheater and closing the space between the groups.

Similar results can also be secured with the inner sections of the tube banks constructed as shown in Fig. 3 or Figs. 4 and 5, the illustrations being for a tube bank corresponding in location to the tube bank 10 in Fig. 1. In Fig. 3 the tube bank construction employs a variation both in tube size and spacing. The two inner or furnace row tubes $10^a$ are of uniform diameter and staggered relation. The tubes in the remaining three rows are divided into three outer distinct groups longitudinally of the bank. The tubes $10^b$ of the group adjacent the front wall are of smaller diameter than the tubes $10^a$ and spaced on similar centers. The tubes $10^c$ of the group intermediate the length of the bank are similar in diameter and spacing to the tubes $10^a$ providing a decreased gas flow area thereacross in comparison to the gas flow area through the tube rows $10^b$. The tubes $10^d$ of the group adjacent the rear wall are similar in diameter, but more closely spaced longitudinally than the tubes $10^b$. With this arrangement the free gas flow area will successively decrease from the front end of the tube bank to the rear end.

In Figs. 4 and 5 a second modified construction of the inner section of a tube bank is illustrated. In this tube bank design the two inner or furnace rows of tubes 26 are of similar diameter and spacing and the three outer rows $26^a$ of smaller diameter but of similar spacing throughout. The desired variation in gas flow area longitudinally of the bank is secured by varying the effective area of the intertube spaces of the outer tube rows $26^a$. As indicated in Fig. 5 the tubes $26^a$ in the tube bank section adjacent the front wall 13 have unobstructed intertube spaces. The intertube spaces of the tubes $26^a$ in the intermediate and rear sections of the bank however, are partly obstructed by integral metallic studs $26^b$ projecting laterally into the intertube spaces. The intertube spaces of the rear tube section are made more obstructed than the intertube spaces of the intermediate tube section by a closer vertical spacing of the studs, as shown in Fig. 5.

Figs. 6, 7 and 8 illustrate the invention as embodied in another well known type of steam boiler adapted for marine use. In this boiler two oppositely inclined banks of steam generating tubes **30** and **31** are arranged between a steam and water drum **32** and mud drums **33** and **34** respectively at opposite sides of the setting. The mud drum **34** is arranged at a higher elevation than the drum **33** and the bank **31** given a lesser inclination than the bank **30**. Each of the tube banks is divided into inner and outer tube sections with the sections of the bank **30** spaced sufficiently to permit the installation of a group of steam superheater tubes therebetween. The tube banks are arranged for a single pass gas flow transversely thereof, with the gases passing over the banks **30** and **31** exiting through gas outlets **35** and **36** respectively. The A-shaped furnace **37** defined by the tube banks has a vertically inclined wall **38** below the drum **34**, and through which liquid fuel burners **39** discharge.

The fuel burners **39** are arranged along the full length of the furnace in a position causing the heating gases to be directed toward the lower part of the tube bank **30**. The velocity of the heating gases is relatively high, so that their inertia would ordinarily cause a greater convection heating of the tube bank **30** than of the bank **31**. With the described arrangement a portion of the heating gases will tend to enter the tube bank **30**, pass upwardly therein, and then outwardly into the upper portion of the bank **31**, causing the intermediate and lower portions of the front rows of tubes in the bank **30** and the upper portions of the front rows of tubes in the bank **31** to be more intensely heated than the other tubes of the banks.

In accordance with my invention a more uniform heating of the banks **30** and **31** and of all portions of the tubes therein is accomplished by arranging the tubes in the inner sections of those banks substantially as shown in Figs. 7 and 8. As shown, the two front rows of tubes in each bank are of uniform size and transverse spacing. The remaining tubes $30^a$ and $31^a$ in each of the inner sections are of smaller diameter. The tubes $30^a$ have their lower and intermediate portions closely spaced and arranged as shown in Fig. 7 relative to the intertube spaces of the larger diameter tubes so as to decrease the gas flow area through those portions of the tube bank. The upper portions of the tubes $30^a$ are more widely spaced, as shown in Fig. 8, to provide a larger gas flow area through that section as compared to the intermediate and lower portions of the inner section of the bank. With this arrangement a larger portion of the heating gases will be deflected towards the tube bank **31** and a more equal division of the gases between the tube banks thereby effected as well as a more uniform distribution of the gases throughout the height of the tube bank **30**.

A similar arrangement of the tubes $31^a$ is employed to secure a more uniform distribution of the gases throughout the height of the tube bank **31**. For this purpose the upper portions of the tubes $31^a$ are arranged substantially as shown in Fig. 7, while the lower portions of those tubes are arranged as shown in Fig. 8. By this arrangement a larger portion of the heating gases entering that tube bank will be forced to pass across the lower portion thereof.

Where the weight of the boiler is of primary importance, as in a marine installation, the desired heating gas flow can be best obtained by spacing the tubes of the banks in accordance with my invention. If desired, spacers or connections may be employed on or between the tubes to avoid any change in the original arrangement under operating conditions. The optimum tube arrangement can be determined generally by calculation, and the calculated arrangement checked by measurement of the variations in drum position in operation, or by measurement of individual tube temperatures by means of wires of predetermined fusion temperature stretched between the tube ends and examination of such wires after a period of known operating conditions to determine whether or not such tubes have exceeded their desired maximum temperature. The various tube bank constructions disclosed effectively neutralize the disadvantages of an unsymmetrical fuel burner location and the operation of the boiler with a larger number of tubes absorbing heat at the maximum heat absorption rate which they can safely withstand substantially increases the steam generating capacity of each unit, while eliminating any danger of local overheating of the tube banks.

While in accordance with the provisions of the statutes I have illustrated and described herein the best forms of the invention now known to me, those skilled in the art will understand that changes may be made in the form of the apparatus without departing from the spirit of the invention covered by my claims, and that certain features of my invention may sometimes be used to advantage without a corresponding use of other features.

I claim:

1. Fluid heating apparatus comprising a furnace, fuel burning means in said furnace, a bank of fluid heating tubes arranged for a heating gas flow from said furnace transversely of the tubes therein and so arranged relative to said furnace and fuel burning means that the velocity of approach of the heating gases in said furnace varies relative to the front of said tube bank, said tube bank having substantially all of the tubes in the row nearest said furnace being parallel and similarly positioned throughout their lengths relative to the longitudinal center line of said furnace and the gas flow area between the tubes of said bank relatively proportioned to provide a relatively small flow area through a portion of the bank in position to receive heating gases having a high velocity of approach and a larger flow area through another portion of the bank in position to receive heating gases having a lower velocity of approach.

2. Fluid heating apparatus comprising a furnace, fuel burning means in said furnace, a bank of fluid heating tubes arranged for a heating gas flow from said furnace transversely of the tubes therein and so arranged relative to said furnace and fuel burning means that the velocity of approach of the heating gases in said furnace varies along the length of said tube bank, said tube bank having substantially all of the tubes in the row nearest said furnace being parallel and similarly positioned throughout their lengths relative to the longitudinal center line of said furnace and the gas flow areas between the tubes of said bank relatively proportioned to provide a variation in gas flow area longitudinally of said bank effecting a substantially uniform convection heating of corresponding tubes in said tube bank.

3. Fluid heating apparatus comprising a fur-

nace, fuel burning means in said furnace, a bank of fluid heating tubes arranged for a heating gas flow from said furnace transversely of the tubes therein and so arranged relative to said furnace and fuel burning means that the velocity of approach of the heating gases in said furnace varies along the length of said tube bank, said tube bank having substantially all of the tubes in the row nearest said furnace being parallel and similarly positioned throughout their lengths relative to the longitudinal center line of said furnace and the gas flow areas between the tubes of said bank relatively proportioned to provide a relatively small flow area through the longitudinal portion of the bank in position to receive heating gases having a high velocity of approach and a larger flow area through the longitudinal portion of the bank in position to receive heating gases having a lower velocity of approach to thereby effect a substantially uniform convection heating of the tubes in the same longitudinal row of said tube bank.

4. Fluid heating apparatus comprising a furnace, fuel burning means in said furnace, a bank of fluid heating tubes arranged for a heating gas flow from said furnace transversely of the tubes therein and so arranged relative to said furnace and fuel burning means that the velocity of approach of the heating gases in said furnace varies along the length of the tubes in said tube tank, said tube tank having the gas flow areas between the tubes relatively proportioned to provide a relatively small flow area through the portion of the tube length in position to receive heating gases having a high velocity of approach and a larger flow area through the portion of the tube length in position to receive heating gases having a lower velocity of approach to thereby effect a substantially uniform heating of corresponding tubes in said tube bank throughout their lengths.

5. Fluid heating apparatus comprising a furnace, fuel burning means in said furnace, a bank of fluid heating tubes arranged for a heating gas flow from said furnace transversely of the tubes therein and so arranged relative to said furnace and fuel burning means that the velocity of approach of the heating gases in said furnace varies along the length of said tube bank, said tube bank having the diameters of the tubes in different longitudinal portions of said bank relatively proportioned to provide a relatively small gas flow area through the longitudinal portion of the bank in position to receive heating gases having a high velocity of approach and a larger gas flow area through the longitudinal portion of the bank in position to receive heating gases having a lower velocity of approach.

6. Fluid heating apparatus comprising a furnace, fuel burning means in said furnace, a bank of fluid heating tubes arranged for a heating gas flow from said furnace transversely of the tubes therein and so arranged relative to said furnace and fuel burning means that the velocity of approach of the heating gases in said furnace varies along the length of said tube bank, said tube bank having substantially all of the tubes in the row nearest said furnace being parallel and similarly positioned throughout their lengths relative to the longitudinal center line of said furnace and the spacing of the tubes in different longitudinal portions of said bank relatively proportioned to provide a relatively small gas flow area through the longitudinal portion of the bank in position to receive heating gases having a high velocity of approach and a larger gas flow area through the longitudinal portion of the bank in position to receive heating gases having a lower velocity of approach.

7. Fluid heating apparatus comprising a furnace, fuel burning means in said furnace, a bank of fluid heating tubes arranged for a heating gas flow from said furnace transversely of the tubes therein and so arranged relative to said furnace and fuel burning means that the velocity of approach of the heating gases in said furnace varies along the length of said tube bank, said tube bank having the diameters and spacing of the tubes in different longitudinal portions of said bank relatively proportioned to provide a relatively small gas flow area through the longitudinal portion of the bank in position to receive heating gases having a high velocity of approach and a larger gas flow area through the longitudinal portion of the bank in position to receive heating gases having a lower velocity of approach to thereby effect a substantially uniform convection heating of corresponding tubes in said tube bank.

8. Fluid heating apparatus comprising a furnace, fuel burning means in said furnace, a bank of fluid heating tubes arranged for a heating gas flow from said furnace transversely of the tubes therein and so arranged relative to said furnace and fuel burning means that the velocity of approach of the heating gases in said furnace varies along the length of said tube bank, said tube bank having tubes in different longitudinal portions of said bank provided with projections thereon extending into and obstructing the intertube spaces, said projections being proportioned relative to the associated intertube spaces to provide a relatively small gas flow area through the longitudinal portion of the bank in position to receive heating gases having a high velocity of approach and a larger gas flow area through the longitudinal portion of the bank in position to receive heating gases having a lower velocity of approach to thereby effect a substantially uniform convection heating of corresponding tubes in said tube bank.

9. Fluid heating apparatus comprising a furnace, fuel burning means in said furnace, a pair of oppositely inclined banks of fluid heating tubes at opposite sides of said furnace, each of said tube banks being arranged for a heating gas flow from said furnace transversely of the tubes therein and so arranged relative to said furnace and fuel burning means that the velocity of approach of the heating gases in said furnace varies along the length of said tube banks, each of said tube banks having substantially all of the tubes in the row nearest said furnace being parallel and similarly positioned throughout their lengths relative to the longitudinal center line of said furnace and the gas flow areas between the tubes in different longitudinal portions of said bank relatively proportioned to provide a relatively small gas flow area through the longitudinal portion of each bank in position to receive heating gases having a high velocity of approach and a larger gas flow area through the longitudinal portion of each bank in position to receive heating gases having a lower velocity of approach to thereby effect a substantially uniform convection heating of corresponding tubes in each of said tube banks.

10. Fluid heating apparatus comprising a furnace, fuel burning means in said furnace, a pair

of oppositely inclined banks of fluid heating tubes at opposite sides of said furnace, each of said tube banks being arranged for a heating gas flow from said furnace transversely of the tubes therein and so arranged relative to said furnace and fuel burning means that the velocity of approach of the heating gases in said furnace varies along the length of the tubes in each of said tube banks, each of said tube banks having the gas flow areas between the tubes in different portions along the length of the tubes of said bank relatively proportioned to provide a relatively small flow area through the portion of each bank in position to receive heating gases having a high velocity of approach and a larger flow area through the portion of each bank in position to receive heating gases having a lower velocity of approach to thereby effect a substantially uniform convection heating of the tubes in each of said tube banks substantially throughout their length.

11. Fluid heating apparatus comprising a furnace, fuel burning means at one end of said furnace, a pair of oppositely inclined banks of fluid heating tubes at opposite sides of said furnace, each of said tube banks being arranged for a heating gas flow from said furnace transversely of the tubes therein, each of said tube banks having substantially all of the tubes in the row nearest said furnace being parallel and similarly positioned throughout their lengths relative to the longitudinal center line of said furnace and the gas flow areas between the tubes in different longitudinal portions of said bank relatively proportioned to provide a relatively small flow area through one longitudinal portion of each bank and a larger flow area through another longitudinal portion of each bank to thereby effect a substantially uniform heating of similarly positioned tubes in each tube bank.

12. Fluid heating apparatus comprising a furnace, a pair of oppositely inclined banks of fluid heating tubes at opposite sides of said furnace, each of said tube banks being arranged for a heating gas flow transversely of the tubes therein, fluid fuel burners below one of said tube banks and arranged to discharge towards the opposite tube bank so that the velocity of approach of the heating gases in said furnace varies along the length of the tubes in said opposite tube bank, said opposite tube bank having the gas flow areas between the tubes in different portions of said bank relatively proportioned to provide a relatively small flow area through the portion of said bank in position to receive heating gases having a high velocity of approach and a larger flow area through the portion of said bank in position to receive heating gases having a lower velocity of approach to thereby effect a substantially uniform distribution of the heating gases between said tube banks.

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