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HIGH TEMPERATURE FLUID HEATER

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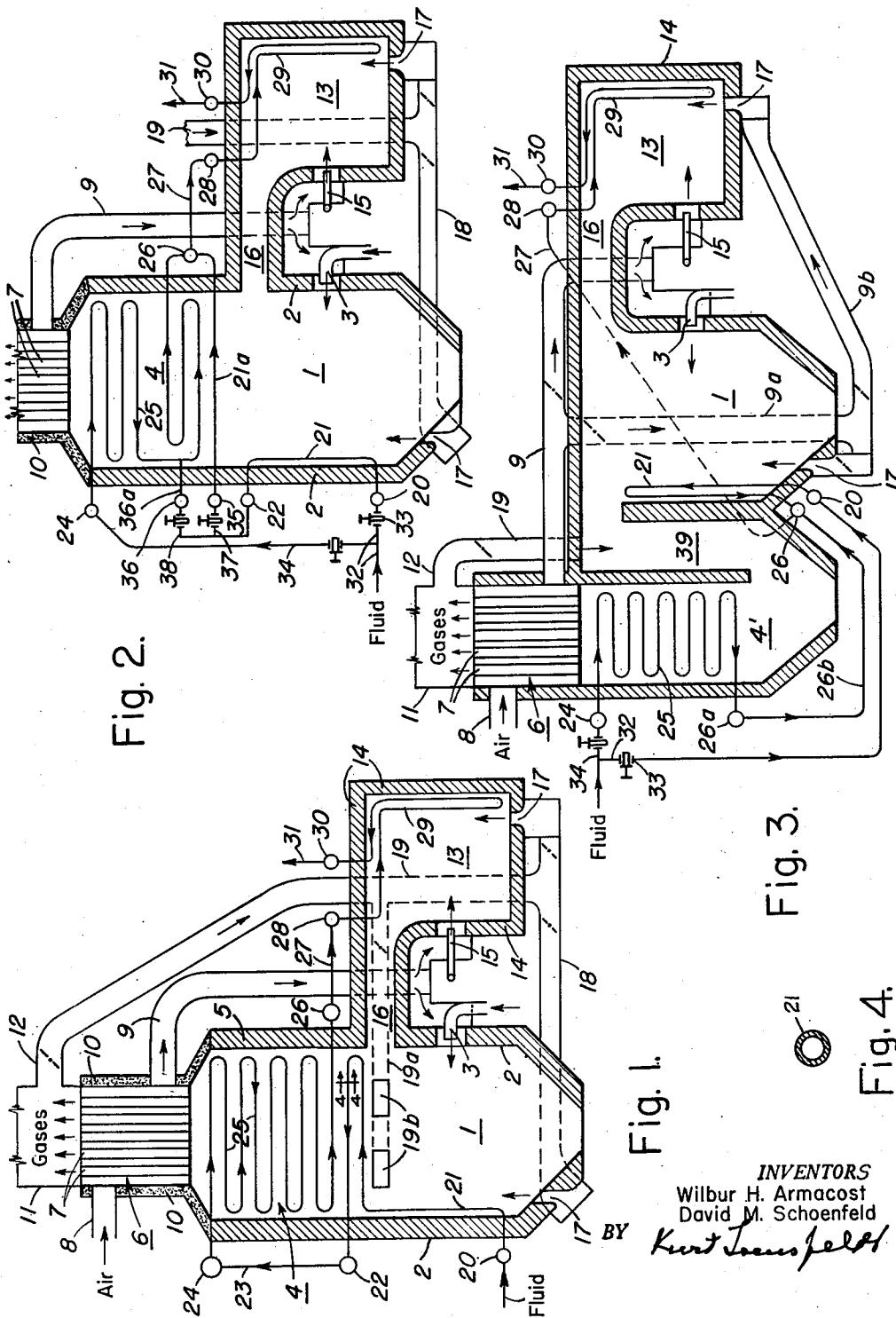


Fig. 2.

Fig. 3.

Fig. 1.

Fig. 4.

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HIGH TEMPERATURE FLUID HEATER

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This invention relates to heaters for heating fluids to high temperatures.

To heat a fluid to a high temperature it is generally customary to pass the fluid through a plurality of tubes to which heat is imparted by exposure to radiation, or by flowing over the outer surface of such tubes the products of combustion of a fuel, or by a combination of both. By so doing the products of combustion do not contaminate the fluid being heated. At pressures up to about 50 lb. per sq. in. gage and temperatures up to about 850 deg. F., the art for accomplishing these ends is well understood and developed. However, when it is necessary to heat fluids at pressures of up to 450 lb. per sq. in. absolute or higher to temperatures of 1300 deg. F. or higher, special precautions must be observed.

These precautions have to do with the selection of materials comprising the tubes and headers carrying the fluid to be heated to secure proper strength and life at the elevated temperatures, the arrangement of the tubes of different materials in order to secure the greatest economy in design and construction, and the quality of the fuel or fuels used to provide the heat. To heat fluids under pressure to temperatures in excess of about 850 deg. F. it is necessary to employ for the tubing heat resistant steel alloys in which the principal alloying components are varying percentages of chromium and nickel.

Up to temperatures in the range 1100-1150 deg. F. the character of the fuel used does not become of importance. Above this temperature range, however, the character of the fuel is of the utmost importance since it has been found that certain ingredients in the fuel, such as sulphur which becomes a component of the flue gases of combustion, react with the nickel in such alloys. This combination with the nickel reduces the strength, ductility and temperature resistant properties of the alloys to the point where the original materials, now modified, are no longer suitable for the purpose intended. Thus the life of the equipment is shortened to the point where it is no longer safe and must be discarded or replaced.

It is an object of this invention to provide novel means for overcoming the above difficulty.

Other objects and advantages will become apparent as the description hereof proceeds.

Of the drawings Figures 1, 2 and 3 are vertical cross sections through fluid heaters that incorporate illustrative forms of the invention, and Figure 4 is a cross section through one of the heater's fluid conduits.

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In practicing this invention we divide the total fluid-heating surface into two portions; we expose the first portion to conventional sulphur-containing products of furnace fuel combustion and thereby bring the fluid temperature up to some given value such as 1100 to 1150 deg. F.; and we expose the second portion to substantially sulphur-free furnace combustion gases and thereby further raise the fluid temperature to 1300 deg. F. or higher. The here-disclosed embodiments of this arrangement effectively avoid deterioration of the heat-resistant alloy steel in the fluid heater parts due to high-temperature combination of certain combustion-gas ingredients (such as sulphur) with nickel or other ingredients of the alloy.

In Figure 1 there is shown a first furnace 1 comprising combustion chamber walls 2 and provided with a burner or burners 3 for introducing a fuel, such as pulverized coal, to be burned within the furnace for the production of combustion gases that contain sulphur in customary amounts. This first furnace is provided with an off-take 4 surrounded by upper walls 5. In the illustrative arrangement shown the off-take 4 terminates in an air heater 6 of the tubular form in which the gases pass upwardly through a multiplicity of tubes 7 arranged in parallel, while the air for combustion to be heated enters through duct 8, passes around tubes 7 and leaves through duct 9. The air heater 6 is enclosed by walls 10 which connect to flue 11. Flue 11 is provided with a branch duct 12.

The apparatus of Figure 1 further includes a second furnace 13 surrounded by walls 14 and provided with a burner or burners 15 for introducing fuel, such as oil or natural gas, which is substantially sulphur free. In the illustrative arrangement shown, the products of combustion leaving this second furnace 13 pass through conduit 16 into the upper portion of the first furnace 1; hot air duct 9 conducts the heated air from the air heater 6 to the respective burners 3 and 15 of both furnaces 1 and 13; and each of these two furnaces is provided with a nozzle 17 connected to a duct 18 which in turn is connected to duct 19 for conducting flue gases from the flue 11 to said nozzles.

The fluid to be heated is delivered to header 20 from which it is carried through a multiplicity of parallel tubes 21 (here represented diagrammatically but each having the circular contour shown in Figure 4) upwardly along a wall 2 of furnace 1 opposite the burners 3 thence across the top of furnace 1 and back to header 22. Obviously some tubes 21 may be arranged

along the side wall of the furnace. From header 22 the fluid passes upwardly through conduit or conduits 23 into header 24. From header 24 a multiplicity of parallel tubes 25 (again shown diagrammatically but actually having the Figure 4 contour) conduct the fluid through offtake 4 in a number of sinuous passes back and forth thereacross to header 26. From header 26 the fluid is conducted via conduit or conduits 27 to header 28. From header 28 it passes through a multiplicity of parallel tubes 29 (each again of the Figure 4 contour) which pass across the roof of furnace 13 thence down and up along wall 14 of said furnace 13 opposite burners 15 to header 30. From header 30 fluid is conducted by a conduit 31 to the point of use.

In operation of the Figure 1 apparatus, the fluid tubes 21 and 25 in the first furnace 1 receive from the sulphur-containing combustion gases therein heat only sufficient to raise the fluid temperature (as at header 26) to not higher than some given range such as 1100 to 1150 deg. F. Below this temperature range the combination of combustion-gas ingredients (such as sulphur) with nickel and other ingredients of the alloy-steel tubes is not objectionable. Fluid tubes 29 in the second furnace 13 further extract from the sulphur-free combustion gases therein more heat which additionally raises the fluid temperature to 1300 deg. F. or higher. In the absence of sulphur these elevated temperatures have no injurious effect on the tube alloy steel.

In Fig. 2 is illustrated another apparatus for practicing applicants' novel method for heating fluids. This embodiment is basically the same as that shown in Fig. 1, however incorporates features rendering the heating of said fluid more flexible with respect to fluid temperature control. This flexibility is accomplished by providing a number of by pass circuits enabling the operator to control the flow of fluid through some of the heating surfaces. Accordingly a by pass is provided by conduit 34 to by pass heating surface 21 and by conduit 37 and by tubes 21a to by pass heating surface 25. There is also provided a by pass by conduits 38 and 36a to by pass only a portion of heating surface 25.

Thus in Figure 2 the basic arrangement of furnaces 1 and 13 and air heater for combustion air is the same as in Figure 1. The arrangement of the fluid heating tubes 21, 25 and 29 which are connected serially in Figure 1 are in part connected in parallel or in series-parallel in Figure 2. The fluid to be heated enters header 20 through conduit or conduits 32 provided with valve 33. A branch from conduit or conduits 32 conducts a portion of the fluid through a valved conduit or conduits 34 to header 24. From header 20 a portion of the fluid passes through a multiplicity of parallel tubes 21 along a wall of furnace 1 to header 22.

From header 24 the remaining portion of the fluid passes through a multiplicity of tubes 25 in the offtake 4 downwardly through one group in counter flow with respect to the rising gases from the furnace 1 thence through another group upwardly in parallel flow to the gases to header 26. Header 22 connects to headers 35 and 36 via valved connections 37 and 38. A multiplicity of tubes 36a equal in number to the tubes 25 within the offtake 4, connect the tubes 25 to header 36 at a point intermediate the groups which are in counter and parallel flow. A multiplicity of tubes 21a from header 35 pass across the top of furnace 1 to header 26. From header

26 the fluid heating tubes 29 are connected to headers 26, 28 and 30 and are arranged the same as in Figure 1.

By closing connection 38 and opening connection 37, portions of the fluid to be heated flow in parallel from intake conduit 32 to header 26 via tubes 25 and via tubes 21 and 21a. By opening connection 38, closing connection 37 and removing tubes 21a, portions of the fluid to be heated flow in parallel from intake conduit 32 to tubes 36a via the counterflow group of tubes 25 and via tubes 21. Thereafter the parallel flowing fluid portions join at the junction of tubes 25 and 36a and flow together through the remaining parallel flow group of tubes 25 to header 26. Optionally the valves may be omitted and the resistances through the circuits so balanced that the desired flow of fluid is obtained through the respective tubes 21, 21a and/or 25.

In Fig. 3 is illustrated a third arrangement of an apparatus for practicing applicants' improved method of heating fluids to a comparatively high temperature. The Fig. 3 variation is again an improvement over the basic form shown in Fig. 1. The distinction between Fig. 3 and Fig. 1 is three fold; first, an idle pass 39 is provided between heating surfaces 21 and 25; second, provision is made for the heated fluid to flow in a parallel flow relationship through heating surfaces 21 and 25 instead of in a serial flow relationship as shown in Fig. 1; and third, air instead of gas is used to establish a blanket between heating surfaces 21 and 29 to protect same from direct flame impingement of the hot flame issuing from burners 3 and 15 respectively. The two first named distinguishing features are designed to afford a closer control over the flow and temperature of the heated fluid and to result in a more thorough mixing of combustion gases (coming from duct 19, furnace 1 and furnace 13) in idle pass 39 before passing over heating surface 25.

Thus in Figure 3 furnaces 1 and 13 are arranged as in Figures 1 and 2 and again interconnected by conduit 16. The offtake from furnace 1 delivers the products of combustion into an idle pass 39 from which the products pass through offtake 4', the air heater for combustion air 6 and flue 11. As in Figure 1, the hot air leaving the air heater 6 passes through duct 9 to the burners 3 and 15. A branch duct 9a from duct 9 delivers air to a duct 9b which in turn is connected to each of the nozzles 17. The branch duct 12 from flue 11 connects via duct 19 directly into the furnace pass 39.

In this Figure 3 organization the fluid to be heated passes through the fluid heating tubes 25 and 21 in parallel, that portion passing through tubes 25 from header 24 discharges into header 26a, thence passes via conduit or conduits 26b to header 26 and the remaining portion passes through conduit or conduits 32 and valve 33 to header 20 and thence through heating tubes 21 to header 26. Leaving header 26 the two fluids join and pass through conduit or conduits 27 to header 28, through heating tubes 29, to header 30 and through conduit or conduits 31 to the point of use.

By the arrangement shown in Figure 3 the products of combustion leaving the furnace 1 may be tempered within the down pass 39 by admixture of flue gases delivered through duct 19 into said pass. In the Figure 1 organization such tempering may be effected by taking a branch duct 19a off of duct 19 which delivers flue

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gases into the top of furnace 1 through openings 19b. This last means of admitting the tempering gases, however, is not as effective as that shown in Figure 3.

In the Figure 3 organization hot air is delivered from duct 9 via ducts 9a and 9b to the nozzles 17. In Figure 1 flue gases are admitted to the nozzles 17. In either case, whether heated air or flue gases are used, the nozzles 17 function to throw a blanket of relatively cool gas or air across the surface of the heating tubes 21 and 29 to shield them against direct impingement of the hot flame leaving the burners 3 and 15. Preferably hot air is so passed through the nozzle 17 discharging into furnace 13 so as to avoid the impingement of a sulphur-containing gas onto the tubes 29 therein or to dilute it.

In all of the foregoing organizations of Figs. 1, 2 and 3 the total amount of heating surface for heating the fluid is divided so that that portion of the heating surfaces (tubes 25, 21 and 21a) in which the fluid is brought up to the approximate temperature range of 1100-1150 deg. F. may be heated by the products of combustion of fuels burned in the first furnace 1 that may contain appreciable quantities of sulphur and that portion of the heating surface (tubes 29) in which the fluid is heated from the aforementioned temperature range up to temperatures of about 1300 deg. F. or higher is provided with heat from the products of combustion from fuels burned in the second furnace 13 containing substantially no sulphur.

By this unique arrangement deterioration of heat-resistant alloy steels from combination with sulphur (or other ingredients) from the fuel with nickel (or other ingredients) in the alloy is avoided as earlier indicated. It will be evident, moreover, that the flue gases from the second furnace may be discharged into the first furnace at any convenient location; also that the two furnaces may be combined into a single setting adjacent to each other, or may be separate if desirable.

For steel alloys resistant to higher temperatures greater percentages of chromium and nickel are used than for similar alloys resistant to lower temperatures. As a result the prices for the alloys resistant to higher temperatures are higher than the prices of alloys resistant to lower temperatures. The arrangement using two furnaces and two fuels to provide longer life of the alloy materials also permits arrangements of heating surfaces and selection of materials therefor in order to use the least amount of expensive alloy material and the greatest amount of inexpensive alloy material to accomplish a given result.

Also in the accomplishment of these ends the disposition of the heating surfaces may be such that some of the heat is imparted to the surfaces by radiation and some by convection from the flue gases of combustion flowing over the surfaces, or by a combination of these two means. The gases of combustion may flow over the tubes in relation to the fluid flowing through the tubes either in countercurrent, in parallel, or in a combination of countercurrent and parallel flow, in order to take advantage of the tempering differential existing between gases of combustion and fluid being heated to hold the temperature of the metal in the tubes to a degree suitable to prevent their deterioration and promote long life.

While preferred embodiments of the invention have been shown, it will be understood that

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changes in construction, combination and arrangement of parts may be made without departing from the spirit and scope of the invention.

We claim:

1. In a method for heating a fluid under pressure to an elevated temperature in a heat exchanger fabricated of material including heat resisting and nickel-steel alloy tubing and exposed in part to combustion gas containing sulphur ingredients which at metal temperatures below a given range fail to substantially affect the nickel contained in said alloy tubing but which at metal temperatures above said given range enter into a chemical reaction with the nickel contained in said alloy rendering said alloy tubing unsuitable for service under high pressure and high temperature conditions; the steps which comprise flowing said fluid through the nickel-steel alloy tubing of a first portion of said heat exchanger while exposing said first portion tubing to said combustion gas sulphur ingredients, the cooling action of said fluid serving to maintain the metal temperature of said first portion nickel-steel alloy tubing below said given range whereby said combustion gas sulphur ingredients are substantially prevented from entering into chemical reaction with the nickel contained in said first portion alloy tubing; and flowing the partially heated fluid from said first portion tubing through the tubing of a second portion of said heat exchanger while exposing said second portion alloy steel tubing to combustion gas that is substantially free of the aforesaid sulphur ingredients and at elevated temperatures causing the metal temperature of said second portion alloy tubing to rise above said given range whereby said combustion gas is substantially prevented from affecting the strength and heat resisting qualities of said second portion alloy tubing.

2. In a method for heating a fluid under pressure to an elevated temperature in a heat exchanger fabricated of material including heat resisting and nickel-steel alloy tubing and exposed in part to certain combustion gas containing sulphurous compounds which at metal temperatures below a given range fail to substantially affect the nickel contained in said alloy tubing but which at metal temperatures above said given range enter into a chemical reaction with the nickel contained in said alloy rendering said alloy tubing unsuitable for service under high pressure and high temperature conditions; the steps which comprise flowing said fluid through the steel tubing of a first portion of said heat exchanger while exposing said first portion tubing to combustion gas containing sulphurous compounds, the cooling action of said fluid serving to maintain the metal temperature of said first portion steel tubing at a degree which is below said given range; and flowing the partially heated fluid from said first portion tubing through the tubing of a second portion of said heat exchanger said tubing being composed of heat resisting nickel-steel alloy while exposing said second portion alloy steel tubing to combustion gas that is substantially free of any sulphurous compounds and at elevated temperatures causing the metal temperature of said second portion alloy tubing to rise above said given range whereby said combustion gas is substantially prevented from affecting the strength and heat resisting qualities of said second portion alloy steel tubing.

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3. In a method for heating a fluid under pressure to an elevated temperature in a heat exchanger fabricated of material including heat resisting and nickel-steel alloy tubing and exposed in part to certain combustion gas containing sulphurous compounds which at metal temperatures below 1100-1150° F. fail to substantially affect the nickel contained in said alloy tubing but which at metal temperatures above 1100-1150° F. enter into chemical reaction with the nickel contained in said alloy rendering said alloy tubing unsuitable for service under high pressure and high temperature conditions; the steps which comprise flowing said fluid through the nickel-steel alloy tubing of a first portion of said heat exchanger while exposing said first portion tubing to combustion gas containing sulphurous compounds, the cooling action of said fluid serving to maintain the metal temperature of said nickel-steel alloy tubing below 1100-1150° F. whereby the sulphurous compounds in said combustion gas are substantially prevented from entering into chemical reaction with the nickel contained in said first portion alloy tubing; and flowing the partially heated fluid from said first portion tubing through the tubing of a second portion of said heat exchanger while exposing said second portion alloy steel tubing to com-

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bustion gas that is substantially free of any sulphurous compounds and at elevated temperatures causing the metal temperature of said second portion alloy tubing to rise above 1100-1150° F. whereby said combustion gas is substantially prevented from affecting the strength and heat resisting qualities of said second portion alloy tubing.

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