Nov. 21, 1950 D. H. GREENE 2,530,958

APPARATUS FOR HEATING FLUIDS

Filed April 29, 1947

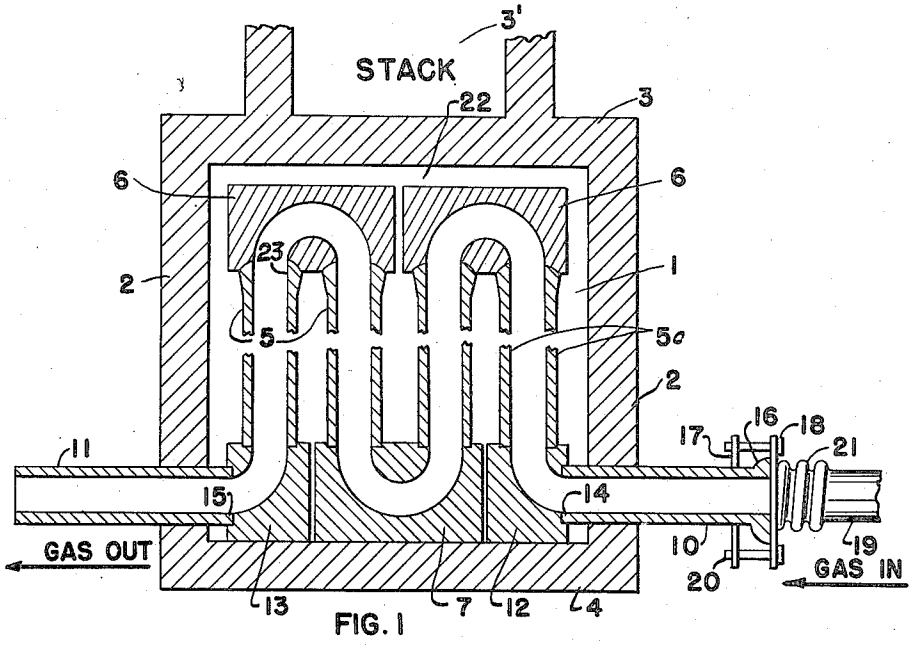


FIG. 1

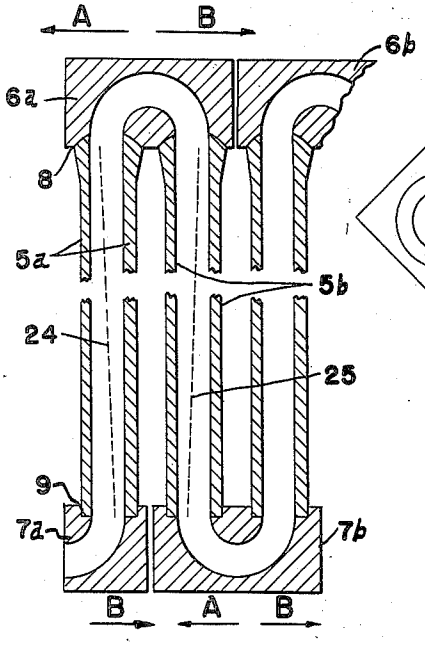


FIG. 2

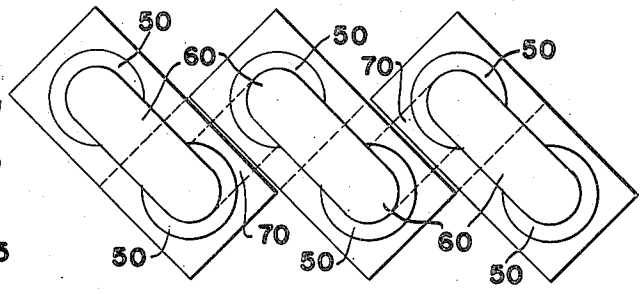


FIG. 3

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Patented Nov. 21, 1950

2,530,958

UNITED STATES PATENT OFFICE

2,530,958

APPARATUS FOR HEATING FLUIDS

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Application April 29, 1947, Serial No. 744,563

5 Claims. (Cl. 263—20)

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This invention relates to an improved apparatus for heating fluids, particularly gases, to high temperatures.

As is known, it is possible to effectively heat gases to temperatures of 1800° F. and below by installing a metallic tube or series of tubes in a suitably heated furnace. For operation in such a temperature range, steels of various analyses and certain non-ferrous alloy tubes have been employed heretofore. However, when gases are to be heated to elevated temperatures above 1800° F. or 2000° F., such alloy tubes are not suitable. Under such very high temperature operation stresses are imposed on the tubes inducing distortion and with even most expensive heat resistant alloy tubing the alloys soon become soft and lose their rigidity. The high initial cost of the alloy tubes coupled with constant necessary replacement with concomitant loss of operating time due to shut down imposes serious economic restrictions on their use.

As is known, at the present time refractory tubing is available which will withstand temperatures of the order of 2000° F. and above. This type of tube may be fabricated from readily available refractories such as alumina, zirconia, beryllium oxide and silicon carbide. These refractories also may be molded or otherwise formed into units such as return bends, L's and the like. It is thus possible by associating the tubes with return bends or L's to construct a continuous coil of any desired length which coil may be disposed either horizontally or vertically in a furnace. Likewise, manifolds can be fabricated from these refractories so that, if desired, two or more tubes can be disposed in the coil in parallel.

It is apparent that a continuous coil of the described type comprising a plurality of tube units and return bends or equivalent connecting elements necessarily involves a series of joints between the several elements. While a continuous tube of this type presents the advantage of marked utility at high temperatures, in the past it had been found practically impossible to construct such a continuous coil which would be gas-tight over any commercially practical period of operation. The present invention provides a solution for this problem of producing a gas-tight continuous refractory tubing for operation at highly elevated temperatures.

In order to enable a more ready comprehension of the invention typical, though not exclusive, physical embodiments are shown in the accompanying drawing in which:

Fig. 1 is a sectional elevation of a furnace containing a continuous refractory coil according to the invention.

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Fig. 2 is an enlarged detail of a section of the refractory coil shown in Fig. 1, and

Fig. 3 is a diagrammatic plan view illustrating an alternative disposition of the coil elements.

The rationale of the invention as well as the advantages to be derived from its use can be more readily appreciated from a consideration of the mechanism of the failures which have been encountered heretofore. In the past, when refractory coils of the type discussed have been employed for heating fluids at high temperatures difficulties arose due to the fact that at the high temperatures involved both linear and cubical expansions are relatively large. As will be appreciated, in this type of construction, the tubes and return bands, due to thermal expansion, assume a position at high temperatures quite different from that prevailing at low temperatures. As a practical matter, for efficient operation, the continuous coil should be gas-tight when cold and yet remain gas-tight under operating conditions at temperatures above 2000° F. It has been found by experience that joints that are gas-tight at lower temperatures may not prevent the leakage of the gas at higher temperatures due to the displacement of the elements of the continuous coil with consequent fracture of the joints and tubes.

The salient object of the present invention therefore is to produce a continuous coil made up of associated tubes and return bends or equivalent interconnecting members in which a novel type of floating movement is permited between the elements thus obviating or compensating for the mechanical stresses which have heretofore caused leakage at the joints and, in many instances, fracture of the tubes themselves.

It has been ascertained that this desirable result may be achieved by establishing floating curvilinear contact surfaces between the tubes and certain of the interconnecting elements, such as return bends, manifolds, L's and the like, and applying to the joints between the tubes and interconnecting units a cementitious material which is softened but which is still gas-impervious at the higher operating temperatures, permitting relative movement between the tubes and interconnecting members without rupture of the seals at the joints. This novel structural correlation, as will be seen more fully hereinafter, insures the desired rigidity in the coil structure as a whole while rendering it gas-tight,

at both high and low temperatures, for protracted operative periods.

As shown in the drawing the improved continuous coil may be embodied in a suitable furnace 1, having the side walls 2, roof 3 with associated stack 3' and the floor 4. The coil is constructed of material such as silicon carbide or equivalent highly refractory compounds. The coil itself is comprised of the fabricated standard interchangeable and readily replaceable tube sections 5 of suitable length which are joined together by the upper return bends 6 at the joints 8 and lower return bends 7 at the joints 9. Obviously, the coil may be made up of any desired number of tube units and associated return bends. The coil may be connected to units exterior of the furnace in any suitable manner. In one example the tubes 10 and 11 extend exteriorly of the furnace and may be connected to the coil by means of the L's 12 and 13 respectively at the joints 14 and 15. The tube 10, as shown, is provided with suitable means to facilitate its connection with a metallic conduit. This may be done in any desired manner. In the method shown in Fig. 1 the tube 10 is provided with an enlarged collar 16 and with the securing flange 17. A similar flange 18 is welded or otherwise attached to the metallic conduit 19. The flange 18 may thus readily be brought into tight contact with the collar 16 by means of the bolts 20. Any suitable gasket material may be interposed between the flange 18 and the collar 16 to insure a gas-tight joint.

The metallic tube 19 may comprise a portion of an ordinary rigid metallic tubing or pipe system. In order to compensate for the linear expansion of tube section 10, which is subjected to the high temperatures, it is desirable to insert a short length of flexible metallic tubing, such as section 21, between tubes 10 and 19. Such a flexible tubing provides, in effect, an expansion joint absorbing the differences in linear expansion during the operation. In lieu of the flexible tubing 21 any other similarly functioning connection may be employed.

It will be particularly observed that the tubes are supported wholly on the floor of the furnace through the medium of the lower return bends while, on the other hand, the upper return bends are spaced an appreciable distance from the roof of the furnace, as shown at 22. Hence, in this type of construction the weight of the tubes is taken as a vertical compression load and the tubes are free to expand and contract in a vertical direction with changes of temperature in the furnace.

As previously pointed out, a novel type of joint is established between the upper return bends and the tubes. This is shown in more detail in Fig. 2. As there shown, the return bends 6 and 7 are disposed so that the horizontal axis of each is parallel to the floor while the tubes 5 are disposed vertically with their axis normal to the horizontal axis of the return bends. The upper ends of the tubes 5 are specially conformed. As will be seen, the bearing or contact surface between the upper end of the tubes 5 and the upper return bend 6 is curvilinear. Preferably also, the section of tube 5 adjacent the contact or bearing surface is thickened, as shown at 23. This not only increases the strength of the tubes at this section but also provides increased bearing or contact area. It will be observed that the abutment established between the upper end of the tube 5 and the return bend 6 thus constitutes, in effect, a type of ball and socket bearing surface, the purpose of which will presently appear. The lower ends of the tubes 5, as shown, fit into angular rather than curvilinear sockets in the lower return bends 7. The tubes 5 are joined to the upper return bend 6 and to the lower return bend 7 by means of a suitable cement.

In the past, such joints could be made gas-tight and remain gas-tight if the tubular system was not permitted to rise a great deal in temperature. However, in earlier constructions as the system was brought up to the desired high temperature, expansion of the several units took place. As will be observed, the tubes expand upwardly since the bottom return bends to which the tubes are connected rest on the furnace floor. Since the tubes and return bends are of different shape and cross-sectional dimension the extent of both linear and cubical expansion of the two is different. At the high temperatures the upper return bends expand in all directions while the lower return bends expand in all directions except downwardly, being restrained from such movement by the furnace floor. Expansion of the return bends in a vertical direction manifestly does not tend to change the position of the tubes relative to the return bends. However, expansion of the return bends in a direction parallel to their horizontal axis does modify or change the vertical position of the tubes and it is this movement which has been one of the important factors in the unsatisfactory operation of prior refractory tubular systems.

The effect of such a displacement of the tubes 5 from a vertical position can be more readily appreciated by a reference to Fig. 2. It will be observed that each upper return bend 6A and 6B is connected to two tubes, namely, 5A and 5B. Similarly, each lower return bend 7A and 7B is connected to two tubes 5A and 5B. With increase in temperature that portion of the upper return bend 6A to which the tube 5A is connected expands laterally in the direction indicated by the arrow A while simultaneously the portion of such upper return bend to which the tube 5B is connected expands laterally in the opposite direction indicated by the arrow B. At the same time the section of the lower return bend 7A to which tube 5A is connected expands in the lateral direction indicated by the lower arrow B. Since the tube is constrained to move with the return bend it is apparent that the tube 5A, shown on the left hand side of Fig. 2, for example, tends to assume a position the axis of which is shown by the dotted line 24. It will be appreciated at this point that the slope of line 24 is exaggerated to more pointedly illustrate this displacement of the tube and not as attempting to show its precise position. Similarly, the tube 5B, due to lateral expansion of the return bends, will tend to assume a position the horizontal axis of which is indicated by the dotted line 25. It is thus apparent that while tubes 5A and 5B may be vertical and parallel when cold yet as the temperature is increased they tend to converge at the bottom and diverge at the top. It is obvious that if joints 8 and 9 are rigid a fracture would soon occur either in the tube, or in the joint, or both, to allow the tube to assume such non-vertical position at the higher temperature. Now, according to the present invention this result is avoided by establishing or providing flexible joints between the tubes and the upper return bends on the one hand, and the lower return bend on the other.

As previously explained, a curvilinear or ball and socket type of joint is established between the upper return bends and the tubes. With this type of construction lateral expansion of the upper return bend 6, as viewed in Fig. 2, tends to force such return bend to move in relation to the tube instead of, as in prior constructions, constraining the tube to take up this total expansion. Inasmuch as the joint between the upper return bend and the tube is a sector of a sphere the quality of the joint, i. e., the continuous contact between the abutting surface is not impaired by this relative movement.

As noted previously, the curvilinear contact surface is not used as a joint between the lower return bends and the lower ends of the tube. This is because the coil or tubular system as a whole must be substantially rigid. It has been found from experience that the lower joint 9 may be formed, as shown, i. e., as a simple angular joint properly cemented. As has been intimated previously, the cement employed in the joints is of prime importance in establishing and maintaining a gas-tight fit over the whole operative temperature range of the furnace. It has been found that this gas-tight fit may be secured by utilizing a cement which is relatively rigid when cold but becomes softened or plasticized at high temperatures so as to permit that relative degree of movement of the tube that the upper curvilinear bearing surface had not accommodated. It has been found that in lieu of utilizing cement that becomes plastic at high temperatures the cement may be applied in the form of a powder. It should be observed that the thickness or depth of the plastic or powder joint must be great enough to withstand the pressure of the gas in the tubular system. In this connection it should be noted that at the relatively cooler portion of the system, i. e., adjacent the inlet line 10, the pressure is highest and care must be exercised in insuring the proper depth of plastic at the joints in this area.

It is apparent that within the broad scope of the invention a number of ramified and specifically different associations of the tubes 5 and the return bends 6 and 7 may be employed. An example of such a modified form of continuous coil is shown diagrammatically in Fig. 3. As there shown, the vertically positioned pairs of tubes 50 are disposed in an offset or staggered relationship. The upper return bends 60 are positioned in a plane such that the major horizontal axis is normal to the major horizontal axis of the lower return bend 70. In this type of continuous coil the expansion of the return bends, in effect, imparts a rotational motion to the tubes and commensurately reduces angular displacement. As in the case of the structure shown in Figs. 1 and 2, the employment of a curvilinear contact surface between the upper ends of the tubes and the upper return bends, together with the employment of plastic or powder cement for the lower joint minimizes or obviates the effect of the expansion of the return bends.

As mentioned previously, the continuous coil formed by the described association of tubular elements and return bends may be connected in circuit to units located exteriorly of the furnace in a number of ways. In the structure shown in Fig. 1 the inlet pipe 10, if a separate element, is connected to the L 12 through an angular joint 14, similar to joint 9. It will be understood that a ball and socket joint at this particular location

would be undesirable because of the resulting lack of rigidity of the tubular system. It has been found that an insert joint at 14 is not as effective in retaining a pressure-tight fit as is the joint 9. This is probably due to the fact that the joint 9 tends to remain tight due to the weight of the superposed structure, namely, the weight of the tube 5 and the associated upper return bend. However, improved joints at this section of the structure may be produced by forming the tube 10 and L 12 in one piece thus completely eliminating the joint 14. There are a number of other methods of insuring a gas-tight fit at this section of the apparatus. For example, the L 12 may be replaced with a return bend and the inlet line or pipe 10 may be fitted vertically in such return bend in the same manner as the tubes, then extended vertically through the roof of the furnace. The end of the pipe 10 positioned exteriorly of the furnace may then be joined or connected to a metallic tube 19 in the manner shown in Fig. 1. Again, if desired, the L 12 may be eliminated and the first tube 5C (Fig. 1) may be extended down through the floor of the furnace and connected exteriorly of the furnace with a metallic conduit 19 in a manner equivalent to that shown in Fig. 1.

It is apparent that the modified types of connection of the inlet line or conduit 10 to the first tube are equally applicable to the connection between the last tube of the series and the outlet or discharge line 11. It is again to be noted, at this point, that the pressure exerted at the joint 15 is somewhat lower than that against joint 14 and this fact should be recalled in forming the cemented joints.

The efficacy of utilizing the principles of the invention will be more readily appreciated from a consideration of actual operations in which continuous tubular coil structures fabricated according to prior methods were directly compared with similar structures embodying the novel principles of the invention. A furnace was constructed in accordance with Fig. 1 with the exception that the joints 8, 9 and 14 were made rigid. The tubes and return bends were constructed of silicon carbide properly bonded. Air was preheated in a furnace fitted with typical metallic heating tubes and up to a temperature of 1600° F. This air was then introduced into the high temperature refractory furnace wherein the temperature was raised to 2500° F. While, as noted, the refractory furnace was brought up to the operating temperature very slowly, in conformity with good operating practice, serious leaks developed after approximately six weeks of operation and became progressively worse with continued use of the furnace. After an eight weeks' period of operation the furnace was gradually cooled and the leaks repaired by applying a cement which was basically the same material as that of which the tubes and return bends were fabricated. This repair permitted an additional six weeks of operation after which time the leaks recurred to a degree which materially impaired the operation of the furnace. The furnace could have been repaired again after such operation but the time involved in cooling, repairing and reheating the furnace was so great as to render it uneconomical.

After the described period of operation the tubes and return bends were critically examined. It was found that not only was there disruption at the joints resulting in substantial leakage but that the tubes themselves in many instances had fractured close to the joints. Thus, the air

leaked from both the impaired joints and the cracks in the tubes.

A furnace was constructed embodying the principles of the invention to establish a direct comparison with older structures. Ball and socket joints, as indicated in Fig. 2, were used between the upper end of the tubes and the upper return bends while the lower angular joints 9 were cemented using a silicon carbide base cement to a depth of 1½ inches. The cement used throughout the furnace was essentially the same differing only in a temperature at which it became plastic. As will be understood the particular cement used in any part of the furnace is dictated or established by the temperature of the air inside the tubes at the particular point where the cement is employed. The furnace embodying the novel features of the invention was brought on stream in the manner described and was operated for a period of three months without any perceptible damage to any of the tubes, return bends or L's and with but minor damage to any of the joints excepting joint 14.

The furnace was then modified in accordance with principles heretofore discussed, namely, by removing the L 12, substituting a return bend therefore and extending tube 10 vertically through the roof 3 of the furnace. It was found that in this structure the tubes, return bends and L 13 were intact and undamaged after a total period of operation of nine months while the blow holes and porosities in the joints were so small and so minor in extent that the loss of air due to leaks through the joints was not practically measurable.

While preferred modifications of the invention have been described it will be understood that these are given to illustrate the novel principles involved and not as limiting the invention to the particular design or arrangement of the several units of the coil structure shown.

I claim:

1. An apparatus for heating fluids comprising a furnace, a continuous coil within the furnace through which fluids to be heated are passed, the coil including a series of vertically positioned, refractory, ceramic tubes and a series of upper and lower refractory, ceramic return bends of different shape and cross sectional dimensions than the tubes and connected with the tubes to form a continuous coil, the coil being characterized by a spherically concave-convex joint between the upper return bends and the tubes and by an angular joint between the lower return bends and the tubes.

2. An apparatus for heating fluids comprising a furnace, a continuous coil within the furnace through which fluids to be heated are passed, the coil including a series of vertically positioned, refractory, ceramic tubes and a series of upper and lower refractory, ceramic return bends of different shapes and cross sectional dimensions than the tubes and connected with the tubes to form a continuous coil, the coil being characterized by a spherically concave-convex joint between the upper return bends and the tubes and by an angular joint between the lower return bends and the tubes, said joints being sealed with a refractory cement.

3. An apparatus for heating fluids comprising a furnace, a continuous coil within the furnace through which fluids to be heated are passed, the coil including a series of vertically positioned, refractory, ceramic tubes and a series of upper and lower refractory, ceramic return bends of different shape and cross sectional dimensions than the tubes and connected with the tubes to form a continuous coil, the coil being characterized by a spherically concave-convex joint between the upper return bends and the tubes and by an angular joint between the lower return bends and the tubes, said joints being sealed with a refractory cement which is plastic at the operating temperature of the furnace.

4. An apparatus for heating fluids comprising a furnace, a continuous coil within the furnace through which fluids to be heated are passed, the coil including a series of vertically positioned, refractory, ceramic tubes and a series of upper and lower refractory, ceramic return bends of different shape and cross sectional dimensions than the tubes and connected with the tubes to form a continuous coil, the coil being characterized by a spherically concave-convex joint between the upper return bends and the tubes and by an angular joint between the lower return bends and the tubes, said joints being sealed with a refractory cement of the same general composition as the tubes and return bends and which is plastic at the operating temperature of the furnace.

5. An apparatus for heating fluids comprising a furnace, a continuous coil within the furnace through which fluids to be heated are passed, the coil including a series of refractory, ceramic lower return bends mounted directly on the floor of the furnace, a series of upper refractory, ceramic return bends spaced from the roof of the furnace, a series of vertically positioned, refractory, ceramic tubes connecting the upper and lower return bends, the coil being characterized by a spherically concave-convex joint between the upper return bends and the tubes, means including an expansion joint to connect one end of the coil to an inlet line exteriorly of the furnace and means to connect an outlet line to the other end of the coil.

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