Nov. 11, 1952 C. KELLER 2,617,405

TUBULAR GAS HEATER, IN PARTICULAR FOR SOLID FUELS

Filed June 14, 1949 3 Sheets-Sheet 1

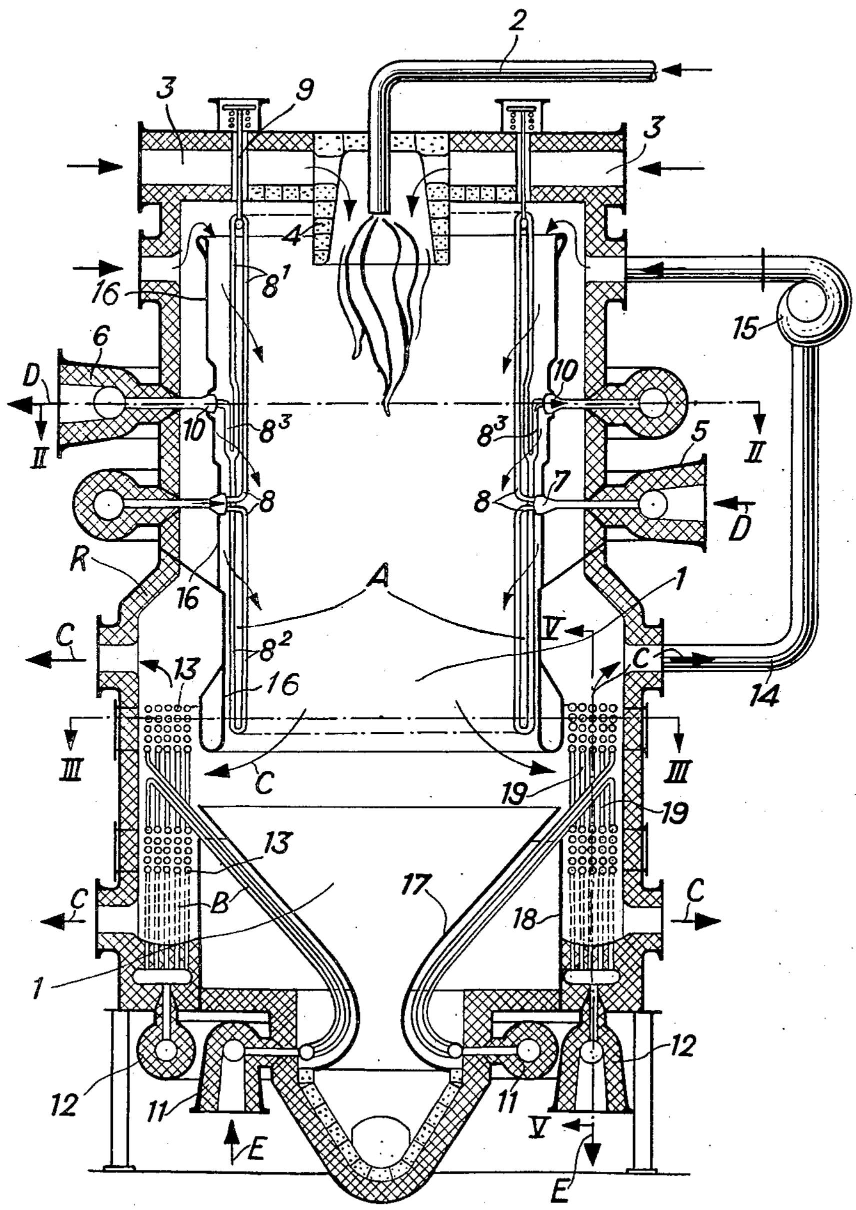

Fig. 1

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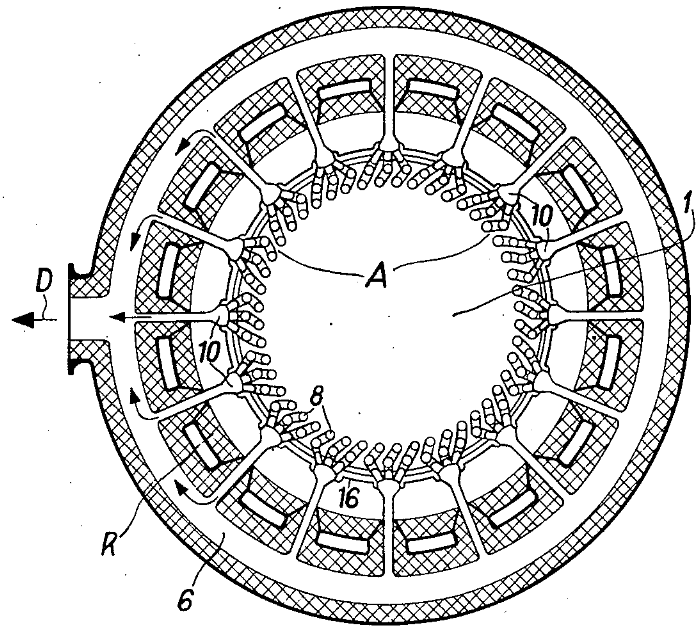

Fig. 2

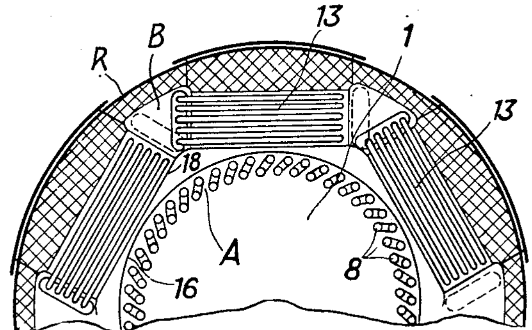

Fig. 3

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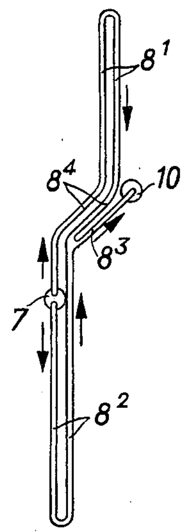

Fig. 4

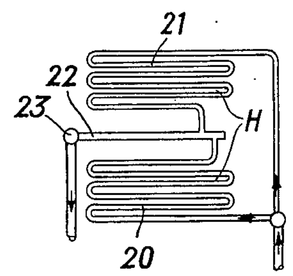

Fig. 6

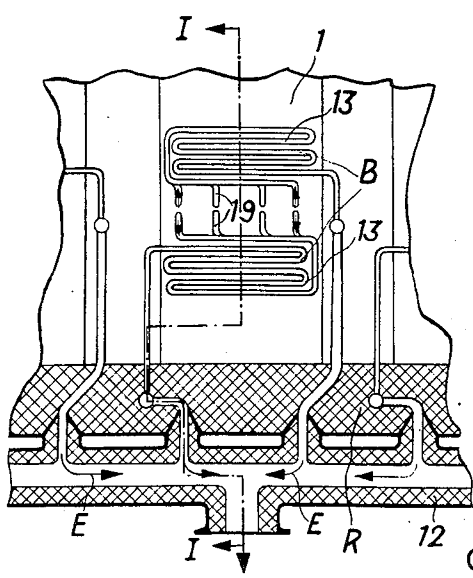

Fig. 5

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TUBULAR GAS HEATER, IN PARTICULAR FOR SOLID FUELS

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10 Claims. (Cl. 126—109)

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The invention relates to a tubular gas heater, in particular for solid fuels, having a vertical combustion chamber axis, which is primarily intended for use in gas turbine installations with an indirect heat supply, in which the working medium is twice heated at different pressures. In thermal power plants of this nature, the gaseous working medium, preferably air, is usually heated in a heating system by an indirect external heat supply after having been brought to higher pressure in at least one compressor, and is then heated a second time in a second heating system after having been partially expanded while giving up energy in at least one turbine, and is finally further expanded while giving up energy in at least one further turbine.

The object of the invention is to provide such a gas heater comprising two heating systems, which is constructed to meet the peculiarities of gaseous working media and also those of solid fuels. The peculiarities in question necessitate in some respects substantial changes in construction as compared with normal steam boiler constructions, which changes are essential as a whole to the operation of the gas heater itself and of heat power plants of the aforesaid type, of which such a heater forms a part.

In this connection, it must be borne in mind that the pressure losses in the pipes of steam power plants have only a small influence on the overall efficiency of the plant, whereas they have a substantial influence thereon in thermal power plants which are operated solely with gaseous working media. However, it is known that particularly favourable values arise with regard to the pressure losses in the heating system of tubular gas heaters if tubes of small diameter, namely of from 2 to 30 mm., and of smaller length and in correspondingly larger numbers are connected in parallel. Since such tubes in gas heaters are heated to a much higher temperature in operation than is the case in steam boilers because, as is known, the heat transfer is lower with gas than with water or steam and in addition the gaseous working medium must be brought to a higher temperature for the purpose of increasing the efficiency of the plant than the steam in normal steam boiler installations, they must be made of highly heat-resistant, that is to say alloy material, which generally has a much higher coefficient of thermal expansion than the steel usually employed in steam boilers. Consequently, many structural difficulties arise. The many short tubes of small diameter should be so arranged that the working medium is distributed

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as evenly as possible to all the tubes and that heat is transferred as equally as possible to them in order that none of these tubes, which are highly stressed under normal conditions, may be heated to higher temperature than that contemplated by the design. The admissible temperature of the material must be accurately maintained to within a few degrees. At the same time, the tubes should also be so arranged that the great expansions produced by the high temperatures and the high coefficient of thermal expansion are not transferred to parts lying outside the air heaters, for example headers, since otherwise extensive and costly constructions would be necessary in order to prevent such expansions from being transmitted to the engines. In steam power plants, in which the expansions are much smaller ab initio for the aforesaid reasons, the relatively small tube diameters employed owing to the high steam pressures and owing to the high permissible speeds, allow of taking up the expansions in bends in the tubes. However, this is impracticable in installations operated only with gaseous working medium because the tube diameters are here larger for installations of equal output and in addition such bends would entail heavy pressure losses. In order to give a clear idea of the importance of such expansions, it is mentioned, for example, that a heating tube designed for medium working conditions and having a length of 10 m., expands, from the cold condition to the operative condition in which it has a mean temperature of about 650° C., by over 100 mm. However, not only the heater tubes, but also the distributors and headers thereof must be so fashioned and arranged that they transmit as little thermal expansion as possible to other parts of the thermal power plant.

In order to heat a gaseous working medium twice at different pressures, it appears at first sight, for reasons of construction and regulation, to be obviously logical to employ a separate heater for the heating at each pressure stage. Various considerations lead to the conclusion that this is not always the best solution, since allowance must be made for the fact that frequently a heat transfer by radiation is most economical because it causes no pressure losses and may be advantageous in particular when burning solid fuels, because in order to precipitate dry ash, a great amount of heat must be extracted as rapidly as possible from the combustion gases before they come into contact with the heater tubes, while in addition the walls of the combustion chamber must be effectively cooled. Therefore, if two heaters are provided, the associated heating system in each heater would have to be disposed partly in the combustion chamber for the purpose of absorbing radiant heat, and the other part would have to be sequentially arranged, as a contact heating surface. In addition, if two heaters are provided, a correspondingly larger number of distributing pipes and headers, and in addition passes for the combustion air and the flue gases, auxiliary arrangements and the like would be required. This would lead to increased pressure and temperature losses and to increased expenditure of material. Moreover, a greater amount of space would be required for the whole installation.

In order to meet the various aforesaid requirements while avoiding the disadvantages of known constructions, in a tubular gas heater of the type referred to at the beginning, the heating of the two gas currents at different successive pressure stages takes place, in accordance with the invention, in two tubular heating systems, each of which is at least mainly arranged symmetrically around the axis of a common combustion chamber and of which one tubular system is exposed directly to the radiation from the combustion chamber and forms the boundary of one part of the combustion chamber, while the other tubular system is substantially shielded from the direct radiation heat of the combustion chamber and is heated by contact with the heating gases flowing from the combustion chamber.

An embodiment of the subject of the invention is illustrated in simplified form by way of example in the accompanying drawings, in which:

Figure 1 is a view chiefly in axial longitudinal section through a tubular gas heater having a vertical combustion chamber axis. A portion of the view is a section on the line I—I of Figure 5,

Figure 2 is a horizontal section on the line II—II of Figure 1,

Figure 3 is a horizontal section on the line III—III of Figure 1,

Figure 4 is a fragmentary view showing one tube unit of the upper tubular system.

Figure 5 is a developed vertical section on the line V—V of Figure 1.

Figure 6 shows a modification of one of the units of the lower tubular system as viewed in Fig. 5.

In the figures, 1 is the combustion chamber of a tubular gas heater R having a vertical combustion chamber axis, which is, in the example illustrated, adapted to burn solid fuel. 2 is a pipe through which pulverised fuel and primary air carrying it are fed, and 3 are channels serving to feed secondary air. The media fed through the pipe 2 are mixed with the secondary air in a burner 4, which is arranged at the top in the heater R coaxially with the longitudinal axis of the said heater.

A and B are two tubular heating systems in which a current of air is to be heated at two different pressure stages by means of an external heat supply, the heating taking place in the heating system A at the lower pressure stage and in the heating system B at the higher pressure stage. The heating system A is completely coaxial and the heating system B, at least mainly (see Figure 3) coaxial with the axis of the common combustion chamber 1. The heating system A situated above the heating system B is exclusively exposed directly to the radiation heat of the combustion chamber, and forms at the same time the boundary of the upper part of the combustion chamber 1. The heating system B, on the other hand, is substantially shielded from the direct radiation heat of the combustion chamber 1 and is heated by contact with the heating gases flowing from the said combustion chamber in the direction of the arrows C. The described arrangement of the two heating systems A and B is found to be particularly advantageous when the working medium of the thermal power plant is expanded to a lower extent in its first expansion stage than in the second, as is the case, for example, when the consumer of useful energy of the plant is coupled with the turbine of the second pressure stage. In such a case the temperature of the working medium at the point of admission to the tubular heating system B is lower than at the point of admission to the tubular heating system A, so that the lower admission temperature of the heating system B can be utilised to cool as much as possible by convection in this system the heating gases flowing in the direction of the arrows C. The arrangement illustrated, in which the tubular heating system B is provided beyond the tubular heating system A, considered with reference to the direction of flow C of the heating gases, permits the fullest possible utilisation of the heat contained in these gases.

In the illustrated embodiment, the distributor 5 and the header 6 of the tubular heating system A are arranged in juxtaposition to one another and approximately midway of the height of that part of the combustion chamber 1 which is bounded by this system. The working medium flowing through the system A in the direction of the arrows D passes from the annular chamber of the distributor 5 into tube-cluster heads 7, which are disposed coaxially with the axis of the combustion chamber. Connected to each cluster head 7 are a number of tubes 8 of small diameter, each of which comprises two parallel-connected hairpin-shaped strings 8^1 and 8^2, which extend in opposite directions but both mainly in the axial direction of the combustion chamber 1, so that they lie one above the other in a cylindrical area (see Fig. 4). Each string 8^1 is suspended from a support 9 resiliently mounted on the heater jacket. The two strings 8^1, 8^2 of each tube 8 join one another in proximity to a second cluster head 10 to form a common branch 8^3 which, as shown in Figure 4, does not extend parallel to the strings 8^1 and 8^2, but is disposed obliquely thereto, which is also the case with two lengths 8^4 (see Fig. 4) of the string 8^1. Owing to the hairpin shape of the strings 8^1, 8^2 and the oblique lengths 8^3 and 8^4 which permit outward bending, substantially no expansion occurs at the outlet end of the tubes 8 because the small relative expansion which might occur owing to unequal heating and unequal length of the strings 8^1 and 8^2 can be compensated for without difficulty by means of the aforesaid inclined lengths 8^3 and 8^4.

Owing to the fact that the two strings 8^1, 8^2 are combined to form a common branch 8^3 before being connected to the cluster heads 10 it is also possible for the two currents which flow in parallel through the strings 8^1, 8^2 to mix before entering the cluster head 10, so that the branch 8^3 takes on the mean temperature of these two currents and not the temperature of the more highly heated component current. This fact assists in increasing the operational safety of the heater, especially as the working medium is not heated to the required final temperature until it reaches the said branch 8^3.

The various cluster heads 10 are connected to the annular space in the header 6. The housing of the distributor 5, and that of the header 6, which housing serves as a pressure jacket, tapers conically towards the combustion chamber 1 and provides, in conjunction with the tubes connecting the annular spaces in the distributor 5 and in the header 6 to the cluster heads 7 and 10 respectively, a seal between the said hollow spaces and the combustion chamber 1.

A distributor 11 and a header 12 are associated with the heating system B operating at higher pressure, which is heated by contact. The direction in which the working medium flows through this system B is indicated by the arrow E. The distributor 11 and the header 12 are fashioned similarly to the corresponding parts 5 and 6 respectively of the heating system A. The heating system B also comprises a number of tube bundles sub-divided into equal sectors 13, which are individually accessible and removable and are mainly arranged coaxially with the longitudinal axis of the combustion chamber 1. As will be seen principally from Figures 3 and 5, the plurality of sectors 13 is arranged in two superposed groups which, as shown in Figure 1, are traversed by the heating gases in two streams in the direction indicated by the arrows C.

In order to protect the tubes 8 of the heating system A from contact with the flame of the burner 4, a pipe 14 and a fan 15 mounted therein are provided, which in the known mannner permit flue gases already substantially cooled to be returned into the combustion chamber 1, into which they penetrate through the gaps between the tubes 8. 16 is a sheet-metal cylinder which is mounted between the heating system A and the casing of the heater R coaxially with respect to the said system and fulfills a double purpose, namely of guiding the returned flue gases and of absorbing the radiation heat radiating to the outside between the heating tubes 8 and transmitting the said radiation heat to the rear of the heating tubes 8. Consequently, the temperature of the said heating tubes 8 is better balanced over their whole range, so that dangerous heat stresses are avoided in the tubes 8 of the heating system A. The returned, cooling flue gases also ensure at the same time the necessary cooling of the sheet-metal cylinder 16. It is advisable to make the said cylinder 16, as well as an ash chute 17, a cylindrical guide wall 18 for the heating system B and indeed as many such parts as possible of sheet metal instead of masonry, because any accumulation of heat must be avoided in gas heaters in order that the tubes may not be overheated when the thermal power plant is relieved of load, that is to say when the quantity of circulating working medium is reduced. Such overheating would be particularly dangerous when the circuit was suddenly loaded again, that is to say when the working medium was suddenly placed under full pressure again.

As in the described tubular gas heater the two tubular heating systems A and B are each arranged substantially symmetrically about the vertical axis of the combustion chamber and in addition the combustion chamber 1 is cylindrical and the heating gases are axially guided in this chamber, while the dissipation of flue gas takes place uniformly in all outward directions, the various tubes 8 and 13 of the heating systems are substantially equally heated, which is important with regard to safety of operation. Before entering the heating system B heated by convection, the heating gases are considerably diverted and mixed with the circulating gases which are introduced laterally into the top of the combustion chamber 1 and flow down substantially along the heating system A, whereby the said heating gases undergo a further rapid cooling, so that the ash is dry when it falls into the ash chute 17. To ensure separation of the ash by cooling, the flue gases are preferably allowed to flow also between walls 19 formed of vertical standing tubes.

As has been described with reference to the tubes 8 of the heating system A, the tubes of the two groups of the heating system B may also have common end pieces, in which the working medium is brought to the required final temperature. Such a construction is shown in Fig. 6 in which the tubes 20 and 21 of two groups of a heating system H have a common end piece 22 connected to a cluster head 23.

Although the advantages hereinbefore referred to are obtained primarily in tubular gas heaters of the type in which different pressures prevail in the two tubular heating systems, it is advisable also to apply the invention in cases where substantially the same pressure prevails in the two heating systems.

A gas heater according to the invention can also be designed to use liquid or gaseous fuels, or for operation at will with solid, liquid and gaseous fuels, just as is the case with pulverised-coal fired steam boilers which also can be operated with gas or oil burners.

What is claimed is:

1. A tubular gas heater primarily intended for use in gas turbine installations in which the working medium is twice heated at different pressures, comprising in combination, a furnace structure enclosing a vertical generally cylindrical chamber at least a portion of which, adjacent one end of said chamber, serves as a combustion zone, said furnace structure also defining lateral offtake passages adjacent the other end of said chamber for the escape of combustion gases; means operatively associated with said one end of said chamber for causing combustion in said combustion zone; two tubular heating systems for the passage of gas to be heated, said systems being arranged one above the other within said chamber, and each including tube units arranged symmetrically about the axis of said chamber, one of said heating systems surrounding said combustion zone whereby it is exposed directly to the radiant heat of combustion, said system itself forming a part of the boundary of said combustion zone, while the other of said heating systems is displaced from the combustion zone in the direction of the axis of the chamber; distinct supply and discharge connections for the flow of gas to and from each of said systems; and baffling means interposed between the combustion zone and said other of said systems, serving to protect the latter from radiant heat from said zone and including an annular partition which defines between itself and the enclosing wall of said cylindrical chamber a flow path within said chamber and leading to said offtakes in which path at least a portion of said second tubular system is located, whereby the off-flowing products of combustion flow in heat exchanging contact with said other tubular system.

2. A tubular gas heater primarily intended for use in gas turbine installations in which the working medium is twice heated at different pres-

sures, comprising in combination, a furnace structure enclosing a vertical generally cylindrical chamber, at least a portion of which, adjacent one end of said chamber, serves as a combustion zone, said furnace structure also defining lateral offtake passages adjacent the other end of said chamber for the escape of combustion gases; means operatively associated with said one end of said chamber for causing combustion in the combustion zone within said chamber; a tubular heating system designed for the passage of gases to be heated at the lower of said different pressures, said system comprising inlet and discharge connections and a plurality of substantially identical units arranged symmetrically around the axis of said chamber and said combustion zone and each comprising a pendant hairpin loop and an upstanding hairpin loop connected in parallel between said inlet and discharge connections; suspending means for sustaining said upstanding loops; a second tubular heating system designed for the passage of gas to be heated at the higher of said two different pressures, the last named system including inlet and discharge connections and being offset from the first in the direction of the axis of said chamber; and baffling means interposed between the combustion zone and the second named tubular system serving to protect the latter from radiant heat from said zone and including an annular partition which defines between itself and the enclosing wall of said cylindrical chamber a flow path within said chamber in which path at least a portion of said second tubular system is located, whereby the products of combustion flow to said offtakes in heat exchanging relation with the tubes of said second system.

3. The combination defined in claim 2 in which the tubes of the first unit include lateral offset portions between the pendant and the upwardly extending hairpin loops and extending between similar reverse bends in the tubes of respective loops and the inlet and discharge connections to which the loops are connected in parallel are located each in proximity to respective ones of said bends.

4. A tubular gas heater primarily intended for use in gas turbine installations in which the working medium is twice heated while at different pressures, comprising in combination, a furnace structure enclosing a vertical generally cylindrical chamber, the upper portion of which serves as a combustion zone, said furnace structure also defining lateral offtakes leading from the lower portion of said chamber for the escape of combustion gases; means operatively associated with the upper end of said chamber for causing combustion within said combustion zone; two tubular heating systems for the passage of gas to be heated, one of said systems being arranged in the upper portion of said chamber and including tube units arranged symmetrically about the axis of said chamber and surrounding said combustion zone whereby it is exposed directly to the radiant heat of combustion, said system forming a part of the boundary of said combustion zone; another heating system located symmetrically about the axis of the lower portion of said chamber and below the combustion zone; supply and discharge connections for the flow of gas to and from each of said systems; and baffling means interposed between the combustion zone and the second named system serving to protect the latter from radiant heat from said zone and including an annular partition which defines between itself and the enclosing wall of said cylindrical chamber a flow path within the chamber in which path at least a portion of said second tubular system is located, whereby products of combustion flow to said offtakes in heat exchanging contact with the second named tubular system.

5. A tubular gas heater primarily intended for use in gas turbine installations in which the working medium is twice heated at different pressures, comprising in combination, a furnace structure enclosing a vertical generally cylindrical chamber, at least a portion of which serves as a combustion zone, said furnace structure also defining lateral offtake passages displaced from said zone toward an end of said chamber and arranged for the escape of combustion gases; means operatively associated with an end of said chamber for causing combustion within said combustion zone; a plurality of tube bundles arranged to surround said combustion zone whereby they are exposed directly to radiant heat of combustion, each of said bundles being composed of pairs of oppositely extending hairpin loops approximately parallel with the axis of said chamber; parallel flow connections for said hairpin loops comprising a distributor and a collector which encircle said chamber and are connected with said loops; a second tubular heating system offset from said combustion zone in the direction of the axis of said chamber and arranged approximately symmetrically about said axis in a zone near the cylindrical wall of the chamber and lying between the combustion zone and said offtakes; baffles within the chamber interposed between the second tubular heating system and said combustion zone protecting the latter from radiant heat from said zone and including an annular partition which defines between itself and the wall of said chamber, a passage through which off-flowing products of combustion flow in heat exchange contact with the tubes of said second system, said system being located at least in part in said passage; and inlet and discharge connections for said second tubular system.

6. The combination defined in claim 5 in which the two hairpin loops of a pair extend one up and the other down from their connections with said distributor and collector and each is bent adjacent a corresponding connection, said bends being in relatively reverse directions, whereby the loops of a pair are laterally offset; and yieldable suspender means are provided for supporting the upper end of the upward extending hairpin loop.

7. A tubular gas heater primarily intended for use in gas turbine installations in which the working medium is twice heated at different pressures, comprising in combination, a furnace structure enclosing a vertical generally cylindrical chamber, at least a portion of which serves as a combustion zone, said furnace structure also defining lateral offtake passages displaced from said zone toward an end of said chamber and arranged for the escape of combustion gases; means operatively associated with said chamber for causing combustion in said combustion zone; two tubular heating systems for the passage of gas to be heated, said systems being arranged one above the other within said chamber, and each including tube units arranged symmetrically about the axis of said chamber, one of said heating systems surrounding said combustion zone whereby it is exposed directly to the radiant heat of combustion, said system including separate inlet and discharge connections and forming a

part of the boundary of said combustion zone, the other of said heating systems being displaced from the combustion zone in the direction of the axis of the chamber and lying between said zone and said offtakes, said other heating system being sub-divided into substantially equal sectors each of which includes a distributor and a header whereby each may be connected or disconnected as a unit; and baffling means interposed between the combustion zone and said other of said systems, protecting the latter from radiant heat from said zone and including an annular partition which defines between itself and the enclosing wall of said cylindrical chamber a flow path within said chamber and leading to said offtakes, in which path the off-flowing products of combustion flow in heat exchanging contact with said other tubular system, said system being located, at least in part, in said flow path.

8. A tubular gas heater primarily intended for use in gas turbine installations in which the working medium is twice heated at different pressures, comprising in combination, a furnace structure enclosing a vertical generally cylindrical chamber, at least a portion of which serves as a combustion zone, said furnace structure also defining lateral offtake passages displaced from said zone toward an end of said chamber and arranged for the escape of combustion gases; means operatively associated with said chamber for causing combustion in said combustion zone; two tubular heating systems for the passage of gas to be heated, said systems being arranged one above the other within said chamber, and each including tube units arranged symmetrically about the axis of said chamber, one of said heating systems surrounding said combustion zone whereby it is exposed directly to the radiant heat of combustion, said system having its own inlet and discharge connections and forming a part of the boundary of said combustion zone, the other of said heating systems being displaced from the combustion zone in the same direction as are said offtakes but by a less distance, said second heating system being sub-divided into substantially equal sectors each of which comprises two superposed groups of tubes with a distributor and a header common to the two groups whereby connection and disconnection of the sectors as units is rendered practicable; and baffling means interposed between the combustion zone and said other of said systems, protecting the latter from radiant heat from said zone and including an annular partition which defines between itself and the enclosing wall of said cylindrical chamber a flow path within said chamber and leading to said offtakes in which path the off-flowing products of combustion flow in heat exchanging contact with said other tubular system, said system being located, at last in part, in said flow path.

9. A tubular gas heater primarily intended for use in gas turbine installations in which the working medium is twice heated at different pressures, comprising in combination, a furnace structure enclosing a vertical generally cylindrical chamber, at least a portion of which serves as a combustion zone, said furnace structure also defining lateral offtake passages displaced from said zone toward an end of said chamber and arranged for the escape of combustion gases; means operatively associated with said chamber for causing combustion in the combustion zone within said chamber; a tubular heating system designed for the passage of gases to be heated at the lower of said different pressures, said system comprising inlet and discharge connections and a plurality of substantially identical units arranged symmetrically around the axis of said chamber and said combustion zone and each such unit comprising at least one pendant hairpin loop and at least one upstanding hairpin loop connected in parallel between said inlet and discharge connections; suspending means for sustaining said upstanding loops; a sheet-metal envelope encircling said tubular heating system and spaced from it and from the wall of said cylindrical chamber and terminating short of the ends of said cylindrical chamber; a second tubular heating system designed for the passage of gas to be heated at the higher of said two different pressures, the last named system being offset from the first in the same direction as are said offtakes but by a less distance, said system being sub-divided into portions displaced from one another in the direction of the axis of the chamber; circulating means for passing products of combustion in contact with one of said portions and then past one end of the envelope to the space between said envelope and the walls of said chamber; and baffling means interposed between the second of said portions and said combustion zone and serving to intercept radiant heat from said zone, said baffling means including an annular partition which defines between itself and the enclosing wall of said cylindrical chamber a second flow path within said chamber through which products of combustion flow to said offtakes in heat exchanging relation with the second portion of said second system, said second system being located, at least in part, in said second flow path.

10. The combination defined in claim 9 in which the first tubular system extends beyond the other end of said envelope whereby combustion products delivered by said circularing means tend to flow around the end of the envelop and then in contact with tubes of the first system.

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