VAPOR GENERATOR

Filed March 4, 1966 2 Sheets-Sheet 1

FIG. 1

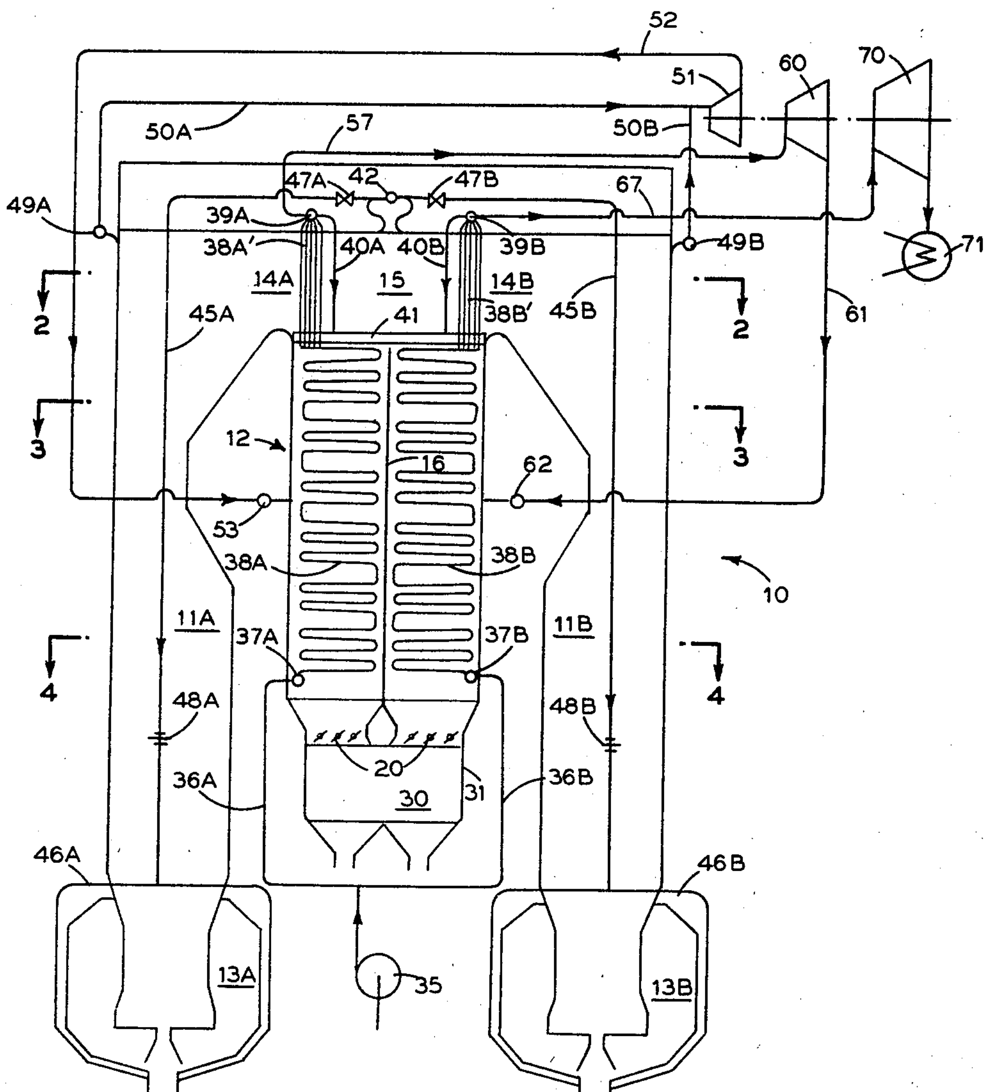

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FIG. 2

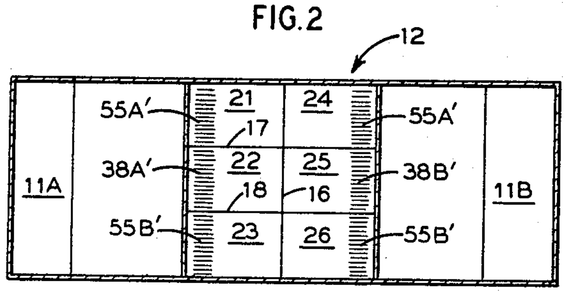


FIG. 3

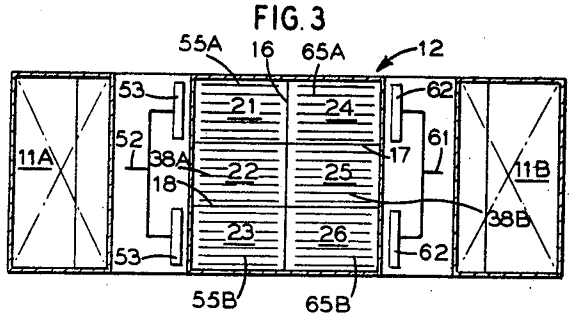
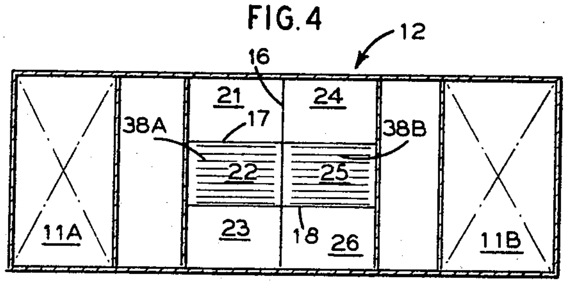


FIG. 4



3,396,705 VAPOR GENERATOR

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ABSTRACT OF THE DISCLOSURE

A vapor generator having plural independently operable combustion chambers each having an associated radiation chamber which discharges combustion gases into a common plenum chamber from which the gases are directed to and through a convection pass that is divided into a plurality of parallel-flow convection gas passages provided with individual dampers for regulating the gas flow through each. The heating surface of the vapor generator is so arranged that the combustion and radiation chamber walls are lined with evaporator and high pressure superheater surface, and the convection pass contains economizer and reheater surface sections located within respectively separate gas passages.

This invention relates generally to vapor generators and more particularly to a once through high capacity vapor generator having multiple, independently operable combustion chambers and employing one or more stages of vapor reheat.

Combustion chambers for vapor generators are generally designed to operate most effectively at their maximum or rated capacities. Moreover, it is known that at capacities significantly below the rated capacity, the operation of combustion chambers becomes difficult due to ignition stability problems. Also, in those chambers from which ash is withdrawn in the form of molten slag, low load operation is particularly troublesome because of the difficulties in maintaining the ash in a molten state. To overcome these difficulties, it has become common practice to provide multiple, independently operable combustion chambers so that, as the load on the steam generator decreases, one or more of the combustion chambers can be shut down in order that the remaining chambers can be operated at or near their rated capacity.

Although the use of such plural combustion chambers may solve the combustion problems associated with low load operation, when one or more of the combustion chambers is not operating, the outlet vapor temperature of the unit may be adversely affected. This tendency for steam temperature to drop will be particularly prevalent in units designed with single or multiple stages of reheat because, during partial or low load conditions, the steam expands more in the turbines than at full load. Thus, at partial or low load conditions steam enters the reheater sections at lower enthalpy conditions than would exist at full load.

The regulation of reheat steam temperatures at reduced load conditions is further aggravated by the known fact that, in for example a steam cycle employing two stages of reheat, in order to maintain constant reheat steam temperature at reduced loads, the first (high pressure) reheater requires a greater percentage of the total heat absorption than does the second (low pressure) reheater.

It is the object of the present invention to provide a vapor generator employing one or more stages of reheat and having its heating surfaces arranged to substantially overcome the above discussed adverse effects normally attendant with partial or low load operation.

According to the present invention there is provided

a once-through vapor generator having a plurality of separate, independently operable combustion chambers, each of which is associated with a corresponding furnace or radiation chamber into which hot combustion gases are discharged. The plural radiation chambers are arranged to discharge the gases into a common plenum or mixing chamber from which the gases are directed to and through a convection pass which is divided into a plurality of parallel-flow convection gas passages through which heating gas flow can be individually regulated by dampers. The arrangement of heating surface in this vapor generator is such that the walls of the combustion and radiation chambers are lined with evaporator and high pressure superheater surface. The heating surfaces in the hotter portion of the convection pass are primarily reheat surface, while the remaining surfaces in the convection pass are economizer surfaces. The desired degree of reheat temperature control may be obtained by dividing the convection pass into a plurality of passages equal in number to two plus twice the number of reheat stages, so as to provide a pair of passages in which are disposed the economizer surface, and a separate pair of passages for the heating surface of each of the reheat stages. In the preferred arrangement the convection pass is divided by a center division wall into two compartments, each of which is further subdivided by walls into three smaller parallel-flow gas passages. The two center passages preferably contain the economizer heating surface throughout their full length, the two passages on one side of the economizer contain the first or high pressure stage reheater surface, and the remaining two passages on the other side contain the second or low pressure stage reheater surface. With this preferred arrangement of heating surface in the convection pass, it is possible, by manipulation of the individual convection pass dampers, to regulate the gas flow through the various passages and thereby adjust reheat steam temperatures so that they are maintained relatively constant over a substantially greater load range than has heretofore been possible.

For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the following description which refers to the accompanying drawings in which FIG. 1 is a schematicized sectional side view of a vapor generator according to the present invention and its incorporation into a multiple stage reheat steam cycle; FIG. 2 is a sectional view taken along line 2—2 of FIG. 1; FIG. 3 is a sectional view taken along line 3—3 of FIG. 1; and FIG. 4 is a sectional view taken along line 4—4 of FIG. 1.

Referring to the drawings, there is shown a vapor generator **10** which includes a pair of spaced, upright radiation chambers **11A** and **11B** between which is disposed a common upright convection pass **12**. Connected with the lower ends of the radiation chambers **11A**, **11B** are corresponding associated combustion chambers **13A** and **13B** which are independently operable and to which fuel and air are supplied for combustion and generation of hot gaseous combustion products. The upper ends of the radiation chambers **11A**, **11B** are formed on their opposing sides with gas outlets **14A** and **14B** which lead to the gas mixing chamber **15** disposed above and communicating with the convection pass **12**.

As shown, the convection pass **12** is transversely subdivided by division wall **16** into a pair of equal sized compartments, each of which is further subdivided by walls **17** and **18** positioned at right angles to the division wall **16** so as to form six parallel-flow gas passages **21**, **22**, **23**, **24**, **25** and **26**, all of which communicate at their upper ends with the mixing chamber **15**. Dampers **20** are disposed at the lower ends of the gas passages so that gas flow through the individual passages can be apportioned and regulated. A collection chamber **30**, communicating with the lower ends of all of the gas passages, is provided at the bottom of the convection pass 12 and connects with a laterally extending duct 31 leading eventually to an exhaust stack (not shown) through which the cooled combustion gases are discharged into the atmosphere.

Feedwater discharged from a pump 35 flows through parallel supply lines 36A and 36B to the economizer inlet headers 37A and 37B and thence upwardly through the tubular economizer sections 38A and 38B which are respectively disposed within the entire height of the two central gas passages 22 and 25. At the upper end of the convection passages 22 and 25, upwardly extending portions 38A′ and 38B′ of the tubes of economizer sections form the central portions of radiation screens which shield the mixing chamber 15 from radiation from gases in the radiation chambers 11A and 11B. The heated feedwater flowing upwardly through the economizer screen tubes 38A′ and 38B′ is collected in the economizer outlet headers 39A and 39B and then flows in parallel downwardly through lines 40A and 40B to the header 41 from which the heated feedwater is passed through tubular elements (not shown) lining the walls and roof the mixing chamber 15 and is eventually collected in header 42. At this point the heated feedwater, which is now approaching the saturation condition is passed via the parallel supply lines 45A and 45B to fluid distribution systems (shown generally at 46A and 46B) which supply the heated fluid to the water walls lining the combustion chambers 13A, 13B and the radiation chambers 11A, 11B. Disposed respectively within the supply lines 45A and 45B are valves 47A and 47B and fluid meters 48A and 48B which provide for the metering and control of the fluid supply to the plural combustion chambers 13A and 13B. The fluid then flows upwardly through the walls of the combustion and radiation chambers and absorbs heat from the gaseous combustion products therein. It should be noted that the radiation and combustion chambers contain a major portion of the vapor generating heating surface, and substantially all of the high pressure superheating surface. The highly superheated steam is collected in superheater outlet headers 49A and 49B at the top of the radiation chambers 11A, 11B and passes via lines 50A and 50B to the high pressure steam turbine 51.

From the exhaust of the turbine 51, the expanded steam passes via line 52 to the high pressure (first stage) reheat inlet header 53 and through the high pressure tubular reheater sections 55A and 55B disposed respectively in the upper portions of gas flow passages 21 and 23. Upwardly extending portions 55A′ and 55B′ of the reheater tubes (along with the tube portions 38A′ of the economizer) form a radiation screen separating the radiation chamber 11A from the mixing chamber 15. The reheater steam is collected in a high pressure reheater outlet header (not shown) and passes via line 57 to the high pressure reheat turbine 60. From the exhaust of the turbine 60, the expanded steam passes via line 61 to the low pressure (second stage) reheat inlet header 62 and through the low pressure tubular reheater sections 65A and 65B disposed respectively in the upper portions of gas flow passages 24 and 26. Upwardly extending portions 55A′ and 55B′ of the reheater tubes (along with the tube portions 38B′ of the economizer) form a radiation screen separating the radiation chamber 11B from the mixing chamber 15. The reheated steam is collected in low pressure reheater outlet header (not shown) and passes via line 67 to the low pressure reheat turbine 70, after which the exhaust steam is passed into the condenser 71 for eventual recycling to the vapor generator 10.

When firing crushed or pulverized coal in the combustion chambers 13A, 13B, the average full-load gas temperature entering the radiation chambers 11A, 11B is about 2300° F. It is known that the characteristic of a radiant superheater is such that steam temperature does not decrease appreciably with load changes in the upper half of the load range. Accordingly, since substantially all of the superheater heating surface is disposed in the radiation chambers 11A, 11B, there will be only a slight decrease in superheat steam temperature over the upper half of the load range of either of the chambers 11A, 11B. However, since the reheaters consist almost wholly of convection heating surface, load decreases normally would be accompanied by a siginficant decrease in outlet reheat steam temperature. This effect can, however, be overcome by regulating the gas flow through the various passages of the convection pass 12 in such a manner that the reheater heating surfaces are provided with sufficiently high temperature heating gases to obtain the desired reheat temperatures.

By way of nonlimiting example and to demonstrate the operability of the above described unit, it will be assumed that the load on the vapor generator 10 has been reduced to 50%. It should be recognized that, at this reduced load, most vapor generators experience considerable problems both as to combustion conditions (e.g. combustion stability and fluidity of molten ash) and as to maintaining of superheat and reheat steam temperatures. To overcome these problems, at the 50% load point, one of the combustion chambers and its associated radiation chamber (say 13A and 11A) would be shut off, and the other (13B, 11B) would then be operated at their full load combustion conditions, thereby eliminating any combustion-side problems. By means of valve 47A, the flow of fluid to the chambers 13A, 11A via line 45A would be substantially eliminated so that practically the entire fluid flow would be delivered to chambers 13B, 11B via line 45B. Under these conditions the steam temperature from the radiant superheater disposed in the radiation chamber 11B would be essentially the same as under full load conditions. In passing through the turbine 51, however, the steam would expand to a greater degree than at full load due to the decerased volume of flow, so that the steam delivered to the first stage reheater would be at a subnormal enthalpy. Similarly, because of greater expansion of steam in the high pressure reheat turbine 60, steam delivered to the second stage reheater would be at a subnormal enthalpy. In order to maintain reheat temperatures at or near their full load levels, as a base adjustment the gas flow through one each of the passages in which the economizer, the high pressure reheater, and the low pressure reheater are disposed would be cut off. (Assume that gas flow is cut off through passages 22, 23 and 24.) In order to further adjust reheat steam temperatures, the flow through remaining passages could be varied. For example, the flow to both of the reheaters 55A and 65B (and passages 21 and 26) could be increased by decreasing gas flow through the remaining economizer passage 25. Further, the heat absorption balance between the first and second reheat stages could be adjusted by manipulation of the dampers 20 associated with passages 21 and 26 in order to provide the greater proportion of heat absorption necessary to maintain the reheat temperature in the first or high pressure stage.

From the above, it will be appreciated that various adjustments can be made as to the apportionment of gas flow among the passages of the convection pass 12 in order to maintain temperature conditions at various load levels. Of course, the particular adjustments required will depend to a great degree on the particular unit characteristics and the conditions prevalent during operation.

The arrangement of the mixing chamber 15 is particularly well adapted for use in conjunction with the above described subdivided convection pass 12 since it affords a means whereby the outflow from the radiation chambers 11A, 11B is thoroughly mixed so as to provide uniformity of gas temperature entering the passages of the convection pass 12. The tubular screens at either side of the mixing chamber 15 act as flow guides for the gas entering the chamber 15, and when one of the radiation chambers is shut down, the screen serves to shield the inoperative radiation chamber from absorption of radiant heat in the gases discharging from the operative radiation chamber.

What is claimed is:

1. A vapor generator for use in a vapor cycle employing at least one reheat stage, said vapor generator comprising means forming a plurality of separate independently operable combustion chambers, means forming a plurality of radiation chambers, each of which is separately connected with a corresponding one of said combustion chambers for the flow of gaseous combustion products therefrom, means forming an upright convection gas pass connected at its one end in gas flow communication with all of said radiation chambers, means dividing said convection gas pass into a plurality of parallel flow gas passages, damper means disposed at the opposite end of said gas pass to individually regulate the flow of gas through each of said passages, vapor generating heating surface disposed entirely within said combustion chambers and said radiation chambers, high pressure vapor superheating surface disposed entirely within said radiation chambers, tubular economizer heating surface arranged within at least one of said gas passages, and tubular reheating surface arranged within at least one other of said gas passages not occupied by any economizer heating surface.

2. A vapor generator according to claim 1 wherein said reheating surface includes a high pressure reheater section and a low pressure reheater section, each of which is arranged within at least one of said gas passages.

3. A vapor generator according to claim 2 wherein said convection pass is divided into a plurality of passages equal in number to two plus twice the number of reheat stages.

4. A vapor generator according to claim 3 wherein said convection pass is divided into six passages, two of which are occupied by economizer surface, two of which are occupied by high pressure reheater surface, and two of which are occupied by low pressure reheater surface.

5. A vapor generator according to claim 1 wherein means are provided for apportioning the flow of fluid from the economizer heating surface among the plural combustion and radiation chambers.

6. A vapor generator according to claim 1 further including walls defining a gas mixing chamber at said one end of said convection pass communicating with all of said radiation chambers and all of said passages.

7. A vapor generator according to claim 6 wherein the mixing chamber walls are cooled by tubes serially connected for fluid flow with the economizer heating surface.

8. A vapor generator according to claim 6 wherein screen tubes formed by extensions of the heating surfaces in said convection pass are disposed between said radiation chambers and said gas mixing chamber.

9. A vapor generator according to claim 8 wherein said convection pass is divided into a plurality of passages equal in number to two plus twice the number of reheat stages.

10. A vapor generator according to claim 6 wherein said plurality of radiation chambers includes a pair of spaced upright radiation chambers, and said convection pass is disposed between said radiation chambers, whereby combustion gas is generated and each of said combustion chambers flow in an inverted U-shaped path upwardly through a radiation chamber and then through said mixing chamber and downwardly through said convection pass, and means are provided for apportioning the flow of fluid from the economizer heating surface among said pair of radiation chambers.

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CHARLES J. MYHRE, *Primary Examiner.*