

June 2, 1964

V. Z. CARACRISTI

3,135,244

VAPOR GENERATOR

Filed July 27, 1961

4 Sheets-Sheet 1

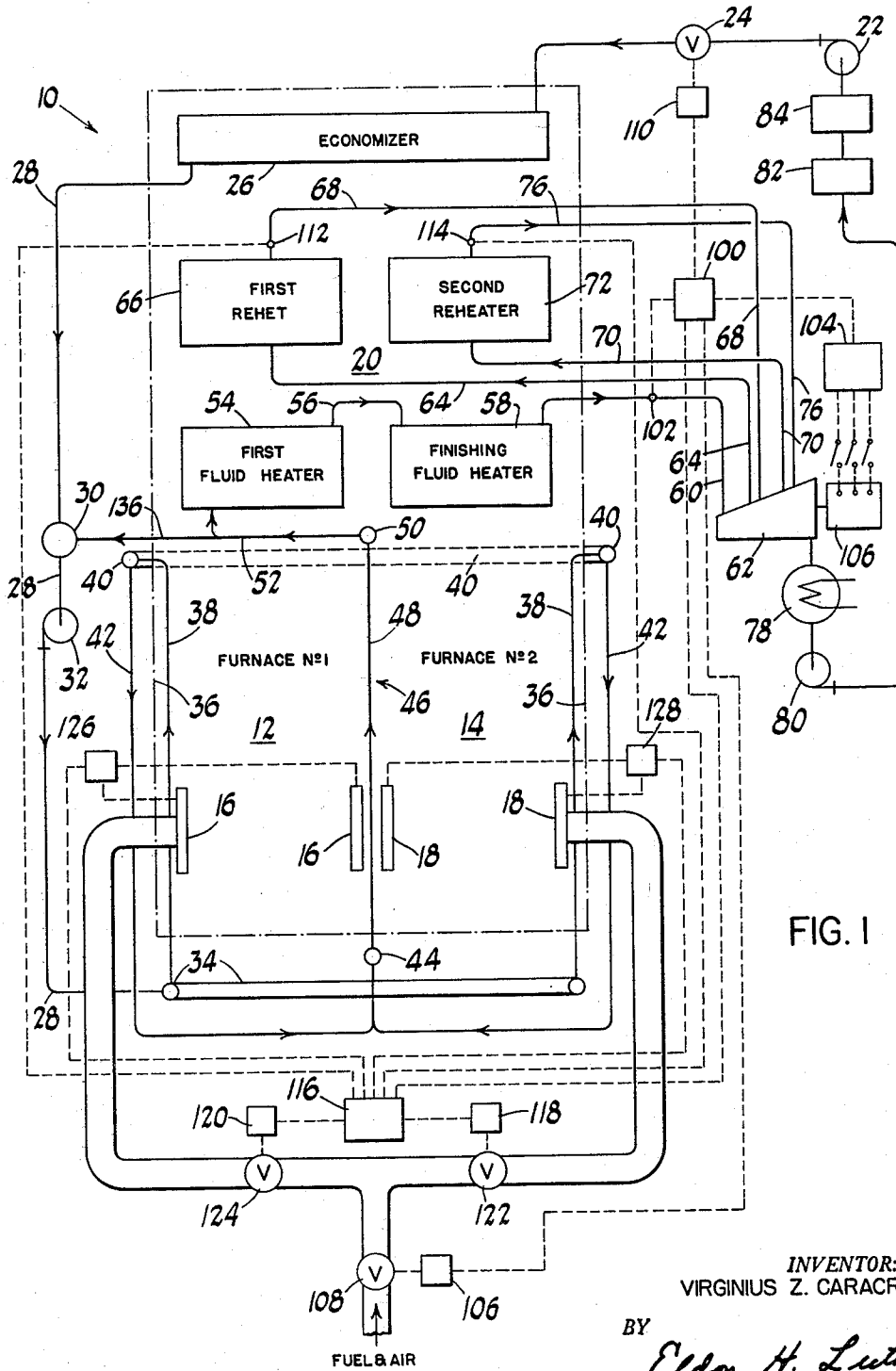


FIG. 1

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4 Sheets-Sheet 2

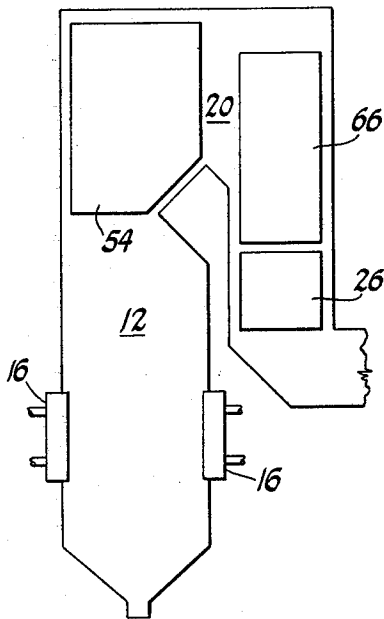


FIG. 5

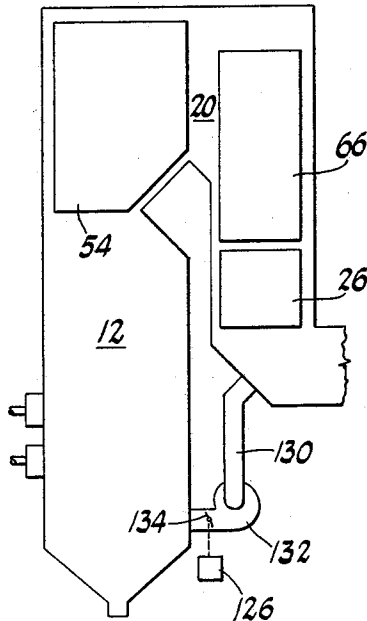


FIG. 6

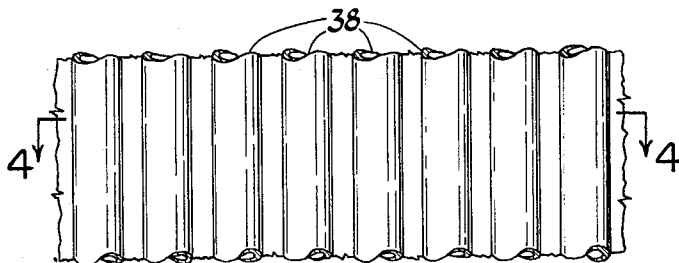


FIG. 3

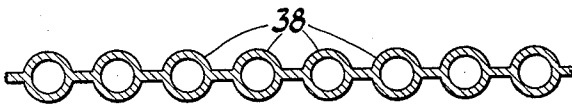


FIG. 4

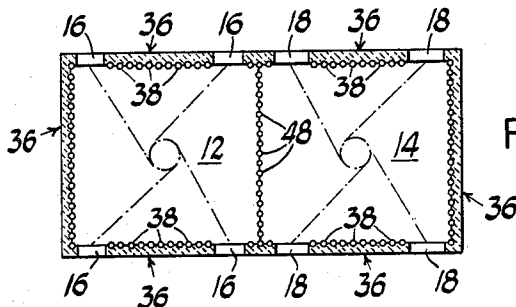


FIG. 2

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4 Sheets-Sheet 3

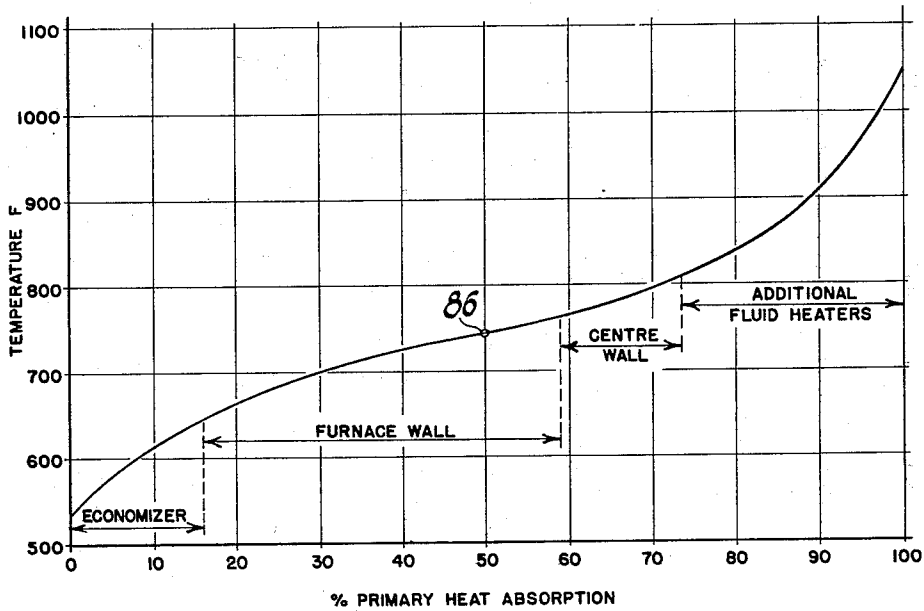


FIG. 7

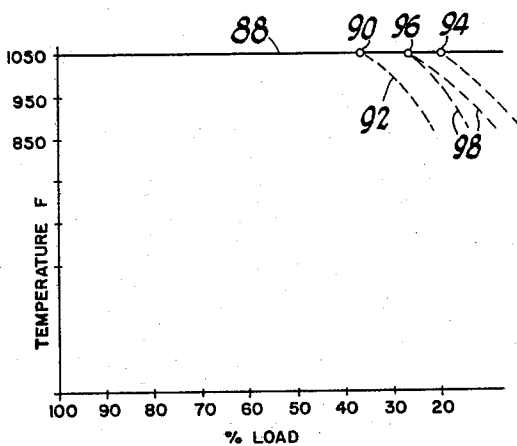


FIG. 8

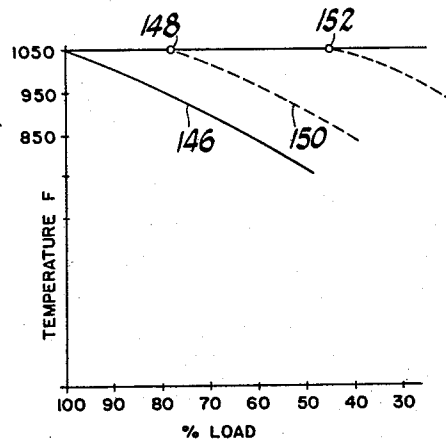


FIG. 10

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4 Sheets-Sheet 4

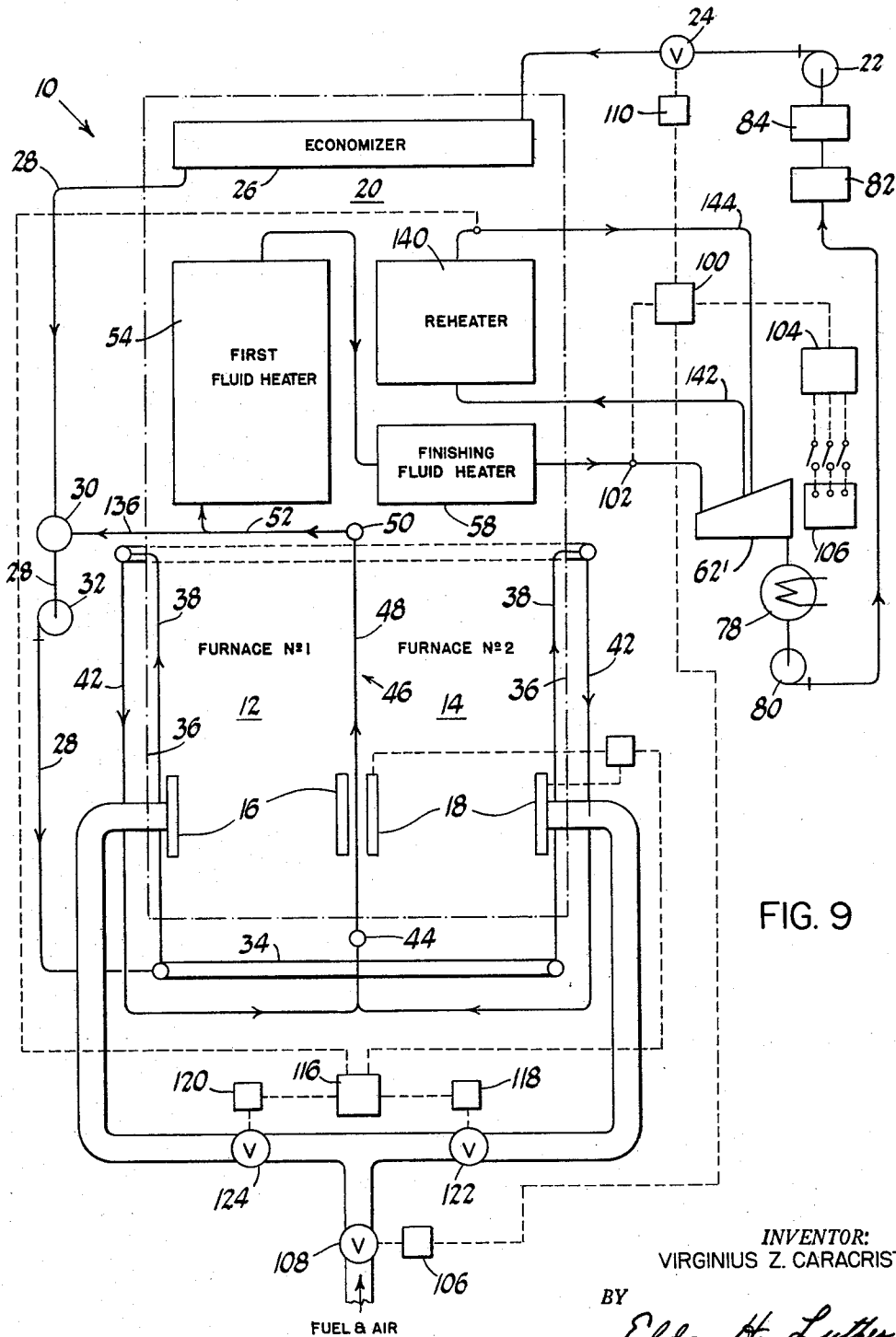


FIG. 9

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3,135,244

VAPOR GENERATOR

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Filed July 27, 1961, Ser. No. 127,173

21 Claims. (Cl. 122-240)

This invention relates to high pressure, high temperature vapor generators and has particular relation to such generators operating at supercritical pressure.

The invention is concerned with such generators having a pair of furnaces with independently controlled firing rates and from which extend a gas pass that contains various heat exchange sections. The furnaces are separated by means of a common division wall and the outer walls of each furnace are lined with heat exchange tubes while the partition wall is comprised of tubes in generally side-by-side relation. The supercritical vapor generator has a through-flow circuit and the furnace wall tubes and partition wall tubes form a part of this circuit with the arrangement being such as to provide minimum temperature differentials transversely of the furnace walls while permitting the two furnaces to be fired in a biased manner, i.e., fired at different rates. This bias firing may be originally designed into the unit with one furnace having a greater capacity than the other or it may be a controlled rate bias for the purpose of extending the control range over which the reheat temperature of the generator may be maintained at its desired value.

In accordance with the invention a supercritical vapor generator is provided wherein the primary fluid or working medium is first passed through an economizer and is thereafter passed through tubular members which line the outer walls of each of the furnaces with the through-flow being directed in parallel flow relation through these tube members. After thus passing through the outer wall tube members the through-flow is then directed through the center or partition wall and from this wall through additional heat exchange surface disposed in the gas pass means extending from the furnaces. The vapor generator is operated on the reheat cycle, having a single reheat in one modification and a double reheat in another modification, and the respective reheats are disposed so that they are in the gas streams issuing from the furnaces with each reheat being subjected primarily to the heating influence of the gases produced in one of the furnaces.

By directing the through-flow first through the outer furnace wall tubes and then through the center furnace wall tubes the most favorable conditions are obtained with regard to providing minimum temperature differentials transversely of the furnace walls. This is due to the characteristics of the supercritical fluid. The specific heat of the supercritical fluid is the greatest at the transition point and adjacent to this point. This means that in this region a large change in the heat absorption of the fluid results in a relatively small change in the temperature. By arranging the through-flow circuit as aforesaid, i.e., the outer furnace walls upstream of the center or partition wall, in the organization of the invention the transition zone will lie in the furnace wall tubes and will be nearer the outlet of these tubes than would be the case if the through-flow passed first through the center wall and then through the outer wall tubes. This has the effect of permitting bias firing to be employed with the center wall arrangement without developing large temperature differentials transversely of the outer furnace walls which would in turn greatly complicate the support of these walls, particularly in a welded wall construction, and result in producing excessive stresses.

With the arrangement of the invention bias firing may

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not only be designed into the unit originally, with one furnace having a greater capacity than another, but in addition to or in lieu of this an extension of the reheat control may be provided by varying the relative firing rates of the two units with load changes. This reheat control may supplement other reheat control actions and provide an extension of the load range over which the reheat temperature may be retained at its desired value.

Accordingly, it is an object of this invention to provide an improved vapor generator operating at supercritical pressure and of the divided furnace design employing a partition wall separating the two furnaces.

Other and further objects of the invention will become apparent to those skilled in the art as the description proceeds.

With the aforementioned objects in view, the invention comprises an arrangement, construction and combination of the elements of the inventive organization in such a manner as to attain the results desired as hereinafter more particularly set forth in the following detailed description of an illustrative embodiment, said embodiment being shown by the accompanying drawing wherein:

FIG. 1 is a schematic representation in the nature of a flow sheet illustrating a vapor generator organized in accordance with the invention and operating on the double reheat cycle;

FIG. 2 represents a transverse sectional view through the furnaces of the generator of FIG. 1 and discloses the configuration of the furnaces showing the tubular division wall separating them;

FIG. 3 is a fragmentary elevational view of a portion of one of the walls of the furnaces in FIG. 2 showing that the tubes are vertically arranged in side-by-side relation and are welded together;

FIG. 4 is a sectional view taken generally along line 4-4 of FIG. 3;

FIG. 5 is a diagrammatic view in the nature of a vertical section from front to back of one of the furnaces and associated gas pass of FIG. 1 and shows the general configuration thereof and the general disposition of the heating surface therein;

FIG. 6 is a view similar to that of FIG. 5 but showing a modified control arrangement with FIG. 5 illustrating a tilting burner facility while FIG. 6 provides a gas recirculation type of control;

FIG. 7 is a graph or curve which represents the percent of heat absorption in the through-flow circuit of the supercritical vapor generator plotted against the temperature of the through-flow as it passes through this circuit;

FIG. 8 is a curve which graphically illustrates the extension of the range over which the reheat temperature may be controlled by means of bias firing;

FIG. 9 is a schematic representation in the same general nature as that of FIG. 1 but illustrates a vapor generator operating on the single reheat rather than the double reheat cycle; and

FIG. 10 is a curve illustrating the extension of the control range that is obtainable with bias firing employed in the FIG. 9 organization.

Referring now to the drawings, wherein like reference characters are used throughout to designate like elements, the illustrative and preferred embodiment of the invention depicted therein includes a vapor generator designated generally 10 and comprising a pair of furnaces identified as 12 and 14 which are fired in their lower region by means of burners 16 and 18, respectively, with a common gas pass 20 extending from the outlet of the furnaces and receiving the combustion gases egressing therefrom.

The vapor generator is operated at supercritical pressure and accordingly is provided with a through-flow circuit through which the primary fluid or working medium is forced at said supercritical pressure by means of a feed

pump identified as 22. From this feed pump the through-flow passes through the control valve 24 and then to and through the economizer 26. From the economizer the through-flow is conveyed by conduit 28 to and through mixing vessel 30 and recirculating pump 32 to the header 34 which extends beneath the outer walls of each of the furnaces 12 and 14. These outer walls, identified in FIG. 2 as 36, are lined with vertically extending tubes 38 which are in side-by-side relation and are welded together to form a generally imperforate metallic, pressure resistant inner surface for the furnace walls. The lower ends of each of the tubes 38 connect with the header 34 and each of the tubes extends up along the outer wall of one of the furnaces, traversing the furnace only once, and is connected at its upper end with an outlet header 40 which extends about both of the furnaces. After passing through the furnace wall tubes 38, the through-flow is conveyed from the header 40 through the downtakes 42 to the inlet header 44 located beneath the partition wall 46. This partition wall is comprised of vertically extending side-by-side tube members preferably of larger diameter than tubes 38 in the outer walls in order to increase the flow area of the center wall, with the center wall tubes being identified as 48 and connected at their lower end with header 44 and at their upper end with header 50. These tubes 48 may be welded together in the manner of the outer wall tubes or they may be merely in tangent relation and unwelded. From the header 50 the through-flow is conveyed via conduit 52 to the first fluid heater 54 which is disposed so it is heated primarily by the combustion gases egressing from the furnace 12 and then through conduit 56 to the finishing fluid heater 58 where it is heated to its desired temperature with the fluid being conveyed from this finishing fluid heater through conduit 60 to the high pressure stage of turbine 62.

In the illustrative arrangement of FIG. 1 the vapor generator is operated on the double reheat cycle and after the primary fluid has expanded through a portion or first stage of the turbine it is conveyed via conduit 64 to the first or high pressure reheater 66 which is subjected primarily to the heating influences of the combustion gases generated in furnace 12. The reheated working medium is conveyed from this first reheater via conduit 68 back to turbine 62 where it is additionally expanded and is thereafter again reheated being conveyed through conduit 70 to the second reheater 72 which is so disposed as to be subjected primarily to the combustion gases generated in furnace 14. After being reheated a second time, the working medium is conveyed through conduit 76 back to the turbine. The exhaust from the turbine is directed to the condenser 78 with condensate pump 80 pumping the condensate from the condenser through the fluid heater 82 and deaerator 84 to the feed pump 22.

By arranging the furnace wall tubes 38 upstream of the partition wall tubes 48 in the through-flow circuit, the differential temperature or temperature gradient that will develop in the tubes 36 transversely of the walls, particularly in the upper region and adjacent the outlets of these tubes, because of differential firing of the furnaces, is maintained at a relatively low value. This differential firing of the furnaces may be by accident or design. This relative low temperature differential is obtained because by arranging the circuit in this manner the supercritical pressure medium passing through the tubes is in a condition or state where it is relatively insensitive insofar as change of temperature is concerned, as a result of a change in the heat content of the fluid. To state this in another way the supercritical fluid traversing the tubes 38 is at a location in the entire through-flow circuit where its specific heat is at its highest value. Furthermore by arranging the through-flow circuit in this manner the effluent from the outer furnace walls will be mixed in header 44 at the beginning of the center wall. A further mixing will occur in header 50 so the temperature of the fluid entering heater 54, there being several inlet pipes for this

heater, will be generally uniform. It should be noted that bias firing of furnaces 12 and 14 does not adversely affect partition wall 46 and does not cause different fluid temperatures to be produced transversely of this wall.

This is best shown by referring to FIG. 7, which is a curve depicting the percentage of heat absorbed by the primary fluid as it traverses the through-flow circuit plotted against the temperature of this fluid as it traverses this circuit. It will be noted that the curve has a generally flat portion somewhat centrally located intermediate its two ends with this flat portion being the zone of highest specific heat and with the location identified generally as 86 being the location on the curve which is known as the transition zone of the supercritical fluid which zone is the zone of highest specific heat. In this region there is the least temperature change in the fluid per unit of heat variation or in other words for each B.t.u. of heat absorbed, the temperature change resulting therefrom is at its minimum value. In connection with this curve it will be noted that as the through-flow traverses the economizer it may be heated from a temperature somewhat above 500° to a temperature somewhat above 600° and as it traverses the furnace walls it is further heated to a temperature somewhat above 750° with the portion of the curve that is embraced within this fluid wall heating zone being a relatively flat portion particularly with regard to the outlet region of the furnace walls. Upon leaving the furnace wall tubes and passing through the center wall tubes the temperature of the fluid is further heated to about 800° with the slope of the curve in this region substantially increasing, representing a substantial decrease in the specific heat. Upon leaving the center wall and passing through the additional fluid heaters the temperature is further raised to a desired and final value, as for example 1050° F., and with the slope of the curve in this region being relatively steep.

Accordingly, it will be appreciated that by arranging the through-flow circuit in the manner described, even though the two furnaces are bias fired to a substantial extent, as for example one furnace being fired at a 10 percent greater rate than the other, the temperature of the fluid egressing from the tubes 36 in each of the furnaces will not be inordinately large and will be substantially less than if the center wall were upstream of the furnace walls in the through-flow circuit. It is desirable to maintain the temperatures of the tubes in the outer furnace walls of both furnaces at a generally uniform value or as uniform as possible since they are supported in a manner which makes this extremely desirable with common buckstays extending across the walls of both furnaces. With the welded wall construction shown and described this uniform temperature is desirable to maintain stresses at a minimum value.

Bias firing of the furnaces in the arrangement described may be employed to extend the range of operation of the vapor generator over which the two reheat temperatures may be maintained constant and at their desired value. Furthermore, it should be noted that bias firing may be inadvertently produced in a unit since it is quite difficult to accurately meter the fuel and air to insure that the firing of the two furnaces is identical and moreover bias firing may be designed into the unit where it is desired that one of the furnaces in a divided furnace arrangement be of greater capacity than another.

With regard to the reheat control that is obtained by means of bias firing in the FIG. 1 arrangement the bias firing effect may be utilized to extend the range of control that is produced by some other control means such as gas recirculation or tilting burners. In FIGS. 1, 2, and 5 there is diagrammatically represented a tilting tangential type of firing system. In this system burners are disposed preferably adjacent the corners of each of the furnaces and direct their fuel and air tangent to a vertically disposed centrally located imaginary cylinder in the furnace. The burners are tiltable in a manner so that the zone of

combustion may be moved longitudinally toward and away from the furnace outlets. It will be appreciated that if the zone of combustion is moved toward the furnace outlets a greater quantity of heat is made available to the reheaters located in the gas pass 20 for a given firing rate. This type of control, as well as the construction of the burners in the organization of this invention may be similar to that shown and described in U.S. Patent No. 2,636,875 granted November 28, 1944, to H. Kreisinger and V. Z. Caracristi.

The tilting burner control may be effective to control the two reheat temperatures over a substantial range. However since the two reheats require varying amounts of heat with varying load the control that may be obtained with the tilting burners would be limited by the reheat which requires the greater control effect. This may be explained in another way by pointing out that the two reheat temperatures tend to vary with respect to each other as the load varies if there is no control action at all applied to maintain these temperatures at their desired value. The vapor generator is designed so that at maximum or design rating the temperature of the primary fluid as well as the temperature of both of the reheats are at their desired or design value. As the load decreases from this maximum value the two reheat temperatures will tend to decrease with one of the reheat temperatures tending to decrease at a faster rate than the other. Whether this is the high pressure or low pressure reheat, i.e., the first or second reheat, depends upon the design of the unit and the particular cycle of the entire power plant.

FIG. 8 shows that tilting burners may be effective to maintain the two reheat temperatures at their desired value (1050° F.) as the load falls from the 100 percent value with the straight line identified as 88 showing the reheat temperatures being thus controlled. At the point identified as 90 the tilting burner control has reached the limit of its ability to control the temperature of one of the reheats, for example, the high pressure or first reheat. Accordingly, if no other control action were initiated the high pressure reheat temperature, from the point 90, would follow the curve 92 as the load is further decreased. However, with respect to the other reheat temperature (the second or low pressure reheat in the example chosen) tilting burner control would be effective to maintain the temperature of this reheat at its desired value to the point identified as 94. Accordingly, at the point 90 bias firing may be utilized to extend the control range over which the two reheat temperatures may be retained at their desired value. At this point 90 bias firing may be used to increase the proportion of the total fuel fired in the furnace 12 relative to that in furnace 14 to bring the high pressure reheat temperature up to its desired value. Since at point 90 the tilting burner control is still effective to maintain the low pressure reheat at its desired value the fact that the firing rate in furnace 14 is decreased will be compensated for by means of the tilting burner control. The bias firing is thus effective to overcome the tendency of the two reheats to develop different temperatures and the control range, by means of the combination of bias firing and tilting burners, may be extended to the point identified as 96. This is the limit of the control of the two reheat temperatures that can be obtained with this combination of control actions with the reheat temperatures decreasing as represented by curves 98 as the load decreases beyond that represented by the point 96. By combining the tilting burner and bias firing controls in this manner a simple arrangement may be utilized to extend the control range over that which may be had with tilting burners per se.

It will be understood that the primary fluid temperature is maintained constant throughout the desired operating range of the vapor generator with this being accomplished through suitable control equipment which is effective to control the necessary parameters to effect this result with

this including controlling the feed of the through-flow by means of the valve 24 and adjusting and controlling the total fuel fired to the furnaces with the ratio of the through-flow and fuel being maintained at the necessary value to provide a generally constant primary fluid temperature delivered to the turbine.

In FIG. 1 there is diagrammatically represented in a very simplified fashion an arrangement for controlling the temperature of the primary and the two reheat fluid temperatures. As illustratively disclosed there is provided a control device identified as 100 which receives a signal responsive to the primary fluid temperature such as at the location 102 and which receives a signal from the load responsive device 104. This device 104 receives its signal from the electrical load that is supplied by the generator 106. The fuel and air supply is controlled from the control device 100 through the supplemental control device 106 which is effective to control valve 108 while the feed control valve 24 is regulated through the control 100 and the supplemental control device 110. The reheat temperatures are sensed at the locations 112 and 114, respectively, providing a signal that is supplied to the control device 116 with this control device in turn being effective to adjustably proportion the total fuel and air between the two furnaces through the supplemental control devices 118 and 120 which respectively control the valves 122 and 124. The control device 116 is also connected with the control device 100 so as to provide a load responsive signal for anticipatory purposes. The tilting burners for each of the furnaces are independently controlled and as diagrammatically shown the control mechanism 126 is effective to regulate the tilting burner 16 for the furnace 12 while the control mechanism 128 is effective to regulate the tilting burners 18 for the furnace 14. These control mechanisms 126 and 128 are regulated from the control device 116. Through this control system the primary fluid temperature is maintained constant and at its desired value throughout the load range over which the vapor generator is operated and reheat temperatures are maintained at their desired value in accordance with the previously explained curve of FIG. 8.

FIG. 6, which is in the nature of a vertical section from front to rear of the vapor generator taken through the furnace 12, shows the general configuration that the generator has and the disposition of the heat exchange surfaces therein. FIG. 6 is a view similar to that of FIG. 5 but shows a modification wherein in lieu of the tilting burner type of control gas recirculation type of control for the reheat temperature is employed. This type of control is known in the art and in accordance therewith cooled recirculating gases that have traversed the reheater are reintroduced into the furnace as the load is decreased with the amount of gas recirculated being increased with decreasing load to maintain the reheat temperature at its desired value. This type of control may be used to effect the desired control of the reheats in lieu of the tilting burner control and the bias firing may be employed in conjunction with this gas recirculation control in the same manner as with the tilting burner control to extend the control range with regard to the reheat temperature. As illustratively disclosed the recirculating gases are conveyed from the lower end of gas pass 20 through the gas recirculation duct 130 into the lower region of furnace 12 with recirculating fan 132 being disposed in duct 130 and with adjustable damper 134 being operative to control the quantity of recirculated gases. This damper is controlled by the control mechanism 126.

In the supercritical vapor generator of the invention, the through-flow circuit has superimposed thereon a recirculating system or circuit which is effective to recirculate fluid through the tubular furnace walls and through the center or partition wall. There is provided a conduit 136 which is connected with the outlet conduit 52 from the header 50 and which leads to the mixing vessel 30. The recirculating pump 32, which is a centrifugal pump

operated by a constant speed motor and is free-floating on the through-flow system, is effective to cause a recirculation of working medium to be provided through the conduit 136 and accordingly through the tubes of the outer furnace walls and the center wall. The recirculating pump 32 is constructed and operated so as to automatically provide the amount of recirculation necessary to insure that adequate flow velocity is had in the furnace wall and center wall tubes. The construction and operation of this pump is preferably similar to that shown and described in U.S. Patent No. 3,135,252 of June 2, 1964, in the name of Willburt W. Schroedter entitled "Recirculation System for Steam Generator."

This recirculation of fluid enables the parallel tube, welded wall furnace construction previously described to be employed with a minimum of stresses being set up therein. It also enables larger tubes to be used than would otherwise be the case with these larger diameter tubes being less restrictive and accordingly less affected by deposit build up. Furthermore the recirculation reduces the temperature variation between the inlet and the outlet of the furnace wall and center wall tubes which in turn results in providing a more uniform temperature distribution transversely of the furnace walls in the supercritical arrangement.

It will be noted that the fluid heaters 54 and 58 are subjected primarily to the heating effect of the gases from a single furnace with this having the advantage of permitting bias firing to be employed and at the same time not developing a plurality of streams of the working fluid which are at substantially different temperatures and which must be mixed. The temperature of the fluid leaving the heater 54 through several outlet conduits that extend from the heater will be generally at the same value while a similar condition will prevail with regard to the fluid heater 58.

In lieu of employing the double reheat cycle, the vapor generator may be operated on the single reheat cycle with the FIG. 9 providing a diagrammatic representation of such a system. In this FIG. 9 representation the primary circuit or through-flow circuit is the same as that in FIG. 1 representation with the single reheater being identified as 140 receiving working medium from turbine 62' through conduit 142 and delivering the reheat vapor to the turbine through conduit 144. In the FIG. 9 arrangement bias firing may be utilized to control the reheat temperature with the bias firing acting as a supplemental control to either tilting burner or gas recirculation control. To illustrate the control action that may be employed, FIG. 10 represents the reheat temperature plotted against load. If there were no control action at all the reheat temperature would decrease as, for example, along the line 146 as the load is decreased. By means of bias firing and of the total fuel fired increasing the proportion of that fired into furnace 14 relative to that fired into furnace 12 with decrease load the reheat temperature may be maintained constant to the point identified as 148 and then fall off along the curve 150. By means of either tilting burner or gas recirculation type of control the reheat temperature may be maintained constant to the point identified as 152 with these controls being effective to further extend the control of the reheat temperature beyond that of point 148. It will be appreciated that in lieu of utilizing the bias firing type of control initially and then the additional control action, the tilting burner or gas recirculation control may be first utilized to the limit of its ability and then bias firing may be used to further extend the range of load over which the reheat temperature may be maintained constant.

In both the double and the single reheat systems described the bias firing control is effective to increase the load range over which accurate control of the reheat temperatures may be had.

While I have illustrated and described a preferred embodiment of my invention it is to be understood that such

is merely illustrative and not restrictive and that variations and modifications may be made therein without departing from the spirit and scope of the invention. I therefore do not wish to be limited to the precise details set forth but desire to avail myself of such changes as fall within the purview of my invention.

What I claim is:

1. A supercritical vapor generator comprising in combination a through-flow circuit, means for forcing the working medium through said circuit at supercritical pressure, a pair of furnaces, a tubular partition wall separating said furnaces, means independently firing said furnaces, tubular members lining the furnace walls, the furnaces having a gas passageway extending therefrom, said partition wall and said furnace walls forming part of the through-flow circuit, the portions of the through-flow circuit being so disposed that the transition zone of the circuit is located in the tubular members lining the furnace walls, means directing the through-flow first through the tubular members on the furnace walls and directly therefrom through the partition wall, additional heat exchange surface heated by the gases produced in said furnaces and means for conveying therethrough the through-flow egressing from the partition wall, and reheater means subjected to the combustion gases generated in one of said furnaces.

2. In a vapor generator having a pair of furnaces separated by a tubular partition wall with means independently firing said furnaces the method of operation comprising passing the primary fluid through a continuous path at supercritical pressure, in the course of said path directing said fluid in confined streams adjacent the inner surface of the outer furnace walls and thereafter through the tubes of said partition wall, regulatingly imparting heat to said fluid so that the transition zone is in said confined streams, directing the effluent from the partition wall in heat exchange relation with at least the gas stream produced in one of said furnaces, utilizing a portion of the energy of the primary fluid and reheating this fluid by passing the same in heat exchange relation with at least the gases produced in one of said furnaces.

3. The method of producing vapor comprising burning fuel in a first zone and producing a combustion gas stream and burning fuel in a second zone and producing a combustion gas stream, passing a working fluid at supercritical pressure in confined streams intermediate said two zones and absorbing heat produced in said zones and in confined streams about the outer regions of said zones with said fluid being first directed in the confined streams about said outer regions and then between said zones, imparting heat to said fluid such that the transition zone is in the confined streams about said outer regions, further directing said fluid in heat exchange relation with the gases produced in said furnaces, expanding said fluid and thereafter reheating the same by conveying the fluid in heat exchange relation primarily with the gases evolved in one of said furnaces, adjustably proportioning the firing of the furnaces increasing the relative proportion for said one furnace with decreasing load.

4. A supercritical vapor generator comprising in combination a pair of furnaces separated by a tubular partition wall, means separately firing each of said furnaces, gas pass means through which the combustion gases from the furnaces are directed, a through-flow circuit including tubular members lining the inner surface of the outer furnace walls and heat exchange surface in said gas pass means with the portions of the through-flow circuit being so disposed that the transition zone of the circuit is located in the tubular members lining the inner surface of the furnace walls, means forcing the working medium at supercritical pressure through said circuit including means directing the fluid first through the tubular members lining the outer furnace walls and then through the tubular members of the partition wall, means thereafter directing the fluid through said additional heat exchange surface, reheat-

er heat exchange surface disposed in the gas pass means in a manner so that it is subjected primarily to the heating effect of the gas stream produced in one of said furnaces, means adjustably proportioning the total fuel fired to the two furnaces effective to increase the firing rate of said one furnace relative to that of the other furnace with decreasing load.

5. The organization of claim 4 including means independent of the firing rate effective to regulate the heat content of the combustion gases egressing from said one furnace.

6. The organization of claim 5 wherein the last-named means comprises means operative to adjust the zone of combustion toward and away from the furnace outlet.

7. The organization of claim 5 wherein the last-named means comprises means for reintroducing combustion gases into the furnace after traversal of the reheater.

8. A vapor generator of the type described operating on the reheat cycle and at supercritical pressure comprising in combination a through-flow circuit, means operative to force the working medium through said circuit at supercritical pressure, a pair of side-by-side furnaces separated by a partition wall comprised of longitudinally extending parallel tubes, gas pass means extending from the furnaces and receiving the combustion gases therefrom, longitudinally extending parallel side-by-side tubes lining the inner surface of the furnace walls, an economizer at the low temperature region of the gas pass means, said economizer, partition wall and furnace wall tubes forming a portion of the through-flow circuit with means directing the through-flow from the economizer through the furnace wall tubes in parallel flow relation and thereafter through the partition wall tubes, the portions of the through-flow circuit being such that the transition zone is in the furnace wall tubes, additional heat exchange surface disposed in the gas pass means and means conveying the through-flow thereto after traversal of the partition wall tubes to heat the fluid to its desired temperature, and reheater means subjected primarily to the heating influence of the combustion gases generated in one of the furnaces.

9. The organization of claim 8 including means superimposed on the through-flow circuit operative to increase the flow through the furnace wall and partition wall tubes over and above that of the through-flow.

10. The organization of claim 8 including means independent of the total firing rate of the unit for controlling the reheat temperature including means to adjustably proportion the total firing between the two furnaces, increasing that of said one furnace relative to that of the other with a decrease in load, and means operative to adjust the zone of combustion toward and away from the furnace outlet.

11. A supercritical vapor generator operating on the reheat cycle and comprising in combination a pair of upright side-by-side furnaces, a partition wall separating said furnaces and comprised of vertically extending parallel flow tubes, vertically extending parallel flow tubes lining the outer furnace walls, gas pass means receiving combustion gases from said furnaces, means independently firing said furnaces, means directing through-flow at supercritical pressure first up through the outer furnace wall tubes and then up through the partition wall tubes, the heat exchange surface of the generator being such that the transition zone is in the furnace wall tubes, additional heat exchange surface in the gas pass means and means for conveying the through-flow therethrough, reheater heat exchange means subjected primarily to the heating influence of the combustion gases generated in one of said units, and means for controllably proportioning the total firing of the two furnaces increasing the relative proportion for said one furnace with decreasing load.

12. In a supercritical vapor generator having a pair of furnaces separated by a partition wall and gas pass means extending from said furnaces, the method of operation

comprising forcing the working medium at supercritical pressure through a continuous circuit including directing the medium up through tubes that line the outer walls of the furnaces and then up through the tubes of the partition wall, thereafter conveying the fluid in heat exchange relation with the gases produced in the furnaces, utilizing a portion of the energy of the thus heated working medium and thereafter reheating the same by conveying it in heat exchange relation primarily with the combustion gases generated in one of said furnaces, regulating the reheat temperature with varying load by means of regulating the heat content of the combustion gases egressing from said one furnace independent of the firing rate and by means of adjustably proportioning the total fuel fired between the two furnaces.

13. In a vapor generator operated on the double reheat cycle and at supercritical pressures and including a pair of side-by-side furnaces effectively separated by a tubular partition wall, said furnaces being lined with longitudinally extending tubular members welded together to provide a generally imperforate furnace lining and means independently firing the furnaces the method comprising directing the working medium at supercritical pressure first through the tubes on the outer furnace walls and then through the partition wall tubes, thereafter conveying the fluid in heat exchange relation with the combustion gases egressing from the furnaces, utilizing a portion of the energy of the thus heated working medium and reheating the same by conveying it in heat exchange relation primarily with the combustion gases generated in one of said furnaces, utilizing a further portion of the energy of the reheated steam and again reheating the same by conveying it in heat exchange relation primarily with the combustion gases generated in the other of said furnaces, regulating the two reheat temperatures with varying load by adjustably proportioning the total firing between the two furnaces and by varying the heat content of the gases egressing from the furnaces independent of the firing rate.

14. The method of claim 13 wherein the heat content of the gases is varied by adjusting the zone of combustion with relation to the furnace outlets.

15. The method of claim 13 wherein the heat content of the gases is varied by introducing into the furnace combustion gases after they have effected the reheating of said vapor.

16. A vapor generator comprising in combination a pair of furnaces separated by a partition wall and having gas pass means extending therefrom, said partition wall being formed of vertically extending side-by-side tubes, similarly disposed tubes lining the inner surface of the outer furnace walls with these latter tubes being welded together to form a generally imperforate structure, a through-flow circuit through which the working medium is conveyed at supercritical pressure and including the furnace wall and the partition wall tubes, said circuit including means directing the through-flow first through said furnace wall tubes in parallel flow relation and then through said partition wall tubes, additional heat exchange surface in the gas pass means connected to receive the through-flow after traversal of said center wall tubes, a recirculating system connected across the center wall and furnace wall tubes in superimposed relation on the through-flow circuit with the inlet of this system connected to the through-flow system downstream of the center wall tubes and the outlet connected upstream of the furnace wall tubes, pump means effective to recirculate fluid through these tube portions and being operative to increase the recirculation with decreasing load, a first reheater subjected primarily to the combustion gases egressing from one of said furnaces and a second reheater subjected primarily to the combustion gases of the other furnace, means operative to adjustably proportion between the two furnaces the total fuel fired, and means operative

to adjust the zone of combustion in each furnace toward and away from the furnace outlet.

17. A vapor generator comprising in combination a pair of furnaces separated by a partition wall and having gas pass means extending therefrom, said partition wall being formed of vertically extending side-by-side tubes, similarly disposed tubes lining the inner surface of the outer furnace walls with these latter tubes being welded together to form a generally imperforate structure, a through-flow circuit through which the working medium is conveyed at supercritical pressure and including the furnace wall and the partition wall tubes, said circuit including means directing the through-flow first through said furnace wall tubes in parallel flow relation and then through said partition wall tubes, additional heat exchange surface in the gas pass means connected to receive the through-flow after traversal of said center wall tubes, a recirculating system connected across the center wall and furnace wall tubes in superimposed relation on the through-flow circuit with the inlet of this system connected to the through-flow system downstream of the center wall tubes and the outlet connected upstream of the furnace wall tubes, pump means effective to recirculate fluid through these tube portions and being operative to increase the recirculation with decreasing load, a first reheater subjected primarily to the combustion gases egressing from one of said furnaces and a second reheater subjected primarily to the combustion gases of the other furnace, means operative to adjustably proportion between the two furnaces the total fuel fired, and means to recirculate combustion gases after traversal of the reheat means back into the furnace in such a manner as to decrease the heat absorption in the furnace.

18. The method of generating vapor comprising burning fuel at a first zone and creating a combustion gas stream, burning fuel at second zone adjacent said first zone and creating a combustion gas stream, directing a primary fluid at supercritical pressure through a continuous path including conveying the fluid in confined streams about the zones of combustion and then conveying the fluid in confined streams intermediate said zones of combustion, thereafter conveying said primary fluid in heat exchange relation with said combustion gas streams, expanding the thus heated primary fluid at a first stage, reheating the fluid by conveying the primary fluid in heat exchange relation with the combustion gas stream generated in one of said zones, expanding the reheated fluid at a second stage and thereafter again reheating the same by conveying it in heat exchange relation primarily with the combustion gases generated in the other zone, controlling the temperature of the primary fluid by suitable controlling actions including controlling the total fuel firing, controlling the two reheat temperatures by adjustably proportioning the total fuel between the two zones and regulating the heat content of the combustion gases egressing from said zones independent of the firing rate.

19. In a vapor generator operating at supercritical pressure and comprising a pair of upright furnaces in side-by-side relation said furnaces being separated by a partition wall having vertically extending tubes and the outer furnace walls being lined with vertically extending tubes which are in parallel flow relation and welded together generally throughout the furnace height, a recirculating system connected across the furnace wall and center wall

tubes collectively operative to provide a recirculation of the working fluid therethrough, gas pass means extending from said furnaces and a through-flow circuit through which the working medium is conveyed at supercritical pressure, the method of operation comprising independently firing the two furnaces, directing the through-flow up through the furnace wall tubes and thereafter up through the partition wall tubes, regulating the heat absorption so that the transition zone is in the furnace wall tubes, passing the through-flow after traversal of the center wall tube in heat exchange relation with the gases produced in the furnaces, expanding the thus heated working medium at a first zone and reheating the same by directing it in heat exchange relation primarily with the combustion gases produced in one of said furnaces, thereafter expanding fluid at a second zone and again reheating it by conveying it in heat exchange relation primarily with the combustion gas stream generated in the other furnace, maintaining the reheat temperatures at a generally constant value throughout a predetermined load range by regulating, independently of the firing rate, the heat content of the combustion gases passing from each furnace, and extending this control range by adjustably proportioning the total fuel between the two furnaces.

20. The method of claim 19 wherein the heat content of the gases is controlled by introducing cooled combustion gases back into the furnace.

21. A vapor generator comprising in combination a pair of furnaces separated by a partition wall and having gas pass means extending therefrom, said partition wall being formed of vertically extending side-by-side tubes, tubes lining the inner surface of the outer furnace wall with these tubes extending longitudinally of the furnace, being in parallel side-by-side relation with each tube traversing the furnace once and with adjacent tubes being welded together so as to form a rigid structure, a through-flow circuit through which the working medium is conveyed at supercritical pressure and including the furnace wall tubes and the partition wall tubes, said circuit including means directing the through-flow through said furnace wall tubes in parallel flow relation and then through said partition wall tubes and with the portions of the circuit being so related that the transition zone is in the furnace wall tubes; additional heat exchange surface in the gas pass means connected to receive the working fluid of the vapor generator, and means operative to independently fire each of the furnaces and control the firing rate as desired.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,135,244

June 2, 1964

Virginus Z. Caracristi

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 12, line 29, after "furnaces" insert -- effectively

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Signed and sealed this 3rd day of November 1964.

(SEAL)

Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents