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CONTROL SYSTEM FOR ONCE-THROUGH FLOW VAPOR GENERATOR

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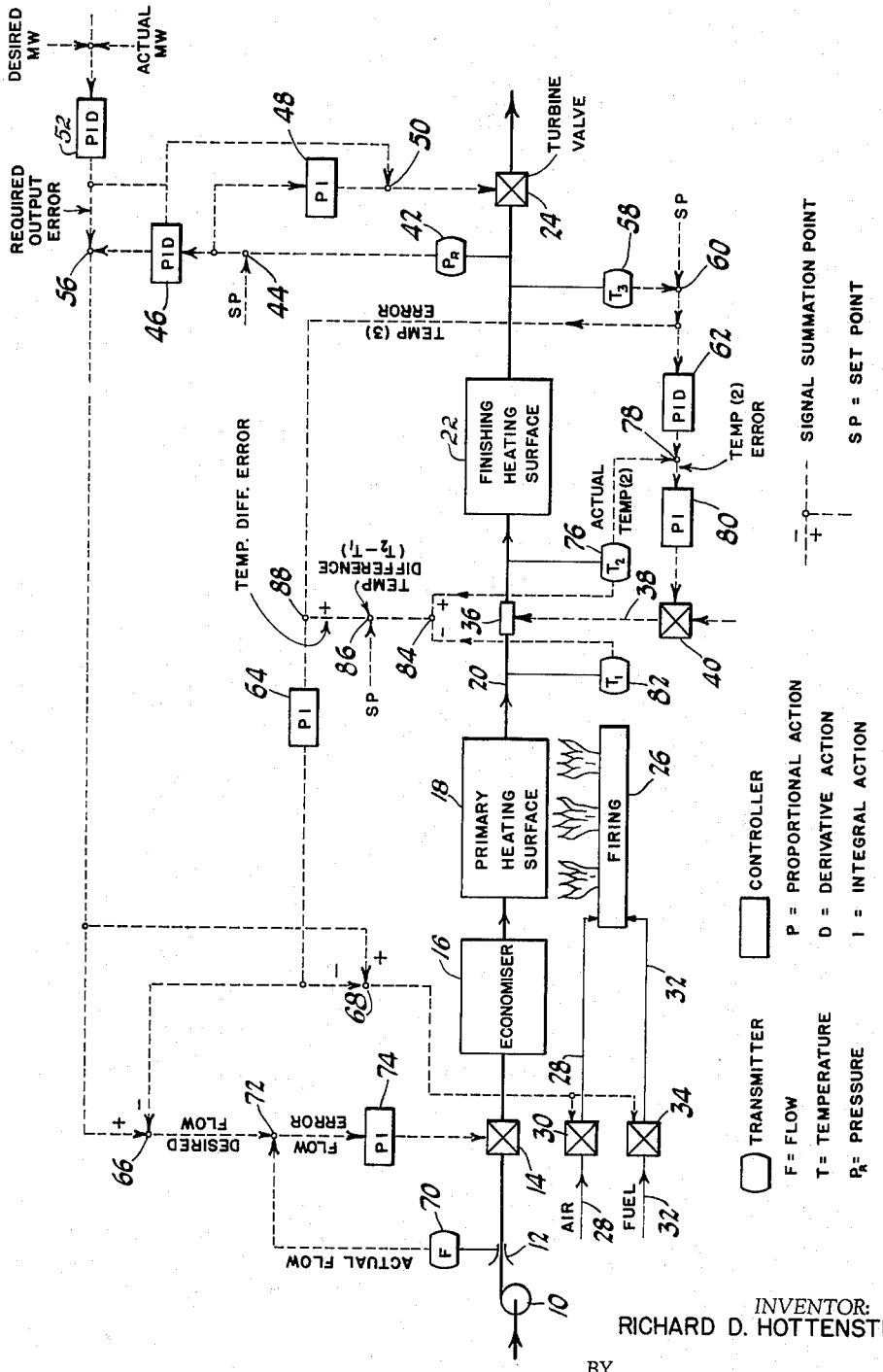

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CONTROL SYSTEM FOR ONCE-THROUGH FLOW VAPOR GENERATOR

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This invention relates generally to forced once-through flow generators and has particular relation to an improved control system for such a generator whereby the final vapor temperature of the generator is maintained constant notwithstanding that the load on the generator varies.

In forced once-through flow vapor generators the working medium is forced, by suitable pump means, through what is termed the through flow circuit of the vapor generator. Such vapor generators include both supercritical and subcritical operation with the vapor generator shown and described in U.S. application No. 127,395 of W. W. Schroedter filed July 27, 1961 and assigned to the same assignee as the assignee of the instant application, being an example of a modern supercritical vapor generator through the through flow circuit of which the feedwater is forced at supercritical pressure. The control system of the present invention employs a desuperheater is the superheating portion of the through flow system which has for its purpose the rather rapid correction of transient variation in the steam temperature. The steam temperature as well as the pressure of the vapor issuing from the once-through flow vapor generator is controlled primarily by suitably regulating the flow of feedwater to and through the supercritical circuit and the firing of fuel in the furnace which forms a part of the vapor generator. By suitably regulating the ratio of feedwater and fuel or firing rate, the pressure and temperature of the vapor egressing from the through flow vapor generator may be regulated throughout a predetermined load range. However, since the vapor generators to which the invention pertains are very massive structures, the regulation that is obtained in this manner has a considerable time delay which, if no other control action were provided, would result in considerable overshooting and undershooting of the desired temperature. The desuperheater as employed with the invention is operated during normal operation of the vapor generator, intermediate of its upper and lower extreme limits so that it may quickly effect a decrease or an increase in the temperature of the vapor in the through flow circuit as required to maintain the final vapor temperature at its desired value. The desuperheater is accordingly effectively controlled in response to the final vapor temperature and when this temperature varies from its desired value, the desuperheater will be operated in response to this variation in a manner to cause this temperature to return to its desired value.

In order that the desuperheater will be maintained, during normal operation, at a level of operation intermediate its upper and lower extreme limits, the temperature difference in the through flow fluid immediately upstream and immediately downstream of the desuperheater is utilized to adjust the ratio of feedwater flow through the through flow circuit to the firing of the vapor generator with this adjustment or regulation being such as to maintain this temperature difference at a predetermined valve. Accordingly, the control system operates so that as a result of a change in the final temperature of the vapor of the vapor generator from its predetermined value, the desuperheater is operated so as to effect a rather rapid return of this temperature to its desired value. At the same time the flow of fluid through the vapor generator and the firing rate is adjusted so as to cause the

final temperature to return to its desired value with the time required before this adjustment of the through flow and firing is felt at the output of the vapor generator being greater than the corresponding time for the desuperheater. This change in the desuperheater operation to provide a rapid correction of the vapor temperature results in the temperature difference across the desuperheater also changing. This in turn causes a readjustment of the ratio of the through flow to the firing rate which in turn affects the final temperature of the vapor generator and accordingly the action of the desuperheater with the ultimate effect being that the final temperature is maintained generally at its desired value and the temperature difference across the desuperheater is returned to its desired value so that the desuperheater is again operating well within its upper and lower extreme limits and is capable of correcting other sudden transient variations of the final temperature of the vapor regardless of whether an increase or a decrease in the desuperheating capacity is required to effect the correction.

Accordingly, it is an object of the present invention to provided a forced through flow vapor generator with an improved control organization.

A further object of the invention is to provide a forced through flow vapor generator provided with a desuperheater and wherein the temperature difference across the desuperheater in utilized as a control parameter.

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 the single figure is a diagrammatic representation of a forced through flow vapor generator employing the improved control system of the invention.

Referring now to the drawing, wherein like reference characteristics are used throughout to designate like elements, the diagrammatically represented force through flow vapor generator, which may be either supercritical or subcritical, includes the feedpump 10 which forces the feedwater through the flow measuring device 12 and the flow control valve means 14 into and through the economizer 16. From the economizer the vaporizable working fluid flows through the heating surface 18 and from this heating surface the fluid flows through the connecting conduit 20 to and through the final or finishing heating surface 22. Upon egressing from this final heating surface, the fluid is in vapor form with the final temperature and pressure of this vapor being at a desired value for delivery to a prime mover, such as a turbine, with the fluid passing through the valve 24 which may be the turbine valve and then to the prime mover which is not illustrated and which in a conventional system drives an electric generator. As is conventional in power plane systems, the vapor after leaving the prime mover is condensed, heated by suitable preheaters, de-aerated and returned to the through flow circuit, being forced again through this circuit by means of the feed pump means 10.

In the illustrative organization heat is supplied to the vapor generator by means of the firing means 26 which is supplied with air through the duct 28 and regulating means 30 and is supplied with fuel through the conduit 32 and the regulating means 34.

After traversing the economizer 16 and the heating surface 18, the working fluid of the vapor generator is in vapor form and partially superheated to its desired tem-

perature. In passing through the conduit 20 to the final superheating surface 22, the amount of this superheating is reduced by means of the attemperator or desuperheater 36 that is connected into this conduit 20. In the illustrative arrangement this desuperheater is of the spray or direct contact type wherein relatively cool water, which may be feedwater or other water substantially pure to be introduced into the through flow system of the vapor generator, is sprayed into the superheater vapor traversing the conduit 20. The purpose of the desuperheater is to provide what may be termed a transient control for the final vapor temperature of the vapor generator or in other words to effect a rather rapid transient temperature correction. In order that the desuperheater may effect either an increase or decrease in the final vapor temperature, it is necessary that, during normal operation of the vapor generator, the desuperheater operate intermediate its upper and lower extreme limits. The lower limit may be that obtained when there is no flow of the cool desuperheating fluid to the desuperheater 36 while the upper limit is that obtained when the maximum flow of the cool desuperheated fluid is provided through the desuperheater. The desuperheating fluid is conveyed to the desuperheater through the conduit 38 with the regulation of this fluid flow being obtained by means of the regulator 40.

It will be understood that the desuperheater may take a different form other than the direct contact spray desuperheater hereinbefore described with the invention including other types of desuperheaters, such as the indirect heat exchanger type of desuperheater.

While the desuperheater, as mentioned hereinbefore, is for the purpose of providing a relatively rapid correction for transient variations in temperature of the vapor egressing from the vapor generator, the primary control for this temperature is obtained through adjustment of the feedwater flow through the vapor generator as well as the firing of the vapor generator with the relatively quick acting desuperheater control action being desired because of the inherent rather substantial time lag in the massive vapor generator between adjustment of the feedwater flow and the firing and the effect of this adjustment being evidenced in the conditions of the vapor egressing from the vapor generator.

The pressure of the vapor leaving the vapor generator is sensed by the pressure sensing device 42 with the device 42 providing a signal which is compared with a desired setpoint signal at the summation point 44. This comparison will provide an error signal if the pressure is not at its desired value which error signal will be transmitted to the controller 46 and the controller 48. The signal from the controller 48 is compared at the summation point 50 with the output signal of the controller 52. The input signal of the controller 52 is an error signal produced by comparing a signal representing the desired megawatt output of the power plant system, i.e., the generator that is driven by the turbine supplied with vapor from the vapor generator, and a signal representing the actual megawatt output. Any difference between these two values provides an error signal which is fed to the controller 52. The signal resulting from the comparison of the output signal of controller 48 and the output signal of controller 52 at summation point 50 is employed to regulate the valve 24 controlling the supply of vapor to the prime mover. The output of controller 46 and the output of controller 52 are combined at summation point 56 with this signal in turn being employed for regulating the feedwater flow and the firing.

The temperature of the vapor leaving the vapor generator is sensed by the temperature sensitive device 58 which provides a signal that is compared with a desired set point at the summation point 60. The resulting signal is conveyed as the input to the controller 62 and the controller 64 with this signal being a temperature error signal or in other words a signal representing the variation of the temperature (T_3) from its desired value or set point. The output of the controller 64 is combined with the output signal from summation point 56 at the summation points 66 and 68. The output signal from summation point 68 is operative to regulate the air flow regulating means 30 and the fuel flow regulating means 34 while the output of summation point 66, which provides a signal that represents the desired feedwater flow, is compared at summation point 72 with a signal produced by the flow responsive device 70 representing the actual flow. The output signal from summation point 72 represents flow error which is the input of the controller 74 with this controller in turn regulating the flow control valve means 14 to adjust the flow of feedwater to and through the through flow circuit of the vapor generator.

The output of the controller 62 provides a signal which acts as a set point for the temperature T_2 immediately downstream of the desuperheater with T_2 being the temperature of the through flow at this location. The temperature sensor device 76 responds to this temperature and provides a signal representative thereof and which is compared at the summation point 78 with the output signal of the controller 62 or in other words the set point and with this comparison providing an error signal which is conveyed as the input to the controller 80. The output signal of controller 80 is operative to adjust the regulator 40 for admission of the desuperheater fluid to the desuperheater 36. Accordingly as a result of a change in the temperature T_3, an error signal is supplied to the controller 80 which in turn causes a readjustment of the regulator 40 with this operation being such as to cause the temperature T_3 to return to its desired value. However, also as a result of this temperature T_3 varying from its desired value, an error signal is supplied to the controller 64 the output of which is effective to cause a readjustment of the ratio of the firing of the vapor generator and the feedwater flow thereto so as to return the temperature T_3 to its desired value.

In order for the desuperheater 36 to be able to rapidly correct transient temperature variations including both an increase and a decrease in the final temperature of the vapor of the vapor generator, it is necessary that the desuperheater be maintained, during normal operation, so that it is within and well displaced from its upper and lower extremes of capacity. If no means were provided to insure that the desuperheater was maintained intermediate these ranges and preferably well displaced from either extreme, the condition would soon exist where the desuperheater was at or close to one extreme or the other and accordingly could effect a transient correction only in one direction. To insure that such a condition does not exist, the temperature of the through flow immediately upstream and downstream or in other words across the desuperheater 36 is sensed with the temperature sensing device 82 responding to the temperature T_1 (upstream temperature) and providing a signal which is compared with the T_2 signal produced by device 76 (downstream temperature) with this comparison being effected at the junction 84 so that a temperature difference signal results with this difference signal being compared at the summation point 86 with a set point signal representing a particular desired temperature difference between T_1 and T_2. The output of the summation point 86 represents a temperature difference error signal with this signal being combined with the temperature error signal from summation point 60 at junction 88 as the input of controller 64. Thus the temperature difference across the desuperheater is utilized to adjust the ratio of the feedwater flow and the firing rate so as to maintain this temperature at its desired value. Accordingly when there is a rapid change in the temperature T_3, such as may occur when slag suddenly falls from the heating surface 22, the desuperheater 36 is effective to provide a rapid correction of this temperture while as a result of the variation in T_3 the ratio between the feedwater and the firing rate is adjusted to provide a primary or permanent correction.

It is noted that the desuperheater will respond to a change in temperature of the through flow at the location of T_2 and provide a corrective action even before this temperature change reaches the outlet of the vapor generator or in other words the location of T_3. Thus, should there be a sudden temperature change, as might be caused from slag suddenly being removed from the heating surface 18, this change in temperature will be detected by the temperature responsive device 76 which provides an indication of the temperature T_2 and the signal thus produced will be compared with the set point signal produced by the controller 62 thereby producing an error signal which is received by the controller 80 and which is effective to adjust the regulator 40 so as to correct the upset in temperature. This change in the positioning of the regulator 40 will, of course, change the temperature differential across the desuperheater, i.e., the difference in temperature between T_1 and T_2 which will in turn readjust the ratio of the through flow to the firing rate so as to bring this temperature difference back to its desired value.

When the desuperheater is adjusted to effect the desired transient temperature correction, the temperature difference across the desuperheater changes with this in turn causing a readjustment of the ratio of the feedwater flow and the firing rate so as to tend to bring this temperature difference back to its desired value. The over-all result is that the temperature T_3 is rapidly corrected and the desuperheater is eventually readjusted so that the temperature differential thereacross is returned to its desired value after it has performed its function of providing a transient correction.

In order to have the temperature differential across the desuperheater 36 returned to its predetermined value after an upset due to a transient temperature change in the system of the once-through flow vapor generator, it is necessary that the ratio of the feedwater flow and the firing rate be adjusted for this purpose. This may be accomplished either by varying the feedwater per se or varying the firing rate per se. However, in the illustrative system depicted in the drawing, the feedwater and firing rate are varied simultaneously but in opposite directions. This control operation is provided by the controller 64 with the output of this controller effecting such a manipulation of the feedwater flow and firing rate.

The control system of the invention may be either electrical in nature or may be hydraulic or may employ air pressure. An electric system is preferred because of its convenience and the controllers indicated may be either controllers of the type manufactured by Leeds and Northrup Company or the Hagan Company or others which manufacture three-action type, i.e., providing proportional action, integrating action and differential action. As indicated, the controllers 48, 64, 74, and 80 need not provide or use the differential action since differential action here will be of no particular advantage. It may be used if desired, however. The summation points indicated need no controlling hardware if an electrical system is used since they are merely wiring points where D.C. voltage signals are combined or compared. The temperature, pressure and flow transmitters or transducers can be of the standard Leeds and Northrup Company or Hagan Company type with these transmitters transmitting a signal that is compatible with the controller inputs.

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 once through flow vapor generator comprising firing means and a through flow circuit having a superheating portion, desuperheating means in said superheating portion operative to lower the temperature of the through flow in passing through this last-named means, adjustable means regulating the effectiveness of said desuperheating means, means responsive to the temperature of the through flow at a location downstream of the desuperheating means in the through flow circuit effective to regulate said adjustable means to correct transient temperature changes in said fluid and means responsive to the temperature difference of the through flow across said desuperheating means and little or no superheating surface effective to regulate the firing rate and flow through said through flow circuit so as to maintain this difference at a generally predetermined value.

2. The organization of claim 1 wherein said desuperheating means is a direct contact spray desuperheater and said adjustable means is an adjustable control controlling the introduction of the desuperheating spray.

3. In a fuel fired vapor generator having a so-called through flow circuit through which the vaporizable medium is forced by a pump being superheated to a desired temperature during traversal of the circuit and also having a desuperheater operative to control transient variations of the final temperature of the through flow fluid during operation the method comprising operating the desuperheater intermediate and displaced well from its upper and lower limits of effectiveness during normal operation of the unit, regulating the temperature and pressure of the fluid egressing from the through flow circuit and delivered to the point of use through manipulation of the firing of the unit and the feed of fluid to the through flow circuit in direct response to deviations from a desired value, correcting transient variations in the temperature of the through flow through regulation of the desuperheater intermediate said upper and lower limits, and detecting the temperature difference across the desuperheater and little or no superheater surface, and adjusting the ratio of the through flow to the firing rate to return this difference to a predetermined value.

4. In a once through flow vapor generator the combination of a through flow circuit, means forcing the vaporizable fluid through said circuit, means imparting heat to said fluid, means intermediate the extremities of said circuit operative to pass a lower temperature fluid in heat exchange relation with the through flow to decrease the temperature of the latter, means responsive to the final temperature of the through flow directly operative to control the flow through the through flow circuit and the heat imparted thereto to maintain this temperature at a generally predetermined value, temperature responsive means being effective to regulate the effectiveness of the means directing the lower temperature fluid in heat exchange relation with the through flow, and means responsive to the difference in temperature of the through flow entering the location where the lower temperature fluid is passed in heat exchange relation therewith and the temperature of the through-flow leaving the location where the lower temperature fluid is passed in heat exchange relation therewith effective to regulate the flow through the through flow circuit and the heat imparting means to maintain this difference at a generally predetermined value.

5. A vapor generator comprising in combination tubular heat exchange surface including superheater means and through which surface the vaporizable fluid is forced, means controlling the flow of this fluid through this surface, firing means for imparting heat to said fluid during traversal of such surface, desuperheater means associated with said superheater means and operative to partially desuperheat the vapor traversing this surface, means sensing the outlet temperature of the generator and directly operative to regulate the firing means and the flow control means to maintain this temperature at a generally predetermined value, said temperature sensing means also di-

rectly regulating said desuperheater to thereby provide a relatively fast correction of steam temperature variations, means sensing the temperature difference across said desuperheater and little or no superheating surface and operative to adjust the ratio of the flow of vaporizable fluid and firing rate to maintain said difference at a generally predetermined value.

6. In a vapor generator supplying superheated vapor to a variable load and wherein fluid is forced through heat exchange surface including superheater surface with there being fuel firing means for generating and imparting heat to the fluid traversing such surface, means providing for regulation of the vapor temperature egressing from the vapor generator for supply to the load including desuperheating means associated with the superheater surface of the unit and normally operating intermediate its upper and lower limits, means responsive to the temperature of the vapor egressing from the vapor generator operative to adjustably regulate said desuperheater to maintain this temperature at its desired value and also operative to regulate the flow through the vapor generator and the firing thereof to maintain this temperature at its desired value, and means sensing the temperature difference across the desuperheater and little or no superheater surface and in response thereto regulating the ratio of the flow through the vapor generator to the firing rate to maintain this temperature difference at a predetermined value.

7. In a forced through flow vapor generator fired with a suitable fuel and producing superheated vapor, said generator having associated therewith a desuperheater, the method of controlling the temperature of the superheated vapor comprising sensing said temperature and in response thereto adjusting the desuperheating capacity of the desuperheater to provide a relatively rapid correction of a temperature variation, also in response to the sensing of said temperature independently adjusting the fluid flow through the vapor generator and the firing of the vapor generator to maintain said temperature generally constant, measuring the temperature of the through flow immediately upstream and immediately downstream of the desuperheater and in response to the difference in these measurements regulating the ratio of the flow through the vapor generator and the firing rate so as to maintain the difference between these two temperatures at a generally predetermined value.

8. The method comprising pumping a vaporizable fluid through a circuit, burning a fuel and imparting heat to said fluid during its traversal of said circuit thereby vaporizing said fluid and raising it to a predetermined final degree of superheat, passing a lower temperature fluid in heat exchange relation with the vaporized fluid prior to the latter reaching its final degree of superheat, providing a first control for maintaining said final temperature at its desired value including sensing said final temperature and in response thereto regulating the heat input to the vaporizable fluid and the flow of this fluid through the circuit and providing a second control of said temperature having a response time substantially less than said first and including adjusting the passage of the low temperature fluid in heat exchange relation with said vaporizable fluid in response to the final temperature of the latter and readjusting the passage of this low temperature fluid in heat exchange relation with the vaporizable fluid after a change thereof by sensing the temperature difference in the vaporizable fluid immediately prior to and after the location where the low temperature fluid is passed in heat exchange relation with the vaporized fluid and in response to such temperature difference adjusting the ratio of the flow through the circuit and the rate of burning fuel to maintain such difference at a predetermined value.

9. The method of claim 8 wherein said lower temperature fluid is introduced into direct contact with said vaporized fluid.

References Cited by the Examiner

UNITED STATES PATENTS

2,966,896	1/61	Volger	122—479
3,086,503	4/63	Profos	122—448

FOREIGN PATENTS

217,051	9/61	Austria.
358,096	12/61	Switzerland.

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