May 10, 1966 P. PROFOS 3,250,259

METHOD AND APPARATUS FOR CONTROLLING RATE OF TEMPERATURE CHANGES OF HEAT GENERATORS DURING STARTUP AND SHUTDOWN

Original Filed Aug. 19, 1959 4 Sheets-Sheet 1

FIG. 1.

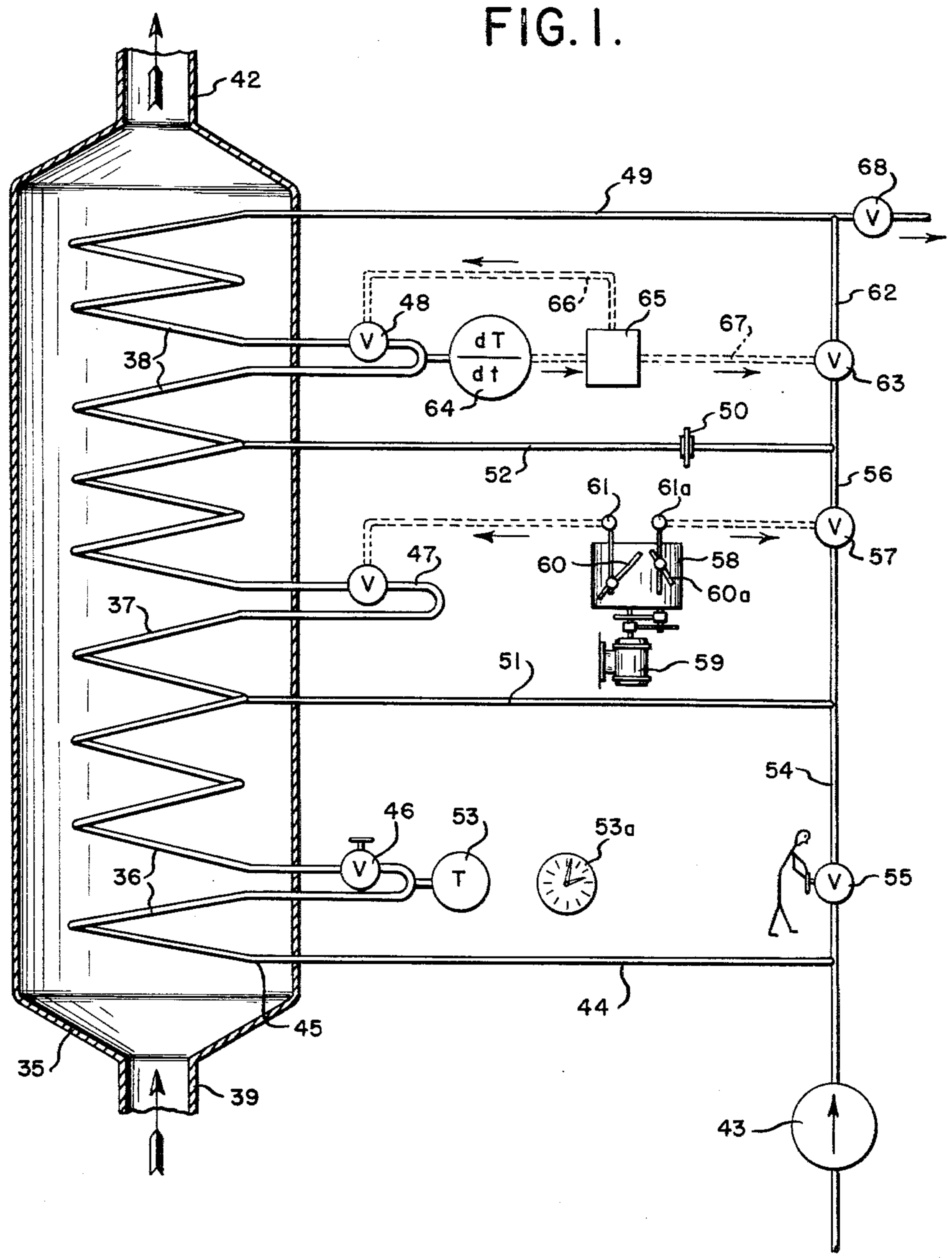

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FIG. 2

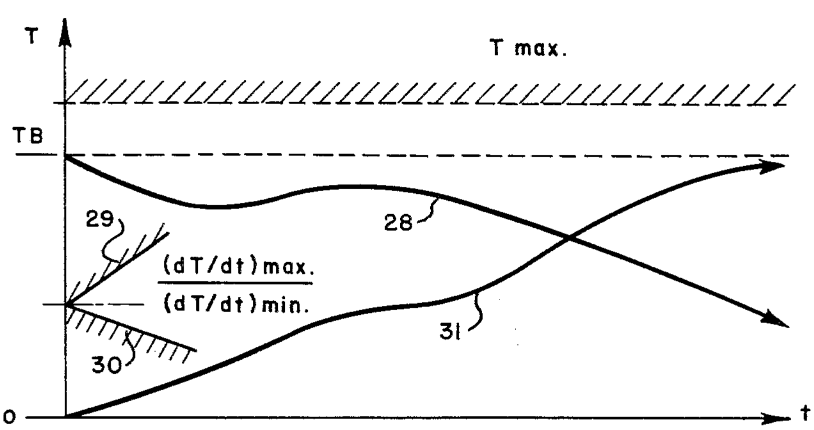

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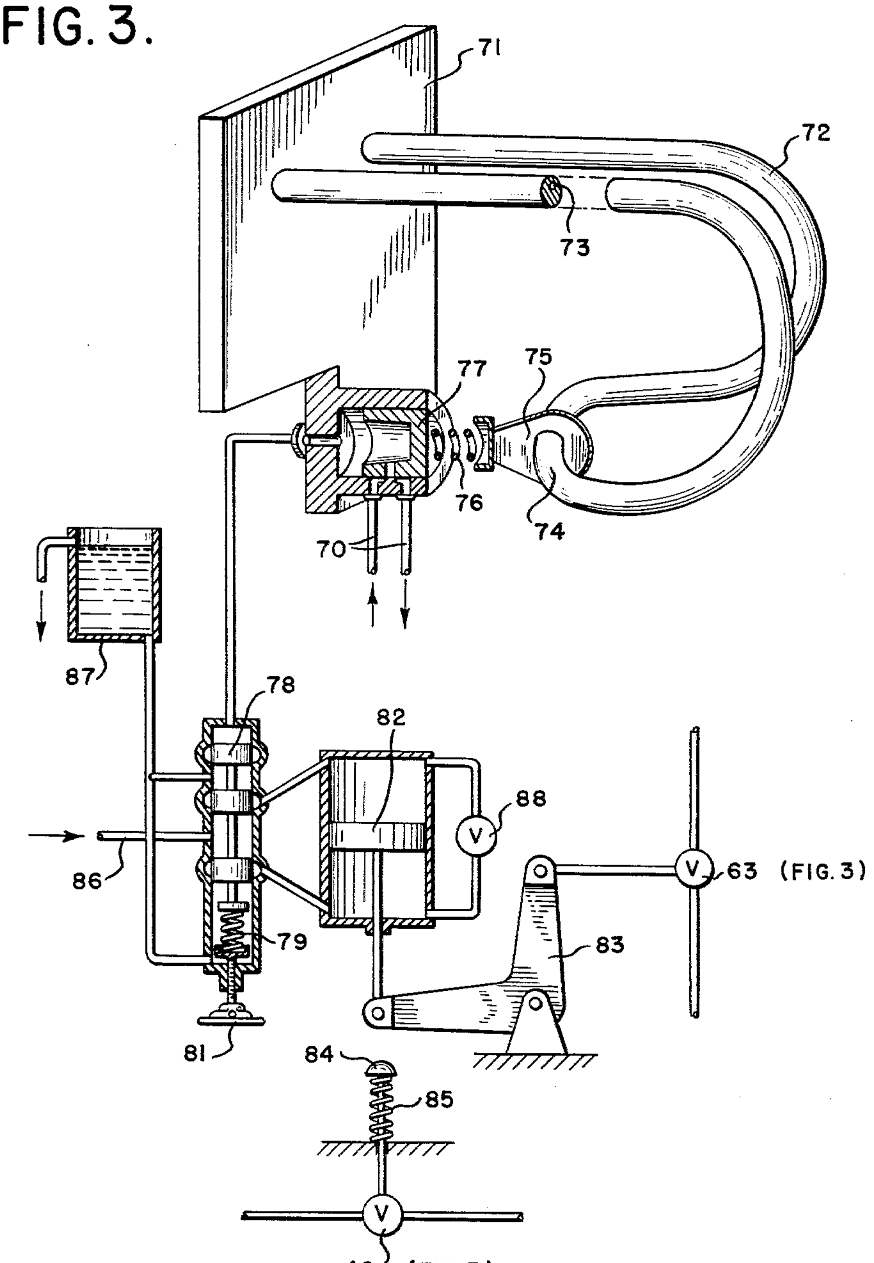
FIG. 3.



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Original Filed Aug. 19, 1959 4 Sheets-Sheet 4

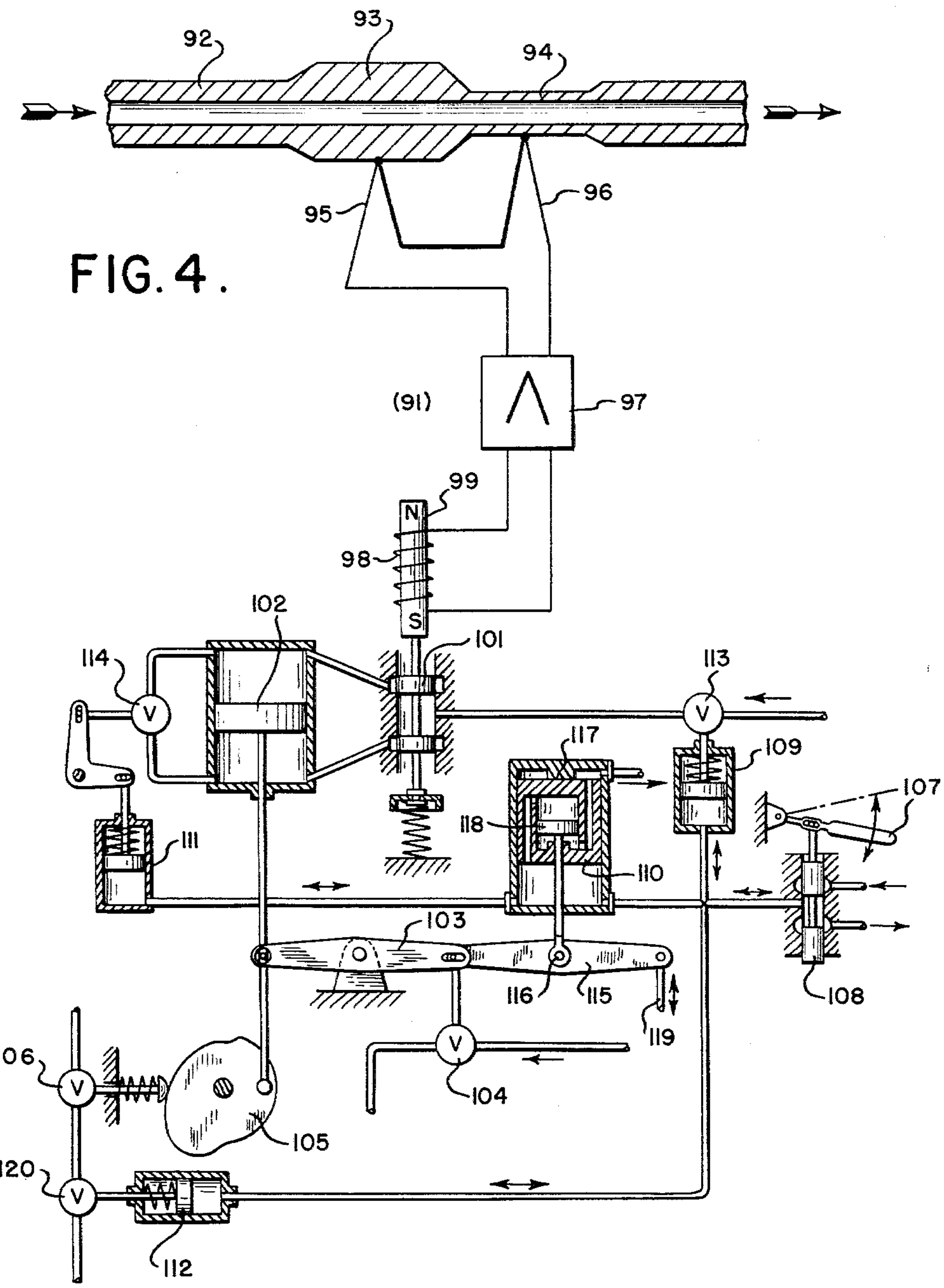

FIG. 4.

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METHOD AND APPARATUS FOR CONTROLLING RATE OF TEMPERATURE CHANGES OF HEAT GENERATORS DURING STARTUP AND SHUTDOWN

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Original application Aug. 19, 1959, Ser. No. 834,683, now Patent No. 3,102,513, dated Sept. 3, 1963. Divided and this application June 21, 1963, Ser. No. 289,612
Claims priority, application Switzerland Sept. 4, 1958
17 Claims. (Cl. 122—406)

This application is a division of my application entitled "Method and Apparatus for Controlling Rate of Temperature Changes of Heat Generators During Startup and Shutdown," Serial No. 834,683, filed August 19, 1959, now Patent No. 3,102,513, which is assigned to the same assignee as the present invention.

This invention relates to apparatus for controlling the rate of temperature change in different sections of heat transfer or exchange systems during startup and shutdown, particularly heat transfer or exchange systems having wall parts bathed by a flowing medium the temperature of which varies and which serves for heating and for cooling different parts of the heat transfer system.

When starting up steam generators and, especially, when shutting them down, it is known to allow a cooling medium to flow through the tube system or at least through a part thereof, in order to control the cooling of the parts heated during operation, more especially those parts in the radiation zone, for the purpose of protecting the material composing those parts and to carry off the heat radiated from the heated chamber walls in the radiation zone, which radiation continues to act on those parts after the extinction of the fire. In the startup of an ordinary steam generator the amount of water being circulated is customarily adjusted as a function of a temperature, usually a temperature measured at the output end of the evaporating section of the boiler. Consequently the amount of working substance flowing through those portions of the boiler downstream of the evaporator is not adjusted to the variation in time rate of temperature change occurring in those downstream heating surfaces. In accordance with the invention such surfaces are protected by the provision of suitable coolant flow irrespective of the main control of circulating water. Moreover the invention permits accelleration of the startup process by control of the rate of flow of working substance over such downstream surfaces at values corresponding or nearly corresponding to the maximum time rate of change of temperature which can be tolerated by those surfaces.

Apparatus according to the invention effects controlled discharge of a fluid medium from the tube system to be protected both upstream and downstream of a particular part thereof, which part may constitute a wall lining of the boiler, whereby the rate of temperature change of that particular part of the tube system is controlled by varying the rate of discharge of the medium both upstream and downstream of the part according to the temperature T and/or the time rate of change of temperature of dT/dt, which quantity is measured at a predetermined location in that part of the tube system. The discharge is so effected that the quantity remains within predetermined positive or negative limits.

Heat exchange apparatus constructed in accordance with this invention comprises a main channel forming a part of the tube system in a heat transmission installation. This main channel is bounded at least in part by a heat exchange surface which is exposed to a variable source of heat, such as a furnace, exterior to this main channel. The apparatus further comprises means to drive a heat exchange medium through the main channel. A by-pass channel is coupled across a section of the main channel including the heat exchange surface. The apparatus further comprises measuring means to measure the time rate of change of temperature at a point on the heat exchange surface and means responsive to the measured time rate of change of temperature for regulating the flow of the heat absorbing medium through the main and by-pass channels so as to maintain the time rate of change of temperature of the heat exchange surface within predetermined positive and negative limits.

Exemplary embodiments of the invention are illustrated diagrammatically in the drawing in which:

FIG. 1 shows an installation for the exchange of heat with a by-pass;

FIG. 2 is a graph showing the curves of the temperature during startup and shutdown of a typical heat generator, and showing the desired limiting values of the rate of change of temperatures; and

FIGS. 3 and 4 show the regulating device usable in the apparatus of FIG. 1.

In the graph shown in FIG. 2 the temperature T of the surface 12 heat exchange surface comprising series-connected tube sections **36**, **37** and **38** of FIG. 1 is plotted against the time t. Starting from the operating temperature T_B, the temperature curve **28** drops as cooling progresses. The slope of the curve **28** at each point thereof is an indication of the instantaneous rate of change of temperature (dT/dt). Owing to the nature of the material of which heat exchange surface **36**, **37**, **38** is made, and other factors, a certain value of (dT/dt) must not be exceeded. In FIG. 2 the boundary lines **29** and **30** are for (dT/dt) maximum and minimum; in consequence the inclination of the curve tangents must lie between these limits. A greater rise will give too abrupt heating and a steeper drop a too abrupt cooling of the material. Both are injurious, especially when the heat exchange surface **36**, **37**, **38** consists of temperature sensitive steel. The boundary lines **29** and **30** may have the same or different angles of inclination to the horizontal.

The temperature curve **28**, FIG. 2, which constitutes only an example, first drops steeply thereafter even rising somewhat. This may occur when the hot walls of the furnace chamber effect a more intensive radiation of heat in the heat exchange surface **36**, **37**, **38** upon the reduction in the rate of flow of working substance through that heat exchange surface.

The curve **31** shows the variation of temperature with time when the installation of FIG. 1 is started up. The slope of the curve **31** should not exceed the limits indicated by the lines **29**, **30**.

Referring now to FIG. 1, heat exchange apparatus constructed in accordance with the present invention comprises a tube system, consisting of the sections **36**, **37**, **38**, provided in the housing **35** of a heat exchanger. The tube system **36** to **38** is subjected to the flow of a gaseous medium, for example, which enters and leaves through the connections **39**, **42**. A liquid medium for example flows through the tube system **36** to **38** and is supplied by means of the pump **43**. When the valves **46**, **47**, **48**, are opened, the medium flows through the parts **37** and **38** and through the outlet line **49** to the consumer network.

The outlet **51** is provided between the sections **36** and **37** while between the sections **37** and **38** there is provided an outlet **52** with a constriction **50** limiting the maximum flow therethrough.

In the section **36** there are provided a throttle valve **46**, a measuring device **53** for the temperature T and separately, a chronometer **53**a. The bypass **54** connects the lines **44** and **51**, and can be regulated by means of the valve **55** together with the valve **46** manually, according to the change of temperature per unit of time. The temperature measuring device **53** is read periodically at the end of a certain interval of time read off from the chronometer **53***a*.

The tubing section **37** is likewise provided with a throttle valve **47** and bypass **56** with a valve **57**. The valves **47** and **57** are adjusted by a program regulating device **58**. The drum **58** is driven by the electric motor **59** and has on its wall two contact cams **60** and **60***a*, which cooperate with the contact bars **61** and **61***a*. The valves **47** and **57** are connected to the contact bars **61**, **61***a*. On rotation of the drum **58** the points of contact between the contact cam **60** and the contact bar **61** and between cam **60***a* and bar **61** shift. According to the magnitude of the change of effective resistance of the contact bars **61**, **61***a* in circuit, when the contact point moves upward, the valves **47**, **57** are operated. By changing the contact cams **60**, **60***a* on the drum **58** the valves **47**, **57** may be adjusted in accordance with a different program. Moreover the motor **59** may be controlled, for example, by the temperature of the gas flowing through the housing **35**.

The section **38** can be short circuited by means of the bypass **62** with the valve **63**. The measuring device **64** measures the rate of change of temperature (dT/dt) and passes a signal to the regulator **65**. By way of the signal lines **66** and **67** the regulator **65** controls the valves **48** and **63**. The consumer network is disconnected from the tube system **36** to **38** by means of the valve **68** during the starting and stopping period. The circulation of cooling medium is, however, continued during startup and shutdown notwithstanding closure of the valve **68**, as by the opening of a valve **49′** in a bypass line **49″**.

FIG. 3 illustrates one form which the apparatus **64** and **65** of FIG. 1 may take for control of the valves **48** and **63** in FIG. 1. In FIG. 3 a measuring tube **72** is fastened at **71** and bathes in the medium whose rate of change of temperature is to be measured. The tube **72** has an eccentric bore **73** which may be equally well disposed eccentrically on the inside instead of on the outside of the bent tube. The tube loop **74** is embraced by the clamp **75**, which is connected to the measuring spring **76**. The movement of the loop **74** is transmitted by the spring **76** to the bell **77** and by the admission and discharge of pressure oil by means of the lines **70** is converted into a pressure signal which acts on the slide **78**.

The required value for the rate of change of temperature is given by the initial tension of the spring **79**. The tension of the spring **79** can be altered by means of the hand wheel **81**. If the temperature gradient does not correspond to the required value, the servo-motor piston **82** moves, and in the first instance operates the valve **63**, FIG. 1, by way of the angle lever **83**. If the valve **63** is nearly open, the horizontal arm of the angle lever **83** begins to press the push rod **84** down against the action of the compression spring **85** and thus close the valve **48**, FIG. 1. The elements **72–77** of FIG. 3 measure dT/dt in view of the eccentric location of the bore **73** in tube **72**. The walls of the tube **72** are therefore of non-uniform thickness and respond with unequal speed to temperature changes. In consequence the bending of the tube varies and this constitutes a measure of the rate of change of temperature in the medium to which the tube **72** is exposed.

The pressure fluid for the servo-motor **82** is supplied at the supply line **86** under pressure, while the discharge is effected from the container **87**, the overflow of which determines the regulating pressure. The apparatus of FIG. 3 thus constitutes a servo-mechanism, employing the energy from the source (not shown) which supplies hydraulic fluid under pressure to the line **86**, to adjust the valves **48** and **63** of FIG. 1 in accordance with the time rate of change of temperature (measured by the tube **63**) and in accordance with the setting of hand wheel **81**.

If the valve **63** is used for other purposes the piston **82** can move freely by the opening of the valve **88**, irrespectively of the position of the measuring tube **72**.

FIG. 4 shows a measuring device **91** for measuring the rate of change of temperature using electrical means in conjunction with a length of tube **92** through which the medium flows. The said length of tube **92** has a thickened part **93** and a thinner part **94**, each provided with a thermocouple **95**, **96**. The thermocouples **95**, **96** are connected in series. The difference voltage corresponding to the rate of change of temperature is amplified in the amplifier **97** and passed to a fixed coil **98**. In the coil **98** a permanent magnet **99** is disposed to be slidable against a compression spring connected to the slide **101**. The latter controls the servo-motor piston **102**, from which by way of the two-armed lever **103** the valve **104** is operated and from which further by way of the cam **105** the valve **106** is operated. The difference in temperatures to which the thermocouples **95** and **96** are exposed is a measure of the rate of change of temperature because of the unlike heat capacity of the tube sections **93** and **94** of unlike thickness. Upon a change of temperature in the medium flowing through pipe **92**, this change affects thermocouple **96** sooner than it does thermocouple **95**. The greater the difference in temperatures between **95** and **96** the greater the rate of change of temperature. Valves **104** and **106** do not completely open or close because variation in the opening of these valves affects the flow through line **92**. This variation in flow is perceived by the thermocouples **95** and **96** which provide a feedback signal at slide **101** and control piston **102**.

The valve **104** may in addition also be used for other purposes in the operating phase of startup and shutdown. If the lever **107** is lifted, the slide **108** opens the pressure oil admission for the servo-motor pistons **109**, **110**, **111**, **112** which move against the action of the compression springs. In consequence, the following occurs. The admission of pressure oil to the servo-motor **102** is stopped by closing of the valve **113**. In addition, the piston **102** becomes freely movable by the opening of the valve **114**. At the same time, the two-armed lever **115** receives a fixed pivot point **116**, in view of the fact that the hollow piston **110** is pressed against the stop **117**, and the piston **118** against the piston **110**. The valve **104** can now be operated by the supplementary control **119** instead of by the piston **102**.

By the operation of the servo-motor **112** the valve **120** preceding the throttle element **106** is closed. Conversely, the valve **120** could be installed in a bypass to the valve **106** and be opened by the movement of the servo-motor piston **112**.

While the invention has been described in terms of a number of preferred embodiments, it will be understood that the invention is not limited thereto and that various variations are possible within the spirit and scope of the invention as defined in the following claims.

I claim:

1. A process for starting up or shutting down a heat exchanger including a main fluid medium flow channel having a rate of temperature change-sensitive boundary surface and a bypass channel connected into said main channel upstream and downstream of said surface to provide a channel in parallel therewith, said process comprising the steps of measuring the time rate of change of temperature of said surface, and varying in opposite senses the relative rates of flow in said main and parallel channels upon transgression by said rate of a limiting value.

2. A process for starting up or shutting down a heat exchanger including a main fluid medium flow channel having a rate of temperature change-sensitive boundary surface and a bypass channel connected into said main channel upstream and downstream of said surface to provide a channel in parallel therewith, said process compris-

ing the steps of measuring the time rate of change of temperature of said surface, and varying in opposite senses the relative rates of flow in said main and parallel channels upon transgression by said rate of a limiting value to increase the flow of fluid medium through said main channel when said rate of change of temperature exceeds an upper limit.

3. A process for starting up or shutting down a heat exchanger including a main fluid medium flow channel having a rate of temperature change-sensitive boundary surface and a bypass channel connected into said main channel upstream and downstream of said surface to provide a channel in parallel therewith, said process comprising the steps of measuring the time rate of change of temperature of said surface, and varying in opposite senses the relative rates of flow in said main and parallel channels upon transgression by said rate of a limiting value to reduce the flow of fluid medium through said main channel when said rate of change of temperature falls below a lower limit.

4. Heat exchange apparatus comprising a main channel bounded at least in part by a heat exchange surface, means to drive a heat exchange medium through said channel, a bypass channel coupled to said main channel in parallel with at least a portion of said heat exchange surface, means to measure the time rate of change of temperature at a point on said heat exchange surface, and means responsive to said measured time rate of change of temperature for regulating the flow of said heat absorbing medium through said main and bypass channels so as to maintain said time rate of change of temperature within predetermined positive and negative limits.

5. Heat exchange apparatus comprising a main channel bounded at least in part by a rate of temperature change-sensitive heat exchange surface, means to drive a fluid through said channel, a bypass channel connecting into said main channel upstream and downstream of said surface whereby two channels are provided in parallel, flow control means in one of said parallel channels, means to measure the time rate of change of temperature of said surface, and means responsive to transgression of a limiting value by said rate to adjust said flow control means.

6. Heat exchange apparatus comprising a main channel bounded at least in part by a rate of temperature change-sensitive heat exchange surface, means to drive a fluid through said channel, a bypass channel connecting into said main channel upstream and downstream of said surface whereby two channels are provided in parallel, flow control means in one of said parallel channels, means to measure the time rate of change of temperature of said surface, and means responsive to transgression of a limiting value by said rate to adjust said flow control means to increase the flow of fluid through said main channel when said rate exceeds an upper limit.

7. Heat exchange apparatus comprising a main channel bounded at least in part by a rate of temperature change-sensitive heat exchange surface, means to drive a fluid through said channel, a bypass channel connecting into said main channel upstream and downstream of said surface whereby two channels are provided in parallel, flow control means in one of said parallel channels, means to measure the time rate of change of temperature of said surface, and means responsive to transgression of a limiting value by said rate to adjust said flow control means to reduce the flow of fluid through said main channel when said rate declines below a lower limit.

8. Heat exchange apparatus comprising a main channel bounded at least in part by a rate of temperature change-sensitive heat exchange surface, means to drive a heat-absorptive fluid through said channel, a bypass channel connected into said main channel upstream and downstream of said surface, flow control means in said bypass channel, means to measure the time rate of change of temperature of said surface, and means responsive to transgression of a limiting value by said rate to adjust said flow control means.

9. Heat exchange apparatus comprising a main channel bounded at least in part by a rate of temperature change-sensitive heat exchange surface, means to drive a heat-absorptive fluid through said channel, a bypass channel connected into said main channel upstream and downstream of said surface, flow control means in said bypass channel, means to measure the time rate of change of temperature of said surface, and means responsive to transgression of a limiting value by said rate to adjust said flow control means to reduce the flow of fluid through said bypass channel when said rate exceeds an upper limit.

10. Heat exchange apparatus comprising a main channel bounded at least in part by a rate of temperature change-sensitive heat exchange surface, means to drive a heat-absorptive fluid through said channel, a bypass channel connected into said main channel upstream and downstream of said surface, flow control means in said bypass channel, means to measure the time rate of change of temperature of said surface, and means responsive to transgression of a limiting value by said rate to adjust said flow control means to increase the flow of fluid through said bypass channel when said rate declines below a lower limit.

11. Heat exchange apparatus comprising a main channel bounded at least in part by a rate of temperature change-sensitive heat exchange surface, means to drive a fluid through said channel, a bypass channel connecting into said main channel upstream and downstream of said surface whereby two channels are provided in parallel, separate flow control means in each of said channels, means to measure the time rate of change of temperature of said surface, and means responsive to transgression of a limiting value by said rate to adjust said separate flow control means in opposite senses.

12. Heat exchange apparatus comprising a main channel bounded at least in part by a rate of temperature change-sensitive heat exchange surface, means to drive a fluid through said channel, a bypass channel connecting into said main channel upstream and downstream of said surface whereby two channels are provided in parallel, separate flow control means in each of said channels, means to measure the time rate of change of temperature of said surface, and means responsive to transgression of a limiting value by said rate to adjust said separate flow control means in opposite senses to increase the flow of fluid through said main channel when said rate exceeds an upper limit.

13. Heat exchange apparatus comprising a main channel bounded at least in part by a rate of temperature change-sensitive heat exchange surface, means to drive a fluid through said channel, a bypass channel connecting into said main channel upstream and downstream of said surface whereby two channels are provided in parallel, separate flow control means in each of said channels, means to measure the time rate of change of temperature of said surface, and means responsive to transgression of a limiting value by said rate to adjust said separate flow control means in opposite senses to reduce the flow of fluid through said main channel when said rate declines below a lower limit.

14. Heat exchange apparatus comprising a main channel bounded at least in part by a rate of temperature change-sensitive heat exchange surface, means to drive a fluid through said channel, a bypass channel connecting into said main channel upstream and downstream of said surface whereby two channels are provided in parallel, flow control means in said main channel intermediate the intersections therewith of said bypass channel, means to measure the time rate of change of temperature of said surface, and means responsive to said measuring means to adjust said flow regulating means to maintain said rate between predetermined positive and negative limits.

15. Heat exchange apparatus comprising a main channel bounded at least in part by a multi-sectioned heat exchange surface, means to drive a heat exchange medium through said channel, a bypass channel coupled to said main channel in parallel with at least two sections of said heat exchange surface, a discharge conduit connecting at one of its ends into said main channel at the junction of two sections of said heat exchange surface which are in parallel with said bypass channel and connecting at its other end in to said bypass channel at a point intermediate the extremities of said bypass channel, means to measure the time rate of change of temperature at a point on one section of said heat exchange surface which is coupled in parallel with said bypass channel, and means responsive to said measured time rate of change of temperature for regulating the flow of said heat absorbing medium through said one section of said main channel and through the bypass channel in parallel with said one section so as to maintain said time rate of change of temperature within predetermined positive and negative limits.

16. Heat exchange apparatus according to claim 15, further comprising means for regulating the flow of said heat absorbing medium through a section of said main channel other than said one section and through the bypass channel in parallel with said other section so as to regulate the heating and cooling of said other section in a predetermined manner, the flow of said heat absorbing medium through any one section of said main channel being substantially independent of flow through other sections thereof.

17. Heat exchange apparatus comprising a main channel bounded at least in part by a multi-sectioned heat exchange surface, means to drive a heat exchange medium through said channel, a multi-sectioned bypass channel, remote from said source of heat, coupled to said main channel in parallel with a like number of sections of said

heat exchange surface, a plurality of bidirectional discharge conduits, each conduit coupled between the junction of two sections of said main channel and the junction of two sections of said bypass channel, a valve in each section of said main channel and in each section of said bypass channel upstream and downstream, in the sense of flow of said medium through said channels, of each of said discharge conduits, program controlled means operatively associated with the valve in a first section of said main channel and the valve in the parallel section of said bypass channel for controlling the flow of medium through said first section of said main channel and said parallel section of said bypass channel, means to measure the time rate of change of temperature at a point on a second section of said heat exchange surface which is coupled in parallel with a second section of said bypass channel, and control means operatively associated with the valve in said second section of said main channel and the valve in the parallel section of said bypass channel, said control means being responsive to said measured time rate of change of temperature so as to regulate flow of heat absorbing medium through said second section of said main and bypass channels, independently of flow through said first sections thereof, so as to maintain said time rate of change of temperature within predetermined positive and negative limits.

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