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DEVICE FOR CONTROLLING TEMPERATURE

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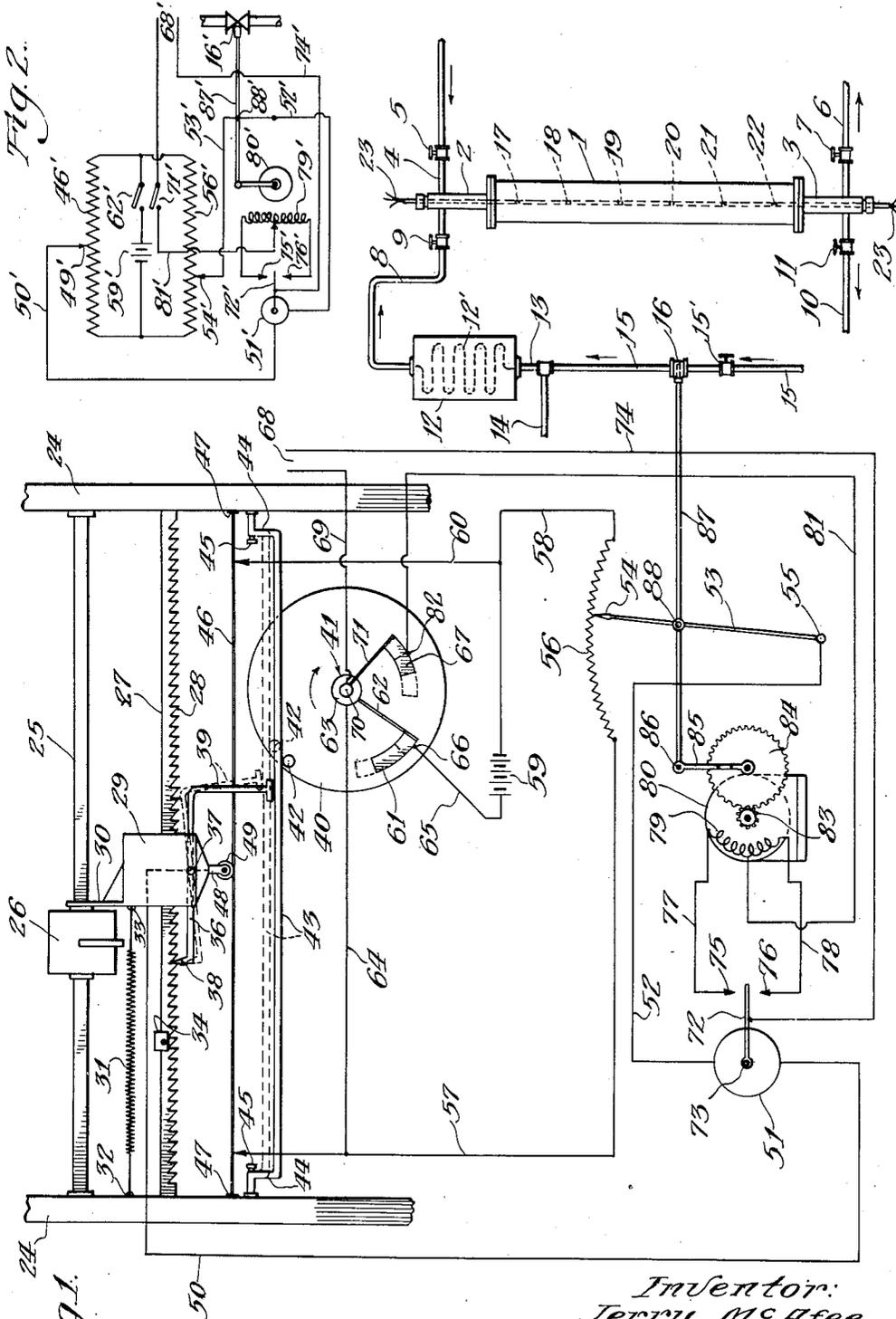


Fig. 1.

Fig. 2.

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## UNITED STATES PATENT OFFICE

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## DEVICE FOR CONTROLLING TEMPERATURE

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This invention relates to improvements in an apparatus for automatically regulating and controlling temperatures and more specifically is directed to the regulation of temperature in a reaction zone in response to changes in temperature within the zone which are transmitted as electrical impulses to a temperature measuring device operatively associated with the reaction zone.

In many catalytically promoted hydrocarbon conversion reactions, such as, for example, catalytic cracking, dehydrogenation, polymerization and other reactions, heavy hydrocarbonaceous materials resulting from the conversion reaction are deposited in a mass of granular contact material which catalyzes, directs or otherwise favorably influences the reaction. These deposits eventually impair the activity of the contact material and its activity can only be maintained at an efficient level by periodically burning the deleterious combustible deposits therefrom. This is ordinarily accomplished by passing a stream of hot oxygen-containing gases through the contact mass after the flow of hydrocarbon reactants to be converted has been discontinued or the stream thereof diverted to another similar reaction zone wherein the conversion reaction is continued in the presence of another mass of the same active contact material. The gaseous medium ordinarily employed for reactivation comprises combustion gases or other relatively inert gas containing a regulated amount of air or oxygen. The reactivating gas stream is introduced into contact with the contaminated material to be reactivated at a sufficiently high temperature to initiate combustion of the contaminants. In order to avoid the development of excessive temperature in the bed of catalyst or contact material during its reactivation, the oxygen content of the reactivating gas stream must be carefully regulated. A high oxygen content results in excessively rapid combustion of the material deposited in the contact mass and the development of high temperatures which destroy or permanently impair its activity.

The present invention provides an improved method and means for automatically regulating the quantity of oxygen, air or other oxygen-containing gas commingled with the stream of relatively inert gases to serve as the reactivating gas mixture, thereby controlling or limiting the temperature developed in the bed of catalyst or contact material undergoing reactivation.

One of the important features of the invention resides in the provision of apparatus for con-

trolling the introduction of air or oxygen and thus controlling the temperature of the material undergoing reactivation which may conveniently be employed in conjunction with conventional temperature indicating or recording instruments now in common use. This involves the employment of essential parts and operating functions of such instruments as motivating means for my control system.

Another feature of the invention resides in the provision thereof whereby the highest temperature prevailing at any of a plurality of points in the mass of contact material undergoing reactivation determines the amount of oxygen present in the reactivating gas stream, any lower temperature prevailing at other points in the contact mass being ineffective. This is particularly advantageous since in most reactivating operations of the nature above described a zone of relatively rapid combustion and resulting high temperature progresses through the mass or bed from a point adjacent the inlet of the reactivating gas stream to a point adjacent its outlet as the reactivating operation progresses. Thus the zone of highest temperature changes during the reactivating operation and a temperature measured at a single point in the bed or mass of contact material will not correspond to the highest temperature prevailing within the bed throughout the operation. By employing a plurality of thermocouples or other temperature sensitive elements at spaced points throughout the length of the bed of contact material, periodically transmitting the impulses generated at each of the thermocouples to a temperature indicating or recording instrument and translating the impulse of greatest magnitude which occurs during each complete cycle of temperature indications or recordings into a force which adjusts the quantity of air or oxygen admitted to the reactivating gas stream, I am able to definitely limit the maximum temperature prevailing at any of said spaced points and thus prevent excessive heating of the contact material in any portion of the bed.

Other objects and advantages of my invention will be apparent from the accompanying drawing and the following detailed description thereof.

In the drawing, Figure 1 is a diagrammatic illustration of the apparatus comprising my invention.

Figure 2 is a schematic view of the electrical circuits employed, the various parts of the circuit being shown diagrammatically.

There are many temperature recording instruments on the market which are employed to give a visual indication or written recordation of temperature conditions under predetermined circumstances. Most of these instruments employ the same general principle of operation. For example, one well known instrument, the "Tagliabue Celestray," has a block which moves in translatory motion in response to the temperature of one or more thermocouples with which the instrument is connected. This block carries a printing head which records, on a cooperatively moving web of paper, the temperature of a predetermined thermocouple. In this case, the essential movement of the instrument which would be employed in my invention would be the movement of the block in response to variations in temperature.

When, as is usually the case in the use of such instruments, the temperatures of a plurality of thermocouples are to be individually measured and recorded, an automatic selector switch is provided which selectively closes the circuit of a predetermined thermocouple with the instrument in timed relation with the movement of the web of paper upon which the respective thermocouple temperatures are recorded. When an instrument is connected with a predetermined number of thermocouples, the operation of once recording the temperature of each thermocouple is known as a "cycle," or "recording cycle." This cyclic movement is also one of the essential movements of the conventional temperature recording instrument which I employ in my invention, as will be hereinafter more fully described.

Referring in detail to the drawing, the reactor tube or chamber indicated by the reference numeral 1 contains a bed of contact material or catalyst, not illustrated, of the type which requires periodic reactivation in the manner above described. During processing of the hydrocarbons or other materials to be converted they are admitted to the reaction zone at a suitable temperature through pipe 4, valve 5 and inlet pipe 2. The reaction or conversion of the reactants occurs during their passage through the reaction zone in contact with the bed of catalyst or contact material disposed therein and the resulting fluid conversion products are discharged from the reaction zone through outlet pipe 3 and the communicating pipe 6 containing valve 7.

During the period of operation in which the catalyst or contact mass is employed for promoting, directing or otherwise favorably affecting conversion of the reactants admitted through pipe 4, deleterious heavy conversion products formed incidental to the desired reaction are deposited on the contact material and eventually retard its activity to such an extent that they must be removed therefrom if the catalyst or contact material is to be efficiently further employed. When this stage in the operation is reached, valve 5 in pipe 4 is closed, the stream of reactants to be converted preferably being diverted to another similar reaction zone containing fresh or freshly reactivated contact material and wherein the conversion reaction is continued. Preferably, after valve 5 is closed, valve 7 in pipe 6 remains open for a sufficient period of time to permit the removal of fluid reactants and conversion products from the reaction zone, such as, for example, by purging the reactor with inert gases or the like. The hot oxygen-containing reactivating gas stream is then ad-

mitted to the reactor, as will be presently described, to burn the deleterious deposits from the contact mass and the resulting spent or partially spent reactivating gases and combustion products are discharged from the reactor through outlet pipe 3 and through the communicating pipe 10 containing valve 11, the latter having been closed during the previous processing phase of the operating cycle.

The reactivating gas stream employed in this particular instance comprises substantially oxygen-free flue gases or the like, admitted to pipe 13 through pipe 14, and regulated amounts of air admitted to pipe 13 through line 15 and the valves 15' and 16. Pipe 13 communicates with a heating coil 12' in heating zone 12 and the mixture of combustion gases and air supplied to the heating coil through pipe 13 are therein brought to a temperature suitable for initiating combustion of the deleterious conversion products deposited in the contact mass upon contact of the reactivating gas stream therewith. The hot reactivating gas stream is directed from coil 12' through pipe 8, valve 9 and inlet pipe 2 to the reaction zone during reactivation of the contact material. Valve 9, like valve 11, is closed during the processing phase of the operating cycle in reactor 1. The heating zone 12 may comprise a furnace setting, heat exchanger or other conventional heating means capable of increasing the temperature of the reactivating gases to the desired value and is preferably operated by any suitable form of conventional control equipment, not illustrated, to maintain a substantially constant temperature in the reactivating gas stream entering the reactor.

Valve 15' in pipe 15 may be a hand-operated valve or a valve controlled by suitable time cycle equipment or the like of conventional form, not illustrated, and is normally fully open while reactivation is taking place in reactor 1 and fully closed during the processing phase of the operating cycle in reactor 1. Its principal function is to permit purging of the reactor of combustible fluid reactants and conversion products following the processing phase of the operating cycle and similar purging of the reactor of oxygen-containing gases following the reactivating phase of the operating cycle, purging being accomplished by leaving valve 15' closed during the purging period and supplying substantially oxygen-free combustion gases or other relatively inert gas to the reactor through pipe 14, heating coil 12', pipe 8, valve 9 and inlet pipe 2.

Valve 16 in pipe 15 is a motor operated valve which, while valve 15' in this line is open, functions to regulate the quantity of air or oxygen admitted to pipe 13 and therein commingled with the relatively inert components of the reactivating gas stream. The opening through valve 16 is regulated through the control mechanism provided by the invention in response and in inverse relation to the maximum temperature prevailing in the bed of contact material undergoing reactivation at any one of a plurality of spaced points therein. Its operation will be hereinafter described in greatest detail in conjunction with the description of the entire control circuit and mechanism.

Since the zone of highest temperature in the bed of contact material undergoing reactivation will vary as reactivation progresses, a plurality of thermocouples designated by the reference numerals 17, 18, 19, 20, 21 and 22 are positioned at spaced points within the bed of catalyst or con-

tact material throughout the length of reactor 1. The wires leading from the thermocouple junctions pass, in the particular case here illustrated, through the ends of inlet and outlet pipes 2 and 3 which latter are sealed to prevent the escape of fluids therethrough from the reaction zone. These lead wires or electrical connections are designated by the reference numeral 23 and are connected by well known means, not illustrated, to a suitable conventional form of temperature measuring or recording instrument of the type hereinbefore mentioned, such as, for example, the Tagliabue Celestray, wherein the impulses from the thermocouples are translated into temperature indications or recordings.

Referring now to the control mechanism which operates valve 16, the reference numerals 24 indicate spaced frame members which may comprise a portion of the recording instrument employed or which may comprise the frame of a separate instrument adapted to contain the essential working elements of my apparatus. A rod 25 is fixedly secured at its opposite ends to the opposite frame members 24, said rod serving as a guide for a block 26, which may comprise the recording head of the high temperature recording meter employed. As has been hereinbefore described, most of said recording meters are constructed along the same principle, the head 26 being moved in response to differences in temperature of the thermocouples 17 to 22 inclusive. For purposes of illustration the head 26, during a recording cycle, will move to the right, as viewed in Fig. 1, when the temperature of the selected thermocouple is higher than the temperature of the last thermocouple measured, and will move to the left when the temperature of a thermocouple being measured is less than the temperature of the thermocouple previously measured.

Heretofore, utilizing a conventional recording instrument, the movements of the head 26 were noted, or the chart which was imprinted by the head 26 was employed to indicate to the operator whether it was necessary to increase or decrease the temperature of the catalyst within the chamber 1. To increase or decrease such temperature a manually operated valve in pipe 15 was manipulated in order to increase or decrease the air supply to the gas heater 12. My invention, herein-after described, provides an automatic means for properly controlling the temperature within the catalyst chamber 1 without manual observation or operation.

A bar 27 is positioned between the spaced frame members 24 and appropriately mounted at its opposite ends to said frame members. The lower surface of the bar is provided with ratchet teeth 28. A traveling head 29 is slidably mounted upon bar 27, said head having an extension 30 which is slidably positioned upon the rod 25. A coil spring 31 is anchored, as at 32, to one of the frame members 24, the opposite end thereof being anchored, as at 33, to the block 29, the function of the coil spring being to normally urge block 29 to the left, as viewed in Fig. 1. An adjustable stop 34 is mounted upon bar 27 and functions as an abutment for the block 29, limiting its travel in response to the spring 31.

The arrangement is such that when the head 26 of the recording instrument moves to the right, it contacts extension 30 of the block 29 and thus moves said block against the tension of spring 31 to the right. A lever 36 is pivotally mounted upon the block 29, as at 37, said lever having a pawl 38 at one end which is adapted to engage

with the ratchet teeth 28. The opposite end of the lever 36 extends downwardly, as indicated at 39 in Fig. 1.

A blade spring (not shown) normally tends to rock lever 36 in a clockwise direction. Hence, when the head 26 moves to the right in response to the measurement of a thermocouple within the chamber 1 which is higher than the thermocouple previously measured, said head moves the block 29 to the right. However, when the head 26 moves to the left, that is, when the temperature of a thermocouple is measured which is lower than the temperature previously recorded, the block 29 is prevented from following the head 26 under the influence of spring 31 by the engagement of the pawl 38 with the ratchet teeth 28. It is clear, therefore, that the position of the block 29 is dependent upon the highest temperature of a predetermined thermocouple which is measured during a recording cycle. This movement is employed as the primary actuating force which sets into movement other agencies for controlling the valve 16.

A disc 40 is mounted upon a fixed hub 41 adjacent the bar 27. The disc 40 is adapted to be rotated in timed relationship with the mechanism of the conventional recording instrument which moves the paper web or chart past the printing head 26. The arrangement is such that the disc 40 makes one complete revolution for a recording cycle, that is, a cycle wherein the temperature of the thermocouples 17 to 22 are each separately measured once. A pin 42 is carried upon the disc 40 adjacent its periphery and extends at right angles to the surface of the disc. A bar 43 having offset ends 44 is carried at its opposite ends by the spaced frame members 24. The bar 43 is rockable about pivots 45 which serve as journals for said bar.

The operation is such that when the disc 40 has rotated a predetermined degree, the pin 42 contacts the lower surface of the bar 43. As the rotation of the disc 40 in a clockwise direction continues, the pin 42 acts to rock bar 43 about the journals 45. In doing so, bar 43 contacts the lower end of the depending member 39 of the lever 36, thereby rocking said lever in counter-clockwise direction and disengaging the pawl 38 from the ratchet teeth 28. Disengagement of the pawl leaves the block 29 free to move under the influence of the spring 31 and said spring causes the block to move to the left until it abuts against the stop 34 or the extension abuts against the head 26. The apparatus is then in condition to commence another cycle of recordings.

A resistance wire 46 is strung between the opposite frame members 24 and is insulated from said frame members by means of insulators 47. A lug 48 extends downwardly from block 29 and a trolley wheel 49 is journaled in the lug 48, said trolley wheel running along and making electrical contact with the wire 46. A wire 50 is grounded upon the block 29 and makes electrical contact with the trolley wheel 49. The opposite end of said wire is connected to an instrument 51 of the galvanometer type. Although a simple galvanometer movement would function, it is to be understood that the instrument 51 may comprise a polarized relay or an electronic tube system which is responsive to currents passed in opposite directions.

The opposite end of the instrument 51 is connected to wire 52 which, in turn, is connected to an arm 53 having a contact point 54. Arm 53 is pivotally mounted at 55 and the arrange-

ment is such that the contact point 54 may be swung to make contact with a variable resistance 56. One end of the resistance 56 is connected by means of wire 57 to a point adjacent the end of the wire 46. The opposite end of the resistance 56 is connected by means of wire 58 to a battery 59 or other source of E. M. F. A wire 60 also connects with wire 58, the opposite end of the wire 60 being connected to the opposite end of the resistance wire 46.

A segmental electric contact member 61 is mounted upon the face of disc 40. An arm 62 extends radially from a ring 63 which comprises the outer portion of hub 41. The outer end of said arm is positioned immediately over the path of travel of the contact member 61 and during a portion of the revolution of the disc 40, the arm 62 makes electrical contact with the member 61. A wire 64 connects wire 57 with the ring 63 and a wire 65 is connected at one end to the battery 59 and at the opposite end to a contact point 66 which is positioned adjacent the path of travel of the contact element 61, whereby electrical contact is made between the point 66 and the member 61 during a portion of travel of the disc 40, the arrangement being such that connection is made by the member 61 between the arm 62 and contact point 66.

Referring particularly to Fig. 2, the variable resistance 46' corresponds to the wire 46; the movable contact point 49' corresponds to the trolley wheel 49; wire 50' corresponds to wire 50 and connects with instrument 51' which corresponds to the instrument 51. The resistance 56' corresponds to resistance 56, and contact point 54' corresponds to the contact point 54, the contact point 54' being connected to the instrument 51' by means of wire 52'. Battery 59' corresponds to the source of electromotive force 59, and switch 62' corresponds to the arrangement comprising arm 62, contact member 61 and contact point 66.

It can readily be seen from the schematic diagram that a bridge arrangement is provided. In this arrangement when switch 62' is closed, that is, during that interval when the member 61 bridges arm 62 and contact point 66, a current will be passed through the circuit comprising wire 50', instrument 51' and wire 52' if the positions of the contact members 49' and 54' are such that a balance of electromotive force is not created. When the contact points 54' and 49' are so adjusted along the variable resistances 46' and 56' as to balance the electromotive forces, no current will flow through the instrument 51'. It can readily be seen that three conditions may exist in the instrument 51'; (1), the current may pass through said instrument in one direction; (2), the current may pass through the instrument in an opposite direction, or (3), no current may pass through the instrument.

Another segmental contacting element 67 is positioned upon the disc 40 in circumferential spaced relationship with respect to the member 61. The reference numeral 68 indicates a source of electric current, a wire 69 connects the center 70 of the hub 41 to one side of the source of electric current. An arm 71 is mounted upon the central member 70 and extends radially from said central member, said arm being angularly spaced with respect to arm 62. The end of arm 71 is positioned over the path of travel of the segmental member 67 and during that period of rotation when the segmental member 67 is beneath arm 71, an electrical connection is estab-

lished between the wire 69 and the segmental member 67. The galvanometer or other current indicating instrument 51 is provided with an arm 72, said arm being swingable about the center 73. When current passes through the instrument 51 in one direction, the arm will swing in a predetermined direction about the center 73. When current is sent through the instrument 51 in the opposite direction the arm 72 will swing in the opposite direction. When no current passes through the instrument 51, the arm 72 is disposed in normal or intermediate position. A wire 74 connected at one end to the source of electric power is connected at its opposite end to arm 72. The arm 72, when in normal or intermediate position, is disposed midway between contact points 75 and 76. When a current is passing in one direction through the instrument 51 the arm 72 makes contact with the point 75 and when passing in the opposite direction the arm 72 makes contact with the point 76.

The contact points 75 and 76 connect respectively by means of wires 77 and 78 to opposite ends of a field winding 79 of an electric motor 80. A wire 81 connects the central portion of the field winding 79 to a contact point 82 which is disposed in the path of travel of the segmental contact member 67. A pinion 83 is mounted upon the shaft of motor 80, said pinion meshing with a spur gear 84. A lever arm 85 is rigidly mounted upon the gear 84 and is pivotally connected as at 86 to link 87. Link 87 intermediate its length is pivotally connected to arm 53 as at 88, the opposite end of said link being connected to valve 16.

The arrangement is such that during the period of rotation of the disc 40 when arm 71 is in contact with the segmental element 67 and the contact point 82 also makes electrical connection with the segmental element, the wire 69 from the source of electrical power 68 is connected with wire 81 which, in turn, is connected to the center of the field winding 79. If current passes through the instrument 51 the arm 72 makes contact with either point 75 or point 76 thereby passing current in one or the other direction through the field winding 79. In this manner the motor 80 may be driven in a clockwise or counter-clockwise direction whereby link 87 is moved to simultaneously open or close valve 16, or increase or decrease the communicating opening in said valve and move the arm 53 to change the value of the resistance on each side of the contact point 54.

In employing my invention the recording cycle will start when the pin 42 is immediately beneath the bar 43 and is moving downwardly. In this position of the disc 40 the segmental elements 61 and 67 are removed from the contact points 66 and 82, and the arms 62 and 71 shall remain stationary. In accordance with the operation of the conventional recording instrument the temperatures of the individual thermocouples 17, 18, 19, 20, 21 and 22 are separately measured in sequence. In view of the fact that the bar 43 is hanging in its lowermost position, the lever 36 is free to rotate and permit the pawl 38 to engage the ratchet teeth 28. Consequently, as the different thermocouples are brought into circuit, the head 26 will move along the rod 25. In moving to the right, as viewed in Fig. 1, the head will move the block 29, but movement to the left will not cause a corresponding movement of the block 29. Hence, said block occupies the position proportional to the highest temperature

indicative of the highest temperature thermocouple. After the recording cycle has been completed, the disc 40, moving in timed relationship with the conventional recording instrument mechanism will have moved to such a position that the segmental contact elements 61 and 67 will pass beneath the arms 62 and 71 respectively. At this period of operation the bridge circuit will be completed and if an unbalanced condition exists, as determined by the position of the trolley wheel 49 upon the wire 48, the arm 72 will move into contact with either the point 75 or 76. Simultaneously, with completing the bridge circuit, the motor circuit will also be completed by the positional relationship of the arm 71, segmental contact 67 and contact point 82. Hence, current will be passed through the field winding 79 in one or the other direction thereby causing motor 80 to rotate clockwise or counterclockwise as the case may be. Rotation of the motor in one direction or the other causes an increase or decrease of flow of air to the gas heater 12. Simultaneously, arm 53 will be moved along the variable resistance 56 to cut in or cut out sufficient resistance to balance the bridge. When the bridge is balanced, that is, when no current flows through the instrument 51, the arm 72 seeks its normal position and, hence, the motor circuit is broken.

During the period when the motor 80 is in operation and the valve 16 is being manipulated and arm 53 is being moved, the disc 40 will have rotated to such a position that the pin 42 is immediately beneath the bar 43 and is rising, that is, the position shown in full lines in the drawing. Further rotation of the disc 40 breaks both of the electrical circuits and simultaneously the pin 42 functions to raise bar 43 into contact with the lower depending end of lever 36, thereby releasing the pawl and permitting the block 29 to return either to the stop 34 or to the position of the head 26. The entire apparatus is then in position to repeat the operation above described.

Of course, it is to be understood that I do not wish to be limited to the specific apparatus herein described. In the first instance, the apparatus is shown highly diagrammatically and in no sense is it intended to be contemplated as being proportional. Many of the instruments shown such as the galvanometer 51 may be replaced by similar devices such as a polarized relay or the like. The reversing motor is shown as one wherein the field of the motor is center tapped. Of course, any suitable reversing motor may be employed. The number of thermocouples employed will depend upon the type of conventional recording meter with which my apparatus is used. Broadly, my invention contemplates employing and taking advantage of the fundamental movements of a conventional temperature recording instrument and, hence, I do not wish to be limited to the use of my invention with any specific temperature recording instrument.

I claim as my invention:

1. A device for controlling the temperature of a catalyst bed during the period of reactivating the catalyst by controlled oxidation which comprises, means movable in response to variations in temperature of spaced points of a catalyst bed, a follower moved progressively by said means as the

temperature increases, means for holding said follower in a position corresponding to the maximum progressive moment of said movable means, reversible electrical means for actuating a valve for controlling the admission of an oxygen-containing gas to the catalyst bed, a resistance bridge, means carried by said follower in contact with, and forming the juncture of two arms of said bridge, whereby movement of said follower changes the resistance ratio of said two arms to unbalance said bridge, means actuated by movement of said electrical reversing means for varying the resistance ratio of the other two arms of the bridge to rebalance the bridge, and means connected between said last mentioned means and said follower contact means for controlling the direction of current through said reversible electrical means.

2. In combination, with a device for indicating by the movement of a measuring head, the temperature of a plurality of spaced points in a catalyst bed, measured sequentially in cyclic manner, of a follower moved forwardly by said measuring head as the temperature of said points increase, means for holding said follower in a position corresponding to the maximum forward movement of said measuring head in a predetermined measuring cycle, reversible electrical means for actuating a valve to control the admission of an oxygen-containing gas to the catalyst bed, a resistance bridge, means carried by said follower in contact with, and forming the junction of, two arms of said bridge, whereby movement of said follower changes the resistance ratio of said two arms to unbalance said bridge, means actuated by movement of said electrical reversing means for varying the resistance ratio of the other two arms of the bridge to re-balance the bridge, and means connected by the said last mentioned means and said follower contact means for controlling the direction of current through said reversible electrical means.

3. In combination, with a device for indicating by the movement of a measuring head, the temperature of a plurality of spaced points in a catalyst bed, measured sequentially in cyclic manner, of a follower moved forwardly by said measuring head as the temperature of said points increase, means for holding said follower in a position corresponding to the maximum forward movement of said measuring head in a predetermined measuring cycle, reversible electrical means for actuating a valve to control the admission of an oxygen-containing gas to the catalyst bed, a resistance bridge normally inoperative during said measuring cycle, means carried by said follower in contact with, and forming the junction of, two arms of said bridge, whereby movement of said follower changes the resistance ratio of said two arms to unbalance said bridge, means actuated by movement of said electrical reversing means for varying the resistance ratio of the other two arms of the bridge to re-balance the bridge, means connected by the said last mentioned means and said follower contact means for controlling the direction of current through said reversible electrical means, and means for rendering said bridge operative at the end of each cycle after the temperatures of all of said points have been measured.

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