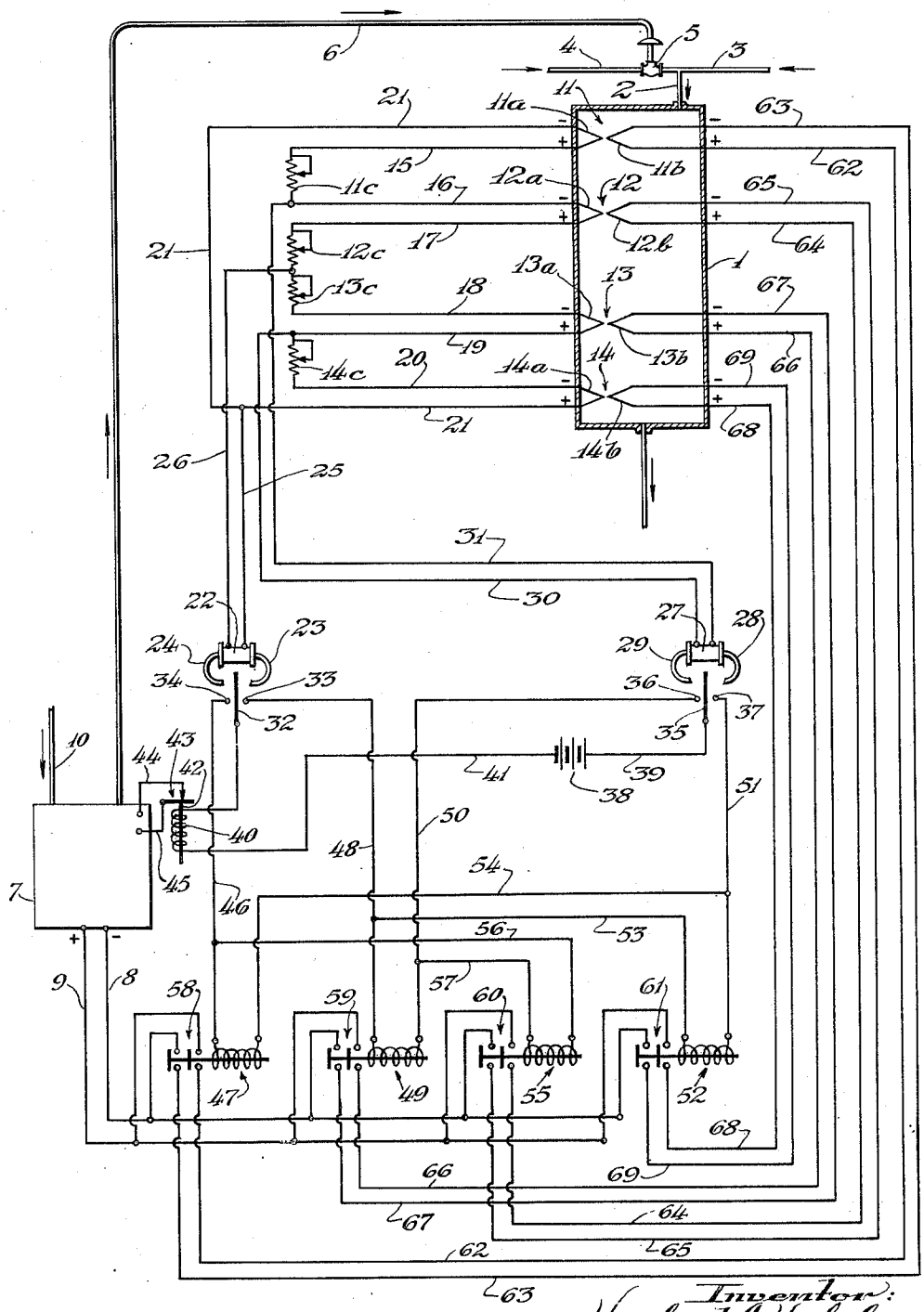
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CONTROL MEANS FOR CATALYTIC CONVERTERS

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## CONTROL MEANS FOR CATALYTIC CONVERTERS

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This invention relates to improvements in a device for controlling the passage of air or an oxygen-containing gas to a chamber where an oxidizing reaction is taking place, and refers specifically to a device which exercises such control in response to the maximum temperature at any one of a plurality of local portions of the reacting mass.

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.

As a feature of my invention, the device contemplated herein can be used with conventional control instruments of the type wherein air or gas pressure upon a diaphragm-operated control valve is regulated in response to the intensity of an electric current. For example, my invention may be employed with the usual air-operated potentiometer temperature controller, whereby variations in electric current intensity are transformed into variations in the passage of air or other oxygen-containing gas to a catalytic chamber during periods of catalyst reactivation.

Briefly described, my invention comprises a plurality of pairs of thermocouples positioned at spaced portions of a reactivating mass, the thermocouples being so arranged that the thermocouples constituting each pair are subjected to substantially the same temperature within the mass. Each pair of thermocouples consists of a primary couple and a secondary couple, and all of the primary couples are electrically connected together to form a bridge. A polarized relay, or other equivalent instrument responsive to directional flow of electric current, is connected to alternate couples, two of such relays being contemplated, whereby a combination of responses are produced in said relays by an unbalancing of the bridge. The relays, in turn actuate a pair of single-pole double-throw switches, which, being connected in a local circuit including the secondary thermocouples, select that thermocouple which is exposed to the highest temperature within the reactivating mass and connects the selected thermocouples to, for instance, an air-operated potentiometer temperature controller, whereby admission of air or other oxygen-containing gas to the reactivating mass is controlled.

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

The single figure in the drawing is a schematic, partially diagrammatic, illustration of my improved device.

Referring in detail to the drawing, 1 indicates a reactor tube or chamber which contains a mass or bed of contact material or catalyst (not shown) of the type which requires periodic reactivation in the manner hereinbefore described. During the processing of the hydrocarbons or other materials to be converted, they are admitted to the reaction chamber 1 at a suitable temperature through an inlet pipe (not shown). The reaction or conversion of the reactants occurs during passage through the reaction zone in contact with the bed of catalyst or other contact material and the resulting fluid conversion products are dis-

charged from the chamber 1 through a suitable outlet pipe (not shown).

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 to the chamber, 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, the introduction of the stream of reactants to the chamber 1 is stopped and is preferably diverted to another similar reaction zone containing fresh or freshly reactivated contact material and wherein the conversion reaction is continued. The hot oxygen-containing, reactivating gas stream is then admitted 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 chamber 1.

A pipe 2 is connected at the upper portion of the chamber 1, said pipe being connected, in turn, to pipe 3 through which hot combustion gases may be passed to the chamber 1. Pipe 2 is also connected to a pipe 4 controlled by valve 5 through which air or an oxygen-containing gas may be passed. The valve 5 is a pressure operated valve of the diaphragm type, the diaphragm portion thereof being connected to a pipe 6.

The other end of pipe 6 connects into instrument 7 which may comprise an air operated potentiometer temperature controller. The instrument 7 is of conventional construction and, per se, constitutes no part of my invention. The instrument 7 is of the general type which controls the air pressure in pipe 6 in response to and in proportion to the intensity of electric current which passes through the instrument from wires 8 and 9. A pipe 10 also connects into the instrument 7 and supplies said instrument with air under a substantially constant pressure.

The arrangement is such that when the electric current passed through the wires 8 and 9 to the instrument 7 varies, the pressure within pipe 6 varies in a proportional relationship with the current variations. As the pressure within pipe 6 varies, valve 5 will be automatically operated to permit an increase or decrease of flow of air or other oxygen-containing gas through pipe 4 to pipe 2 whereby the gas passed through the bed of catalyst or contact material within chamber 1 is varied.

A plurality of pairs of thermocouples 11, 12, 13 and 14 are positioned at appropriately spaced points in the bed or mass of catalyst or contact material within the chamber 1. Each pair of thermocouples comprises a primary couple and a secondary couple, that is, the pair 11 comprises primary couple 11*a* and secondary couple 11*b*; pair 12 comprises primary couple 12*a* and secondary couple 12*b*; pair 13 comprises primary couple 12*a* and secondary couple 13*b*; and, pair 14 comprises primary couple 14*a* and secondary couple 14*b*. Each of the secondary couples is disposed adjacent its respective primary couple in such manner that the couples constituting each pair will be subjected to substantially the same temperature.

All of the primary couples are connected in series, the circuit being completely closed to form a four-armed bridge of the Wheatstone type, that is, the positive side of couple 11*a* is connected by leads 15 and 16 to the negative side of couple 12*a*; the positive side of couple 12*a* is connected by leads 17 and 18 to the negative side of the couple 13*a*; the positive side of couple 13*a* is connected by leads 19 and 20 to the negative side of couple 14*a*; and, the positive side of couple 14*a* is connected by lead 21 to the negative side of couple 11*a*.

It is desirable that the resistance of each of the primary couples be equal so that when all couples are subjected to the same temperature, the bridge will be balanced. Accordingly, variable balancing resistors are employed to compensate for inequalities in resistance of the couples due, perhaps, to corrosion, unequal lead wire lengths, etc. A balancing resistor 11*c* is interposed between leads 15 and 16; balancing resistors 12*c* and 13*c* are connected in series between leads 17 and 18; and, a balancing resistor 14*c* is interposed between leads 19 and 20. Resistor 11*c* can be employed to vary the resistance of the arm which includes couple 11*a*; resistor 12*c* can vary the resistance of the arm which includes couple 12*a*; resistor 13*c* can vary the resistance of the arm which includes couple 13*a*; and, resistor 14*c* can vary the resistance of the arm which includes couple 14*a*. Preferably the bridge is balanced when all of the couples are cold or are maintained at the same temperature.

A polarized relay 22, having pole pieces 23 and 24 is connected from between couples 11*a* and 14*a*, by means of lead 25, to the midpoint between resistors 12*c* and 13*c*, by lead 26. A similar polarized relay 27, having pole-pieces 28 and 29 is connected from between couples 13*a* and 14*a*, by lead 30, to between couples 11*a* and 12*a*, by lead 31. Associated with the relay 22 is a swingable armature or switch-arm 32 which normally maintains a central position between pole-pieces 23 and 24 when no flux passes between said pole-pieces. Depending upon the direction of current through the relay 22, arm 32 will be drawn to the pole-piece 23 or to pole piece 24. In swinging to pole-piece 23, arm 32 makes contact with a switch-point 33, or, if swung to pole-piece 24, said arm makes contact with switch-point 34. An arm 35 and cooperating switch-points 36 and 37 are associated with relay 27, in the same manner hereinbefore described with respect to relay 22, arm 32 and switch-points 33 and 34.

A battery 38 is connected to the switch-arm 35 by lead 39. The other side of the battery is connected to solenoid 40 by lead 41, the opposite side of said solenoid being connected to switch-arm 32. The solenoid, when current is passed therethrough, functions to move plunger 42 which opens switch 43 which is normally closed. The instrument 7 contains a potentiometer and a galvanometer and current passing through the galvanometer controls the air pressure in pipe 6. Switch 43 is connected, by leads 44 and 45, in shunt with the galvanometer and, hence, when said switch is closed and the galvanometer is shunted, the air pressure within pipe 6 remains constant until switch 43 is opened again placing the galvanometer in control position. Accordingly, when my device is in operation, solenoid 40 functions to place the galvanometer in control position whereby the air pressure in pipe 6 may be varied.

Switch-point 34 is connected by lead 46 to one side of a power relay 47. Switch-point 33 is con-

nected by lead 48 to one side of power relay 49 and switch-point 36 is connected by lead 50 to the other side of relay 49. Switch-point 37 is connected by lead 51 to one side of power relay 52, the other side of said relay being connected by lead 53 to switch-point 33. Switch-point 37 is also connected by lead 54 to the opposite side of relay 47. A fourth power relay 55 is connected by leads 56 and 57 to switch points 34 and 36 respectively.

Associated with each of the power relays 47, 49, 55 and 52 is a double-pole, single-throw switch 58, 59, 60 and 61, respectively. Secondary couple 11b connects with one side of switch 58 by means of leads 62 and 63; secondary couple 12b connects to one side of switch 60 by means of leads 64 and 65; secondary couple 13b connects to one side of switch 59 by means of leads 66 and 67; and, secondary couple 14b connects to one side of switch 61 by means of leads 68 and 69. The opposite sides of all of said switches 58, 59, 60 and 61 connect to leads 8 and 9. All of said switches are normally open and actuation of a selected relay connects a corresponding selected secondary couple to the control instrument 7.

Specifically, the function of my invention is to automatically select that pair of thermocouples which is at the highest temperature and connect the secondary couple of the pair with the pressure controller 7 so that the introduction of air or other oxygen-containing air through pipe 4 may be increased or decreased as occasion demands. The selection of the proper pair is dependent upon an unbalanced condition of the bridge comprising the primary couples and relays 22 and 27.

There are a number of conditions wherein an unbalance occurs, all of which will be hereinafter discussed. For example, using $T_{11}$, $T_{12}$, $T_{13}$ and $T_{14}$ as the temperatures of the respective pairs of thermocouples 11, 12, 13 and 14, and using $R_{22}$ and $R_{27}$ as the current through the polarized relays 22 and 27 (directionally indicated):

| Thermal relation of pairs of couples | $R_{22}$ | $R_{27}$ |
|---|---|---|
| (A) $T_{11}=T_{12}T_{13}=T_{14}$ (balanced) | 0 | 0 |
| (B) $T_{11}$ highest (others equal or unequal) | + | + |
| (C) $T_{12}$ highest (others equal or unequal) | + | − |
| (D) $T_{13}$ highest (others equal or unequal) | − | − |
| (E) $T_{14}$ highest (others equal or unequal) | − | + |
| (F) $T_{11}$ lowest (others equal) | − | − |
| (G) $T_{13}$ lowest (others equal) | − | + |
| (H) $T_{12}$ lowest (others equal) | + | + |
| (I) $T_{14}$ lowest (others equal) | + | − |
| (J) $T_{11}=T_{13}$ and $T_{12}=T_{14}$ | 0 | 0 |
| (K) $(T_{11}=T_{14})$ $(T_{12}=T_{13})$ | 0 | + |
| (L) $(T_{13}=T_{12})$ $(T_{11}=T_{14})$ | 0 | − |
| (M) $(T_{13}=T_{14})$ $(T_{11}=T_{12})$ | − | 0 |
| (N) $(T_{11}=T_{12})$ $(T_{13}=T_{14})$ | + | 0 |

The conditions represented by (B), (C), (D) and (E) are those substantially always met with in practice. The conditions represented by (F), (G), (H) ,(I), (J), (K), (L), (M) and (N) are theoretically possible, but are unlikely to be met with in practice. However, these conditions will also be discussed.

When condition (B) exists, current will pass in a positive direction through both relays 22 and 27, and arm 32 will move into contact with switch-point 34, and arm 35 will swing into contact with switch-point 37. Current will then flow from the positive side of battery 38, through arm 35, leads 51 and 54, through relay 47, lead 46, arm 32, solenoid 40 and through lead 41 to the negative side of the battery. This current flow will open the short-circuiting switch 43 thereby placing the galvanometer in instrument 7 in a pressure-controlling position. Simultaneously, relay 47 will act to close switch 58 thereby connecting secondary couple 11b, the hottest couple, with the leads 8 and 9 whereby the galvanometer, and hence the air pressure upon valve 5 will be controlled directly in response to the voltage built up at the couple 11b. Likewise, if conditions (C), (D) or (E) obtain, thermocouples 12b, 13b or 14b will be connected by switches, 60, 59 or 61, respectively, to leads 8 and 9 to control the pressure on valve 5 directly from the hottest couple.

It will be noted that when any of the relays 47, 49, 55 or 52 are selected, the non-selected relays will be in series with each other. Consequently, the relays 47, 49, 55 and 52 must have such characteristics as to be inoperable except with currents above one-third of their normal operating current.

When conditions (F), (G), (H) or (I) obtain, a secondary thermocouple other than the one with the lowest temperature will be selected. Hence, the air or oxygen-containing gas will be admitted under the control of a hotter thermocouple since the temperatures of each of the remaining thermocouples are equal.

When conditions (A), (J), (K), (L), (M) or (N) obtain, none of the secondary thermocouples will be connected to the instrument 7 until the temperature of one couple changes enough to unbalance the bridge, and the couple at the maximum temperature will then be selected, since, where two couples are at the same temperature while the other two are at different temperatures, the one at maximum temperature would be selected. Of course, in view of the fact that switch 43 normally short-circuits the pressure controlling galvanometer of the instrument 7, under the conditions in question the pressure within pipe 6 will remain substantially constant until an unbalance occurs.

As has been hereinbefore stated, the conditions (A), (J), (K), (L), (M) or (N) will obtain infrequently and the period of the conditions is necessarily of short duration before the desired unbalance occurs. Hence, for all practical purposes, inasmuch as conditions (B), (C), (D) and (E) are by far the most common, my device will automatically and substantially instantly control the passage of air or other oxygen-containing gas to the chamber 1 in response to the highest temperature thermocouple.

If desired, the secondary thermocouples may be eliminated and the relays 47, 55, 49 and 52 may function to connect the primary thermocouples 11a, 12a, 13a and 14a, respectively, to the leads 8 and 9. However, although this arrangement is broadly contemplated by my invention, the form described herein in detail is preferred. The instrument 7 is of the conventional type manufactured by Brown Instrument Company, the C. J. Tagliabue Company, Leeds and Northrup Company and others.

I claim as my invention:

1. In combination with a catalyst chamber adapted to contain a bed of catalyst, including means for introducing an oxygen-containing gas to the catalyst chamber for reactivating the catalyst by controlled oxidation, a device for controlling the temperature of the catalyst bed during the period of reactivation which comprises, four pairs of thermocouples positioned in said bed of catalyst, each pair of thermocouples being spaced in said catalyst bed from each other pair

and each pair comprising a primary couple and a secondary couple disposed adjacent each other so as to be subjected to substantially the same temperature, said primary couples being connected together in series to form a bridge, means connected between alternate primary couples responsive to the directional flow of current between the respective alternate couples, four power relays, a source of electromotive force, said means comprising switches for selectively connecting one of said power relays to said source of electromotive force to energize the selected power relay, electrically actuated control means for controlling the passage of oxygen-containing gas through said gas-introducing means, to said chamber, means connecting said secondary couples through said respective power relays to said control means, said energized relay completing the circuit from a predetermined secondary couple to the control means.

2. In combination with a catalyst chamber adapted to contain a bed of catalyst and means for introducing an oxygen-containing gas to the catalyst chamber for reactivating the catalyst by controlled oxidation, a device for controlling the temperature of the catalyst bed during the period of reactivation which comprises, four pairs of thermocouples positioned in spaced relation in said bed of catalyst, each pair of thermocouples comprising a primary couple and a secondary couple disposed adjacent each other so as to be subjected to substantially the same temperature, said primary couples being connected together in series to form a bridge, a pair of polarized relays connected between alternate primary couples actuated by the flow of current between the respective alternate couples, a pair of switches actuated by said polarized relays, a source of electromotive force connected to said switches, four power relays each connected in series with said switches and selectively electrically connected by said switches to said source of electromotive force, electrically actuated control means for controlling the passage of oxygen-containing gas through said gas-introducing means to said chamber, means connecting said secondary couples to said respective power relays to said control means, said power relays being respectively interposed in said connecting means to selectively connect a predetermined secondary couple to said electrically responsive control means in response to selection of said power relay by said polarized relays.

3. In combination with a catalyst chamber adapted to contain a bed of catalyst and means for introducing an oxygen-containing gas to the catalyst chamber for reactivating the catalyst to control oxidation, a device for controlling the temperature of the catalyst bed during the period of reactivation which comprises, four pairs of thermocouples positioned in spaced relationship of said bed of catalyst, each pair of thermocouples comprising a primary couple and a secondary couple disposed adjacent each other so as to be subjected to substantially the same temperature, said primary couples being connected together in series to form a bridge, a pair of polarized relays connected between alternate primary couples, a double-throw switch actuated by each of said polarized relays, a source of electromotive force, four power relays, connections between said switches and said power relays, said polarized relays acting to actuate said switches to selectively connect a predetermined power relay and the source of electromotive force in response to an unbalanced condition of the bridge, electrically actuated control means for controlling the passage of oxygen-containing gas through said gas-introducing means to said chamber, means connecting said secondary couples through said respective power relays to said control means, said connecting means being controlled by the said predetermined power relay to connect the hottest thermocouple to said electrically actuated means, whereby the flow of oxygen-containing gas to said chamber is reduced.

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