United States Patent

Bajek et al.

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[45] **Mar. 14, 1972**

[54] CONTROL OF REACTION ZONE SEVERITY BY RESPONSE TO OCTANE NUMBER OF EFFLUENT LIQUID PHASE

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[52] **U.S. Cl.**.....**23/253 A**, 23/253 PC, 23/263, 23/288, 208/139, 208/DIG. 1, 235/151.12, 235/151.13

[51] **Int. Cl.**.....**B01j 9/04**, C10g 35/04, G01n 33/00

[58] **Field of Search**.....23/253, 253 A, 253 PC, 263, 23/288, 230, 230 A, 230 PC; 208/DIG. 1, 139; 196/132; 235/151.12, 151.1, 151.13, 151.3, 151.35

[56] **References Cited**

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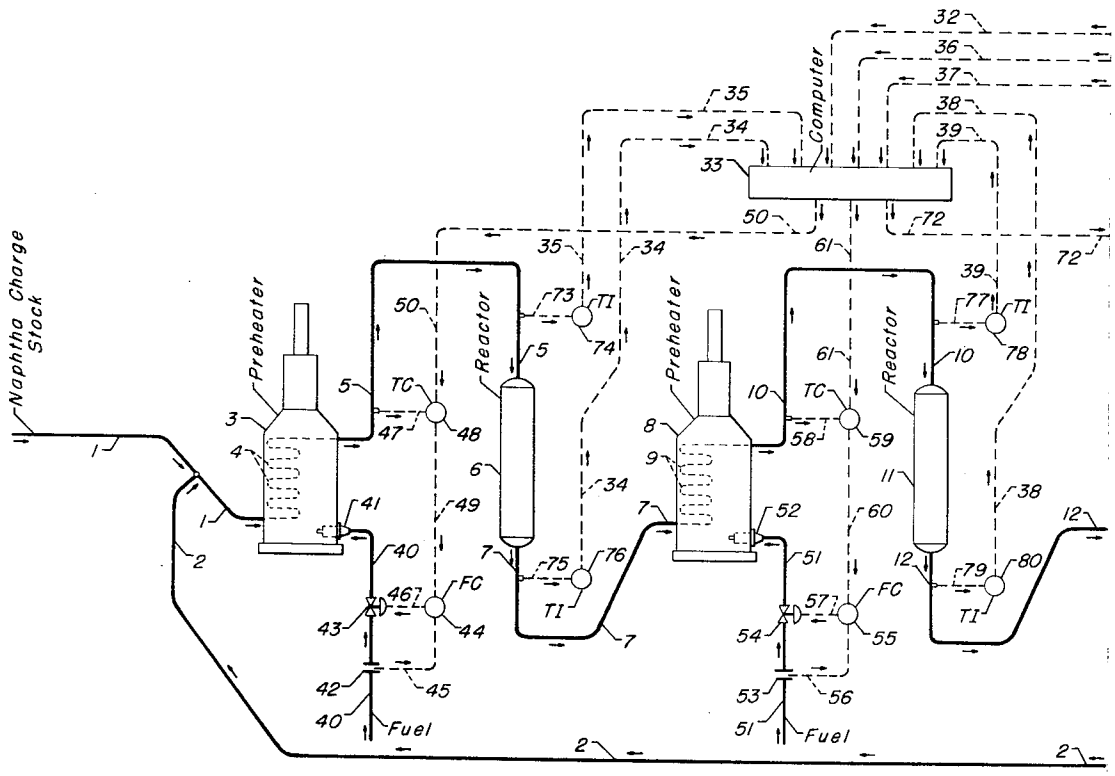
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3,497,449	2/1970	Urban	23/253 X

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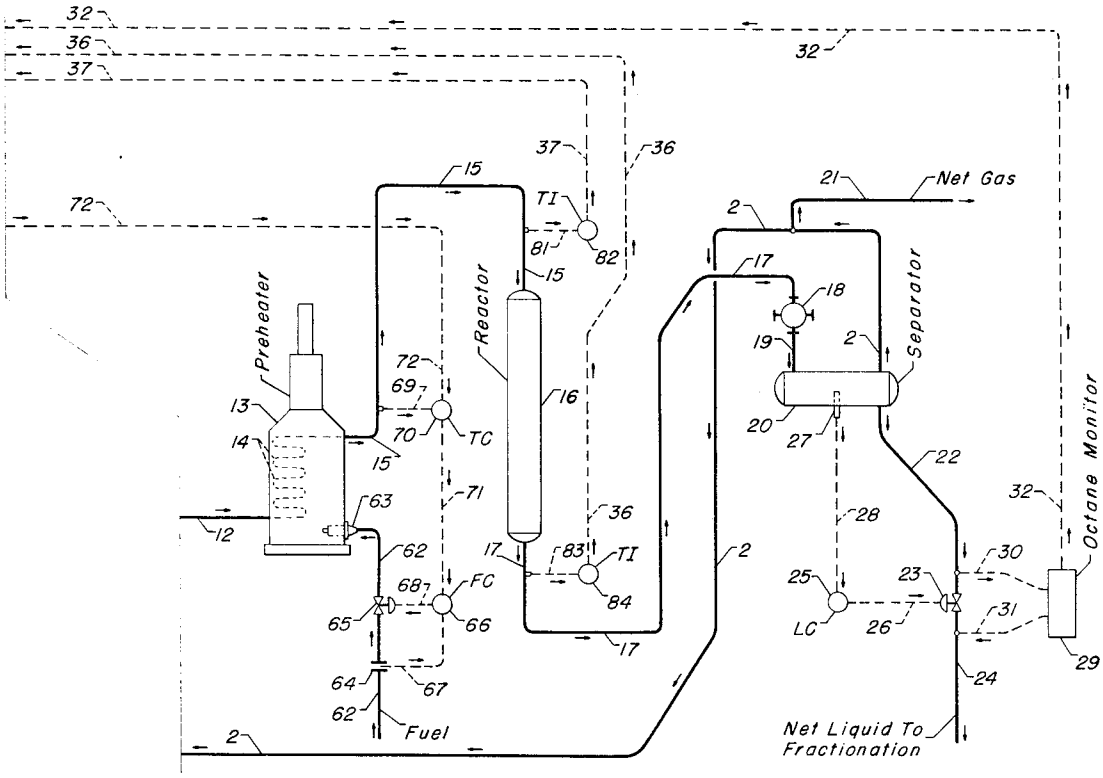
[57] **ABSTRACT**

An improved control system for adjusting and controlling reaction zone severity in a continuous flow hydrocarbon conversion process, wherein a hydrocarbon charge stock is passed through a reaction zone at conversion conditions comprising elevated temperature and pressure, and the resulting product effluent is separated into a vapor phase and into a liquid phase comprising gasoline boiling range hydrocarbon constituents. A sample of liquid phase effluent is continuously passed without intervening depressurization from the phase separator into a hydrocarbon analyzer which measures the octane number of the liquid phase sample. The octane measurement is effected by an analyzer comprising a stabilized cool flame generator with a servo-positioned flame front which provides a real time output signal indicative of sample octane number. The analyzer output signal is received by a computer which is operatively responsive to said analyzer output signal, and which develops a computer output signal which is a function of sample octane number and severity of conversion conditions within the reaction zone. The control system provides improved operation in a hydrocarbon conversion process comprising a plurality of conversion zones whereby conversion conditions within each zone may be independently adjusted in a manner sufficient to maintain the octane number of the separator liquid phase at a constant predetermined level.

19 Claims, 2 Drawing Figures



[15] **3,649,202**
[45] **Mar. 14, 1972**



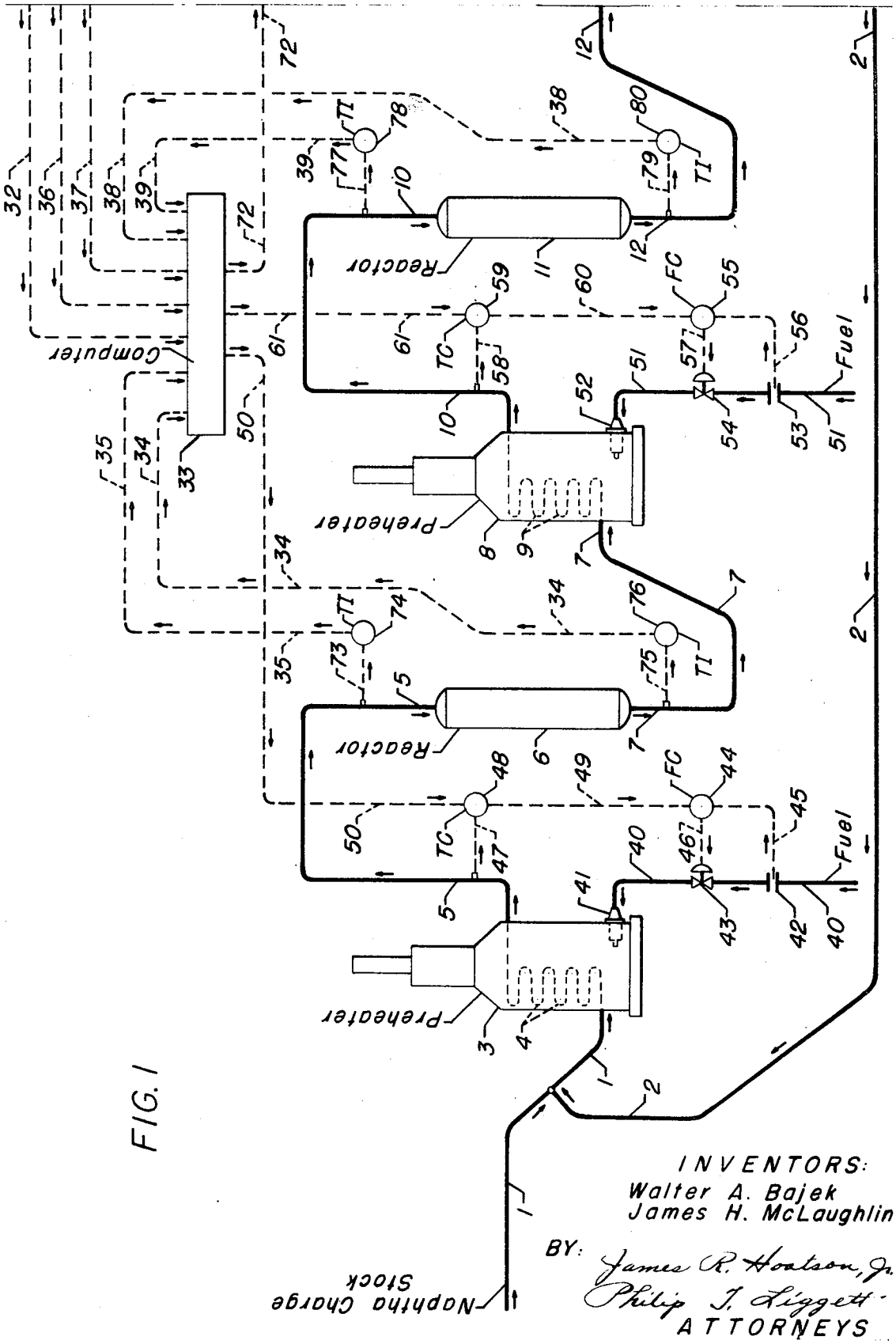


FIG. 1

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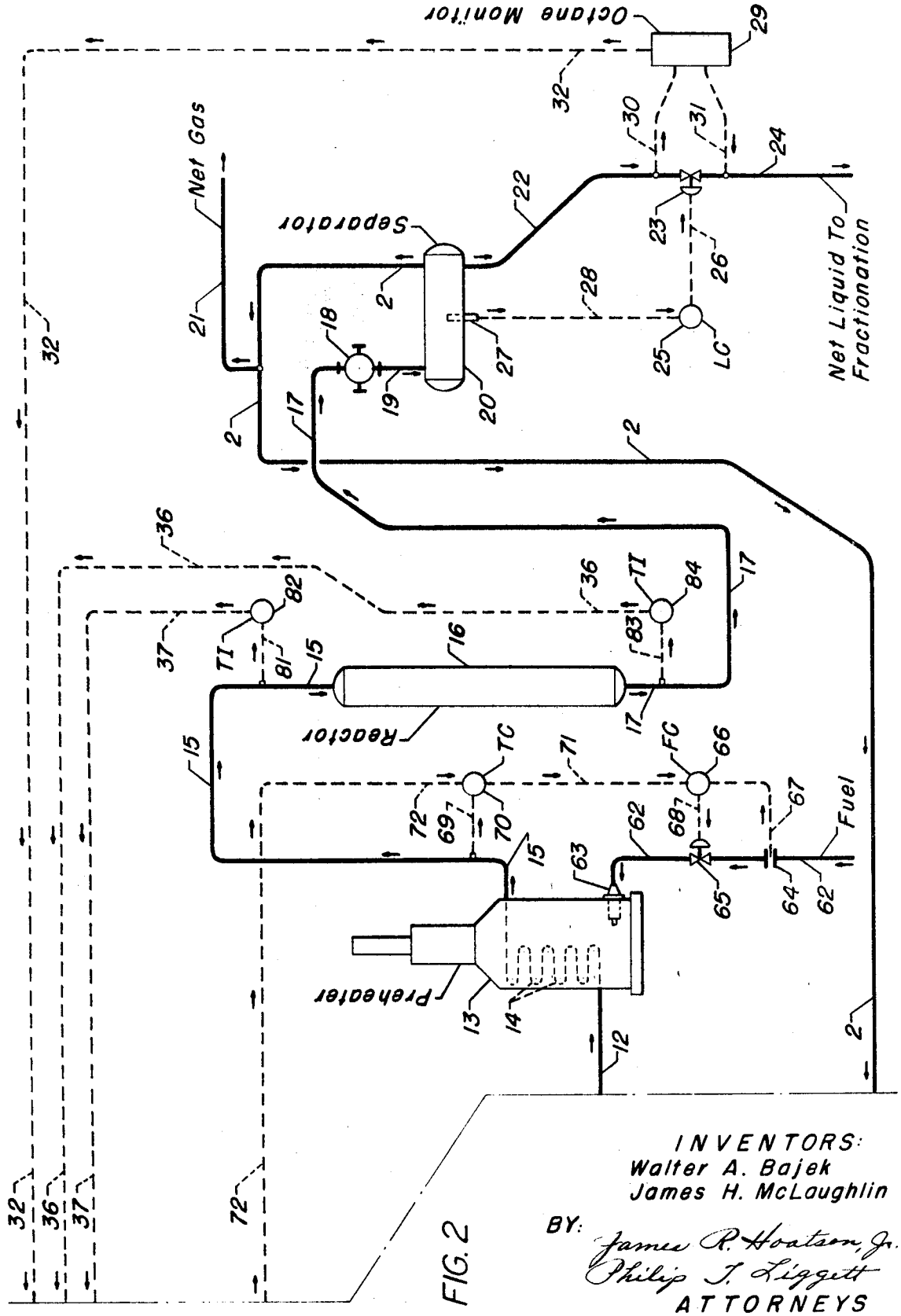


FIG. 2

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CONTROL OF REACTION ZONE SEVERITY BY RESPONSE TO OCTANE NUMBER OF EFFLUENT LIQUID PHASE

FIELD OF THE INVENTION

The invention of this application is a process control application of the hydrocarbon analyzer described in U.S. Pat. No. 3,463,613 issued Aug. 26, 1969 to E. R. Fenske and J. H. McLaughlin, all the teachings of which, both general and specific, are incorporated by reference herein.

As set forth in U.S. Pat. No. 3,463,613, the composition of a hydrocarbon sample can be determined by burning the sample in a combustion tube under conditions to generate therein a stabilized cool flame. The position of the flame front is automatically detected and used to develop a control signal which, in turn, is used to vary a combustion parameter, such as combustion pressure, induction zone temperature or airflow, in a manner to immobilize the flame front regardless of changes in composition of the sample. The change in such combustion parameter required to immobilize the flame following a change of sample composition is correlatable with such composition change. An appropriate readout device connecting therewith may be calibrated in terms of the desired identifying characteristic of the hydrocarbon sample, as, for example, octane number.

Such an instrument is conveniently identified as a hydrocarbon analyzer comprising a stabilized cool flame generator with a servo-positioned flame front. The type of analysis effected thereby is not a compound-by-compound analysis of the type presented by instruments such as mass spectrometers or vapor phase chromatographs. On the contrary, the analysis is represented by a continuous output signal which is responsive to and indicative of hydrocarbon composition and, more specifically, is empirically correlatable with one or more conventional identifications or specifications of petroleum products such as Reid vapor pressure, ASTM or Engler distillations or, for motor fuels, knock characteristics such as research octane number, motor octane number or composite of such octane numbers.

For the purpose of the present application, the hydrocarbon analyzer is further limited to that specific embodiment which is designed to receive a hydrocarbon sample mixture containing predominantly gasoline boiling range components, and the output signal of which analyzer provides a direct measure of octane number, i.e., research octane, motor octane or a predetermined composite of the two octane ratings. For brevity, the hydrocarbon analyzer will be referred to in the following description and accompanying drawing simply as an "octane monitor."

An octane monitor based on a stabilized cool flame generator possesses numerous advantages over conventional octane number instruments such as the CFR engine or automated knock engine monitoring systems. Among these are: elimination of moving parts with corresponding minimal maintenance and downtime; high accuracy and reproducibility; rapid speed of response providing a continuous, real-time output; compatibility of output signal with computer or controller inputs; ability to receive and rate gasoline samples of high vapor pressure, e.g., up to as high as 500 p.s.i.g., as well as lower vapor pressure samples (5–250 p.s.i.g.). These characteristics make the octane monitor eminently suitable not only for an indicating or recording function, but particularly for a process control function wherein the octane monitor is the primary sensing element of a closed loop control system comprising 0, 1, 2 or more subloops connected in cascade.

DESCRIPTION OF THE PRIOR ART

The present invention has as its principal objective, the direct control of reaction zone severity in a continuous flow hydrocarbon conversion process, wherein a hydrocarbon charge stock is passed through a reaction zone at conversion conditions comprising elevated temperature and pressure, and the resulting product effluent is separated into a vapor phase and into a liquid phase comprising gasoline boiling range constituents.

Typical of such a hydrocarbon conversion process is catalytic hydroreforming, wherein a naphtha fraction is passed into a reaction zone containing a noble metal catalyst in the presence of a molar excess of hydrogen. The basic processing technique and a preferred catalyst are indicated in U.S. Pat. Nos. 2,479,109 and 2,479,110, issued to Vladimir Haensel, wherein the catalyst comprises alumina, platinum, and halogen. Reforming is undertaken at a temperature in the range of from about 600° F. to about 1,100° F.; at a pressure in the range of from about 100 p.s.i.g. to about 1,000 p.s.i.g., but more normally in the range of from about 200 to about 500 p.s.i.g.; at a liquid hourly space velocity in the range of from about 0.5 l./hour to about 10.0 l./hour; and in the presence of from about 0.5 to about 10.0 moles of hydrogen per mole of hydrocarbon.

As understanding of the reaction mechanisms occurring within the reforming zone has increased, it has become possible to adjust to operating techniques and catalyst composition to enhance the specific reaction desired. Thus, it is a primary purpose of catalytic reforming to subject a substantially sulfur, nitrogen, oxygen, olefin, and metal free gasoline boiling range or naphtha boiling range charge stock to high temperature and pressure in the presence of hydrogen in order to enhance the antiknock properties of the hydrocarbons contained therein. It has been determined that such enhancement, resulting in a high octane gasoline product, is derived from four specific chemical reactions; (1) the dehydrogenation of naphthenic hydrocarbons to produce the corresponding aromatic derivative, (2) the dehydrocyclization of paraffinic hydrocarbons to produce corresponding aromatic hydrocarbons, (3) the hydrocracking of high molecular weight hydrocarbons to produce lower molecular weight hydrocarbons, and (4) the isomerization of normal paraffinic hydrocarbons to produce branched chain isomers of equal molecular weight.

Each of these four reaction mechanisms upgrade low octane hydrocarbons to high octane hydrocarbons, but as the automotive manufacturers have increased engine compression ratios it has become necessary to adjust operating techniques in order to control the reaction mechanisms selectively to maximize octane with minimum loss of liquid product yield and minimum production of paraffinic gas (methane, ethane, and propane). It has thus been determined that the dehydrogenation of naphthenes to aromatics is promoted by operating at lower pressure levels; that dehydrocyclization of paraffins to aromatics is promoted by low pressure and high temperature; that hydrocracking of paraffins is promoted by high pressure, high temperature, and high residence time of the charge stock on the catalyst; and that isomerization of paraffins is promoted by intermediate temperature, and a catalyst comprising a much higher halogen content than normally employed. Since aromatic hydrocarbons have higher octane ratings than other hydrocarbons of equivalent molecular weight, catalytic reforming has showed a current tendency to operate at higher temperatures and lower pressures in order to enhance the resulting gasoline octane rating by increasing the aromatic hydrocarbon content of the gasoline. Therefore, the catalytic reforming unit producing high octane motor fuel, typically is maintained at operating conditions sufficient to enhance dehydrogenation of naphthenes and the dehydrocyclization of paraffins in order to maximize the production of both aromatics and hydrogen, maximum hydrogen being desired since it is normally consumed elsewhere in the typical petroleum refinery. The production of aromatic hydrocarbons is enhanced by catalytic reforming at a temperature in the range of from about 850° F. to about 1,050° F. and at a pressure in the range of from about 100 p.s.i.g. to about 400 p.s.i.g. when the end boiling point of the charge stock is about 350° F., but when the end point of the charge stock is about 400° F. or more, the preferred pressure is about 500 p.s.i.g. in order to maintain catalyst stability.

The operator of the catalytic reforming unit judiciously selects the operating conditions which he believes will most economically produce the desired high-octane gasoline. The naphtha charge stock is passed into the reaction zone under conditions of temperature, pressure, catalyst composition, hydrogen to hydrocarbon ratio, etc., which will produce a reactor effluent having the composition necessary to result in the desired high-octane product. When analysis indicates that the product does not meet octane specification, it is normal in the art for the operator to manually change conditions within the reaction zone to compensate for any deviation from specification.

The resulting hot vaporous reactor effluent containing hydrogen, normally gaseous hydrocarbons and gasoline boiling range hydrocarbons is withdrawn from the reaction zone, cooled, condensed, and passed to a separation zone which is normally a single-stage gravity-type phase separator maintained substantially at reforming pressure of, say, 50–500 p.s.i.g. The liquid hydrocarbon or unstabilized reformate phase is in equilibrium therein with the gas phase containing a major proportion of hydrogen. The hydrogen-rich vapor phase is withdrawn and a portion thereof is recycled to the inlet of the catalytic reforming zone for circulation across the catalyst together with the naphtha charge. The liquid hydrocarbon phase from the separator is then ultimately fed to a distillation zone which normally comprises a stabilizer column. The liquid phase contains a substantial portion of dissolved hydrogen and C_1–C_4 hydrocarbons which must be removed in order that the stabilized reformate will meet vapor pressure and octane number specifications. A typical sample of catalytic reformate from a separator operating at 250 p.s.i.g. consists of:

Component	Mol %
H_2	2.5
C_1	0.5
C_2	1.5
C_3	2.5
i-C_4	2.5–3.5
n-C_4	2.5–3.5
i-C_5	3.5–5
n-C_5	3.5–5
C_5 –400° F. endpoint	81.0–76.0

The overhead from the stabilizer column is predominantly C_4 and lighter hydrocarbons, and the column bottoms is stabilized gasoline typically comprising predominantly C_5 to about 400° F. endpoint material.

By and large it has been the practice to operate such a catalytic reforming unit mostly "in the dark" so far as octane number of the stabilized gasoline product is concerned. That is to say, the stabilizer column bottoms is manually sampled perhaps once every eight hour shift or perhaps even only once a day. The samples are picked up and taken to the laboratory where each sample is run and the result is then transmitted back to the unit operator who, until then, has not been able to ascertain what change, if any, should have been made at the time the sample was taken.

Therefore, to be on the safe side, the unit operator will usually run the reforming reaction zone with excessive heat input in order to guarantee that the octane quality of the reformate gasoline will meet specification. The net result is that the resulting stabilized reformate will actually exceed product specifications with respect to octane a good part of the time. This mode of operation increases the refiner's costs since, as those skilled in the art know, decrease in product yield accompanies increase in product octane number.

The control problem is further complicated by the not uncommon practice of using a single stabilizer column to process more than one gasoline stream. For example, a single stabilizer column will often receive plural or combined feeds which may comprise unstabilized reformates from two or more independently operated catalytic reforming units. An upset in the operation of a single such reformer will carry through to the stabilizer and be reflected in off-specification product so that the stabilizer bottoms product is no longer indicative of only the operation of a single reformer.

Continuously meeting octane number specification is, thus, an exceedingly difficult and haphazard task when employing a single stabilizer column to handle a plurality of gasoline streams. When the octane number of the stabilizer bottoms falls below the specification level, it often is not possible to determine which of the plural unstabilized reformate feeds to the column is the source of the low octane number gasoline boiling range hydrocarbon components in the final stabilized gasoline product. If the reaction severity is increased at the wrong reforming unit, there is the danger that the resulting yield loss will far outstrip the resulting value of octane enhancement for the combined stabilized gasoline. In addition, it is often found that the stabilizer bottoms fraction does not meet the octane number specification despite the fact that the catalytic reforming unit is operating properly. When such a condition is not recognized, remedial steps may be taken at the reaction zone with no corresponding remedial result being obtained in the octane number of the stabilized gasoline product. The result may later be found to be caused by misoperation of the stabilizer column. Or the result may later be found to be caused by the introduction of extraneous material into the stabilized gasoline product, as when it is found that the stabilizer reboiler is leaking hot oil heating medium into the gasoline product.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an improved method for continuously monitoring the quality of a hydrocarbon product produced in a continuous flow hydrocarbon conversion process.

It is another object of the present invention to provide an improved control system in combination with the reaction zone of a continuous flow hydrocarbon conversion process for use in adjusting and maintaining severity of conversion within the reaction zone.

It is a further object of the present invention to provide such a continuous monitoring and control system for use in adjusting and controlling conversion severity in a manner sufficient to provide a hydrocarbon product having a constant predetermined level of quality.

It is a particular object of the present invention to provide such an improved continuous monitoring and control system for use in a hydrocarbon conversion process comprising a plurality of reaction zones, wherein conversion conditions within each zone are independently adjusted in a manner sufficient to maintain the octane number of the effluent liquid hydrocarbon at a constant predetermined level.

These and other objects of the present invention, as well as the advantages thereof, will be more clearly understood as the invention is more particularly disclosed hereinafter.

In accordance with the present invention, the octane monitor comprising a stabilized cool flame generator with servo-positioned flame front is connected to receive a continuous sample of the liquid phase of the reactor effluent, directly from the vapor-liquid separator of the reforming reaction zone without intervening depressurization below the separator pressure. Since the liquid phase sample which is sent to the combustion chamber of the octane monitor thus remains at substantially the reaction zone pressure, the sample contains not only the normally liquid hydrocarbon constituents comprising the final gasoline product, but also a substantial amount of dissolved high vapor pressure constituents comprising dissolved hydrogen and normally vaporous hydrocarbons such as methane, ethane, and propane. However, the output signal of the octane monitor can be, and preferably is, calibrated directly in terms of octane number, notwithstanding the presence of a substantial portion of high vapor pressure constituents within the sample. The output signal from

the octane monitor is then transmitted to a computer means which is operatively responsive to the octane monitor output signal, and which in turn develops a computer output signal which is a function of sample octane number and severity of conversion conditions within the reaction zone. The computer output signal is then utilized to reset or adjust heat input to the reaction zone so that the octane number of the liquid phase of the reactor effluent is maintained at a substantially constant predetermined level.

The inventive control system thus assures that the liquid phase of the reactor effluent (the unstabilized reformate gasoline being fed to the stabilizer column) will always remain on specification, relative to octane number, regardless of external upsets or disturbances. The control system thus effects a savings in utility cost in that the reaction zone is thereby operated at a minimum heat input. Raw material cost is also minimized since minimum heat input minimizes the conversion severity and thereby results in a minimum loss of product yield to obtain a gasoline product of substantially constant octane number.

Because there is a direct measurement and control of the octane rating of the unstabilized reformate gasoline, this control system is to be distinguished from those prior art control systems wherein some composition property such as percent aromatics, or conductivity, or dielectric constant, is measured and controlled. All of these latter physical properties are merely an indirect indication of octane rating which is only narrowly correlatable therewith. Such indirect correlation becomes invalid for any significant deviation from the design control point.

The control system of this invention is also to be distinguished from those prior art systems employing automated knock engines as the octane-measuring device. Since the octane monitor utilized within the inventive control system comprises a stabilized cool flame generator, it is normal to introduce the sample directly into the octane monitor substantially at the separator or reaction zone pressure (separator pressure equals reaction zone pressure less the pressure drop through heat exchange equipment and piping). The sample therefore contains a substantial amount of dissolved hydrogen and normally gaseous hydrocarbon vapors within the liquid phase, and such a sample obviously cannot be sent directly to an automated knock engine type of octane measuring device. The knock engines cannot operate at elevated pressures, and the samples thereto must be degassed or otherwise stabilized before injection into the knock engine since a high vapor pressure sample may vapor lock a knock engine type of octane-measuring device.

The control system of this invention is further to be distinguished from the prior art systems employing automated knock engines as the octane measuring device in that the instant octane monitor is compact in size, can be totally enclosed by an explosion proof housing, and therefore can be used in hazardous locations. As a matter of fact, the octane monitor of the present invention is typically field installed immediately adjacent to the reaction zone vapor-liquid separator in order to minimize the run of high pressure tubing conducting the sample of liquid hydrocarbon phase to the combustion chamber of the octane monitor. A knock engine in contrast cannot be employed in hazardous locations and must therefore be situated remote from the sample point.

The sample transport lag or dead time of a close-coupled octane monitor as employed within the scope of the present invention is typically of the order of two minutes or less, and its 90 percent response time is another two minutes. This provides a very good approach to an essentially instantaneous or real time output. By way of contrast, the transport lag alone of a knock engine may be of the order of 30 minutes or more, which those skilled in the control system art will recognize to be a substantial departure from real time output. With that much dead time built into a closed loop it is extremely difficult to achieve and maintain control stability, and undampened cycling may result. Particularly is this true in the system of the present invention since the sample being sent directly to the octane monitor would have to first be degased before such liquid could be injected into the knock engine. Any nonequilibrium or inconsistent degassing will introduce an additional uncontrollable disturbance into the control system since the degasses sample will not be truly indicative of the reactor effluent composition or octane number.

In a broad embodiment it may, therefore, be summarized that the present invention comprises a control system for use and in combination with a continuous flow hydrocarbon conversion process wherein a hydrocarbon charge stock is passed through a conversion zone at conversion conditions comprising elevated temperature, and the resulting conversion product effluent is separated into a vapor phase and into a liquid phase comprising gasoline boiling range hydrocarbon components, said conversion process having charge stock preheating means, said conversion zone, a vapor-liquid phase separation zone, means for passing charge stock to said preheating means, means for passing charge stock from said preheating means to said conversion zone, means for passing conversion product effluent from said conversion zone to said separation zone, and means for supplying heat to said preheating means from an external source, the improved control system for said conversion process which comprises in combination: (a) operatively associated with said heat supplying means, means to vary the heat input to said preheating means; (b) a hydrocarbon analyzer comprising a stabilized cool flame generator with a servo-positioned flame front, continuously receiving a sample of said liquid phase from said separation zone, and developing an output signal which in turn provides a measure of sample octane number; (c) computer means operatively responsive to said analyzer output signal, receiving said signal and developing a computer output signal which in turn is a function of sample octane number and severity of conversion conditions within said conversion zone; (d) means transmitting said computer output signal to said heat input varying means, whereby the heat input to said preheating means is regulated responsive to said computer output signal, whereby the octane number of said liquid phase is maintained at a constant predetermined level.

In a more narrow embodiment, the present invention may be summarized as the foregoing embodiment wherein said computer output signal is a function of said sample octane number and of at least one conversion zone temperature.

In a still more narrow embodiment, the present invention may be summarized as either of the foregoing embodiments wherein said heat input varying means comprises a flow control loop including a flow controller having an adjustable setpoint regulating the flow of heat medium through said preheating means, whereby said setpoint is adjusted in response to said computer output signal.

Preferred specific embodiments of the present invention will incorporate one or more cascaded subloops which more immediately control the heat input to the reaction zone. For example, where the reaction zone is indirectly heated by a fluid heating medium such as combustion gas, steam, reactor effluent, or hot oil, there will typically be a flow control loop on the heating medium to the reactor preheater, the octane monitor output then being sent to the computer which in turn develops a computer output signal which is sent to the flow controller setpoint. Alternatively a reactor inlet temperature control instrument may reset the flow controller and the computer output may reset the temperature controller setpoint. Other embodiments will become apparent in light of the detailed description of the invention which follows.

The invention may now be more clearly understood by reference to the accompanying drawing which sets forth a simplified schematic flow diagram of a typical catalytic reforming reactor system in which particular embodiments of the inventive control system are utilized. Process flow lines and major items of equipment are therein illustrated by solid lines, while the dashed lines represent elements of the inventive control system which transmit input and output signals.

DESCRIPTION OF THE DRAWINGS

With reference now to FIGS. 1 and 2 there is shown a simplified schematic flow diagram for the reactor section of a typical catalytic reforming unit. A low octane number charge stock comprising naphtha or gasoline boiling range hydrocarbon constituents, typically having an end boiling point of about 350° F., enters the reforming process via line 1. A recycle gas stream is injected into line 1 via line 2. This gas stream comprises predominantly hydrogen with a minor portion of normally gaseous hydrocarbon vapor comprising methane, ethane, and propane. The resulting mixture of hydrogen and hydrocarbon passes into a reactor preheater 3 via line 1.

Preheater 3 may be any type of heat exchanger employing any type of heating medium such as steam, hot oil, hot vapor, flue gas, etc. Normally, however, in order to achieve the high temperature required, preheater 3 will be a direct fired furnace as illustrated. The reaction mixture of hydrogen and hydrocarbon is heated within coil 4 in preheater 3. Coil 4 is typically placed in the radiation section and the convection section of the preheating furnace 3.

The heated reaction mixture leave preheater 3 via line 5, typically at a temperature of from about 900° to 1,000° F., depending upon the composition of the hydrocarbon feed stock. The hot mixture passes into a reaction zone comprising reactor vessel 6 at a pressure of from about 100 to 500 p.s.i.g., and typically at a pressure of about 300 p.s.i.g. The reaction zone comprises a bed of noble metal reforming catalyst, and the reaction mixture undergoes a conversion therein to produce lower boiling hydrocarbon constituents having a higher octane number. The reaction primarily comprises the dehydrogenation of naphthenes which is an endothermic reaction. Consequently, the reaction mixture leaves the reaction zone via line 7 at a temperature which is normally from 60° to 150° F. below the reactor inlet temperature, and which typically will be about 100° F. below the inlet temperature. The amount of temperature drop between inlet and outlet sections of the reactor will depend upon the naphthene content of the charge stock, the inlet temperature of the catalyst bed, the hydrogen to hydrocarbon molar ratio within the conversion zone, the pressure of the zone, etc.

The reaction mixture leaving reactor 6 passes via line 7 into a second preheater 8. Preheater 8 also may be any type of heat exchanger employing any type of heating medium, but normally will be a direct fired furnace as illustrated. The mixture of hydrogen and hydrocarbon is heated within coil 9 in preheater 8. Coil 9 is typically placed in the radiation section and the convection section of the furnace 8. The heated reaction mixture leaves preheater 8 via line 10, again, at a typical temperature of from about 900° to 1,000° F.

The hot mixture passes into a second reaction zone comprising the reactor vessel 11, at a pressure between 100 p.s.i.g. and 500 p.s.i.g. and typically at a pressure of about 300 p.s.i.g. The pressure within reactor 11 will be equal to the pressure within reactor 6 less the pressure drop due to the intervening equipment and the catalyst bed within reactor 6. The reaction zone 11 contains a similar bed of noble metal reforming catalyst, and the reaction mixture undergoes a further conversion therein to produce lower boiling constituents having a higher octane number. The reaction primarily comprises the dehydrogenation of naphthenes and dehydrocyclization of paraffins, as well as some isomerization of normal paraffins to isoparaffins. The overall reaction, accordingly, is an endothermic reaction. Consequently, the reaction mixture leaves the reaction zone 11 via line 12 at a temperature which is normally from 20° to 100° F., and typically about 30° F., below the reactor inlet temperature. Again, the temperature drop depends upon the remaining naphthene content of the reaction mixture charged to reactor 11 as well as the inlet temperature of the catalyst bed and the other operating conditions existing therein.

The hydrocarbon and hydrogen mixture next passes via line 12 into a third preheater 13. Preheater 13 also may be any type of heat exchanger employing any type of heating medium but normally will consist of a direct fired furnace as illustrated. The reaction mixture of hydrogen and hydrocarbon is heated within the coil 14 in preheater 13. Coil 14 is typically placed in the radiation section and the convection section of the preheating furnace 13. The heated reaction mixture leaves preheater 13 via line 15, typically at a temperature of from about 900° to 1,000° F., depending upon the composition of the hydrocarbon feed stock.

The hot mixture passes from preheater 13 into a reactor vessel 16 via line 15, at a pressure equal to the pressure of reaction zone 6 less the pressure drop due to the intervening equipment and reactor catalyst beds. The reaction zone within reactor vessel 16 comprises a bed of noble metal reforming catalyst, and the reaction mixture undergoes a further conversion therein to produce lower boiling hydrocarbon constituents having a higher octane number. Since the major portion of the naphthene content of the charge stock has been dehydrogenated in the prior conversion or reaction zones, the reaction within reactor 16 will predominantly comprise hydrocracking of hydrocarbon constituents. Consequently, the reaction will consist of a slightly endothermic or a slightly exothermic reaction. Accordingly, the reaction mixture leaves the reaction zone 16 via line 17 at a temperature which is normally from 10° F. below the reactor inlet temperature to about 10° F. above the inlet temperature. Typically, a reforming operation to produce a motor fuel will produce an effluent in line 17 which has a temperature of about 5° F. above the temperature of the input mixture entering via line 15. Again, of course, the amount of reaction and the temperature drop or temperature rise occurring across reactor 16 will depend upon the remaining naphthene content of the mixture passing to the reactor as well as the inlet temperature, the hydrogen to hydrocarbon ratio, etc.

The final reactor effluent passes via line 17 into a heat exchanger 18 wherein the mixture is cooled and normally liquid hydrocarbon constituents are condensed. The condensed and cooled mixture leaves the heat exchanger 18 at a temperature of from about 60° to 120° F. and normally at a temperature of about 100° F. The cooled mixture then passes into a separator 20 via line 19.

Separator 20 will be at a pressure which is substantially the same pressure as that of the reaction zone 6 but it will be slightly lower due to the pressure drop caused by the intervening equipment and catalyst beds in the system. Thus, whereas the initial pressure at reactor 6 will typically be at an inlet pressure of from 100 to 500 p.s.i.g., separator 20 will typically be at a pressure of about 50 p.s.i.g. less than the reactor 6 pressure. Thus, where the inlet pressure at reactor 6 is 300 p.s.i.g., the pressure at separator 20 will be about 250 p.s.i.g.

The condensed and cooled effluent entering separator 20 via line 19 is separated therein into a vapor phase and a liquid phase. The vapor phase is withdrawn via line 2 for recycle to the first reaction zone inlet. Compressor means, not shown, sends the hydrogen-rich vapor phase via line 2 into line 1 for mixture with the charge stock ahead of preheater 3 as was previously described hereinabove. The catalytic reforming reaction not only upgrades the hydrocarbon constituents to higher octane number components but it also produces hydrogen as a byproduct of the process. Consequently, a net hydrogen-rich gas containing some ethane, methane, and propane is withdrawn via line 21 as a net gas product which is typically sent to further processing units for consumption elsewhere in the refinery.

The liquid phase of the reactor effluent will have a component analysis similar to that presented hereinabove. The liquid phase containing dissolved gaseous components is withdrawn from separator 20 via line 22 and is passed through a control valve 23 and 24, usually into a fractionation zone, not shown. The liquid phase withdrawal rate typically is adjusted and controlled by a liquid level controller 25 which may be operated by a level-sensing means 27 transmitting a level output signal via a transmitting means 28. Level-sensing means 27 may comprise a float mechanism, a dielectric probe,

a DP cell, or any other similar level sensing device. The level controller **25** adjusts the valve **23** by transmitting an electrical, pneumatic, or hydraulic output signal thereto via line **26**.

An octane monitor **29** utilizing a stabilized cool flame generator with a servo-positioned flame front is field installed immediately adjacent to separator **20**. In a preferred embodiment, the flows of oxidizer (air) and fuel (effluent liquid phase sample) are fixed, as is the induction zone temperature. Combustion pressure is the parameter which is varied in a manner to immobilize the stabilized cool flame front. Upon a change in sample octane number, the change in pressure required to immobilize the flame front within the octane monitor provides a direct indication of the change of octane number in the sample delivered to the combustion chamber. Typical operating conditions for the octane monitor are:

Airflow	3,500 cc./min. (STP)
Fuel Flow	1 cc./min.
Induction Zone Temperature	700° F. (Research Octane)
	800° F. (Motor Octane)
Combustion Pressure	4–20 p.s.i.g.
Octane Range (Max.)	80–102*

*The actual calibrated span of the octane monitor as here utilized will, in general, be considerably narrower. For example, if the target octane is 95 clear (research method), a suitable span may be 92–98 research octane. When a relatively narrow span is employed, the octane number change is essentially directly proportional to the change in combustion pressure.

Dashed lines **30** and **31** represent a suitable sampling system providing a continuous sample of the liquid phase of the reactor effluent to the octane monitor **29**. The sample is withdrawn from separator **20** or from line **22** upstream of control valve **23** and passed into the octane monitor via line **30** without intervening depressurization. The sample system comprises a sample loop of high-pressure tubing taking a liquid sample at a rate of about 100 cc. per minute from a point upstream of control valve **23** and returning 99 cc. per minute of the sample to point downstream of control valve **23** via line **31**. The sample itself is drawn off within the octane monitor from an intermediate portion of the sample loop and injected at full line pressure at a controlled rate of about 1 cc. per minute into the combustion tube of the octane monitor **29**.

An octane monitor output signal providing a direct measure of the octane number of the liquid phase sample, is transmitted via line **32** to a computer means **33**. In addition, the octane monitor output may be sent to an octane recorder located in the refinery control house, and this will be typically done although it is not shown on the drawing. The computer **33** receives the octane monitor output signal **32**, and additionally receives a number of other input signals which are indicative of conversion conditions within the reaction zones of the catalytic reforming process. Primarily, the additional input signals received by computer **33** are reaction temperature signals which are received by input lines **34**, **35**, **36**, **37**, **38**, and **39** form sources to be disclosed hereinafter.

Computer **33** receiving input signals of octane number and temperature, may also receive other inputs indicative of conversion severity or reactor conditions which are not shown in the drawing and which will be discussed more fully hereinafter. Additionally, computer **33** contains an internal program which is responsive to the octane number input of line **32**, and which generates output signals **50**, **61**, and **72** which are a function of the octane number of the liquid phase sample withdrawn from receiver **20** via lines **22** and **30**, and which additionally are a function of the conversion conditions within the reaction zones **6**, **11**, and **16** of the hydrocarbon conversion process. Output signals **50**, **61**, and **72** are generated by computer **33** in a manner sufficient to adjust conversion conditions within the reaction zones **6**, **11**, and **16** in a manner sufficient to maintain the octane number of the liquid phase of the effluent at a substantially constant predetermined level of octane. In the typical application of the inventive control system, the computer output signals respond to the octane monitor output signal to adjust conversion temperatures within reactors **6**, **11**, and **16**.

Heat input to each reaction zone is provided by introducing a combustible fuel into each reactor preheater. Referring now to preheater **3**, there is shown a fuel inlet line **40** which passes combustible material into a bank of combustion nozzles **41** contained within the furnace **3**. The fuel, which may be a liquid or a gas, is burned within the combustion zone and the hot combustion gas passes through the furnace and out the stack. As the fuel is burned and the resulting combustion gas passes through the furnace **3**, it imparts the necessary heat input into the reaction mixture contained within the coil **4** by means of radiation and convection.

The heat input into the reaction mixture is controlled and adjusted by varying the flow of fuel to the bank of combustion nozzles **41**. This control of fuel is achieved by means of a flow control loop contained in line **40**. The flow control loop comprises a control valve **43** and a flow sensing means **42** which for illustrative purposes is shown as an orifice device. A flow signal line **45** transmits the flow signal from orifice **42** to flow controller **44**. Flow controller **44** then transmits an output signal to the flow control valve **43** via line **46**. The setpoint of flow controller **44** is automatically adjustable.

Referring now to the preheater **8**, there is shown a fuel inlet line **51** passing a combustible fluid to preheater **8** and into a bank of combustion nozzles **52** contained therein. Again, the fuel may be liquid or gas, and it is burned within the furnace in order to transmit heat to the hydrogen and hydrocarbon mixture contained within the coil **9** by means of radiation and convection. The heat input into the reaction mixture contained within coil **9** is controlled and adjusted by varying the flow of fuel to the bank of combustion nozzles **52**.

The control of the flow of fuel is achieved by means of a flow control loop contained in line **51**. The flow control loop comprises a control valve **54** and a flow sensing means **53** which for illustrative purposes is shown as an orifice. A flow signal line **56** transmits the flow signal from orifice **53** to flow controller **55**. Flow controller **55** then transmits an output signal to the control valve **54** via line **57**. The setpoint of flow controller **55** also is automatically adjustable.

Referring to preheater **13**, there is shown a fuel inlet line **62** passing a combustible fuel to a bank of combustion nozzle **63**. Again, the fuel may be liquid or gas and the fuel is burned within the furnace to impart the necessary heat input into the reaction mixture contained within coil **14** by means of radiation and convection. The heat input into the reaction mixture contained within coil **14** is controlled and adjusted by varying the flow of fuel to the bank of combustion nozzle **63**. This control of the flow of fuel is achieved by means of a flow control loop contained in line **62**. The flow control loop comprises a control valve **65** and a flow sensing means **64** which for illustrative purposes is shown as an orifice. A flow signal line **67** transmits the flow signal from orifice **64** to flow controller **66**. Flow controller **66** then transmits an output signal to the control valve **65** via line **68**. Again, the setpoint of flow controller **66** is automatically adjustable.

In addition to the flow control loop which is provided at the fuel inlet at each preheater, there is preferably associated therewith a temperature control device also having an automatically adjustable setpoint, which senses the corresponding reactor inlet temperature as detected by a thermocouple or other temperature sensing means located in an inlet section of the associated conversion or reaction zone.

Referring, for example, to preheater **3** there is shown a thermocouple means **47** contained in reactor inlet line **5**, transmitting a temperature signal to a temperature controller **48**. The temperature controller **48** produces a temperature output signal which is transmitted via line **49** to the flow controller **44** to adjust or reset the automatically adjustable setpoint of the flow controller **44**. The temperature controller **48**, also having an automatically adjustable setpoint, in turn receives the computer output signal via line **50**. Computer **33**, thus adjusts the temperature of the associated reaction zone contained within

reactor 6 by resetting the automatically adjustable setpoint of the associated temperature controller 48 which in turn then resets the automatically adjustable setpoint of the associated flow controller 44. In this manner, the reaction severity or the severity of conversion conditions within the reactor 6, is adjusted responsively to the octane number of the liquid phase sample and as a function of conversion severity within the associated reaction zone 6.

Similarly at preheater 8, there is provided a temperature controller 59 receiving a temperature output signal from a thermocouple 58 contained in reactor inlet line 10. Temperature controller 59 produces a temperature output signal which is transmitted via line 60 to the automatically adjustable setpoint of the associated flow controller 55. The temperature controller 59, also having an automatically adjustable setpoint, receives a computer output signal via line 61. Computer 33 transmits the output signal via line 61 as a function of the associated reaction zone severity and the octane number of the liquid phase sample received at octane monitor 29. The computer output signal 61 adjusts or resets the setpoint of the temperature controller 59 and the temperature output signal of temperature controller 59 is transmitted via line 60 to adjust or reset the setpoint of the associated flow controller 55. In this manner, conversion severity within the reaction zone contained within the associated reactor 11 is adjusted by controlling the reactor inlet temperature.

Additionally, referring now to preheater 13, there is disclosed a temperature controller 70 receiving a temperature input signal from thermocouple 69 contained in reactor inlet line 15. Temperature controller 70 in turn produces an output signal which is transmitted via line 71 to the automatically adjustable setpoint of the associated flow controller 66. Temperature controller 70 also has an automatically adjustable setpoint which receives a computer output signal via line 72 from computer 33. The computer output signal passing via line 72 is a function of the sample octane number and of the conversion conditions contained within the conversion zone of the associated reactor vessel 16. The signal transmitted via line 72 to temperature controller 70 automatically adjusts or resets the setpoint of the temperature controller 70 which in turn then develops and transmits via line 71 the temperature control output signal which automatically adjusts or resets the setpoint of the associated flow controller 66. In this manner, the conversion severity within the catalyst bed contained within the associated reactor 16 is adjusted responsive to the octane number of the liquid phase of the reactor effluent and as a function of the conversion severity within the reaction zone, by adjusting the reaction temperature.

In order to provide at least one primary measure of conversion severity as an input to computer 33, there is provided at each reactor vessel, means for measuring the temperature of an inlet section, and preferably also an outlet section, of the reaction zone.

Referring now to reactor 6, there is provided in line 5 a temperature sensing means such as thermocouple 73 passing a temperature signal to a temperature indicating device 74. The temperature indicator 74 transmits a temperature output signal via line 35 to computer 33 which provides an inlet temperature input to the computer for the associated reactor 6. Additionally, there is provided in line 7 a temperature-sensing means such as thermocouple 75 which senses and transmits to temperature indicator 76 the temperature of an outlet section of the conversion zone contained within the associated reactor 6. Temperature indicator 76 in turn transmits this temperature signal via line 34 to computer 33 and thereby provides an input indicative of reaction or conversion severity within reactor 6.

Similarly at reactor 11 there is provided in line 10 a temperature-sensing means such as thermocouple 77 transmitting a temperature signal to a temperature indicator 78 which in turn transmits via line 39, the temperature input signal to computer 33 which indicates the temperature of an inlet section of reactor 11. Additionally, at an outlet section of the reactor 11, and typically in line 12, there is provided a thermocouple 79 or other temperature-sensing means transmitting a temperature signal to temperature indicator 80 which in turn transmits the temperature signal via line 38 as a temperature input to computer 33.

Additionally at reactor 16 there is provided means for sensing inlet and outlet temperatures. A thermocouple 81 is provided in line 15 to measure the temperature of an inlet section of the conversion zone within reactor 16. The temperature signal is transmitted from thermocouple 81 to a temperature indicator 82 which in turn transmits the temperature signal via line 37 to computer 33 as an input to the computer. In addition, there is provided a thermocouple 83 or other temperature-sensing means measuring the temperature of an outlet section of the conversion zone contained within the associated reactor 16. The outlet temperature is transmitted to a temperature indicator 84 which in turn sends the temperature signal via line 36 to computer 33 as an input to the computer indicative of conversion zone severity.

PREFERRED EMBODIMENTS

As set forth hereinabove in describing the drawing, the octane monitor 29 comprising a stabilized cool flame generator with a servo-positioned flame front continuously receives a sample of the liquid phase from the separator 20 via lines 22 and 30. The octane monitor develops an output signal which in turn provides a measure of the sample octane number. The octane monitor output signal is transmitted to the computer 33 which is operatively responsive to the octane monitor output signal, and which receives the signal and develops a plurality of computer output signals, each computer output signal being associated with one of the plurality of conversion zones comprising reactors 6, 11, and 16, and each computer output signal being a function of the sample octane number and of the severity of conversion conditions within the associated conversion zone. Each computer output signal is transmitted to a heat input varying means which is associated with the corresponding conversion zone at the correspondingly associated preheater. In this manner, the heat input into each associated preheating means is independently regulated responsive to the associated computer output signal and in this manner the octane number of the liquid phase of the hydrocarbon effluent is maintained at a constant predetermined level.

Computer 33 contains an internal program sufficient to provide for the generation of the computer output signals 50, 61, and 72 which are not only functions of the octane number of the sample of liquid phase effluent, but which are also functions of conversion conditions within each conversion zone comprising reactors 6, 11, and 16. As set forth hereinabove, the conversion conditions are fed into the computer program by the reaction zone temperature inputs 34, 35, 36, 37, 38, and 39. Those skilled in the art realize that the primary measure of conversion severity within each reaction zone of a catalytic reforming unit, or other similar hydrocarbon conversion process, is the temperature level existing within the reaction zone.

However, other computer inputs may be provided, and typically will be provided, as indications of reaction severity and as input functions required by the computer program. Among those provided in a typical catalytic reforming process are: (1) pressure within the conversion zone and typically the pressure at separator 20; (2) recycle gas flow rate into line 1 from line 2; (3) recycle gas purity as determined by molar percent of hydrogen; (4) naphtha feed flow rate into the process via line 1; (5) naphtha feed component analysis and specifically the volume distribution between paraffin naphthene, and aromatic constituents; (6) naphtha feed gravity; (7) naphtha feed boiling point curve data; and, (8) volume of catalyst loaded in each reactor within the conversion process.

These additional computer inputs may be continuous inputs into computer 33 as provided by appropriate monitoring and/or control devices or they may be manual inputs which

are fed into the computer by the operator as constant values for the computer program. For example, the pressure of the catalytic reforming process will typically be measured and monitored by a pressure sensing and control means at separator **20**. Since pressure may be very easily monitored by available pressure sensing equipment it will be typical to transmit the pressure reading to the computer **33** as a continuous input. In addition, recycle gas flow rates may be easily measured by a commercially available flow control and measuring device installed in line **2**. The flow control device will continuously monitor the flow rate of the recycle gas in line **2** and continuously transmit the flow information into computer **33** as an input thereto. Recycle gas purity is also easily monitored by commercially available equipment and transmitted to computer **33** as a continuous input. Among the commercial methods utilized are gas density measurements, partial pressure measurements, or component distribution analysis by a continuous chromatographic monitoring device. The naphtha feed flow rate also will be easily monitored and transmitted into the computer **33** by providing a typical flow control and sensing means in line **1** which transmits a continuous reading of the flow rate directly into computer **33**. The naphtha feed component analysis typically will be fed manually into the computer **33** as a constant value for any given storage tank containing the naphtha charge stock. As the naphtha charge stock is depleted in one tank the analysis of the subsequent tanks fed into the catalytic reforming process will then be fed into computer **33** to provide new constant inputs for which the computer program is appropriately adjusted. However, alternatively a monitoring device suitable to provide an analysis of the distribution between paraffin, naphthene, and aromatic constituents may be provided in line **1** for continuous feeding of an input into computer **33**. The naphtha feed gravity may be fed into the computer **33** manually as a constant value for a given naphtha charge stock being fed from a specific charge tank, or commercially available gravity instruments may be utilized to continuously transmit a gravity reading directly into computer **33** as a continuous input. In addition, the boiling point data for a specific tank of naphtha charge stock may be placed manually into computer **33** as a constant input, or alternatively, the naphtha charge stock may be continuously fed to a boiling point monitor of the type which are commercially available, in which case the boiling point monitor will transmit directly to computer **33** a continuous input of the boiling point curve for the naphtha charge stock. However, the volume of catalyst loaded in each reactor will not vary during a specific operation of the catalytic reforming process and consequently, the volume of catalyst loaded in each reaction zone will be manually fed into the computer as a constant value for the computer program.

Of course, in order to maintain the octane number of the liquid phase of the effluent leaving separator **20** at a constant value, there is not only required the octane number input value which is transmitted from the octane monitor **29** via line **32**, but there is also required an input value for the target octane number to which the sample octane number must be compared. This target octane number will be manually put into the computer to provide a constant value, and when the specifications required for the octane rating of the gasoline product are changed during operations, the new target octane number must be manually put into the computer to displace the prior target value and become a new constant value to which the computer program is adjusted.

Thus, computer inputs which are manually fed into the computer **33** will provide constant values in the internal computer program until they are superceded by new input data. As disclosed hereinabove, a change in target octane number will provide a new specification value for which the conversion conditions of the process will be adjusted in order to provide that the sample of liquid phase effluent will be produced at the new octane value which is required to make specification gasoline product. Similarly, any change in composition of the naphtha charge stock will require manual input of the new naphtha data in order to adjust the computer program for changes in the naphtha composition characteristics, where such characteristics are not otherwise being continuously monitored and fed into the computer.

Utilizing the computer inputs, both the manual inputs of constant value and the continuous inputs of monitored values, by means of the internal computer program, computer **33** generates signals **50**, **61**, and **72** in a manner sufficient to adjust conversion severity within the individual reaction zones **6**, **11**, and **16** to hold the octane number of the liquid phase of the effluent to a constant value as set by the target octane number. While other reactor conditions could be changed in order to adjust severity to maintain the octane number at the constant value, it is preferable to send the computer output signals to change reaction temperatures within each reaction zone. Control of conversion severity by temperature adjustment and control is preferred since, as those skilled in the art realize, reaction temperature provides the primary and most direct correlation with octane number of the liquid phase of the effluent. Therefore, when the octane number of the liquid phase falls below the specified target octane number, the octane monitor transmits the output signal via line **32** to computer **33**, which then transmits the computer output signals in a manner sufficient to raise the temperature within the reaction zones. On the other hand, when the octane number of the sample rises above the target octane number value, the computer output signals will be transmitted to decrease the temperatures at the reaction zones.

It is also within the scope of the present inventive control system to adjust the temperatures at each reaction zone individually in a manner to hold a fixed number of degrees Fahrenheit (or Centigrade) between each reactor inlet. Thus, temperature **77** could be adjusted to provide a fixed number of degrees below temperature **73** and temperature **81** may be maintained a fixed number of degrees below temperature **77**. In this manner, it is possible to vary the reactor inlets while holding the octane number at a constant value.

As is well known to those skilled in the art, the endothermic heat of reaction occurring within the reaction zones is an indirect measure of octane number. This is because the amount of endothermicity which occurs within the reaction zone is primarily dependent upon the degree of dehydrogenation of naphthene compounds and the amount of dehydrocyclization of paraffins to produce aromatic compounds. Since aromatic compounds are the primary contributor to high octane value in the resulting liquid phase of the reactor effluent (and in the ultimate gasoline product), it is readily apparent that the degree of endothermicity is an indirect measure of octane number. Therefore, the amount of temperature difference between an inlet section and an outlet section of each conversion zone within reactors **6**, **11**, and **16** provides an indirect correlation and measure of octane number.

Therefore, it is within the scope of the inventive control system to provide that the temperature difference across each conversion or reaction zone will reset the reactor inlet temperature if and when the temperature difference is shifting within a given reactor. A declining temperature difference across a given reaction zone is indicative of a loss or decline of catalyst activity therein. Such a temperature decline, therefore, anticipates a loss of octane number since the degree of dehydrogenation of naphthenes and dehydrocyclization of paraffins is being reduced. Therefore, if the temperature difference is declining, the computer **33** sensing the temperature inputs **34** through **39** will produce computer output signals **50**, **61**, and **72** which will compensate for a decline in catalyst activity by raising the appropriate reactor inlet temperature independently at that reactor which shows a declining temperature difference. This then will produce a higher heat of reaction due to an increased degree of dehydrocyclization and dehydrogenation thus producing a higher amount of aromatics, and resulting in a higher octane number for the liquid phase of the reactor effluent. Conversely, if the temperature difference across a given reaction zone is rising, computer **33**

may reset the inlet temperature to a lower level in order to reduce the temperature difference while holding a constant octane number on the liquid phase of the effluent.

While the multiple cascade arrangement illustrated in the drawing represents the preferred embodiment, it is within the scope of this invention to omit the temperature controllers **48**, **59**, and **70** and to reset the associated flow controllers **44**, **55**, and **66** directly by the computer output signals transmitted via lines **50**, **61**, and **72**. Alternatively, the flow controllers **44**, **55**, and **66** could be omitted, in which case the computer output signal lines **50**, **61**, and **72** would be connected with the associated temperature controllers **48**, **59**, and **70** and output signals **49**, **60**, and **71** would be connected directly with the flow control valves **43**, **54**, and **65**. It may be expected however, that elimination of either or both of these control loops will obviously result in a poorer overall system. Since the octane number of the liquid phase of the reactor effluent is not directly correlatable with the flow of fuel to the individual preheaters but is correlatable with inlet temperature of the reaction zone or with temperature drop across a reaction zone it is obvious to those skilled in the art that the temperature controllers should be included in the control system as well as the flow controllers in order to achieve optimum control stability.

However, those skilled in the art will realize that all control loops could be eliminated from the control system without detracting from the effectiveness thereof. In such an embodiment, the computer **33** would receive all necessary input signals but the computer output signals **50**, **61**, and **72** would be directly connected to the control valves **43**, **54**, and **65**. In such an embodiment employing direct computer control, the internal computer program would optimize heat input to obtain the most economic achievement of octane number.

In any case, whether or not computer **33** sends output signals directly to control valves or to intermediate control loops, those skilled in the art realize that computer **33** may comprise an analog or a digital device in association with appropriate signal converters. Computer **33** will include, either internally or in association therewith, suitable converters to make the input signals compatible with the internal computer program. Similarly, computer **33** will include converters to make output signals compatible with the final control elements.

From the foregoing discussion, the method of operation of the inventive control system is now readily apparent to those skilled in the art. In addition, the advantages of the present invention are equally apparent.

The primary advantage is that the present invention provides an improved continuous monitoring and control system for use in varying conversion severity, and specifically the heat input to a reaction zone, responsive to the octane number of the effluent liquid hydrocarbon discharged from the reaction zone, whereby the octane number of the ultimate gasoline product is maintained at a constant predetermined level. In particular, reaction severity is controlled to produce a hydrocarbon product having a constant predetermined level of quality despite operational upsets and control system deviations which may occur external or internal to the catalytic reforming unit. For example, the inventive control system allows the petroleum refiner to produce a reformate gasoline product of constant octane despite variations in charge stock composition or changes in catalyst activity.

An additional advantage is that since the control system is included in the reaction zone, the response time between a change in reaction severity and a change in sample octane number is a matter of minutes. On the other hand, if the sample sent to the octane monitor is a stabilized gasoline sample from the fractionation zone, the intervening fractional distillation equipment introduces a substantial time lag between a change in reaction zone conversion conditions and the corresponding change in octane number of the finished gasoline product.

As used herein, the terms "reaction zone" and "conversion zone" are held to be equivalent terms. Similarly, the terms "reaction conditions" and "conversion conditions" are used interchangeably, as are the terms "reaction severity" and "conversion severity." However, the terms "separator" and a "separation zone" have a limited definition in accordance with the teachings presented hereinabove. In the instant invention the liquid sample is withdrawn from a vapor-liquid phase separator which those skilled in the art know to be readily distinguishable from any type of component separator or separation zone such as a distillation column or zone.

In the foregoing disclosure the use and application of the improved control system has been disclosed with reference to a catalytic reforming system. Those skilled in the art realize, however, that the inventive control system is not so limited. The inventive control system which has been disclosed hereinabove may be utilized in any hydrocarbon conversion process such as thermal cracking, catalytic cracking, thermal hydrocracking, catalytic hydrocracking, isomerization, alkylation, polymerization, etc. Additionally, while the inventive control system has been disclosed with reference to the control of conversion or reaction severity by the adjustment and control of heat input, those skilled in the art realize that the inventive control system may be utilized to control severity by the adjustment of any other operating variable. For example, in fluid catalytic cracking the inventive control system may be utilized to control the rate of catalyst circulation. In HF alkylation the inventive control system may adjust reaction severity by adjustments to the rate of circulation of isobutane reactant. In polymerization over solid phosphoric acid catalyst, the inventive control system may adjust reaction severity by adjusting the rate of flow of olefin reactant to the reaction zone. In each instance, the adjustments to the conversion or reaction severity made by the inventive control system, will result in the production of an ultimate gasoline product having an octane rating more easily maintained at a constant specification value.

As noted hereinabove, temperature-sensing means **73**, **77**, and **81** detect the temperature of an inlet section of the associated reaction zones **6**, **11**, and **16**. In general, such thermocouples or other sensing means will measure the inlet temperature in the associated reactor inlet lines **5**, **10**, and **15** as illustrated in the drawing. However, the inlet temperature may also be sensed by providing means **73**, **77**, and **81** in the associated reactor vessels **6**, **11**, and **16**, and these thermocouples may be located above the associated catalyst bed or they may be contained within the associated catalyst bed at an inlet section. Similarly, thermocouples **75**, **79**, and **83** measure the temperature of an outlet section of each conversion zone. Normally, such temperature is measured in the associated reactor outlet line as illustrated, but such sensing means could be provided within the associated reactor vessel below the catalyst bed contained therein, or contained within the associated catalyst bed at an outlet section. In addition, it is within the scope of the present invention to provide means associated with each conversion zone to sense a temperature therein which is intermediate to the inlet and outlet sections of the associated catalyst bed.

These and other modifications of the inventive control system will be readily apparent to those skilled in the art, and should in no way be construed to detract from the broadness of the present invention.

However, it may now be summarized that a preferred embodiment of the present invention is an improved control system for use in, and in combination with, a continuous flow hydrocarbon conversion process wherein a hydrocarbon charge stock is passed through a plurality of conversion zones at conversion conditions comprising elevated temperature, and the resulting conversion product effluent is separated into a vapor phase and into a liquid phase comprising gasoline boiling range hydrocarbon components, said conversion process having preheating means associated with each conversion zone, a vapor-liquid phase separation zone, conduit means for passing charge stock to a first preheating means, conduit means communicating each preheating means with the as-

sociated conversion zone, conduit means for passing conversion product effluent from each conversion zone to subsequent preheating means, conduit means for passing conversion product effluent from the last conversion zone of the plurality to said separation zone, and means associated with each preheating means for independently supplying heat to each preheating means from an external source, said improved control system for said conversion process comprising in combination: (a) operatively associated with each heat supplying means, means to independently vary the heat input to each preheating means; (b) a hydrocarbon analyzer comprising a stabilized cool flame generator with a servo-positioned flame front, continuously receiving a sample of said liquid phase from said separation zone, and developing an output signal which in turn provides a measure of sample octane number; (c) computer means operatively responsive to said analyzer output signal, receiving said signal and developing a plurality of computer output signals, each computer output signal being associated with one of the plurality of conversion zones, and each computer output signal being a function of said sample octane number and of the severity of conversion conditions within the associated conversion zone; (d) means transmitting each computer output signal to the heat input varying means associated with the corresponding conversion zone which is in association with said computer output signal, whereby the heat input to each associated preheating means is independently regulated responsive to the associated computer output signal, whereby the octane number of said liquid phase is maintained at a constant predetermined level.

The invention claimed is:

1. In a continuous flow hydrocarbon conversion process wherein a hydrocarbon charge stock is passed through a conversion zone at conversion conditions comprising elevated temperature, and the resulting conversion product effluent is separated into a vapor phase and into a liquid phase comprising gasoline boiling range hydrocarbon components, said conversion process having charge stock preheating means, said conversion zone, a vapor-liquid phase separation zone, means for passing charge stock to said preheating means, means for passing charge stock from said preheating means to said conversion zone, means for passing conversion product effluent from said conversion zone to said separation zone, and means for supplying heat to said preheating means from an external source, the improved control system for said conversion process which consists essentially of the combination:

a. operatively associated with said heat-supplying means, means to vary the heat input to said preheating means;

b. a hydrocarbon analyzer comprising a stabilized cool flame generator with a servo-positioned flame front, continuously receiving a sample of said liquid phase from said separation zone without intervening depressurization below the pressure in the separation zone of said liquid phase sample, and developing an output signal which in turn provides a measure of sample octane number;

c. temperature-sensing means to sense the severity of conditions within said conversion zone, and to develop therefrom an output signal representing said severity conditions;

d. computer means, operatively responsive to said output signal providing a measure of sample octane number and said output signal representing the severity of conditions within said conversion zone, receiving said signals and developing a computer output signal which in turn is a function of sample octane number and severity of conversion conditions within said conversion zone; and,

e. means transmitting said computer output signal to said heat input varying means, whereby the heat input to said preheating means is regulated responsive to said computer output signal, and the octane number of said liquid phase is thereby maintained at a constant predetermined level.

2. The system of claim 1 wherein said computer output signal is a function of said sample octane number and of at least one conversion zone temperature.

3. The system of claim 1 wherein said heat input varying means comprises a flow control loop including a flow controller having an adjustable setpoint regulating the flow of heating medium through said preheating means, whereby said setpoint is adjusted in response to said computer output signal.

4. The system of claim 3 further characterized in the provision of means to sense conversion zone temperature, temperature control means connecting with said temperature-sensing means with such control means having an adjustable setpoint and developing a temperature output signal, and means transmitting said temperature output signal to the setpoint of said flow controller, with said means (e) transmitting said computer output signal to said temperature control means setpoint whereby the latter is adjusted responsive to liquid phase octane number.

5. The system of claim 3 further characterized in the provision of first means to sense a first temperature of said conversion zone, temperature control means connecting with said first temperature-sensing means with such control means having an adjustable setpoint and developing a first temperature output signal, means transmitting said first temperature output signal to the setpoint of said flow controller, second means to sense a second temperature of said conversion zone developing a second temperature output signal, means transmitting said second temperature output signal to said computer means whereby said computer output signal is a function of said sample octane number and of said second temperature, with said means (e) transmitting said computer output signal to said temperature control means setpoint whereby the latter is adjusted responsive to liquid phase octane number.

6. The system of claim 5 wherein said second means senses said second temperature in an inlet section of said conversion zone.

7. The system of claim 3 further characterized in the provision of first means to sense a first temperature of said conversion zone, temperature control means connecting with said first temperature sensing means with such control means having an adjustable setpoint and developing a first temperature output signal, means transmitting said first temperature output signal to the setpoint of said flow controller, second means to sense a second temperature of an inlet section of said conversion zone developing a second temperature output signal, third means to sense a third temperature of an outlet section of said conversion zone developing a third temperature output signal, means transmitting said second and third temperature output signals to said computer means whereby said computer output signal is a function of said sample octane number and of at least one of said temperatures of said conversion zone, with said means (e) transmitting said computer output signal to said temperature control means setpoint whereby the latter is adjusted responsive to liquid phase octane number.

8. The system of claim 7 wherein said computer output signal is a function of said sample octane number and of the temperature difference between said inlet and outlet sections.

9. In a continuous flow hydrocarbon conversion process wherein a hydrocarbon charge stock is passed through a plurality of conversion zones at conversion conditions comprising elevated temperature, and the resulting conversion product effluent is separated into a vapor phase and into a liquid phase comprising gasoline boiling range hydrocarbon components, said conversion process having preheating means associated with each conversion zone, a vapor-liquid phase separation zone, means for passing charge stock to a first preheating means, means communicating each preheating means with the associated conversion zone, means for passing conversion product effluent from each conversion zone to subsequent preheating means, means for passing conversion product effluent from the last conversion zone of the plurality to said separation zone, and means associated with each preheating means for independently supplying heat to each preheating means from an external source, the improved control system for said conversion process which consists essentially of the combination:

a. operatively associated with each heat supplying means, means to independently vary the heat input to each preheating means;

b. a hydrocarbon analyzer comprising a stabilized cool flame generator with a servo-positioned flame front, continuously receiving a sample of said liquid phase from said separation zone without intervening depressurization below the pressure in the separation zone of said liquid phase sample, and developing an output signal which in turn provides a measure of sample octane number;

c. temperature-sensing means to independently sense the severity of conditions within each of the conversion zones, and to develop therefrom a plurality of output signals each representing the severity conditions within a respective one of the conversion zones;

d. computer means operatively responsive to said output signal providing a measure of sample octane number and said plurality of output signals representing the severity of conditions within each of the conversion zones, receiving said signals providing a measure of sample octane number and representing the severity of conditions within each of the conversion zones and developing a plurality of computer output signals, each computer output signal being associated with a respective one of the plurality of conversion zones, and each computer output signal being a function of said sample octane number and the severity of conversion conditions within the associated conversion zone; and,

e. means transmitting each computer output signal to the heat input varying means associated with the corresponding conversion zone which is in association with said computer output signal, whereby the heat input to each associated preheating means is independently regulated responsive to the associated computer output signal, and the octane number of said liquid phase is thereby maintained at a constant predetermined level.

10. The system of claim **9** wherein each computer output signal is a function of said sample octane number and of at least one temperature within the associated conversion zone.

11. The system of claim **9** wherein each heat input varying means comprises a flow control loop including a flow controller having an adjustable setpoint regulating the flow of heating medium through the associated preheating means, whereby said setpoint is adjusted in response to the associated computer output signal.

12. The system of claim **11** further characterized in the provision of means associated with each conversion zone to sense a temperature therein, temperature control means connecting with each temperature sensing means with such control means having an adjustable setpoint and developing a temperature output signal, and means transmitting each temperature output signal to the setpoint of the flow controller associated with the corresponding conversion zone, with each means (e) transmitting the associated computer output signal to the associated temperature control means setpoint whereby the latter is adjusted responsive to liquid phase octane number.

13. The system of claim **11** further characterized in the provision of first means associated with each conversion zone to sense a first temperature therein, temperature control means connecting with each first temperature sensing means with such control means having an adjustable setpoint and developing a first temperature output signal, means transmitting each first temperature output signal to the setpoint of the flow controller associated with the corresponding conversion zone, second means associated with each conversion zone sensing a second temperature therein and developing a second temperature output signal, means transmitting each second temperature output signal to said computer means whereby each computer output signal is a function of said sample octane number and of the associated second temperature, with each means (e) transmitting the associated computer output signal to the associated temperature control means setpoint whereby the latter is adjusted responsive to liquid phase octane number.

14. The system of claim **13** wherein each second means senses said second temperature in an inlet section of the associated conversion zone.

15. The system of claim **11** further characterized in the provision of first means associated with each conversion zone to sense a first temperature therein, temperature control means connecting with each first temperature-sensing means with such control means having an adjustable setpoint and developing a first temperature output signal, means transmitting each first temperature output signal to the setpoint of the flow controller associated with the corresponding conversion zone, second means to sense a second temperature of an inlet section of each conversion zone developing second temperature output signals, third means to sense a third temperature of an outlet section of each conversion zone developing third temperature output signals, means transmitting said second and third temperature output signals to said computer means whereby each computer output signal is a function of said sample octane number and of at least one of said temperatures of the associated conversion zone, with each means (e) transmitting the associated computer output signal to the associated temperature control means setpoint whereby the latter is adjusted responsive to liquid phase octane number.

16. The system of claim **15** wherein each computer output signal is a function of said sample octane number and of the temperature difference between said inlet and outlet sections of the associated conversion zone.

17. In a continuous flow hydrocarbon conversion process wherein a hydrocarbon charge stock is passed through a conversion zone at conversion conditions comprising elevated temperature, and the resulting conversion product effluent is separated into a vapor phase and into a liquid phase comprising gasoline boiling range hydrocarbon components, said conversion process having charge stock preheating means, said conversion zone, a vapor-liquid phase separation zone, means for passing charge stock to said preheating means, means for passing charge stock from said preheating means to said conversion zone, and means for passing conversion product effluent from said conversion zone to said separation zone, the improved control system for said conversion process which consists essentially of the combination:

a. operatively associated with said conversion zone, means to vary the severity of conversion conditions therein;

b. a hydrocarbon analyzer comprising a stabilized cool flame generator with a servo-positioned flame front, continuously receiving a sample of said liquid phase from said separation zone without intervening depressurization below the pressure in the separation zone of said liquid phase sample, and developing an output signal which in turn provides a measure of sample octane number;

c. temperature-sensing means to sense the severity of conditions within said conversion zone, and to develop therefrom an output signal representing said severity conditions;

d. computer means, operatively responsive to said output signal providing a measure of sample octane number and said output signal representing the severity of conditions within said conversion zone, receiving said signals and developing a computer output signal which in turn is a function of sample octane number and severity of conversion conditions within said conversion zone; and,

e. means transmitting said computer output signal to said means (a), whereby the severity of said conversion conditions is regulated responsive to said computer output signal, and the octane number of said liquid phase is thereby maintained at a constant predetermined level.

18. The system of claim **17** wherein said computer output signal is a function of said sample octane number and of at least one conversion zone temperature, and said means (a) varies temperature within said conversion zone.

19. The system of claim **17** wherein said means (a) varies the flow of at least one reactant within said conversion zone.