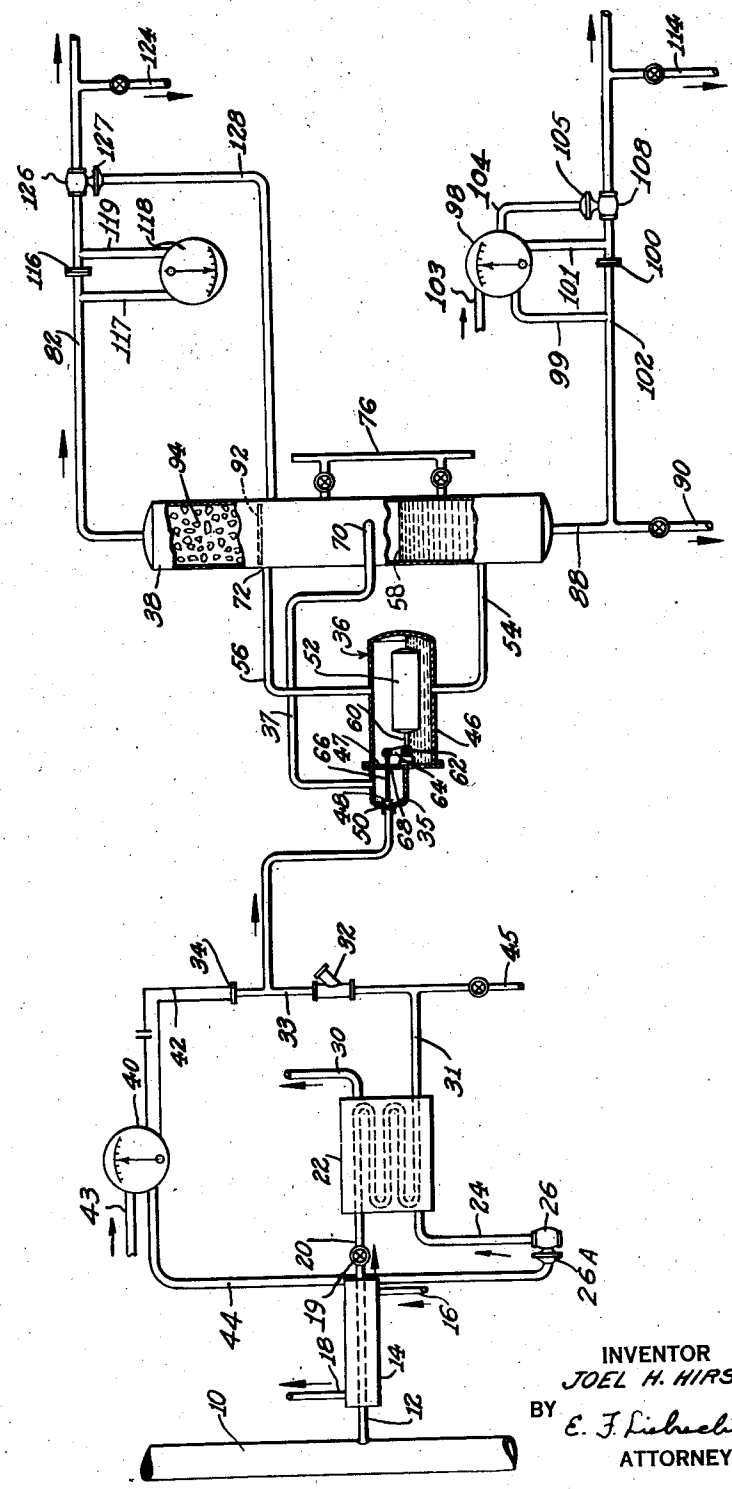
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APPARATUS FOR DETERMINING THE RATE OF HYDROCARBON CONVERSION

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INVENTOR
JOEL H. HIRSCH
BY E. J. Liebrecht
ATTORNEY

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APPARATUS FOR DETERMINING THE RATE OF HYDROCARBON CONVERSION

Joel H. Hirsch, New York, N. Y., assignor to De Florez Engineering Co., Inc., Hartford, Conn., a corporation of Connecticut

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1 Claim. (Cl. 73—51)

This invention relates to an apparatus for determining or controlling the rate of cracking or conversion of hydrocarbon fluids.

In the conversion of higher boiling hydrocarbons to lower boiling hydrocarbons to form motor fuels, it is desirable to rapidly determine the effectiveness of the process to determine the rate at which the conversion takes place. Or having a certain rate of conversion of hydrocarbon fluid established, it is desirable to control and maintain the rate of conversion.

For example, when a higher boiling hydrocarbon, such as gas oil, is to be converted into lower boiling hydrocarbons containing gasoline constituents or motor fuel constituents, it is passed through a heater and generally heated to a relatively high temperature up to about 1200° F. or higher and under a superatmospheric pressure up to about 1000 pounds per square inch or higher. The higher boiling hydrocarbon in passing through the heater is maintained under suitable temperature and pressure conditions for a time sufficient to effect the conversion into lower boiling hydrocarbons. The products of conversion pass through a transfer line to a separator usually under lower superatmospheric pressure to separate vapors from liquid residue. The vapors are then passed to a fractionating zone preferably under superatmospheric pressure to separate condensate oil from a desired lighter fraction.

The rate of conversion is usually expressed as the volume per cent of the gasoline produced, based on the volume of charge of hydrocarbon fluid introduced into the heater; but it might be equally well expressed as the weight per cent of gas plus gasoline formed or the weight per cent gas formed, since for any given character of heater feed stock and set of operating conditions these three quantities are inter-related and may be expressed as mathematical functions of each other.

Some prior methods of controlling hydrocarbon conversion processes utilize the temperature of the stream leaving the heater and/or the rate of fixed gas from the gas separator at the end of the fractionating system. Heater outlet temperature possesses serious disadvantages as a basis for controlling these operations in that the extent of conversion may vary while the outlet temperature remains constant, due to shifting of temperatures or pressures at intermediate points in the heater flow. Gas rate is unsatisfactory in that there is a considerable time lag between the cracking zone and the gas separator and the rate of gas discharge from the separator is seriously affected and to a usually indeterminate extent by changing reflux rates in the towers of the fractionating system.

Furthermore, when two or more cracking zones discharge into a single fractionating system, gas rate from the unit becomes meaningless as a measure of the extent of conversion in the individual zones. Hence, over-cracking may take place in one zone and under-cracking in another without being detected by the gas rate from the unit, which measures only the combined effect. Moreover, with existing means of control the extent of conversion tends to be an average condition with respect to time rather than the maximum attainable without coking of the apparatus; since only a 2° F. change in effective temperature produces about a 6% change in extent of cracking.

For example, when a cracking coil is operating at an average conversion per pass or rate of conversion of 20%, the conversion per pass may vary from moment to moment between fairly wide limits, such as 18% to 22%. Assume in this example that it is the 22% rate which limits the operation by coking the apparatus. Maximum capacity and fuel economy would be attained by operating just below the maximum conversion or the 22% rate at all times. The invention disclosed herein makes this possible. My invention may best be characterized as one which effects its control by measuring continuously and almost instantaneously the net result of the conversion operation rather than some associated property, such as heater outlet temperature, which although related to extent of conversion is not necessarily a true index thereof.

If sampling tests are to have any value in determining or controlling the rate of conversion or cracking, arrangements must be made whereby such tests may be made continuously and quickly. My invention includes apparatus and a method whereby the rate of conversion of the hydrocarbon fluid may be quickly, accurately and continuously determined by measuring the rate of production of gas resulting from the cracking or conversion operation. Or my invention may be used in the control of a conversion process to maintain a desired rate of conversion. My invention may be used for determining the extent of conversion operations generally where hydrocarbon fluids are to be converted into higher or lower boiling hydrocarbons and in the control of such conversion operations.

According to one form of my invention a small, substantially continuous, stream of conversion

products is withdrawn from a sampling connection in the transfer line and the withdrawn conversion products are cooled and passed to a separator which is provided with or associated with means to control the rate of flow of conversion products to the separator. The pressure on the separator is maintained substantially constant and the temperature of the products of conversion introduced into the separator is maintained substantially constant.

In the separator, gases are separated from liquid. The liquid is withdrawn from the bottom of the separator at a substantially constant rate. The gas leaves the top of the separator and is measured by passing it through a flow meter. With the liquid flow rate constant, the gas flow rate represents the gas produced per unit of liquid separated in the separator. The volume of gas produced is measured and from this it is a relatively easy matter to determine the volume per cent gasoline production or conversion per pass obtained. Data are available to show that having a known oil stock and converting it under known pressure and temperature conditions, the amount of gas produced will be in proportion to the amount of gasoline produced.

My invention is especially adapted for measuring the conversion rate or controlling the conversion rate in a conversion operation where two or more conversion zones are used with a single fractionating system as an apparatus constructed to embody my invention may be used with each conversion zone and the conversion rate of each conversion zone may be measured or controlled.

The drawing represents a diagrammatic showing of one form of apparatus adapted for use in practicing my invention. However, the invention is not to be limited to the apparatus shown as other apparatus may be used.

Referring now to the drawing, the reference character 10 designates a pipe in which hydrocarbons are subjected to cracking or conversion or a transfer line which is adapted to convey hot products of conversion leaving a conversion or cracking zone (not shown). According to my invention a small amount of hot products of conversion is preferably continuously removed as a stream through line 12 which communicates with the pipe 10. The products of conversion are at a relatively high temperature and it is necessary to cool them and reduce the temperature to condense normally liquid constituents and separate them from gases. The hot products of conversion are passed through line 12 and are cooled to below cracking temperatures by a shock cooler 14 which surrounds a portion of line 12 and which is provided with an inlet 16 and an outlet 18 for cooling fluid. Water is preferably used as a cooling medium in cooler 14 for initially cooling the hot products of conversion to a relatively low temperature.

The partially cooled products of conversion are then passed through a valve 19 in line 20 and are then passed through a condenser 22 for further cooling the products of conversion to a desired substantially constant temperature. Water is used as a cooling medium in the condenser 22 and is passed through line 24 provided with a control valve 26 and an outlet 30. The control valve 26 is operated by a temperature control device, as will be presently described, in order to vary the extent of opening of the valve to provide more or less cooling water in the condenser 22. The water for shock cooler 14 and condenser 22 may come from a common source.

The cooled and condensed products of conversion are then passed through line 31 and through a line filter or strainer 32 for removing any solid particles from the products of conversion. The filtered products of conversion include gas and liquid and are then passed through line 33 and in contact with a thermostatic device 34 and then introduced into a chamber 35 adjacent a float controlled chamber 36 and then through line 37 to separating chamber 38 wherein gases are separated from liquid. The float controlled chamber 36 and chamber 35 will be described in greater detail hereinafter. The thermostatic device 34 is connected by means of an electric circuit 42 with a meter controller 40. The control device 40 is provided with an air pressure supply line 43 and with a discharge line 44 for applying air pressure to a diaphragm 26A which operates the valve 26. The controller 40 regulates the pressure applied to the diaphragm in response to the thermostat and controls the valve 26 to regulate the amount of cooling water used in condenser 22 for cooling the products of conversion and for maintaining the temperature of the products of conversion substantially constant. A drain pipe 45 may be provided in line 33 below strainer 32, if desired, but no liquid should be withdrawn through pipe 45 at any time while the apparatus is being used for measuring the rate of conversion. Instead of controlling the valve 26 by air pressure, as illustrated, the valve 26 may be controlled by electrical means or other means.

For example, if the products of conversion passing to the separating chamber 38 are at too high a temperature, the temperature control device 40 will operate the control mechanism on the control valve 26 to cause more water to pass through the condenser 22. If the products of conversion are at too low a temperature, the temperature control device will regulate the valve 26 so as to provide less water for the condenser 22. In this way the products of conversion are introduced into the separating chamber 38 at a substantially constant temperature.

The float controlled chamber 36 is provided with the smaller chamber 35 which is separated from the main portion 46 of float chamber 36 by means of a wall 47. The cooled products of conversion from line 33 are introduced into smaller chamber 35 and then through line 37 into separating chamber 38 as will be presently described in greater detail.

A float controlled valve 48 cooperates with valve seat 50 at the inlet end of smaller chamber 35 to control the rate of flow of conversion products to smaller chamber 35. The float 52 is mounted in larger chamber or main portion 46 of float control chamber 36. The float control chamber 36 communicates with separating chamber 38 by means of lines 54 and 56 and in this way the level of liquid in chamber 38 indicated as 58 is communicated to float control chamber 36. Line 54 contains liquid whereas line 56 contains gas. There is no substantial flow in either line 54 or 56. When the level of liquid in chamber 38 rises, the level of liquid in main portion 46 of float control chamber 36 also rises and valve 48 is moved closer to valve seat 50 and greater throttling takes place at parts 48 and 50 and a smaller amount of conversion products is introduced into smaller chamber 35 and hence to separating chamber 38.

The float 52 and its associated parts will now be described. The float 52 is provided with a

float arm 60 which is pivoted at 62 inside the main portion 46 of the float control chamber 36. A lever arm 64 is rigidly connected with the float arm 60 to provide a bell crank construction. The lever arm 64 is pivotally connected to a valve stem 66, the lever arm being provided with a slotted opening through which the valve stem extends. The valve stem extends into smaller chamber 35 and is provided with the valve member 48 at its one end which is adapted to cooperate with the valve seat 50 provided at the entrance to smaller chamber 35 as above described to control the amount of products of conversion being introduced into the smaller chamber 35 through line 33. The valve stem 66 extends through opening 68 in separating wall 47 and the wall 47 with its opening 68 forms a guiding and bearing means for maintaining the valve member 48 in alinement with valve seat 50. The valve stem 66 is adapted to slide freely in the opening 68 in separating wall 47.

By this float valve construction the inflow and outflow are balanced. With liquid outflow from the separating chamber 38 held substantially constant, variations in the amount of cracking result in variations in the gas outflow. Thus the total outflow from separating chamber 38 varies and the inflow is made to correspond through slight variations in the level of the liquid in the chamber 38. With the float control construction a body of liquid is normally maintained in main portion 46 of float chamber 36. The full transfer line pressure may be carried up to the float controlled valve member 48. The pressure in the float chamber 36 is maintained substantially constant, preferably at a lower pressure than transfer line pressure as will be hereinafter described in greater detail.

The products of conversion from smaller chamber 35 are passed through line 37 and are preferably introduced into an intermediate portion of separating chamber 38 and preferably tangentially as at 70 to the inner wall of chamber 38 to assist in separating entrained liquid from the gases. The line 56 from main portion 46 of float controlled chamber 36 communicates with the separating chamber 38 at a higher point as at 72. A gauge glass construction 76 is preferably provided on separating chamber 38 to provide visual means whereby the liquid level may be observed.

The gases in the separator 38 are passed overhead through line 82 and the liquid is withdrawn from the bottom of the separating chamber 38 through line 88. Line 90 is provided for draining the float chamber and separating chamber 38 but no liquid should be withdrawn through line 90 at any time while the apparatus is being used for measuring the rate of conversion.

The upper portion of the separating chamber 38 is provided with suitable contact elements such as Raschig rings 94 or the like supported on a perforated plate 92 to prevent entrained liquid from passing over with the gases. The gas line 56 between main portion 46 of float control chamber 36 and separating chamber 38 communicates with the separating chamber below perforated plate 92 as at 72.

According to my invention the rate of flow of liquid from the separating chamber 38 is maintained substantially constant and, in order to produce this result, a flow control device 98 is provided. The flow control device 98 cooperates with an orifice 100 arranged in line 102 through which passes the liquid withdrawn from the bottom of separator 38. The flow control device is provided with a connection 99 to the pipe 102 upstream from the orifice 100 and with a connection 101 downstream from the orifice. The flow control device is also provided with an air pressure supply line 103 and a discharge line 104 for applying air pressure to a diaphragm 105 which operates a valve 108 in the line 102. Preferably the control valve 108 is placed after the metering device 100 to obviate any possibility of error in measurement due to gassing. The desired rate of flow is maintained by the flow control device 98. The flow control device 98 is set for a predetermined rate of flow of liquid and variations from this flow are compensated for by means of the control valve 108. Instead of controlling the valve 108 by air pressure as illustrated, the valve 108 may be controlled by electric means or other means.

After passing through the metering device 100, the liquid passes through the line 102 into the fractionating equipment or other equipment in the refinery, or into the emergency line, as desired. Whenever it is desired to determine the properties of the gasoline in the liquid passing through line 102, this can be done by withdrawing a sample of the liquid through line 114 and subjecting it to laboratory tests.

The gas passing overhead from the separator 38 through line 82 flows through an orifice 116 in the line 82. A gas rate meter 118 is in communication with the line 82 through a line 117 upstream of the orifice and a line 119 downstream of the orifice in order to measure the amount of gas produced during the conversion operation. After passing through the metering device 116, the gas flows to fractionating equipment, tar stripper accumulating drums or other equipment in the refinery to recover any desired constituents thereof. Samples of the gas for laboratory tests may be withdrawn at 124. While the gas passing through line 82 may be passed to a zone of substantially constant pressure such as those just mentioned above so as to keep the pressure on the float chamber 36 and separating chamber 38 substantially constant, I prefer to use a pressure controlling valve 126 in gas line 82. Pressure controlling valve 126 is placed after metering device 116 in line 82 and is operated by a diaphragm 127 to which pressure is applied through a line 128 communicating with separating chamber 38. In this way the pressure in the chambers 36 and 38 is maintained substantially constant.

In the invention as disclosed, the pressure and temperature are maintained substantially constant in float controlled chamber 36 and separating chamber 38. Also the rate of flow of liquid withdrawn from the separating chamber 38 is maintained constant. Knowing the pressure in the conversion apparatus and the nature of the charging stock, and maintaining the temperature suitable for conversion, the amount of gas produced will be a direct indication of the amount of conversion obtained in the charging stock. In some instances it may be desired to measure the rate of flow of liquid and the rate of flow of gas from the separating chamber to obtain the amount of conversion.

A specific example of the operation of my invention will now be given but it is to be understood that I am not to be restricted thereto. The example is merely by way of illustration to further explain my invention. At first I will briefly describe a general conversion operation and separation of the products of conversion and then I will describe the operation of my invention in con

nection with such a conversion operation. In this brief description apparatus will be referred to which is not shown in the drawing except transfer line 10.

In a conversion operation, a charging stock such as Mid-Continent gas oil having an A.P.I. gravity of 30° is fed to a cracking unit, mixed with unconverted gas oil recycle stock and passed through a heating and conversion zone, wherein it is maintained under superatmospheric pressure of from 500 to 1000 pounds per square inch and heated to a temperature of 800° to 1000° F. The products of conversion leave the conversion zone through the transfer line 10, passing to a separator or evaporating chamber, operated at a lower superatmospheric pressure and a lower temperature, where liquid residue or cracked fuel oil is separated from vapors by condensation. The cracked fuel oil is withdrawn from the bottom of the separator to storage. The vapors pass overhead into a second chamber or fractionating tower. In the fractionating tower gas oil recycle stock which has not been converted into any of the products eliminated from the cracking unit (i. e., gas, cracked gasoline, or cracked fuel oil) is separated from the gas and gasoline by fractional condensation and passes to the bottom of the fractionating tower. Gas and gasoline pass overhead from the fractionating tower and then through condensers to a gas separator where the gas is separated from the gasoline, these materials then being eliminated from the conversion unit to storage or for subsequent treatment. Gas oil recycle stock from the bottom of the fractionating tower mixes with fresh gas oil charging stock and passes again through the heating and conversion zone.

A small portion of the products of conversion passing through the transfer line 10 is preferably continuously removed from the transfer line through line 12 and the products of conversion are suddenly cooled to about 525° F. to 700° F. by passing through the shock cooler 14. The products of conversion are then further cooled to about 90° F. to 135° F. by being passed through the condenser 22. During cooling, the normally liquid hydrocarbon constituents are condensed. The cooled and condensed products of conversion including gases and liquid are then passed through the line strainer or filter 32 and then through line 33 to the small chamber 35 of float controlled chamber 36. The cooled and condensed products of conversion then pass through line 37 to separating chamber 38 wherein gases are separated from liquid.

In passing through line 33 the cooled and condensed products of conversion pass in contact with the thermostatic device 34 and their temperature is measured. The thermostatic device 34 is connected with the control device 40. The temperature of the cooled and condensed products of conversion introduced into the chamber 35 of the float controlled chamber 36 is maintained constant at a temperature between about 90° F. to 125° F., preferably about 110° F. If the temperature of the conversion products is too high, the temperature control device 40 in response to thermostatic device 34 will actuate the control device on valve 26 to introduce more cooling water into the condenser 22. On the other hand, if the temperature of the products of conversion passing through line 33 is too low, the valve 26 will be operated to cut down the flow of cooling water through the condenser 22.

The float controlled mechanism in the float controlled chamber 36 actuates valve 48 to control the amount of products of conversion introduced into the separating chamber 38 so as to normally maintain a body of liquid in separating chamber 38 and main portion 46 of float chamber 36. In the separating chamber 38 the pressure is maintained at about 40 to 60 pounds per square inch, preferably about 50 pounds per square inch. The pressure is maintained constant in chamber 38 by means of the pressure control valve 126 in line 82. Higher pressures may be used in chamber 38 and higher temperatures may also be used.

In practice it is convenient and desirable but not necessary to so set the liquid flow rate that the total gas plus liquid equals 100 pounds per hour or some unit quantity in which case the gas meter will read weight per cent gas directly. The weight of the gas formed divided by the sum of the weight of the gas formed and liquid separated gives weight per cent gas. Also in the example given below where the weight of gas produced is 3 pounds per hour and the weight of liquid withdrawn is 97 pounds per hour, the weight per cent gas based on the hydrocarbon charge fed to the heater is 3%. It is not necessary to know the rate of charging feed stock to the conversion zone in order to obtain the per cent conversion with my invention.

The liquid separated in the separating chamber 38 is withdrawn therefrom at a substantially constant rate of about 97 pounds per hour and this rate of flow of liquid is maintained substantially constant by means of flow control device 98 which actuates the control valve 108 in line 102.

The gases passing overhead from the separating chamber 38 are then measured by passing through the metering device 116 and the amount of gas is recorded or read on the gas meter 118. For example, a gas flow of about 3 pounds per hour under the conditions given above and using the charging stock above given under the conditions given will indicate that about 21% conversion per pass or volume per cent of gasoline is being obtained.

From previous data it is known that there is a definite relation between the amounts of gas and gasoline formed when converting a known cracking stock at various operating conditions. For example, when converting a 30° A. P. I. Mid-Continent gas oil in a cracking process of the type described above, 4% of gas by weight would correspond to about 28 volume per cent of gasoline or conversion per pass through the conversion zone and 2% of gas by weight would correspond to about 14% of gasoline by volume.

For the same feed stock at a given operating pressure in the conversion zone these values of amounts of gas and gasoline produced will vary with the conversions per pass, and with these different values a curve may be drawn wherein volume per cent gasoline formed or conversion per pass is plotted against weight per cent of gas produced. Different curves may be drawn for different operating pressures for the same feed stock and different curves may be drawn for different stocks fed to the conversion zone. Having these curves and knowing the character of the feed stock and pressure in the conversion zone, and measuring the weight per cent of gas produced, the curves will immediately give the volume per cent gasoline produced or conversion per pass. From the above it will be seen that

the relationship between volume per cent of gasoline produced and the weight per cent of gas produced is independent of the temperature. Knowing the pressure in the conversion zone and knowing the feed stock and measuring the weight per cent gas produced is all that is necessary to obtain the conversion per pass.

Data are available, and some have been published, which correlate the gas-gasoline ratio for various cracking stocks (i. e. the weight of gas formation per unit weight of gasoline formation) with the physical properties of the oil charged to the cracking zone and the operating pressure maintained therein. Since my invention gives the weight per cent gas produced, it is only necessary to know in addition the gravity and A. S. T. M. distillation of the oil charged to the cracking zone and the operating pressure in the conversion zone in order to obtain the volume per cent gasoline formed per pass from correlations of the type described above.

Instead of using known data or when no data are available, a curve may be constructed for any given feed stock with my apparatus in place on the cracking unit by operating the unit for short periods at three or four different cracks per pass or conversions per pass, evaluating samples of the liquid withdrawn from the separating chamber 38 for per cent gasoline by laboratory fractionation and plotting these values against weight per cent gas as shown by the gas rate meter 118.

In the specific example my invention has been described as applied to the sampling of products from the transfer line through which the products of conversion leave the conversion zone. However, the sampling line 12 may be connected with the conversion coil at any desired point in the furnace and a stream of conversion products withdrawn and passed through my apparatus to determine the extent of conversion of the charging stock to gasoline at any desired point in the conversion coil or at various points in the conversion coil to determine the extent of conversion of the charging stock as the charging stock passes through the conversion coil.

In addition, knowing the characteristics of the charging stock and where a particular conversion per pass is desired to be maintained, my invention may be used to control the conversion unit and maintain a certain conversion per pass of the charging stock to gasoline. For controlling the conversion unit it is unnecessary to know the conversion per pass in terms of per cent gasoline formed as the only factor of importance according to my invention is to know as quickly as possible when a change in conversion per pass has occurred. For this purpose weight per cent of gas alone is just as good a criterion as volume per cent gasoline.

My invention can also be used as a reset mechanism on a conventional temperature controller. My device is more sensitive than devices in common use for control purposes such as transfer line temperature controllers. For example, an increase of about 2° F. in the effective cracking temperature would produce about 6% increase in the gas rate which is easily measured by my invention.

My invention is especially adapted for measuring the effectiveness of conversion or the conversion per pass of a plurality of conversion zones where such conversion zones are associated with and discharge into a single fractionating system. In this case separate apparatus for determining or controlling the extent of cracking will be used with each conversion zone.

While my apparatus is preferably continuously operated and a stream of conversion products continuously withdrawn through sampling line 12, it is to be understood that, if desired, the invention may be used intermittently and a stream of conversion products may be withdrawn through line 12 intermittently.

My invention is also adapted for use in determining the extent of conversion or for controlling the conversion where other conversion operations such as vis-breaking, reforming, gas polymerization, gas reversion, etc., are to be measured or controlled. In the case of gas polymerization, the gas from the top of the separator 38 is withdrawn at constant rate and the liquid withdrawn through line 102 then constitutes the measure of the extent of conversion.

While I have shown one form of apparatus embodying my invention it is to be understood that this is by way of illustration only and modifications and changes may be made without digressing from my invention.

I claim:

In apparatus for determining the rate of gas formation capable of directly reflecting the extent of cracking in a conversion apparatus wherein hydrocarbons are subjected to conversion, the combination with said conversion apparatus of a sampling line for withdrawing a sample of the products of conversion, means for cooling the withdrawn products to condense the normally liquid hydrocarbons, a separating chamber in communication with said cooling means and adapted to separate gases from liquid, means for controlling the amount of cooled products introduced into said separating chamber, means for regulating the cooling applied to said withdrawn products so as to maintain a substantially constant temperature in the separating chamber, means for maintaining a substantially constant pressure in the separating chamber, means for withdrawing liquid therefrom at a substantially constant rate, a gas outlet from the separating chamber and means for measuring the amount of gas flowing therein.

JOEL H. HIRSCH.