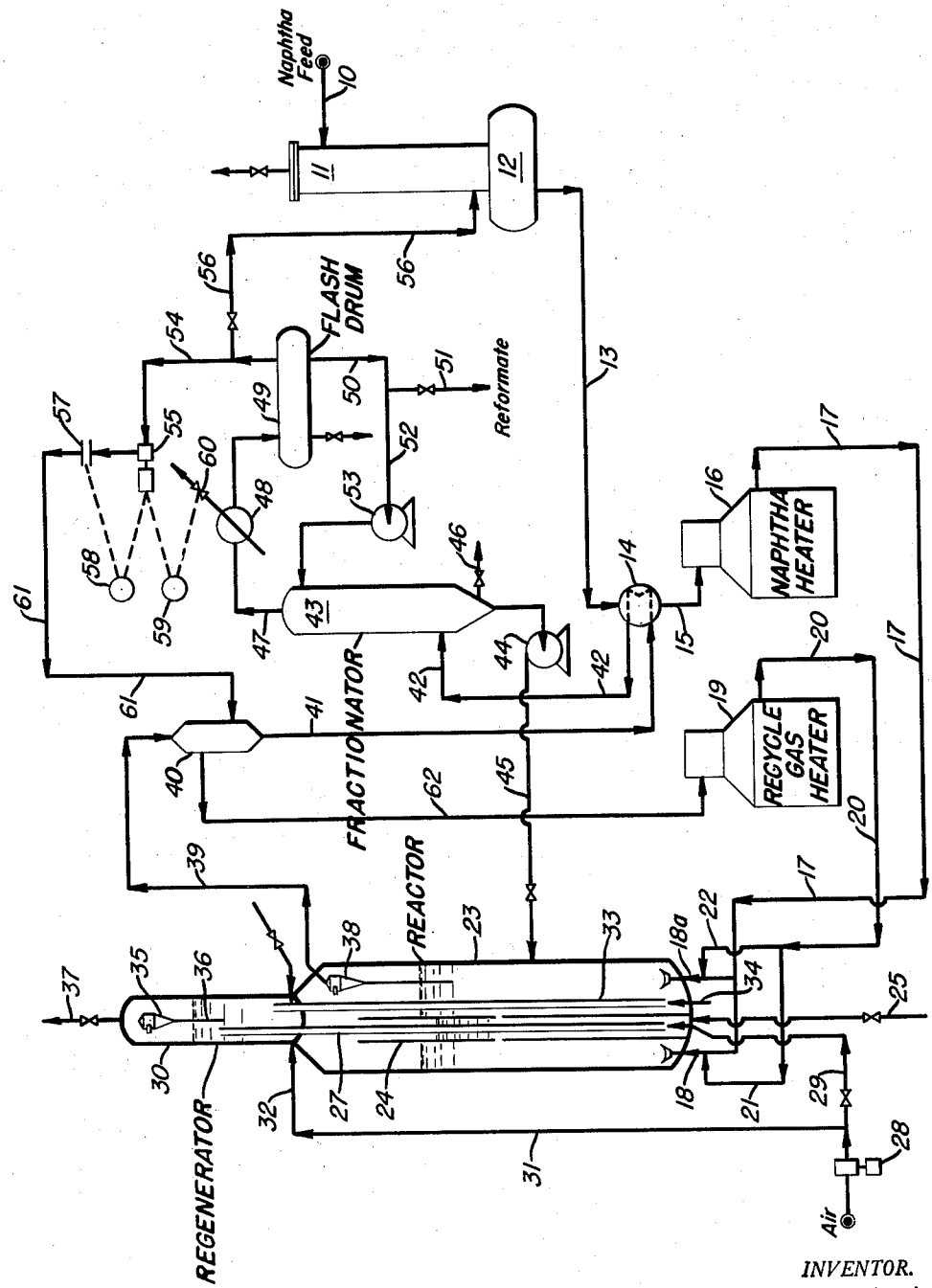
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PROCESS FOR CONTROLLING RECYCLE HYDROGEN GAS

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PROCESS FOR CONTROLLING RECYCLE HYDROGEN GAS

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My invention relates to process control in catalytic processes for conversion of hydrocarbons where hydrogen rich gas is recycled continuously with the hydrocarbon charge stock to the conversion zone. More particularly, the invention relates to a method for correlating control of recycle gas rate and composition in a manner which permits significant economies in the design requirements of recycle gas compressors and which substantially reduces the hazard of operating upsets resulting from recycle gas compressor operation.

Catalytic hydroforming is an example of a hydrocarbon converstion process which operates at a high partial pressure of hydrogen maintained by recycle of hydrogen rich gas separated by distillation or flash condensation from the conversion products. In the catalytic hydroforming process, a naphtha feed is preheated and with recycled hydrogen is charged to a reforming reactor in which the mixture of hydrogen and charge vapors is contacted with a reforming catalyst. The catalyst may be in the form of pellets arranged as a fixed bed or, with finely divided catalyst, may be handled as a fluidized bed or stream of solids. The effluent from the reforming reaction is usually cooled and partially condensed by introuction to a flash drum. Condensed liquids are withdrawn from the drum and fractionated into product fractions of the desired specification. The gas separated from the flash drum is predominantly hydrogen but may contain from about 5 to about 40% of light normally gaseous hydrocarbons depending upon the conditions of operation. The hydrogen rich gas is recycled to the reforming reaction at the desired rate and pressure by means of power driven recycle compressors which may be of the centrifugal or the reciprocating type.

The ratio of hydrogen to hydrocarbon charged to the reaction zone is an important process variable. It is the function of the recycle compressors to control the flow of recycle gas, and hence the hydrogen-to-hydrocarbon ratio, as well as to supply the recycle gas at a constant controlled pressure level. The recycle gas rate is flow-controlled by holding the pressure drop through an orifice constant. Since pressure drop in an orifice is a direct function of gas density, any change in gas density through a change in the composition of the recycle gas must be compensated for by a change in flow rate in order to hold the pressure drop through the orifice constant. This means that the compressor, for operating flexibility, should be designed for the broadest range of conceivable variation in the recycle gas composition. This design burden, however, is expensive, for reduction in recycle gas molecular weight from the usual design operating level requires a marked increase in compressor speed and hence power requirement. For example, it has been found that a reduction in the gas molecular weight from 13.36 to 10 increases the power requirement by about 20% for a centrifugal compressor of 8250 cubic feet per minute design capacity, operating at 209.4 p. s. i. a. and 100° F. intake conditions and 299.4 p. s. i. a. discharge pressure. Since a hydroforming unit ordinarily will start up,

operating with fresh catalyst, with production of recycle gas at a low molecular weight level and will tend slowly but steadily to higher moleular weight with declining catalyst selectivity, investment in compressor capacity to meet reductions in gas molecular weight from the design level appears to most refiners to be an undesirable expenditure. On the other hand, inflexiblity of compressor capacity and control may prove a limiting factor on feed stock variation, and utilization of improved catalysts, as well as cause serious operating difficulties. It is an object of my invention to provide more flexible process control of recycle gas compressors without requiring increased capital investment in compressor capacity.

In practice, the problem of controlling recycle gas compressors is aggravated by the extreme difficulty and virtual impracticability of detecting changes in the molecular weight of recycle gas as a control guide. A laborious laboratory analysis must be made. Although a change in gas composition might be reflected by calculations based on heat balance data, the change probably would not be noticeable. When the molecular weight decreases, the flow of gas increases, but, since the heat capacity of the gas per cubic foot then is less, the total heat conveyed to the reactor would tend to remain about the same. Thus, in conventional operation, molecular weight of the recycle gas is assumed to be constant. Difficulty arises when molecular weight decreases significantly from the design figure, for then the over-speed governor on the compressor will prevent the compressor speed from increasing correspondingly. Hence, actual flow of recycle gas is reduced without knowledge of the operator. This may induce process difficulties, particularly when operating at high severities, since maintenance of the optimum hydrogen partial pressure may be important in maintaining catalyst selectivity for optimum yield and in maintaining catalyst activity. Also, the rapid decrease in the quantity of gas flowing through the compressor resulting from inability to meet the required discharge pressure at the design flow may cause surging and attendant mechanical difficulties. It is also an object of my invention to provide a control system which compensates for incipient pressure drop and compressor speed changes by automatic adjustment of recycle gas composition.

According to my invention, control of the recycle compressors is exercised by maintaining compressor speed substantially constant at constant discharge pressure by controlling the temperature in the flash zone so as to maintain the molecular weight of the recycle gas substantially constant while maintaining the pressure drop of the gas through the flow control orifice constant. Advantageously, the temperature of the flash zone is controlled by passing the flash mixture in indirect heat exchange with a cooling medium prior to introduction to the flash zone and by varying the flow of cooling medium in response to changes in compressor speed. Variations in composition of recycle gas, i. e., molecular weight, are most critical in processes where the catalyst is handled in a fluidized state. In the fluid catalytic hydroforming process, for example, space velocity and catalyst oil ratio are more sensitive variables than in fixed bed processing. Both the speed and change of gas composition therefore are more critical with the fluid process. Hence the invention is applied with particular advantage to fluid catalytic hydroforming.

My invention will be further described in connection with the accompanying drawing which provides in diagrammatic form a simplified flow plan illustrating application to fluid catalytic hydroforming. The operating procedure and conditions described also illustrate the best mode of applying the invention now known to me. Naphtha feed is charged to the process by means of line 10 and is used as a scrubbing medium in absorber

tower 11 in counter-current contact with excess gas produced in the process. The object of the scrubbing operation is to recover volatile hydrocarbons that may have been carried over from the gas recovery system. The feed is collected in accumulator 12 and is passed via line 13 through heat exchanger 14 in indirect contact with reactor effluent and then via line 15 to heater 16. In heater 16, the feed is raised to a temperature of about 900° to 1000° F. e. g., 995° F. The preheated feed is passed by means of line 17 to feed distributors 18 and 18*a*. Preheated recycle gas from recycle gas heater 19 is introduced to distributors 18 and 18*a* by means of line 20 and connections 21 and 22. Usually, the recycle gas is heated to a higher temperature than the feed, of the order of 1100° to 1200° F., e. g. 1190° F. The ratio of hydrogen gas to hydrocarbon feed is of the order of 2/1 to 10/1. At a charging rate of 5000 barrels per day of Mid-Continent naphtha having a boiling range of 250°–400° F., 5000 cubic feet per barrel of hydrogen is a suitable example. A bed of finely divided reforming catalyst, for example, a catalyst comprising molybdenum oxide on an alumina support, is maintained in a fluidized state in reactor 23. The reaction severity may be controlled advantageously by space velocity which is ordinarily in the range of 0.1 to about 5.0 WHSV.

Catalyst circulation within the system is from the fluidized bed of reactor 23 into reactor standpipe 24. Standpipe 24 serves as a spent catalyst stripper and steam is introduced for this purpose at the bottom by means of valved connection 25. Stripped spent catalyst from standpipe 24 drops through a distributor ring (not shown) into the foot of regenerator riser 27 into which regeneration air is introduced by means of compressor 28 and line 29. Catalyst discharges from riser 27 into regenerator 30 where a body of catalyst is maintained as a fluidized bed. Additional regeneration air is introduced into a lower portion of the bed by means of line 31 and connection 32. Regenerated catalyst is returned to the main body of fluidized catalyst in reactor 23 by means of regenerator standpipe 33 at a rate controlled by plug valve 34. Differential densities are maintained throughout the catalyst circulation system to facilitate circulation. For example, the density in the reactor bed may be about 32 #/cubic foot; in stripper 24, 36 #/cubic foot; in riser 27, about 18 #/cubic foot; in the regenerator 30, 33 #/cubic foot; and in the regenerator standpipe 33 about 35 #/cubic foot.

Flue gas produced by burning-off carbonaceous material deposited on the catalyst by means of regeneration air is vented from regenerator 30 through a conventional system of cyclone separators as indicated by cyclone 35 equipped with dip leg 36. Flue gas line 37 is vented to a stack not shown.

Reactor vapors, including steam and volatiles stripped from the catalyst in stripper 24 exit from reactor 23 by means of a system of cyclone separators indicated at 38. The reactor effluent in line 39 is passed through exchanger 40 in indirect heat exchange with recycle hydrogen gas and thence by lines 41 and 42 through fresh feed exchanger 14 into fractionator 43. Means may be provided for collecting a small quantity of heavy oil, as bottoms from fractionator 43, containing catalyst fines carried over from the reactor and for returning this slurry oil to reactor 23 by means of pump 44 and line 45. A minor portion of heavy polymer oil may be removed from the lower portion of fractionator 43 as indicated by valved connection 46. The bulk of the reactor fluid is taken overhead through line 47 at a temperature, for example, of 250° to 300° F. and is passed through cooler 48. The effluent from cooler 48 is introduced to flash drum 49 which is maintained at a pressure of about 200 p. s. i. g. and at a controlled temperature of the order of 100° F. Condensed hydrocarbons are withdrawn from flash drum 49 through line 50 and from thence as product reformate to storage or further fractionation by valved connection 51. Reflux also is provided to fractionator 43 by means of line 52 and pump 53.

The overhead from flash drum 49 is the hydrogen recycle gas stream which is taken by line 54 to compressor 55. Ordinarily, the compressor system will comprise multi-stage, turbo-centrifugal compressors or single stage compressors of the reciprocating type. Net gas production in excess of that required for recycle is passed by means of valved line 56 to absorber tower 11 for removal of entrained hydrocarbons before venting from the system. The flow of recycle gas from compressor system 55 is controlled by a flow controller which may take the form of a conventional orifice meter as indicated by orifice 57 and controller 58. Controller 58 controls the compressor speed as indicated by the dotted line connection. A second controller 59 is operatively connected to the compressor control system so as to record variations in compressor speed, as for example by recording changes in tachometer measurements of R. P. M. Controller 59 is operatively connected with control valve 60 which controls the flow of cooling water through cooler 48 and operates to increase or decrease cooling water flow as recording of compressor speed reflects decrease or increase in power requirements in order to maintain constant flow of recycle gas, as measured by pressure drop, through orifice 57. In this way, provision is made for maintaining automatically the molecular weight of the recycle gas constant in spite of fluctuations in composition of the reactor off-gas occasioned by changes in reactor conditions. Recycle is completed from the compressor system by passage of the gas from line 61 through exchanger 40, and thence by line 62 to recycle gas heater 19.

In the above example, favorable reactor conditions with a Mid-Continent naphtha and a molybdenum-oxide-alumina catalyst are 0.35 WHSV space velocity, 0.65 catalyst to oil ratio, 940° F., 225 p. s. i. g. and 4730 cubic feet of recycle hydrogen per barrel of feed. The recycle gas compressor is designed for a recycle gas molecular weight of 13.27, an intake temperature of 95° F. and a pressure of 202 p. s. i. g. The fractionator overhead temperature is controlled by reflux at 265° F., and the design conditions for the overhead flash drum are 95° F. and 206 p. s. i. g. The flow of cooling water, however, is adjusted automatically in response to changes in compressor speed so as to regulate the temperature of the flash drum and thereby control the molecular weight of the recycle gas. The system compensates automatically for variation in hydrogen production and thus eliminates the need for extra compressor capacity to accommodate increased hydrogen production or the need for detecting decrease in hydrogen production and resulting increase in recycle gas molecular weight. A recording tachometer provides a convenient means for detecting changes in compressor speed. The tachometer output signal may be converted by potentiometric means to the signal operating control valve 60. A pneumatic speed transmitter provides another convenient means for detecting changes in compressor speed. The output of the pneumatic speed transmitter may be used to operate a standard pneumatic control instrument which would actuate control valve 60. A more direct means for controlling the valve 60 would require the use of a meter for sensing changes in gas density directly.

The example describes use of the invention with a fluidized catalyst system, but it is also applicable with systems of the fixed bed or moving bed type. The invention also may be applied to other conversion processes such as hydrodesulfurization or hydrofinishing where a hydrogen-rich gas is circulated between the conversion zone and the product recovery zone. Other reforming catalysts may be used such as platinum-alumina, chromium-alumina and the like.

I claim:

1. In a process for conversion of a hydrocarbon charge

stock in the presence of a catalyst and hydrogen-rich recycle gas wherein the hydrogen-rich gas is separated from conversion products in a flash zone and is recycled to the conversion zone by means of a compressor, the method of maintaining compressor speed substantially constant at constant discharge pressure while maintaining the pressure drop of recycle gas through the compressor flow control orifice constant which comprises controlling the speed of said compressor to compensate for incipient changes in said pressure drop, and regulating the temperature in the flash zone in response to incipient changes in compressor speed so as to maintain the molecular weight of the gas separated therefrom substantially constant.

2. The process of claim 1 in which the temperature of the flash zone is regulated by passing the flash mixture in indirect heat exchange with a cooling medium prior to introduction to the flash zone and varying the flow of cooling medium prior to introduction to the flash zone in response to incipient changes in compressor speed.

3. The process of claim 2 in which the hydrocarbon conversion subjected to control is a catalytic hydroforming process of the fluid type wherein the catalyst is handled in finely divided form.

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