

May 19, 1970

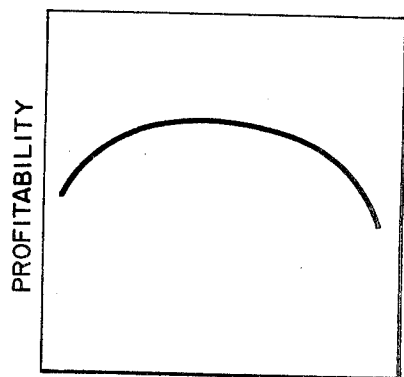
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3,513,087

CONTROL SYSTEM FOR FLUID CAT CRACKER

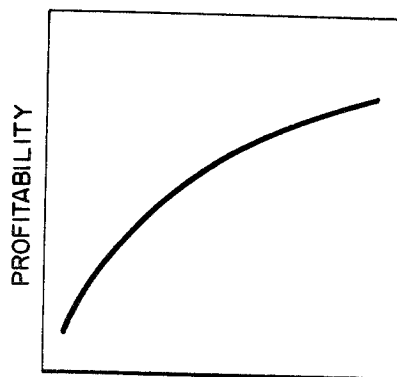
Filed Aug. 30, 1968

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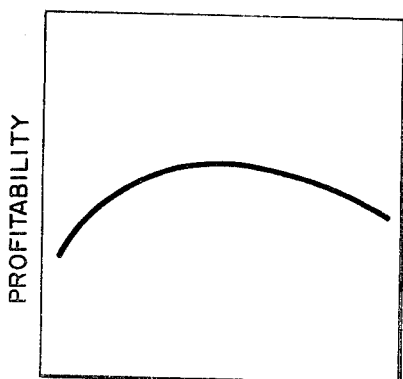
REACTOR TEMP.

FIG. 2



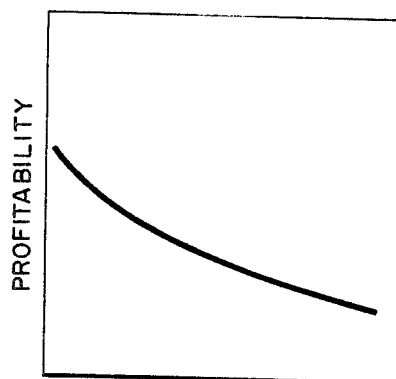
FRESH FEED RATE

FIG. 4



RECYCLE RATIO

FIG. 3



CATALYST LEVEL IN REACTOR

FIG. 5

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CONTROL SYSTEM FOR FLUID CAT CRACKER
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Continuation-in-part of application Ser. No. 702,047, Jan. 31, 1968. This application Aug. 30, 1968, Ser. No. 756,659

Int. Cl. C10g 13/18

U.S. Cl. 208—159

5 Claims

ABSTRACT OF THE DISCLOSURE

Coke deposition rate in the reactor of a fluid cat cracker is controlled by varying the severity and conversion level in the reactor, while maintaining maximum air rate to the regenerator. The temperature at the outlet of the regenerator, which is an indication of afterburning and amount of coke build-up, is used to control reactor temperature and catalyst-to-oil ratio in the reactor (by resetting the reactor temperature recorder control, which in turn controls the flow of hot regenerated catalyst from the regenerator to the reactor), thus controlling coke deposition to make it commensurate with air supply by controlling the severity and conversion level in the reactor.

DISCLOSURE

This is a continuation-in-part of Ser. No. 702,047, filed Jan. 31, 1968, and now abandoned. This invention is an improved control system for a conventional fluid catalytic cracker. The improvement consists of a method and apparatus for maximizing the coke burning rate in the regenerator by operating the air compressor at maximum capacity and controlling the coke deposition rate in the reactor by varying the reaction severity in response to variations in air supply from the compressor.

BACKGROUND

In a fluid cat cracker it is important that the air rate to the regenerator at any instant be commensurate with the rate of coke deposition on the catalyst. When the air supply is insufficient, the concentration of coke on circulating catalyst increases rapidly because a dirty catalyst is less efficient, the rate of coke deposition thereon being a direct function of coke concentration thereon. In revivifying catalyst by burning coke therefrom in the dense phase in a regenerator, typically one-third or more of the carbon in the coke is converted to CO rather than CO₂. Provided the normal regenerator temperature equals or exceeds the ignition temperature of CO (as it typically does) and provided an excess of air is used for regeneration, CO will burn to CO₂ in the upper section of the regenerator above the dense catalyst phase. This phenomenon, known as afterburning, causes a rise in temperature of the flue gases above the dense phase in proportion to the amount of CO converted to CO₂. If a large excess of air is used in the regenerator, the temperature rise due to afterburning can be sufficient to cause severe damage to the upper part of the regenerator and the flue gas discharge circuit. On the other hand, a small amount of afterburning with concomitant low temperature rise can be an excellent control guide because it indicates that the air rate is sufficient to balance the coke deposition rate without being in wasteful or damaging excess.

Historically, operators of fluid catalytic crackers have varied regeneration air rate to counterbalance coke deposition rate. This necessitates operating at conditions which consume less than maximum available air at all

times to provide leeway for moderate increases as well as decreases from minute to minute as coke deposition rate increases or decreases. In recent years, some refiners have resorted to the installation of very elaborate and costly computer control systems to vary severity of the cracking operation to take fuller advantage of the available air supply. Still, they must waste some air for trim control. As a direct result, their coke burning rates are lower than the maximum potential. In turn, they convert less gas oil than the maximum potential capacities of their units, nearly all of which are air capacity limited.

SUMMARY OF THE INVENTION

My invention is a simple low-cost scheme of automatic or semi-automatic control which balances coke deposition rate to air supply rate. This permits the owner of a fluid cat cracker to take full advantage of his installed air compression capacity at all times even though this capacity meanders with changes in atmospheric pressure, temperature, and humidity. This control is accomplished by varying reaction severity to adjust conversion upward or downward as variations in air supply permit the burning of more or less coke. The reaction severity is controlled by varying the temperature and the catalyst-to-feedstock ratio in the reactor in response to the temperature at the outlet of the regenerator. The temperature and the catalyst-to-feedstock ratio is varied by varying the flow of hot regenerated catalyst from the regenerator to the reactor.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified flow diagram of a fluid catalytic cracking unit embodying my invention.

FIGS. 2-5 illustrate the relationship of certain operating variables to profitability of a conventional fluid catalytic cracking unit.

DETAILED DESCRIPTION

Referring to FIG. 1, compressor 1 runs at maximum speed on governor control, delivering all the air it can compress into regenerator 2 in which the pressure is held constant (preferably at about 10-30 p.s.i.g.) by a pressure recorder controller (PRC) 3a operating a back pressure valve in the flue gas exit line 3. Fresh feed and recycle gas oil streams 4 and 5 each on flow rate control (FRC) 4a and 5a, join and pass through furnace 6 into the reactor feed riser 7. The transfer temperature typically varying between about 400° F. and 700° F. from feed preheater furnace 6 is controlled by a temperature recorder controller alarm (TRCA) 8 which positions a valve in the furnace fuel line 9. The temperature in the dense phase 10 of the regenerator is held constant by a temperature recorder controller (TRC) 11 which resets the control point of TRCA 8.

Steam and slurry recycle from the fractionator (not shown) may also be charged to the reactor feed riser at constant rates as indicated. Regenerated catalyst from the dense phase in regenerator 2 flows via a standpipe 12 and slide valve 13 into the lower end of the reactor feed riser 7 where it mixes thoroughly with the steam and oil feed streams. By virtue of its higher temperature (about 1200° F.), the regenerated catalyst surrenders heat to the combined oil feed stream, bringing it to the desired temperature (usually within the range of 890° F. to 960° F.) to effect vaporization and cracking of the latter. The resultant vapors and steam flow up through the reactor feed riser into reactor 14, entraining the catalyst therewith. The temperature within the reactor is controlled to maintain a reactor temperature preferably within the range of about 890-960° F., by a temperature recorder controller alarm (TRCA) 15 which regulates the position

of the slide valve 13 in the regenerated catalyst standpipe 12.

The amount of afterburning which occurs in regenerator 2 is controlled by controlling its flue gas exit temperature with a temperature recorder controller (TRC) 16 which resets the control point on TRCA 15 which directly controls the reactor temperature.

Spent catalyst from reactor 14 gravitates through stripper 17 wherein it is countercurrently swept with steam fed to the base of the stripper via line 18 controlled by a flow recorder control (FRC) 19. This steam stripping removes adsorbed and entrapped oil vapors from the spent catalyst and returns them to the reactor from whence they ultimately flow to the fractionator.

Stripped spent catalyst gravitates from the base of stripper 17 into regenerator 2 via spent catalyst standpipe 20 and slide valve 21. The position of slide valve 21 is regulated by a level recorder controller (LRC) 22 to maintain a constant head of catalyst above the base of stripper. The catalyst level may extend up into the reactor if desired.

Having thus explained the system of controls, it is appropriate to elaborate on how and why it works. Referring to FIG. 2, it will be seen that, at constant coke burning rate, the overall profitability of a typical fluid catalytic cracking operation does not vary significantly with reactor temperature provided the temperature is held in the mid-range, which for a mid-continent gas oil feed will usually be about 900° F. to 925° F. As is well known, this essentially constant profitability range varies with feedstock characteristics and various unit and refinery factors, increasing with increasing aromaticity and nitrogen content. At excessively low or high temperatures, higher coke yield is realized per unit of conversion; hence the conversion capacity of any given unit declines as reactor temperature approaches either extreme.

Referring to FIG. 3, it can be seen that increasing recycle ratio increases cracking efficiency (volume of gasoline yield per volume of gas oil converted), but with steadily declining effect. Since the unit cost of recycling is essentially constant, the overall profitability as a function of recycle ratio goes through a maximum with very little change for some distance on either side of the maximum.

In the typical refinery, profitability of catalytic cracking increases with fresh feed rate as shown in FIG. 4, without limit except for availability of feedstock or cat cracking capacity.

Among the variables which effect the level of conversion are reaction temperature, catalyst to oil ratio, catalyst activity, and catalyst inventory in the reactor. Of these, catalyst inventory in the reactor is the least desirable variable for forcing higher conversion. This has been discussed at great length in numerous publications, and the consensus is that high catalyst inventories in cracking reactors leads to cracking of gasoline fractions and other deleterious reactions. Thus, as indicated by FIG. 5, profitability typically increases with decreasing catalyst level in the reactor without limit provided limiting conversion can be reached in the reactor feed riser without excessive temperature or catalyst cost.

Except for very short term deviations, the heat input to a catalytic cracker must equal the heat output; otherwise system temperatures might rise or fall to damaging levels. The sum total heat input via the feed preheater 6 and via combustion within the regenerator 2 must equal the sum of the radiation losses, the sensible heat surrendered to the flue gas leaving the regenerator, and the sensible, latent, and reaction heats surrendered to the product vapors from the reactor 14.

If, at any time, the temperature of the dense phase 10 in the regenerator should tend to drop, it would signify that the rate of heat removal from the system temporarily exceeded the rate of heat input; the regenerator TRC 11 would react by increasing the control setting of the feed

preheater TRCA 8. This, in turn, would increase the fuel rate (line 9) to the furnace 6 to bring heat input and output back into balance and return the regenerator temperature to its control point. It is readily apparent that by reacting in opposite fashion, the control system just described will limit the degree to which the regenerator temperature can climb above the control point.

The control temperature setting on the TRC 16 must be somewhat higher than that on TRC 11 to insure controlled afterburning. This difference should be at least 5° F. to insure reasonable controllability but should not be so high as to be wasteful of air that might be better used for burning additional coke which would result from raising conversion. In some instances it might be desirable to operate with a flue gas exit temperature 50° F. or more above the regenerator dense phase temperature to maintain a high mean oxygen concentration in the gases rising through the dense phase to reduce the residual coke content on regenerated catalyst to a lower level than would otherwise be achieved. For this control scheme to function properly, it is obviously necessary that the controlled temperature level in the regenerator dense phase exceed the ignition temperature of carbon monoxide. The preferred temperature is about 1200° F. to 1225° F.

If, at any time, the temperature of the flue gas exiting from the top of regenerator should tend to fall below the control point, it would signify that there was a reduction in afterburning because of a drop in oxygen content of the flue gases rising from the dense phase. This, in turn, would signify that the mean concentration of coke on catalyst in the regenerator was rising which would mean that coke was being deposited at a faster rate than it was being burned. The flue gas TRC 16 would immediately lower the control setting on the reactor TRCA 15 which would, in turn, re-position (partially close) the slide valve 13 in the regenerated catalyst standpipe 12. The combination of lower reaction temperature and lower catalyst-to-oil ratio would reduce coke deposition rate by reducing conversion level until coke deposition rate again became commensurate with regeneration air rate (line 1a). It is readily apparent that if the flue gas exiting temperature should tend to rise, it would signify that coke was being deposited at a lesser rate than it was being burned and that the automatic control action would be the exact opposite of that just described to increase conversion rate until the coke deposition and burning rates again became equal.

The feed preheat furnace TRCA 8 includes high and low temperature alarms which alert the operator if the temperature reaches either alarm setting. The operator then takes action to reduce or increase heat input requirement of the system. For example, if the low temperature alarm should sound, the operator may increase recycle rate (line 5) to remove more heat from the system to the fractionator. He might take the opposite action if the high temperature alarm should sound. Alternatively, TRCA 8 might be equipped with a reset mechanism to automatically reset the control setting of the recycle FRC 5a if either temperature alarm point should be reached.

In actual operation, the system may be simplified further by substituting potentiometers or other temperature sensing means for TRC 16 and TRC 11 and allowing the operator to manually reset TRCA 15 and TRCA 8, respectively.

The reactor temperature control 15 includes high and low temperature alarms which alert the operator if the temperature reaches either alarm setting. The operator then takes appropriate action to bring the reactor temperature back within the prescribed range. For example, if the high temperature alarm should sound, he would take some action to increase the severity of some reaction control variable other than temperature. This might be an increase in reactor catalyst level, catalyst activity, or recycle ratio, or a reduction in dilution steam rate to the riser or regenerator dense phase temperature. If the low temperature alarm should sound, the operator would

take some action opposite to those just described. Alternatively, the reactor temperature control might be equipped with one or more reset mechanisms to automatically effect one or more of the changes indicated.

Although the control system could be made more complex as indicated in the last two paragraphs, I prefer the simple version as described and depicted in FIG. 1, relying upon the operator to take appropriate action to keep the reactor and furnace transfer temperatures within the alarm settings.

Although mid-continent gas oil is the only feedstock specifically mentioned above, this plan of control will improve the results obtainable with any feedstock otherwise suitable for catalytic cracking and will be especially beneficial for any feedstock that varies in quality during operations.

Suitable catalysts are conventional fluid catalytic cracking catalysts, which are well known in the art.

The first fluid catalytic cracking unit went on stream in 1942. Since then hundreds of units have been built around the world. Literally thousands of engineers have worked on this process at some time or other; yet apparently none has heretofore thought of this simple scheme of control which permits maximum conversion at all times as limited by air supply. Most units are operating 5 percent or more below capacity. Even those units equipped with complex and costly digital computer controls are operating below the capacities obtainable with the simple inexpensive control scheme described herein.

For example, a test run in a commercial unit substantially as shown in FIG. 1 was conducted using the control system of this invention. The feedstock was a mid-continent gas oil. During this test run, potentiometers were used in place of TRC 16 and TRC 11, the operator manually resetting TRCA 15 and TRCA 8, respectively, as needed. The unit was operated using the maximum available air rate from the compressor (about 27,200 standard cubic feet per minute). Operation of the unit was controlled, in accordance with this invention, so as to balance the coke deposition rate with the coke burn-off rate and at the same time maintain the regenerator temperatures within proper limits. The maximum air rate to the regenerator prior to the use of this system had been about 25,300 s.c.f.m. (representing 92.5% of the maximum air rate available from the compressor), while achieving a gas-oil conversion of 75.6 percent. With the use of this invention during the test, 100% of available air (approximately 27,200 s.c.f.m.) was fed to regenerator (an increase of 7.5 percent) while achieving a gas-oil conversion 79.2 percent.

What is considered new and inventive in this present invention is defined in the hereunto appended claims, it being understood, of course, that equivalents known to those skilled in the art are to be construed as within the scope and purview of the claims.

I claim:

1. In the continuous process of cracking a hydrocarbon feedstock in the presence of subdivided catalyst particles, wherein the hydrocarbon stream effects a fluidized contacting of the particles in a reactor, conversion products are separated from the contacted particles, separated catalyst particles containing coke deposited thereon effect fluidized contacting of air in a separate regenerator, said air being supplied by an air compressor, combustion gas products are separated from regenerated catalyst particles and such regenerated catalyst particles with a reduced coke content are returned to the reactor for contact with hydrocarbon feedstock, the improvement which

comprises: operating the air compressor at maximum capacity with all of the air output going into the regenerator, and controlling the coke deposition rate in the reactor by varying the reaction severity in the reactor in response to variations in the air supply from the compressor.

2. The process of claim 1 in which the reaction severity in the reactor is controlled by varying the temperature and the catalyst-to-feedstock ratio in the reactor in response to the temperature at the outlet of the regenerator while the temperature in the regenerator catalyst bed is held constant.

3. The process of claim 2 in which the temperature and the catalyst-to-feedstock ratio is varied by varying the flow of hot regenerated catalyst from the regenerator to the reactor.

4. In a catalytic cracking unit consisting essentially of:

- (a) A reactor having a first conduit attached to the upper portion thereof, a stripper attached to lower portion thereof, and a temperature recorder controller alarm attached to said reactor;
 - (b) A regenerator having attached to the upper portion thereof a second conduit and means to control the pressure in the regenerator, and having attached to the lower portion thereof a third conduit, equipped with a valve, said third conduit extending up into the lower portion of the regenerator, and a fourth conduit connected to the lower portion of the regenerator, said fourth conduit having an air compressor connected thereto;
 - (c) Means for controlling the operation of said valve in response to temperature variations in the reactor;
 - (d) A conduit connecting the lower portion of the reactor with the bottom end of said third conduit and extending beyond said connection and through a furnace fired by means of fuel supplied to said furnace through a fifth conduit;
 - (e) Means connected to the regenerator and the fifth conduit for maintaining a substantially constant temperature within the regenerator;
- the improvement which comprises:
- (f) Temperature sensing means connected to the upper portion of the regenerator, said temperature sensing means being operatively connected to said means (c).
5. The combination of claim 4 wherein said temperature sensing means comprises temperature control means for changing the control setting of means (c) in response to temperature variations in the upper portion of the regenerator.

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HERBERT LEVINE, Primary Examiner

U.S. Cl. X.R.

208—164; 23—288