March 22, 1949. E. A. JOHNSON 2,464,812

CATALYTIC CONVERSION SYSTEM

Filed Jan. 30, 1942 2 Sheets-Sheet 1

Fig. 1.

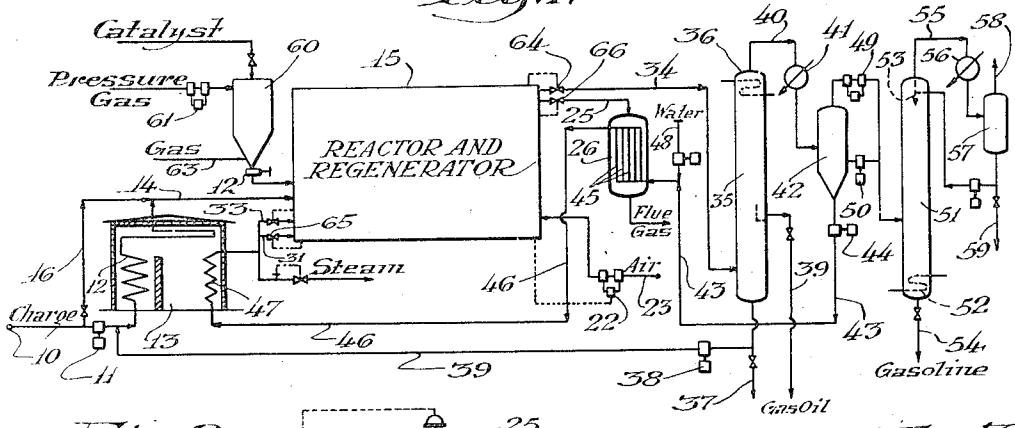


Fig. 2.

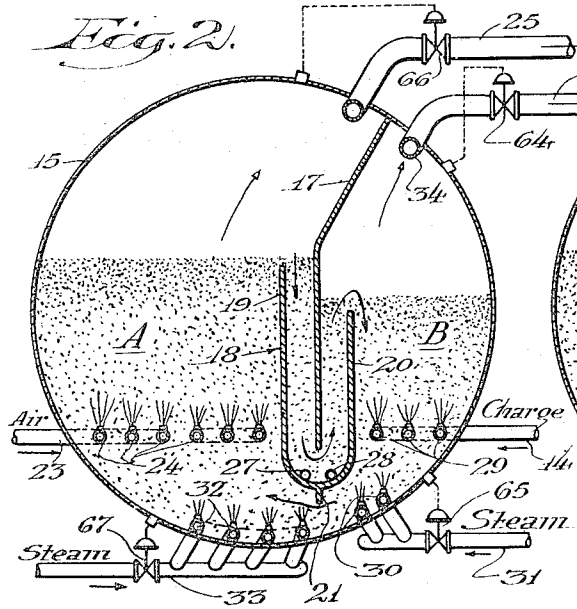


Fig. 3.

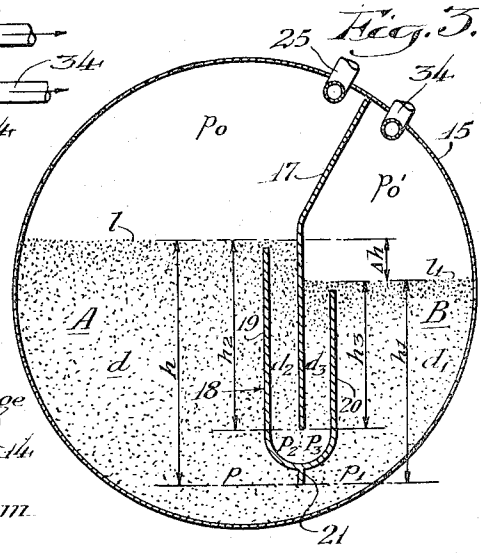
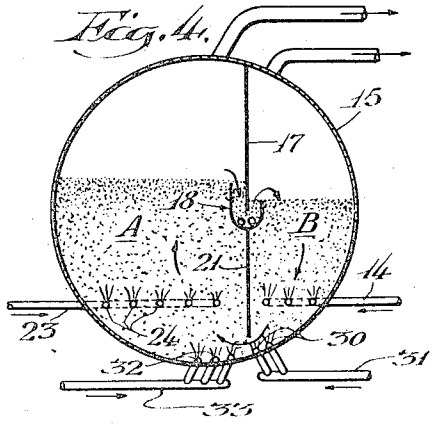


Fig. 4.



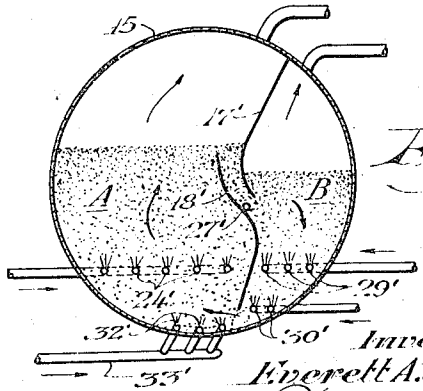


Fig. 5.

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Filed Jan. 30, 1942 2 Sheets-Sheet 2

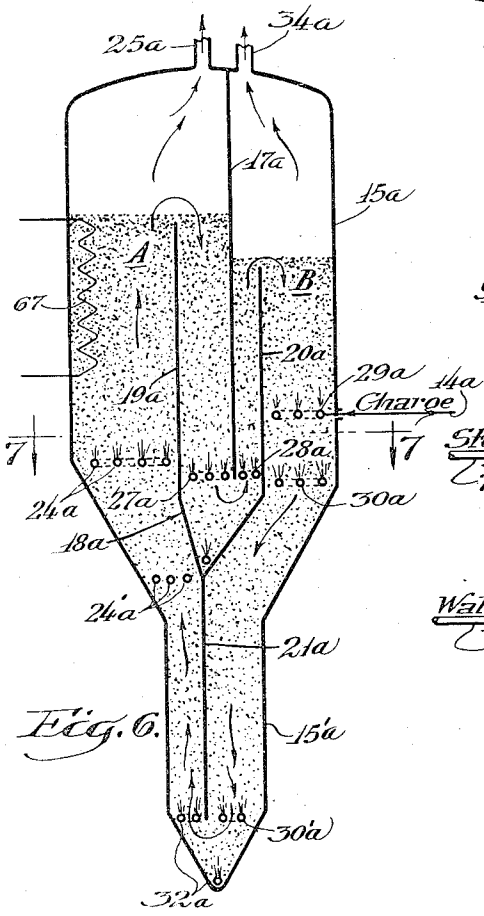


Fig. 6.

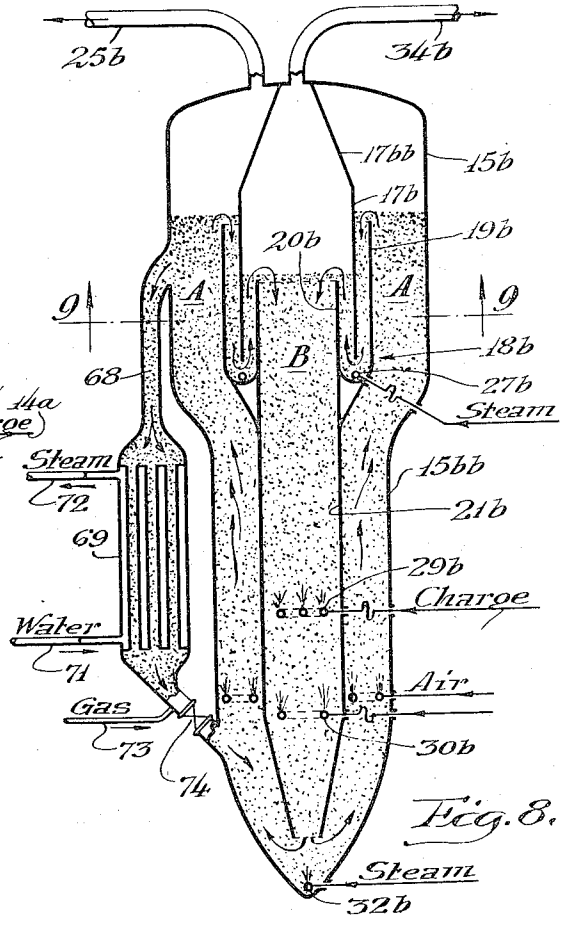


Fig. 8.

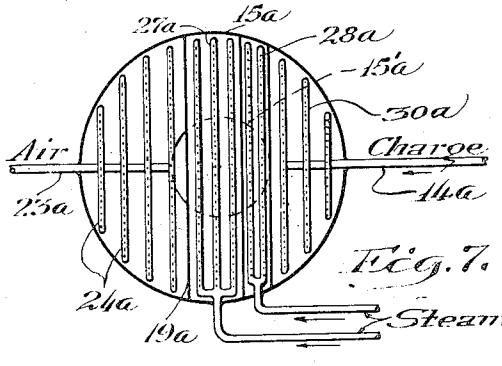
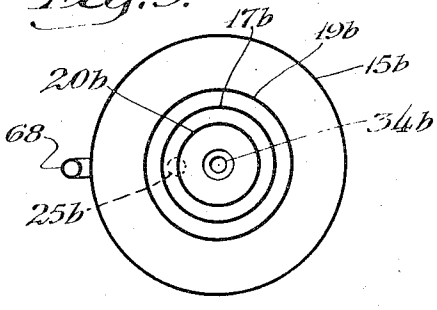


Fig. 7.

Fig. 9.



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Patented Mar. 22, 1949 2,464,812

UNITED STATES PATENT OFFICE

2,464,812

CATALYTIC CONVERSION SYSTEM

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Application January 30, 1942, Serial No. 428,913

8 Claims. (Cl. 23—1)

1

This invention relates to a catalytic conversion system and it pertains more particularly to a system for handling fluidized powdered catalyst.

In the powdered or fluid type catalyst system a powdered catalyst effects a conversion while suspended in a gas or vapor stream. It is then separated from gases or vapors, stripped with an inert gas such as steam, and suspended in a gas mixture for regeneration. The regenerated catalyst is then separated from regeneration gases and resuspended in the original gas or vapor stream for effecting further conversion. While my invention is primarily directed to hydrocarbon conversion systems it is not limited thereto but is applicable to any conversion system wherein a powdered catalyst effects conversion in one zone and is regenerated in another zone or wherein it effects different conversions in two different zones.

In systems of this type the problem of handling powdered catalyst is of great importance because of the enormous bulk of catalyst which must be continuously recycled between the two zones. Ordinary mechanical pumps and conveyors are ruled out because of the abrasive action of the powdered solids. It has been proposed to employ pneumatic handling and conveying means and to obtain the necessary pressure differentials by the pressure head that is developed by aerated catalyst in standpipes. The use of such standpipes has necessitated cumbersome and expensive equipment, structures from 150 to 250 feet high. Furthermore, the use of such standpipe pressuring means has given rise to troublesome problems of differential expansion because of the enormous differences in temperature incident to starting up or shutting down a system and the long pipes or conduits that have heretofore been deemed necessary for conveying catalyst from one part of the system to another. An object of my invention is to avoid all of such expansion difficulties and to eliminate the necessity of the cumbersome and expensive standpipes.

Fluid type catalytic conversion systems have heretofore required a number of valves for controlling the flow of powdered catalyst material in various conduits. These valves are not only expensive and difficult to fabricate but they are a constant source of trouble because of the abrasive action of the aerated solids. An object of my invention is to provide a system which eliminates the use of valves in any conduits handling appreciable amounts of powdered catalyst. The elimination of catalyst valves materially lessens the pressure differentials required for obtaining the desired catalyst flow rates and hence makes

2

possible a marked reduction in the overall height of the equipment.

A further object of the invention is to provide a new and improved type of unitary conversion-regeneration chamber which will require less material, which may be fabricated more easily and which will operate more smoothly and efficiently than any device for the purpose heretofore known to the art. A further object is to provide a system which is equally suitable for large and small installations and which may be easily and at minimum expense supplemented to increase the capacity of a given installation or blocked off to decrease capacity.

A further object is to minimize the amount of work required for the recycling of catalyst from a conversion zone to a regeneration zone and thence back to the conversion zone. Enormous amounts of catalyst must thus be recirculated in systems of this type. My object is to minimize the distances through which catalysts must be conveyed, to minimize the frictional resistance to flow, to minimize catalyst deterioration because of handling and to minimize the errosion and "wear and tear" on equipment which is caused by catalyst flow.

A further object of my invention is to provide improved means for maintaining a fluidized powdered catalyst mass in dense phase throughout the entire conversion, regeneration and recycling system and to minimize catalyst losses. A further object is to provide improved methods and means for utilizing at least a part of the heat of regeneration for supplying at least a part of the heat of conversion. A further object is to provide improved methods and means for obtaining optimum conversion, product distribution, yields, etc. and to avoid any overheating of the catalyst in the regeneration step. Other objects will be apparent as the detailed description of the invention proceeds.

In practicing my invention I effect both conversion and regeneration in a single chamber which is separated into two zones by cooperating internal baffles which are so arranged as to permit catalyst flow from the middle of a first zone to a second zone and from the bottom of the second zone back to the first zone while the spaces above the catalyst in the two zones are separated from each other by one of the baffles. Catalyst is stripped in its flow from one zone to another and aeration gas such as steam is provided to serve the double function of maintaining the catalyst in aerated condition and preventing gases or vapors in either zone from entering the other zone.

The chamber may be a horizontal cylindrical vessel which may be easily elongated or partially blocked off for changing the capacit of a given installation. The horizontal vessel offers new and unique advantages in that it provides for the lowest vertical vapor velocities at substantially the dense phase interface and thereby remarkably decreases catalyst entrainment in the gases leaving the dense phase and thus decreases catalyst losses from the system. The horizontal chambers likewise enable the use of effective baffles and other means for preventing catalyst losses.

The baffle arrangement may consist of a U-shaped baffle around the lower end of a depending upper baffle which may be either vertical or slightly inclined. One leg of the U-shaped baffle may be slightly lower than the other leg and in fact one leg may be actually reversed in direction as will be hereinafter described. The space between the depending baffle and one leg of the U-shaped baffle may be greater than the space between the depending baffle and the other leg of the U-shaped baffle in order to provide for adequate stripping.

The unitary chamber may be vertically mounted instead of horizontally mounted in which case the depending and U-shaped baffles may be of the same type as used for horizontal chambers or may be annular in shape. If a vertical cylindrical chamber is employed it is preferably enlarged at its upper end to avoid any material decrease in cross-sectional area in reaction and regeneration zones because of the space required for the flow of catalyst from a mid point of one zone to the mid point of the other.

Catalyst flow from the reaction zone to the regeneration zone and thence back to the reaction zone is effected by simply controlling the pressures above the dense catalyst phase in the reaction and conversion zones and controlling the vertical gas or vapor velocities in said zones while maintaining the necessary catalyst inventory. The vertical vapor velocities determine the density of suspended catalyst in each zone and also determine the gas lift effect therein. In the zone of lowest catalyst level the catalyst density may be sufficiently greater than the catalyst density in the other zone to provide the necessary pressure differential for causing catalyst to flow from the base of the denser zone to the base of the lighter zone. Catalyst may flow from the top of the dense phase in the lighter zone by virtue of the difference in catalyst level in said zone. Pressure differentials for obtaining catalyst flow may likewise be obtained by regulating catalyst density in the transfer legs between baffle plates. The recycling of catalyst in this system is thus effected entirely by controlling the pressures and catalyst densities in various parts of the system and this in turn is accomplished by regulating gas or vapor velocities in various parts of the system. On one side of the system there is a gas lift effect and the net movement of the catalyst is upwards while on the other side of the system the gravity head of the catalyst is greater than the gas lift effect so that the net movement is downward. By a proper control of the gas lift and gravity effects in various parts of the system, any desired flow direction and catalyst flow rate may be obtained. Aeration steam (and the flowing mass of catalyst itself) prevents reaction vapors from entering the regeneration zone and regeneration vapors from entering the reaction zone.

A single baffle may be the equivalent of two cooperating baffles when it is provided with apertures at its lower and mid points for permitting catalyst flow and is so designed and sealed as to prevent gases in one zone from entering the other.

The invention will be more clearly understood from the following detailed description read in conjunction with the accompanying drawings which form a part of this specification and in which:

Figure 1 is a flow diagram of the conversion system as a whole showing the reactor-regenerator chamber as a horizontal cylindrical vessel.

Figure 2 is a vertical transverse section through said chamber.

Figure 3 is a similar section illustrating the principle of operation.

Figure 4 is a vertical transverse section illustrating a modified baffle arrangement to provide an upper seal.

Figure 5 is a vertical transverse section illustrating an alternative baffle arrangement.

Figure 6 is a vertical section through a vertical cylindrical chamber.

Figure 7 is a horizontal section taken along the lines 7—7 of Figure 6.

Figure 8 is a vertical section illustrating a vertical cylindrical chamber with cylindrical baffles, and

Figure 9 is a horizontal section taken along the lines 9—9 of Figure 8.

My invention will be described as applied to a process of catalytically cracking gas oil but it should be understood that the invention is equally applicable to other hydrocarbon conversion processes such as naphtha reforming, hydrogenation, dehydrogenation, isomerization, alkylation, polymerization, etc. provided that the catalyst and operating conditions be employed as required for the particular process used. The invention is also applicable to catalytic conversion processes generally such as oxidation, reduction, etc.

For catalytic cracking a preferred catalyst may be an acid treated montmorillonite clay commonly marketed as Super Filtrol or it may be a synthetic catalyst consisting essentially of activated silica and a metal oxide. Such a catalyst may be prepared by ball milling silica hydrogel with alumina or magnesia using about 2 to 30%, for example about 15%, of alumina or magnesia. The ball milled dough may be dried at a temperature of about 240° F. and then activated by heating to a temperature of about 900 to 1000° F. Another method of preparing a highly active cracking catalyst is to form a gel from dilute sodium silicate in the presence of an aluminum salt by the addition of excess dilute sulfuric acid. The resulting gel is boiled for an hour or two with an excess of ammonium hydroxide solution before washing, after which it is dried and heated as in the previous example. The silica-alumina or silica-magnesia catalyst may be rendered more stable at high temperatures by the addition thereto of zirconia or aluminum fluosilicate. Thoria or other metal oxides may also be included in the composition. No invention is claimed in the catalyst per se and further description is, therefore, unnecessary.

In the examples hereinafter described the catalyst is in powdered form with a particle size of about 10 to 100 microns. The invention is applicable to other catalyst sizes provided only that the catalyst be of such size and density that it may be aerated and handled as a fluid in the manner herein described. Higher gas or vapor velocities may be required for coarser catalyst particles.

The density of the catalyst particles per se may be as high as 160 pounds per cubic foot but the bulk density of catalyst which has settled for 5 or 10 minutes will usually range from about 30 to 45 pounds per cubic foot. With slight aeration, i. e., with gas or vapor velocities of about .05 to .5 foot per second, the bulk density of this catalyst is usually about 25 to 30 pounds per cubic foot and under such conditions the catalyst is referred to as "aerated catalyst." With vapor velocities of about 1 to 2 or 3 feet per second the bulk density of such catalyst may be about 10 to 25 pounds per cubic foot. It is at such gas or vapor velocities that the powdered catalyst is maintained in the dense turbulent suspended catalyst phase which has been found most satisfactory both in the conversion and regeneration steps. With higher and higher vapor velocities the bulk density becomes less and less. In zones above the level of dense phase catalyst in the reaction and regeneration zones, the average bulk density of catalyst is usually less than 1 pound per cubic foot and under such conditions the catalyst is said to be in the dilute, light or dispersed phase. This dilute phase may contain only about 50 grains or less of catalyst material per cubic foot. The density of aerated catalyst leaving a dense phase zone is usually at least 1 to 5 pounds per cubic foot greater than the density of the dense turbulent suspended catalyst phase in said zone.

The density of the dense turbulent suspended catalyst phase may be controlled within fairly close limits by carefully regulating the vertical vapor velocity of the upward flowing gases or vapors. Thus with a given amount of catalyst in a vertical cylindrical chamber a vertical vapor velocity of 1½ feet per second may give a catalyst density of about 20 pounds per cubic foot and a correspondingly low interface level while a velocity of about 2 to 2½ feet per second may give a catalyst density of only 15 pounds per cubic foot and a correspondingly high interface level. Vertical gas or vapor velocities may thus be employed to regulate catalyst density.

Referring to Figure 1, gas oil charging stock from source 10 is introduced by pump 11 through coils 12 of pipe still 13 and thence through transfer line 14 to the reactor side of vessel 15. A part or all of the charging stock may by-pass the heating coil through line 16 when the heat of regeneration and catalyst-to-oil ratios are such that the heat of regeneration may effect vaporization as well as cracking.

Vessel 15, as illustrated in Figure 2, is a large horizontal cylindrical chamber which, for a 10,000 barrel per day plant, may be about 30 feet in diameter and about 50 feet long. A substantially vertical or inclined baffle 17 is welded or otherwise secured to the top and ends of the chamber but is spaced from the bottom thereof. For this catalytic cracking system this baffle is preferably positioned closer to one side of the vessel than the other so that the reaction or conversion zone which is on one side of the baffle will be only about .5 to .05 the size of the regeneration zone which is on the other side of the baffle. The top part of the baffle may be inclined toward the conversion side of the chamber in order to provide increased catalyst settling area on the regeneration side.

A U-shaped baffle 18 surrounds the lower end of baffle 17 and is likewise welded or otherwise secured to the end walls of the chamber. The two legs of this U-shaped baffle may be of equal length or one leg 19 may be longer than the other leg 20. In Figure 2 the left-hand side of the chamber constitutes regeneration zone A while the right-hand side constitutes conversion zone B. Catalyst flows from zone A downwardly through the space between leg 19 and baffle 17, then upwardly in the space between leg 20 and the lower end of baffle 17 and is thus transferred from a mid point in the regeneration zone to a mid point in the conversion zone. Catalyst flows from the conversion zone to the regeneration zone underneath the U-shaped baffle 18 or the lower extension 21 thereof.

To obtain catalyst flow in the direction indicated the pressure at the base of zone B must be greater than the pressure at the base of zone A and the pressure at the base of the transfer space between baffle leg 19 and baffle 17 must be greater than the pressure at the base of the space between baffle 17 and leg 20. This will be more clearly apparent by reference to Figure 3 wherein:

p is the pressure at the bottom of regeneration zone A
p_1 is the pressure at the bottom of reaction zone B
p_2 is the pressure at the base of the zone between baffles 17 and 19
p_3 is the pressure at the base of the zone between baffles 17 and 20
p_0 is the pressure at the top of the regeneration zone
p_0' is the pressure at the top of the reaction zone
l is dense phase level in regeneration zone A
l_1 is dense phase level in reaction zone B
h is the height of dense phase catalyst in regeneration zine A
h_1 is height of dense phase catalyst in reaction zone B
h_2 is the height of catalyst between baffles 17 and 19
h_3 is the height of catalyst between baffles 17 and 20
d is average density below l in regeneration zone A
d_1 is average density below l_1 in reaction zone B
d_2 is average density between baffles 17 and 19 and
d_3 is average density between baffles 17 and 20.

Since density is expressed in pounds per cubic foot and pressure is expressed in pounds per square inch, we have:

$$p=\frac{hd}{144}+p_0 \qquad p_1=\frac{h_1d_1}{144}+p'_0$$

$$p_2=\frac{h_2d_2}{144}+p_0 \qquad p_3=\frac{h_3d_3}{144}+p'_0$$

The density in various parts of the system must be so regulated that p_1 is greater than p and p_2 is greater than p_3. The density is regulated by simply controlling the vertical velocities of air, steam and oil which is introduced at various points in the system, regulating the pressure at the top of the reactor and regenerator and maintaining the necessary catalyst inventory in the chamber. The general downward flow through the reactor and through the space between baffles 17 and 19 is caused by the pressure head therein, i. e., by gravity. The general upward flow through the regenerator and through the space between baffles 17 and 20 is caused by the gas-lift effects therein. The gas or vapor velocities in all parts of the system are controlled to give the desired balance between pressure head and gas-lift effects.

By way of example, the 10,000 barrel per day

plant herein described may employ a chamber 30 feet in diameter by 50 feet long. Baffle 17 may be about 6 feet from the right wall and 24 feet from the left wall of the chamber at its horizontal diameter and baffles 19 and 20 may be spaced about 2 feet on each side of baffle 17. The bottom of the U-shaped baffle should extend within about 1 or 2 feet from the lower chamber wall under baffle 17; if desired an extension 21 at the base of the U-shaped baffle may extend to within one or two feet of the chamber wall, thus shortening the length of flow around baffle 17 in U-shaped baffle 18. In this particular modification we may have approximately the following conditions:

p_0=4.40	p'_0=5.00	
p =6.18	h =16	d =16
p_1=7.22	h_1=16	d_1=20
p_2=6.74	h_2=14	d_2=24
p_3=5.97	h_3=14	d_3=10

This will give a pressure differential of 1.04 pounds per square inch for effecting flow in a space between baffles and a pressure of .77 per square inch for effecting flow underneath the U-shaped baffle.

By proper selection of catalyst levels, catalyst densities, baffle arrangements and pressures at the top of the reaction-regeneration zones I may obtain pressure differentials ranging from about $\frac{1}{10}$ pound to 5 pounds or more per square inch and by slightly changing the pressure at the top of the reactor or regenerator I may distribute this pressure differential for effecting desired flow rates at the bottom and intermediate parts of the chamber. Thus in the case where:

h is 20	h_2 is 19	d is 14	d_2 is 25
h_1 is 17	h_3 is 16	d_1 is 21	d_3 is 10

the use of equal pressures at the top of the reaction-regeneration zones will give an upper pressure differential of 2.19 pounds per square inch and a low pressure differential of .54 pound per square inch. However, if the pressure at the top of the reactor in this particular reactor is .83 pound per square inch higher than the pressure at the top of the regeneration zone, I obtain a pressure differential of 1.35 pounds per square inch for both the upper flowing stream and the lower flowing stream respectively.

Where the density of the flowing stream between baffles 17 and 18 is substantially uniform, it is desirable to use the U-shaped baffle with relatively short sides and to employ a relatively long baffle extension 21 at the base thereof, the U-shaped baffle in this case simply serving as a seal to prevent the entrance of vapors from one zone to the other. The use of short legs on the U-shaped baffle decreases friction and thus increases the flow rate for a given pressure differential.

The actual rate of flow of the catalyst will depend upon the distance between baffles and in the particular example of a 10,000 barrel per day plant employing a chamber of 30 feet diameter I may employ such pressure differentials as to obtain flow rates that will give a catalyst-to-oil weight ratio of about 14 or 15; in other words, about 14 or 15 pounds of catalyst are introduced into conversion zone B in the same unit of time that one pound of oil charging stock is introduced thereto. The weight space velocity in the reaction zone in this particular example may be about 10 to 12; in other words, for each 10 to 12 pounds of oil which is introduced into the conversion zone per hour there will be about 1 pound of catalyst in said zone. This means that the average residence time of the catalyst in the conversion zone is about .3 to .4 minute. The upward vertical velocity of oil vapors and steam in the conversion zone may be about 1 to 2 feet per second.

The regeneration zone in this particular case is about ten times the volume of the conversion zone and sufficient air is introduced by pump 22 through line 23 and distributor pipe 24 to maintain an upward gas velocity in the regenerator to maintain the desired dense phase conditions. This air also serves as a gas-lift and although catalyst is in dense turbulent suspension throughout the regeneration zone, the net flow of catalyst is upward in this zone. Much of the heat of regeneration is recovered from regeneration gases which are withdrawn through line 25 to waste heat boiler 26. A large portion of the heat of regeneration is stored in the catalyst particles themselves and may thus be utilized to effect conversion in the reaction zone. I prefer to control the temperature in the reaction zone by regulating the amount of heat introduced into the charging stock where large amounts of heat are liberated in the regeneration zone, the heat absorbed by the catalyst may be sufficient to effect the vaporization as well as the cracking of the charging stock in which case the charging stock may be introduced as a liquid or partially in the liquid and partially in the vapor phase. The temperature in the regeneration zone may be about 1000° F. and in the conversion zone about 900° F. in this particular example. Where the rate of catalyst recirculation is not sufficiently rapid to enable the utilization of all of the excess heat of regeneration for vaporizing and cracking the charging stock, I may employ cooling coils or other equivalent means in the regeneration zone for absorbing the excess heat.

It may be desirable to strip oxygen from regenerated catalyst before introducing the catalyst into the conversion zone and this stripping may be effected in the space between baffle 17 and baffle leg 20. Stripping steam for this purpose may be introduced through line 27. The space between these baffles may be as wide as necessary or desirable for effecting this stripping without unduly decreasing the density of the down-flowing catalyst. The gas-lift effect for transferring catalyst from the base of the U-shaped baffle upwardly between baffles 17 and 20 may be supplied by steam introduced through distributing line 28. I may, of course, employ a single distributor at the base of this U-shaped baffle so that a part of the introduced steam will be employed for stripping on the left side of the baffle while another part acts as a gas-lift on the right side thereof. The steam introduced at this point serves the important function of maintaining the catalyst in aerated condition and at proper density and it also serves the important function of a seal for preventing hydrocarbon gases from entering the regeneration zone and for preventing regeneration gases from entering the conversion zone.

The charging stock which is introduced through line 14 is distributed by suitable distributing pipes 29 which pipes in this particular example may be about half-way between the horizontal diameter and the bottom of the vessel. About 4 or 5 feet below the charging stock distributing pipes I provide stripping steam distributing pipes 30 for distributing the steam introduced through line 31. By this means any volatile

hydrocarbons are recovered and removed from the catalyst before it enters the regeneration section and the stripping steam serves, of course, as a component of the upflowing vapors in the conversion zone. Catalysts may be maintained in aerated condition in the very bottom of the reactor by suitable steam distributors 32 connected to line 33 and the steam introduced at this point not only serves the function of maintaining the catalyst in fluidized state but it also serves as a seal to prevent hydrocarbon vapors from entering the regeneration zone and to prevent regeneration gases from entering the conversion zone.

Instead of employing a single elongated horizontal chamber I may employ a plurality of relatively short cylindrical chambers arranged end to end and in such cases I may have the reaction side of one chamber next to the regeneration side of the adjacent chamber for better temperature control and heat utilization. Also, I may employ transverse vertical baffles extending from the sides of the U-shaped baffle (and its lower extension) to the side walls of the horizontal vessel for effectively providing a plurality of reaction and regeneration zones of smaller cross-sectional area. The use of such baffles may insure more uniform operations throughout the length of the chamber. Vertical baffles may serve a particularly useful function in the steam stripping zone for insuring uniform contact of all catalyst with stripping steam. Also, instead of employing distributor pipes extending throughout the length of the horizontal vessel I may employ a manifold along the vessel wall with branch lines extending from said manifold transversely along the bottom side of the vessel. A wide variety of baffles and distributing means may be employed and it should be understood that my invention is in no way limited to the particular baffles and distributing means illustrated in the drawings.

Having thus described a particular example of my reactor and regeneration system, reference will again be made to Figure 1. The conversion products and steam withdrawn from chamber 16 through line 34 are conducted to a scrubbing and frationator tower 35 which is provided at its top with suitable reflux means 36. The heaviest condensate, which may contain entrained catalyst particles, may be withdrawn from the system through line 37 or recycled by pump 38 through line 39 to coils 12 of pipe still 13. A gas oil side stream may be withdrawn through line 39 and a gasoline and lighter components may be taken overhead through line 40 from cooler 41 to separator 42. Water is withdrawn from the bottom of this separator through line 43 and is passed by pump 44 through tubes 45 of waste heat boiler 26 and thence through line 46 to coils 47 of pipe still 13. The steam is heated in coils 47 to about 900° F. and is then ready for use in lines 27, 28, 30, 32, etc. Additional water may be added to the system through line 48.

The gases from separator 42 are compressed by compressor 49 and condensed oil is pumped by pump 50 for introduction into stabilizer tower 51 which is provided with a suitable heater 52 at its base and reflux means 53 at its top. Stabilized cracked gasoline is withdrawn from the bottom of this stabilizer through line 54. Gases are taken overhead through line 55 and cooler 56 to receiver 57 from which gases are taken overhead through line 58 and a butane fraction of reflux condensate is removed through line 59. It should be understood, of course, that the fractionation system hereinabove described may be of any conventional design and the above description is illustrative and only diagrammatic.

Make-up catalyst may be introduced into chamber 15 by charging it into pressure vessel 60, pressuring the vessel by means of compressor 61 and then opening valve 62. The make-up catalyst in this pressure tank may be aerated by gas introduced through line 63. Make-up catalyst is preferably introduced directly into the regenerator so that air may be used as the aerating and pressuring gas. It should be understood, however, that make-up catalyst may be introduced with air through line 23 or with oil vapors through line 14 in cases where there is no danger of plugging distributor pipes.

In the horizontal reactor-regenerator system hereinabove described the pressures in all parts of the system must be carefully controlled. Ordinarily a constant charge rate may be maintained by pump 11. Pressure regulated valve 64 insures the maintenance of the desired pressure at the top of the conversion zone and pressure operated valve 65 regulates the introduction of steam through lines 30 for maintaining the critically close limits on vertical vapor velocities in the reaction zone. The pressure at the top of the regenerator is closely controlled by pressure-operated valve 66 and the vertical gas velocities in the regenerator are primarily controlled by compressor 22 and supplementarily controlled by pressure-controlled valve 67 in line 33 which supplies steam to distributors 32. The amount of steam introduced through lines 27 and 28 is carefully and preferably automatically regulated in accordance with pressure conditions at these points. The pressure-controlled valves, flow regulators, etc. are well known to those skilled in the art and no detailed description of such devices is therefore deemed necessary. It should be pointed out, however, that the average density of catalyst may be readily determined by means of pressure differentials and such pressure differentials serve to warn the operator of any deficiency of catalyst inventory or any departure from desired operating conditions.

In Figure 4 I have illustrated a modification wherein the sides of the U-shaped baffle are relatively short and the bottom extension 21 is relatively long. In such an embodiment it is important that the pressures on both sides of the U-shaped baffle be carefully balanced in order to prevent regeneration gases from entering the conversion zone and conversion gases from entering the regeneration zone.

In Figure 5 I have illustrated another modification of baffle arrangement to illustrate the fact that a U-shaped baffle is not an essential element of my invention. In this case the lower end of baffle 17' is curved toward an intermediate or lower part of the regeneration zone. Cooperating baffle 18' follows the curvature of the lower end of baffle 17' and extends sufficiently close to oil distributor pipes 29' so that regenerated catalyst is dispersed by charging stock vapors into the reaction zone and are thus prevented from short-circuiting said zone. The lower part of baffle 18' may follow the general curvature of the lower part of chamber wall 15 in order to provide a steam stripping zone of substantially uniform cross-sectional area. Baffles 17' and 18' may be one single baffle with an intermediate aperture providing a communication from the mid point in one zone to a mid point in the other.

In Figures 6 and 7 I have illustrated a vertical

chamber 15*a* with a depending baffle 17*a* the lower end of which is surrounded by U-shaped baffle 18*a* having a relatively long leg 19*a* and a relatively short leg 20*a*. The lower extension 21*a* of baffle 18*a* extends down into a narrowed portion 15'*a* of the chamber to increase the seal at the base thereof and to provide a greater pressure differential between relatively dense catalyst to the right of this baffle and less dense catalyst to the left thereof. The space between baffles 19*a* and 17*a* is larger than the space between baffles 17*a* and 20*a* and the space to the right of baffle 21*a* is greater than the space to the left thereof in order that the down-flowing catalyst which is undergoing stripping may have a larger corss-sectional area than the up-flowing catalyst which is entering the reaction and regeneration zones. The overall height of the reactor may be about 80 feet, baffle 17*a* may extend downwardly about 64 feet. Leg 19*a* may be about 50 feet, leg 20*a* may be about 40 feet and the lower part of baffle 18*a* together with extension 21*a* may be about 10 feet. I will then have about the following conditions:

h is 60	d is 16
h_1 is 50	d_1 is 20
h_2 is 47	d_2 is 24
h_3 is 37	d_3 is 10

p_0 is 4 pounds per square inch
p'_0 is 6½ pounds per square inch

and there will be a pressure differential both at the bottom and at the middle of the reactor of about 2.75 pounds per square inch for causing catalyst flow.

The diameter of chamber 15*a* may be about 25 feet or more and the baffles should be so spaced as to provide a cross-sectional area in zone A of about 250 square feet and in zone B of about 125 square feet. The oil inlet distributors 29*a* may be about 25 feet below the top of baffle leg 20*a* and the air distributor 24*a* may be about 50 feet below the baffle leg 19*a*.

In this specific example the catalyst-to-oil ratio may be about 5 and the weight space velocity about 3½, thus allowing a catalyst residence time in the reaction zone of about 3½ minutes. Under such operating conditions it may be necessary to remove any considerable amount of heat from the regeneration zone and I may employ a suitable exchange 67 for that purpose or I may continuously recycle a portion of the dense phase catalyst from this zone through a cooler and back to the regeneration zone. To obtain approximately the same conversion I may employ a catalyst-to-oil ratio of about 7½ and a weight space velocity of about 5½ which will give a catalyst residence time in the reaction zone of about 1½ minutes. This will materially increase the amount of regeneration heat which may be utilized in the reaction zone. For still further utilization of such heat I may employ a catalyst-to-oil ratio of about 14 or 15 and a weight space of about 11 which, as above stated, will give a catalyst residence time of less than half a minute. The catalyst-to-oil ratios may be easily controlled by varying the catalyst bulk densities in various parts of the system and thus varying the pressure differentials, the inventory of catalyst being maintained by the addition of make-up catalyst from time to time.

Generally speaking, the catalyst-to-oil ratios may range from about 1:1 to 20:1 or more, the weight space velocities may range from about 1 weight of oil per hour per weight of catalyst to 15 weight of oil per hour per weight of catalyst and the catalyst residence time may range from about 10 minutes to 10 seconds. It should be understood, however, that my invention is not limited to these particular operating conditions nor to the operating conditions set forth in specific examples. For catalytic cracking the temperature in the reaction zone should usually be maintained between 750° F. and 1050° F. and regeneration temperatures are usually from about 900° F. to 1050° F. or higher.

The modification of my invention illustrated in Figures 8 and 9 is similar to that illustrated in Figures 6 and 7 except that cylindrical baffles are employed, thus simplifying construction and minimizing expansion problems. In this case the upper part of the cylindrical chamber 15*b* may be about 25 feet in diameter and the lower part 15*bb* may have a diameter of about 22 feet. The diameter of cylindrical baffle 17*b* will be about 15 feet and the upper part 17*bb* of the cylindrical baffle may be tapered to provide increased settling space in regeneration zone A. Inner leg 20*b* together with depending baffle 21*b* may form an inner cylindrical chamber about 12½ feet in diameter. Outer leg 19*b* may be about 17 feet in diameter and the bottom of the U-shaped section of annular baffle 18*b* may be at approximately the juncture between the upper section 15*b* and the lower section 15*bb* of the vertical vessel. Thus the cross-sectional area of conversion zone B will be approximately 125 square feet and the cross-sectional area of regeneration zone A will be a little more than 250 square feet. The charging stock inlet distributor 29*b* may be about 25 feet below the level of the dense phase catalyst in the conversion zone B and the air distributors 24*b* may be about 50 feet below the level of dense phase catalyst in regeneration zone A. This will provide for about a 15-foot stripping section below charging stock inlet 29*b* and it will provide for a catalyst level in zone A which is about 10 feet higher than the catalyst level in zone B. The operation may be under substantially the following conditions:

h is 60	d is 16
h_1 is 50	d_1 is 20
h_2 is 20	d_2 is 24
h_3 is 10	d_3 is 10

p_0 is 4 pounds per square inch
p'_0 is 5.5 pounds per square inch

This will give a pressure differential of about 2.1 pounds for effecting the downward and upward flow between the concentric baffles and a pressure differential of about .8 pound for effecting the flow of catalyst at the base of the chamber. The same catalyst-to-oil ratios, weight space velocities, catalyst residence times and operating conditions may be employed in this case as were previously described in connection with Figures 6 and 7.

In Figure 8 I have illustrated the use of an external catalyst cooler for regeneration zone A, the dense phase catalyst flowing downwardly through conduit 68 through tubes in exchanger 69 and thence through conduit 70 back to the lower part of the vessel 15*bb*. Water or other heat exchange fluid may be introduced through line 71 and steam or other fluid withdrawn therefrom through line 72. Aeration gas may be introduced through line 73 and the catalyst flow rate may be regulated by valve 74. Here again, however, it should be understood that cooling coils may be mounted directly in the regenera-

tion where low catalyst-to-oil ratios are employed. With large catalyst-to-oil ratios, i. e., with rapidly circulating catalyst, the excess heat of regeneration may be utilized for effecting at least a partial vaporization of the charging stock as well as the cracking thereof.

The length of baffle leg 20b may be the same as or even greater than the length of baffle leg 19b. When the pressure differential, catalyst flow and steam introduced through line 27b is properly regulated leg 20b may be entirely eliminated and the catalyst may be introduced directly into the conversion zone as it flows past the lower end of baffle 17b. The cooperating baffles should be so shaped as to avoid any possibility of reaction vapors entering the space between baffle 17b and baffle leg 19b.

With properly controlled pressures and properly regulated gas and vapor velocities in various parts of the system the catalyst flow rate can be controlled entirely without the use of valves. It should be understood however that throttling valves and/or check valves may be used if desired to supplement the controls hereinabove described and to prevent any reverse flow of catalyst in the system. Simple flap valves consisting essentially of hinged plates (not shown) may be placed in the system at the points where catalyst enters the conversion and regeneration zones respectively or at any other convenient points.

While my invention has been described as applied to a 10,000 barrel per day unit for the catalytic cracking of gas oil, it should be understood that the invention is not limited thereto. Pressure indicating and control means will, of course, be employed at various points throughout the system. Additional baffles, cyclone separators, electrostatic precipitators and other apparatus may be employed for effecting maximum catalyst recovery. Various heat exchange systems may be employed for effectively utilizing the excess heat of regeneration, etc. Such features are well known to those skilled in the art and will, therefore, not require further description. While I have described in detail a certain conversion process and certain specific examples of baffle arrangements therefor it should be understood that the invention is not limited to such process or to such particular examples. Many modifications and alternative arrangements of the baffles will be apparent to those skilled in the art from the above description. A single baffle, for instance, may be provided with openings at its lower and intermediate parts, respectively, for permitting catalyst flow, and if adequate seals are provided, such structure may be the full equivalent of baffle arrangements hereinabove described. Apparatus features of the invention are claimed in my copending application Serial No. 602,240 filed June 29, 1945 which is a continuation-in-part of this application and of companion application Serial No. 427,947 filed January 23, 1942.

I claim:

1. The method of separately contacting solids of small particle size with a plurality of different gasiform streams in separate first and second contacting zones located adjacent each other with the contacting spaces in said zones being at substantially the same levels, which method comprises separately passing different gasiform streams upwardly through masses of said solids in said separate first and second contacting zones at such velocities that the solids in each zone are maintained in a fluidized state and an interface is maintained between a lower dense phase and an upper light phase in each zone, separately withdrawing gasiform streams from the upper light phases in said respective first and second contacting zones, withdrawing solids from an upper portion of the dense solids phase in the first of said contacting zones, transferring said withdrawn solids through an upper transfer zone into the second contacting zone at an upper level therein while maintaining said solids in dense phase fluidized condition, effecting said solids transfer by the pressure differential caused by having the pressure at the top of the first contacting zone plus the fluidized solids head on the inlet side of the upper transfer zone greater than the pressure at the top of the second contacting zone plus the fluidized solids head on the outlet side of the upper transfer zone, transferring fluidized solids from the lower part of the second contacting zone through a lower transfer zone directly into the dense phase portion of the first contacting zone at a low level therein while maintaining the solids in dense phase fluidized condition, and effecting said last-named solids transfer by the pressure differential caused by having the pressure at the top of the second contacting zone plus fluidized solids head on the inlet side of the lower transfer zone greater than the pressure at the top of the first contacting zone plus fluidized solids head on the outlet side of the lower transfer zone, the fluidized solids head in all cases being the pressure exerted because of the height and density of the respective fluidized solids.

2. The method of claim 1 which includes the step of introducing an aerating gas into at least one of said transfer zones.

3. The method of claim 1 wherein fluidized solids flow downwardly from the dense solids phase in the first contacting zone to the upper transfer zone and then flow upwardly from the upper transfer zone into the dense solids phase in the second contacting zone.

4. The method of separately contacting solids of small particle size with a plurality of different gasiform streams in separate first and second contacting zones located adjacent each other with the contacting spaces in said zones being at substantially the same levels, which method comprises separately passing different gasiform streams upwardly through masses of said solids in said separate first and second contacting zones at such velocities that the solids in each zone are maintained in a fluidized state and an interface is maintained between a lower dense phase and an upper light phase in each zone, separately withdrawing gasiform streams from the upper light phases in said respective first and second contacting zones, withdrawing solids at a level below said interface in the first of said contacting zones, transferring said withdrawn solids through a first transfer zone into the second contacting zone at an upper level therein while maintaining said solids in fluidized condition whereby the fluidized solids in said first transfer zone function as a seal between said contacting zones, effecting the solids transfer by the pressure differential caused by having the pressure at the top of the first contacting zone plus the fluidized solids head on the inlet side of the first transfer zone greater than the pressure at the top of the second contacting zone plus the fluidized solids head on the outlet side of the first contacting zone, withdrawing solids from the second contacting zone at a level

below the interface therein, transferring said last-named withdrawn solids through a second transfer zone directly into the dense phase portion of the first contacting zone while maintaining the solids in fluidized condition, introducing an aerating gas into the solids which are transferred in said second transfer zone and effecting the solids transfer into the second transfer zone by the pressure differential caused by having the pressure at the top of the second transfer zone plus fluidized solids head on the inlet side of the second transfer zone greater than the pressure at the top of the first contacting zone plus fluidized solids head on the outlet side of the second transfer zone, the fluidized solids head in all cases being the pressure exerted because of the height and density of the respective fluidized solids.

5. The method of conducting catalytic reactions and regenerating catalyst in fluidized flow in a process carried out in a first contacting zone and a second contacting zone located adjacent thereto and having its contacting space at substantially the same level as the contacting space in the first contacting zone, which method comprises separately passing different gasiform streams upwardly through the first contacting zone and the second contacting zone respectively at such velocities that the catalyst in each zone is in a fluidized state having an interface between a lower dense phase and an upper light phase, separately withdrawing gasiform streams from the upper light phases in the first and second contacting zones respectively, withdrawing catalyst downwardly from an upper portion of said dense phase in the first contacting zone, transferring said catalyst from said first contacting zone through an upper open transfer zone into said second contacting zone at an upper level in said second contacting zone, effecting said catalyst transfer by the pressure differential caused by having pressure at the top of the first contacting zone plus catalyst head on the inlet side of the upper transfer zone greater than pressure at the top of the second contacting zone plus catalyst head on the outlet side of the upper transfer zone, transferring catalyst from the lower part of said second contacting zone through a lower transfer zone directly into the dense phase portion of the first contacting zone at a low level therein, and effecting said last-named catalyst transfer by the pressure differential caused by having pressure at the top of the second contacting zone plus catalyst head on the inlet side of the lower transfer zone greater than pressure at the top of the first contacting zone plus catalyst head on the outlet side of the lower transfer zone, the catalyst head in all cases being the pressure exerted by fluidized catalyst itself because of its height and density.

6. The method of claim 5 which includes the step of regulating the rate of catalyst transfer through at least one of said transfer zones by controlling the pressure at the top of at least one of said contacting zones.

7. The method of claim 5 which includes the step of regulating the rate of catalyst transfer through at least one of said transfer zones by controlling the catalyst head on at least one side of said transfer zone.

8. The method of claim 5 which includes the steps of regulating the rate of catalyst transfer through at least one of said transfer zones by controlling the pressures at the top of both contacting zones and controlling the upward velocities of said gaseous streams through the dense phases therein.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,984,380	Odell	Dec. 18, 1934
2,304,128	Thomas	Dec. 8, 1942
2,311,564	Munday	Feb. 16, 1943
2,337,684	Scheineman	Dec. 28, 1943
2,360,787	Murphree et al.	Oct. 17, 1944
2,378,342	Voorhees et al.	June 12, 1945