

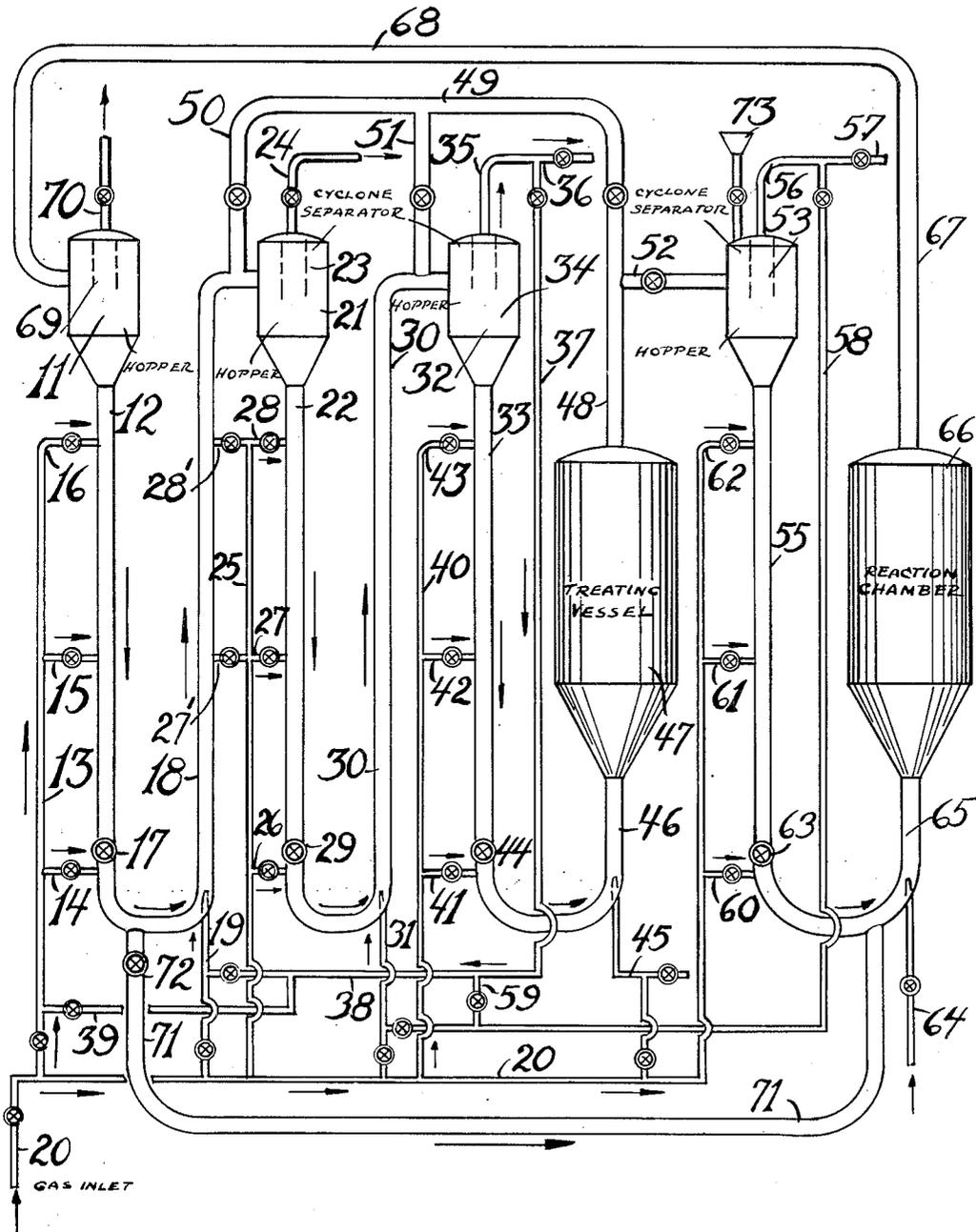
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HANDLING FINELY-DIVIDED MATERIALS

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HANDLING FINELY DIVIDED MATERIALS

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This invention relates to a method of handling finely-divided materials and pertains more particularly to a method of imposing a pressure on such material.

In many types of industrial processes in which powdered materials are involved, it is desirable to place the powder under substantial pressure. One example is catalytic operations in which powdered catalysts are employed. In such operations, sufficient pressure must be imposed on the powder to feed the same into the stream of reactant gases which in turn must be under a pressure adequate to force the resulting mixture through the reaction zone. Also, it may be desirable in many instances to carry out the operation under a substantial pressure.

The main object of the present invention is to provide an improved method of building up pressure on powdered material.

It has heretofore been proposed to place powdered material under a positive pressure by mechanical means, such as, for example, by the use of a compression screw. However, this method gives rise to certain inherent mechanical difficulties. Perhaps the most serious objection to this method is the amount of power required to build up the pressure. The power required increases at a disproportionately greater rate with increase of pressure across the compression screw. In many instances the compression screw becomes seriously eroded or abraded by the powdered material which necessitates frequent replacements. In other cases the application of mechanical pressure may adversely affect the character of the powder being compressed. For example, in catalytic operations involving the use of acid treated clay, it has been found that the use of compression screws tends to agglomerate the clay particles into spheres.

In lieu of a compression screw or other similar mechanical devices, it has also been a practice in some cases to build up the required pressure by means of pressure hoppers in which the powdered material is placed and the required pressure built up by means of a gas imposed above the level of the material in the hopper. This method, however, is objectionable in many cases. For example, in processes which operate continuously requiring continuous removal of the material from the hopper, additional receptacles must be provided so that some may be placed under pressure while the material is being withdrawn from others.

It has also been proposed in isolated cases to build up the required pressure on powdered ma-

terial by means of a vertical column of said powder. By maintaining the powder within the column in a freely flowing state, a static pressure similar to hydrostatic pressure in the case of liquids may be developed at the bottom of the column. However, there are practical limitations with respect to the height of the column which may be employed for building up pressure in this manner.

In accordance with the present invention, a plurality of columns or standpipes is provided and a substantial portion of the static pressure developed from one column is carried over or transferred into a second column in which further pressure is built up. Therefore, by provision of sufficient number of such columns any desired pressure may be imposed on the powder. The present invention is made possible by the fact that finely-divided powdery materials under certain conditions may be made to behave as a liquid.

For a more complete understanding, the invention will be now described in more detail in which reference will be made to the accompanying drawing which is a diagrammatic illustration of an apparatus which may be employed for carrying the invention into effect.

For illustrative purposes, the invention will be described as applied to catalytic processes employing powdered catalysts and more specifically to catalytic cracking of oils in which the invention has found particular application. It will be understood, however, that the invention in its broader phases is not so limited.

Referring to the drawing, the reference character 11 designates a hopper for the powdered material employed in the process. The powdered catalyst from the hopper 11 discharges into a vertical standpipe 12 of a height sufficient to develop a substantial pressure at the bottom thereof. To insure that the powdered material in the standpipe 12 is in freely flowing condition so that the pressure is transmitted to the bottom of said column, a fluidizing gas from the manifold line 13 may be introduced into the standpipe 12 through one or more lines 14, 15 and 16.

The powdered catalyst from the bottom of the standpipe 12 is fed through any suitable valve 17 into a return leg 18 into which a carrier gas is introduced through line 19 leading from the manifold line 20. The amount of carrier gas introduced into the return leg 18 should be sufficient to considerably reduce the bulk density of the stream flowing therein. The diluted stream of powder and gas of low bulk density is trans-

ferred from the bottom of the standpipe 12 through ascending leg 18 into the top section 21 of a second standpipe 22. The upper portion of the hopper section 21 may be provided with a suitable separator for segregating solids from gases, such as a cyclone separator 23. The fluidizing gas separated from the catalyst in the cyclone separator 23 is removed therefrom through line 24. The catalyst from the hopper section 21 feeds into the vertical column or standpipe 22 through which a fluidizing gas from manifold line 25 may be introduced through one or more lines 26, 27 and 28 so as to maintain the powder in the second standpipe 22 in a freely flowing state. If desired, a portion of the fluidizing gas from manifold 25 may be introduced at one or more spaced points in return leg 18 through lines 27' and 28'. Additional pressure is developed by the catalyst at the bottom of the standpipe 22. The bottom of the second standpipe 22 is also provided with a suitable valve 29 through which the catalyst is fed into a return leg 30 in which it intermingles with additional carrier gas introduced through line 31. By reducing the density of the powdered material in the return leg 30, the catalyst may be returned to another separator 34 in hopper 32 located at the top of a third standpipe 33. The fluidizing gas separated from the catalyst in the cyclone separator 34 is removed therefrom through line 35 and may be rejected from the system through line 36. However, this gas is normally at a higher pressure than the gas introduced into the first return leg 18. In accordance with one of the specific features of the present invention, the gas separated in the cyclone separator 34 may be used as a carrier for the catalyst in the return leg 18 and, if desired, it may also be used for maintaining the catalyst in the initial standpipe 12 in a freely flowing condition. To this end, a part or all of the gas withdrawn from the cyclone separator 34 through line 35 may be passed through lines 37 and 38 into line 19 leading to the leg 18. Also, a portion of this gas may be fed through line 39 into manifold line 13, from whence it may be passed into the initial standpipe 12 at one or more spaced points through lines 14, 15 and 16.

The catalyst from the third cyclone 34 feeds into another standpipe 33 which develops additional static pressure. To insure maintaining the catalyst in the standpipe 33 under freely flowing conditions, a fluidizing gas from line 40 may be introduced at one or more spaced lines 41, 42 and 43.

The apparatus hereinbefore described forms in effect a series of U-tubes with the powdered material flowing downwardly in one leg of the tube and upwardly in the other. The progressive building up of pressure on the catalyst is obtained by reducing the density of the catalyst in the up-flowing leg of the U-tubes. The pressure developed by each of the standpipes 12, 22 and 33 depends upon the height and density of the powder therein. The density of the powder in turn depends upon the specific gravity of the particles. In order for the column to transmit its pressure throughout its length, it must be maintained in a fluidized state. This, in most cases, requires the addition of a fluidizing gas to prevent packing of the column. This will reduce the bulk density of the material therein. It is generally preferred to introduce the minimum amount of fluidizing gas which ensures perfect

fluidity, since the density under freely flowing conditions determines the pressure developed per linear foot of standpipe for any given material. Similarly, since the back pressure developed in the up-flowing leg depends on the density of the powder, it is advantageous to employ a large amount of gas therein. The amount of pressure produced in each U-tube may be conveniently controlled by the relative amounts of gas introduced into the two legs. It has been found that in the case of activated clays the maximum density under freely flowing conditions may be of the order of 25 to 35 pounds per cubic foot. In such case, from 4 to 6 linear feet of standpipe may be required for each pound per square inch of pressure developed. It will thus be apparent that for building a pressure of only a few atmospheres in a single standpipe, towers of extreme height would be required. However, by building up the pressure progressively in a series of standpipes as described, a material saving in structural steel and other materials may be realized.

The carrier gas used for reducing the density in return legs 18 and 30 and the gas introduced at various points in the standpipes 12, 22 and 33 may be an inert carrier gas or it may be an active gas capable of undergoing reactions in the presence of the powder or capable of modifying the character of the powder. For example, it may be an oxidizing gas capable of reacting with carbonaceous deposits formed on the catalyst during the cracking operation.

Furthermore, while the carrier gas and fluidizing gas are illustrated as coming from a common manifold 20, it will be understood that the gas introduced into the standpipe for fluidizing may be of a different character than that used as a carrier in the return legs 18 and 30.

Returning to the drawing, the powdered material from the bottom of the third standpipe 33 may be passed through a suitable valve 44 into a stream of gases introduced into the system through line 45. These gases may be of any type which it is desired to contact with the powdered material from the column 33. In many cases, it is desirable to subject catalyst following a treating operation to a conditioning treatment with a gas or vapor before returning the same to the reaction zone. In other cases it may be desirable to add or extract heat from the catalyst before returning it to the reaction zone. In the latter instance the gas introduced through line 45 may be a relatively inert gas utilized as a carrier gas for conveying the catalyst through a heat exchange zone.

As previously mentioned, for illustrative purposes, it will be assumed that the powdered material is a cracking catalyst which has been contaminated with carbonaceous deposits in the cracking of hydrocarbon oil and that it is desired to regenerate the catalyst by treating with an oxidizing medium such as air. The invention is especially useful in such processes because of the increased burning rate and the increased heat transfer rate which result from increase in pressure. The gas preheated to the required treating temperature and introduced through line 45 commingles with the contaminated cracking catalyst withdrawn from the bottom of standpipe 33 through valve 44 and the resulting mixture passes through line 46 to a conditioning vessel 47 in which the gas and catalyst are retained for a period sufficient to condition the catalyst to the desired amount. In the specific case illustrated, this vessel constitutes a regeneration zone.

However, as previously described, this vessel may be a heating or cooling zone in which heat is added or extracted from the catalyst and may be of any suitable construction for attaining the desired results. In most cases, to obtain intimate mixing of the powder and the conditioning gas, it is desirable to pass the reactant mixture through the treating vessel at relatively low velocities so that there is a general tendency for the powdered material to settle out of the gases during the passage therethrough. When operating in this manner, the time of residence of the powdered material within the treating vessel will be materially greater than the time of residence of the gases therein.

The stream of powdered material suspended in the gas is withdrawn from the vessel 47 through line 48. In some cases it may be desirable to return a portion of the catalyst directly to the treating zone without any intermediate treatment. For example, the conditioned catalyst may be cooled and recycled to the treating zone where, by reason of its heat capacity, it is of assistance in maintaining heat control therein. The mixture may, therefore, be transferred through lines 48, 49 and 50 or 51 or both to the inlet of either separator 23 or 34 in the top of the standpipes 22 and 33, depending on the pressure drop obtained in line 46, zone 47 and lines 48 and 49. The catalyst recycled in this manner is discharged from separator 23 or 34 directly into standpipe 22 or 33.

A part or all of the stream of gaseous products and catalyst removed from the reaction zone 47 through line 48 may be passed through line 52 to a cyclone separator 53 or other equivalent separating devices for removing the gaseous reaction products from the powdered catalyst. The gases separated in the separator 53 are removed overhead through line 56 and may be withdrawn through line 57, or they may be passed through lines 58 and 31 and utilized as a fluidizing and conveying gas in the up-flowing leg 30, or by way of cross-over line 59 and lines 38 and 19 in the up-flowing leg 18. If it is desired to allow a considerable time of contact between the gases separated in separator 53 and the up-flowing catalyst, leg 30 may be enlarged to form a reaction vessel similar to vessel 47 in the up-flowing legs 46 and 48. Similarly, a reaction vessel may be built into up-leg 18. The passage of gas separated in separator 34 through lines 37, 38 and 19 into the stream of catalyst flowing upward in leg 18 has already been described.

The catalyst separated in the cyclone separator 53 may feed directly into a further standpipe 55 in which a fluidizing gas for maintaining the catalyst in freely flowing condition may be introduced at any one or more spaced points through lines 60, 61 and 62.

The catalyst from the standpipe 55 may be fed at the desired pressure through a suitable pressure control valve 63 into a stream of fluidizing and reactant gas introduced through line 64. This gas may, for example, be hydrocarbon vapors which it is desired to crack. The resulting suspension of vapors and catalyst then passes through line 65 to a chamber 66 which in the specific case illustrated constitutes a reaction zone. The flow of vapors and catalyst through the reaction zone 66 may be at relatively low velocities as previously described with respect to the conditioning vessel or zone 47 so as to effect intimate mixing between the catalyst and the gas to be treated therewith. Also, as previously

mentioned, in such case the time of residence of the gas in the reaction zone is materially less than the time of residence of the catalyst therein. As a result there is a constant intermixing between the catalyst and the gas which in turn results in maintaining a substantially uniform temperature throughout the full length of the reaction zone.

The contaminated catalyst together with the cracked products passes from the reaction zone 66 through lines 67 and 68 to the cyclone separator 69 located at the top of the initial standpipe 11. In this case, the catalyst separated from the vapors in the separator 69 passes directly to the initial standpipe 12 for return to the regeneration zone.

Reaction products separated from the catalyst in separator 69 are removed therefrom through line 70 and are subjected to further fractionation and purification of the final product in apparatus not shown.

The catalyst removed from the cracked products in separator 69 discharges into hopper 11 from whence a part or all may be passed to the conditioning vessel 47 through standpipes 12, 22 and 33 and return legs 18 and 30. The fluidizing gas introduced into standpipes 12, 22 and 33 and the carrier gas introduced into the return legs 18 and 30 will remove vaporizable hydrocarbons adsorbed or otherwise retained on the catalyst separated in the cyclone separator 69.

In cases where only a portion of the catalyst removed from the cracked products in separator 69 is subjected to conditioning treatment in conditioning vessel 47, the remainder may be returned to the reaction zone 66 through line 71 having a valve 72. When employing this method, for reasons of safety the fluidizing gas introduced into standpipe 12 and up-leg 18 should not be incompatible with the vapors undergoing reaction in zone 66.

Fresh makeup catalyst may be introduced into the circuit through hopper 73.

It will be understood that, whereas in the above-described example it is preferable to conduct the catalyst conditioning treatment at a higher pressure than the reaction pressure, in some cases the pressures will be substantially equal, and in other cases the reaction pressure will be the higher.

From the foregoing, it will be apparent that the present invention has provided a means for building up the desired pressure on powdered materials without the use of any moving parts. It will also be apparent that by the present invention it is possible to treat gas or vapor with a powder concurrently in each of several stages, the overall flow of powder being toward increasing pressure and the overall flow of gas being toward decreasing pressure. In the regeneration of catalysts by burning with air, this offers a distinct advantage in that the burning is more easily controlled, since toward the end of regeneration when the coke content is relatively low the burning rate is favored by the increase in pressure, while in the early stages of regeneration when the coke content is high the oxygen partial pressure is relatively low. This modification of the invention may also be applied in the catalytic cracking of certain hydrocarbon oils in which a higher pressure is employed during early stages of cracking than during later stages. Another application is in the cracking of oils wherein it is desired to treat the cracked products or the gasoline constituents thereof with

additional catalyst at the same or at a lower temperature in order to reduce acid heat.

Still another application is in the reforming of naphtha in the presence of hydrogen, wherein the naphtha after being reformed in a later stage is utilized together with the hydrogen in an earlier stage as a fluidizing and conveying gas at a lower temperature whereupon the gum content of the naphtha is reduced by hydrofining. It will of course be understood that the temperature of standpipes and of up-legs of the U-tubes can be controlled at will by suitably placed heat exchangers or by enclosure in heat exchange baths.

Having described the preferred embodiment of the invention, it will be understood that it embraces such other variations and modifications as come within the spirit and scope thereof.

What is desired to be protected by Letters Patent is:

1. A process for imposing pressure on finely-divided solids which comprises flowing a stream of said finely-divided solid alternately upwardly and downwardly in a sinuous path, maintaining each downwardly flowing stream at a materially higher density than the next succeeding upwardly flowing stream whereby static pressure developed at the bottom of said downwardly flowing streams is substantially greater than the static pressure at the bottom of the next adjacent upwardly flowing stream and transmitting excess static pressure from the bottom of each preceding downwardly flowing stream to the top of the next succeeding downwardly flowing stream to build up successive increments of pressure on said finely-divided solid.

2. In the method defined by claim 1, the further improvement which comprises introducing

a gaseous diluent into the upwardly flowing streams of said finely-divided material to reduce the density and static pressure of the upwardly flowing streams and separating the gaseous diluent from said solids before passing the latter downwardly into the next succeeding stream.

3. In a process for the conversion of hydrocarbon oils wherein the oil in vapor form is converted in the presence of a finely-divided conversion catalyst and wherein it is necessary to develop a positive pressure on the finely-divided catalyst to feed the same into the oil vapors; the improvement in the method of imposing the desired pressure on the catalyst which comprises flowing a stream of said finely-divided conversion catalyst alternately upwardly and downwardly in a sinuous path, maintaining each downwardly flowing stream at a materially higher density than the next succeeding upwardly flowing stream whereby the static pressure developed at the bottom of the downwardly flowing streams is substantially greater than the pressure at the bottom of the next succeeding upwardly flowing stream, transmitting excess static pressure from the bottom of each preceding downwardly flowing stream to the top of the next succeeding downwardly flowing stream to build up the desired positive pressure in successive increments.

4. In the process defined by claim 3, the further improvement which comprises adding a gaseous diluent to the upwardly flowing stream of conversion catalyst passing in said sinuous path and separating the gaseous diluent from the upwardly flowing stream before passing the catalyst to the next succeeding downwardly flowing stream.

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