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CONTROL OF FLOW OF FLUIDIZED SOLIDS

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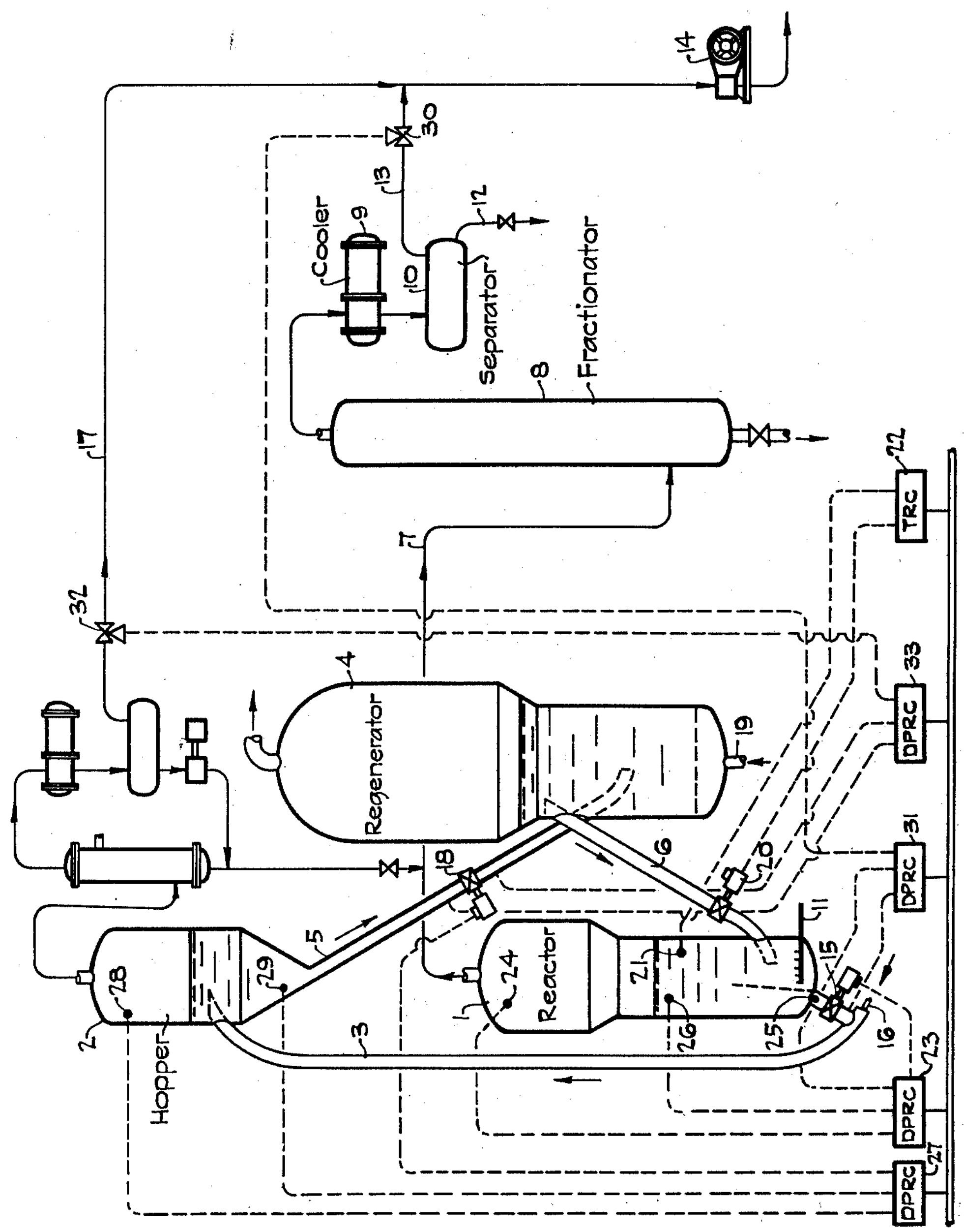

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CONTROL OF FLOW OF FLUIDIZED SOLIDS

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5 Claims. (Cl. 23—1)

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The present invention relates to a system for the control of a continuous flow of fluidized solid to and from a vessel.

It is well known that various non-sticky solid materials when in a finely divided state, i. e., particles of 1 mm. diameter or less, may be brought to a fluidized or pseudo liquid state by proper aeration by air or any other gas or vapor. The solid in this fluidized state behaves in many respects like a true liquid; it seeks its own level, exerts a "hydrostatic" pressure, and may be pumped. In many processes it is desired to flow a continuous stream of a fluidized solid into and out of a tank or other vessel and the flow is controlled in the manner to be expected, namely, through the use of one or more valves placed in the flow lines. When the fluidized solid is withdrawn from such a vessel into an open vessel such a railway car, a barrel, or the like, this method is perfectly satisfactory. In many cases it is necessary to withdraw the solid into a line or vessel against a small but definite pressure. For example, it is often desired to transport the withdrawn solid for an appreciable distance by the most convenient or practical method which is through the medium of a carrier gas or vapor. In such cases difficulties arise due to the fact that even a momentary reversal of the sign of the pressure differential across the flow controlling valve may cause the direction of flow to reverse. In many cases this possibility presents a serious danger which must be carefully guarded against. In the past this danger has been minimized by providing standpipes between the vessel and the valve. The "hydrostatic" head created by such a standpipe provides a back pressure sufficient to prevent momentary reversal of the sign of the pressure differential across the valve which controls the flow. Since the density of the fluidized solid is low compared to a true liquid it will be appreciated that fairly long standpipes are required to obtain even a very nominal "hydrostatic" head.

An object of the invention is to provide a method of control which is self-compensating and automatic. Another object of the invention is to provide a method of control which can be advantageously combined with or coupled with other automatic controls to insure more steady, safe and accurate control of the flow. An object of the invention is to provide a method of control which allows standpipes to be greatly shortened or completely eliminated without danger.

The control system of the invention is best illustrated and described in connection with a particular flow system in which it is exceptionally advantageous. This flow system which is designed for use in the catalytic conversion of hydrocarbons is illustrated diagrammatically in the attached drawing. It is to be understood, however, that the control system of the invention is also applicable to other flow systems where a solid is continuously introduced into a vessel, and the fluidized solid is continuously withdrawn from the vessel through a control valve into a space wherein fluctuations in the pressure are possible.

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The system illustrated will first be described. Referring to the drawing, the system comprises a fluidized catalyst reactor 1, above which is a hopper vessel 2 connected by line 3. A fluidized regenerator reactor 4 is positioned at the proper intermediate level and is connected with the hopper and reactor by lines 5 and 6, respectively. Connected to the fluidized catalyst system by line 7 is a conventional fractionator 8 provided with the usual cooler-condenser 9 and separator 10 for the separation and recovery of liquid products.

The operation of the system is as follows: The oil to be treated is introduced into the bottom of the fluidized catalyst reactor by a distributing line 11. This oil contacts the bed of fluidized catalyst in the reactor under suitable conditions of temperature and contact time. The vaporous products then pass by line 7 to the fractionator 8. The overhead product from the fractionator is cooled and separated in the conventional manner into a liquid product which is withdrawn via line 12 and a gaseous product which is withdrawn via line 13. The gaseous product is compressed by compressor 14 and passed to a suitable absorption system (not shown) in the conventional manner.

The finely divided catalyst in reactor 1 is continuously recycled through the regenerator to burn off carbonaceous deposits. Thus, the finely divided catalyst is continuously withdrawn from the reactor through a control valve 15 into line 3 wherein it is picked up and carried in suspension to the hopper vessel 2 by steam or any other carrier gas introduced via line 16.

The carrier gas is disengaged from the catalyst in the hopper vessel 2. The carrier gas containing considerable amounts of products stripped from the catalyst is withdrawn from the top of the hopper. After suitable cooling and separation of condensed liquid the remaining gas is also passed via line 17 to the compressor 14 and then to the absorption system to recover further product values. The catalyst in hopper **2** collects in the bottom thereof as a fluidized bed. This catalyst is continuously fed to the regenerator **4** via line **5**, the flow being controlled by a valve **18**.

In the regenerator **4** carbonaceous deposite are burned from the catalyst in the fluidized bed by means of air or any other combustion-supporting gas introduced via line **19**. Hot regenerated catalyst is continuously recycled to the reactor via line **6** which contains the control valve **20**.

Control valves **15**, **18** and **20** in plants of this general type are slide valves actuated by hydraulic means which in turn are controlled by a conventional valve positioning mechanism; these valves are therefore shown diagrammatically as such. It will be understood, however, that any other type of valve amenable to automatic control may be employed if desired.

The automatic control of the valve positioning mechanism by means of a differential pressure-recorder-controller instrument is well known. The pressures from two points are led to a balancing arrangement in the instrument. This balancing arrangement then regulates the pressure (from an outside source) upon the valve positioning mechanism.

The flow of catalyst in the system is controlled as follows: The temperature of the bed of catalyst in the reactor **1** is taken at any point **21** in the bed. The obtained indication of the temperature is carried to a conventional temperature-recorder-controller instrument **22** and this instrument controls valve **20**. Thus the flow of hot regenerated catalyst from the regenerator to the reactor is controlled through the temperature-recorder-controller instrument in response to changes in the temperature in the fluidized bed to maintain a substantially steady desired temperature in the reactor.

The flow of fluidized catalyst from the reactor is partly regulated by valve **15** which is controlled in a conventional manner by a differential pressure-recorder-controller instrument **23** which in turn is actuated by the differential pressure between two points in the reactor. This differential pressure is taken between a point **24** in the reactor above the fluidized catalyst bed level and a lower point **25** within the fluidized catalyst bed. The pressure point **26** illustrated may be used in place of pressure point **25** but is primarily of use to determine the density of the fluidized catalyst by means of the differential pressure between points **25** and **26**. Thus, as the differential pressure between points **24** and **25** increases, the differential pressure-recorder-controller actuates the valve positioner to increase the flow through valve **15**, and vice versa.

The control of the flow of the fluidized catalyst from the hopper **2** to the regenerator **4** is also automatic and carried out in the same manner through a differential pressure-recorder-controller **27** which is actuated by the differential pressure between a point **28** above the level of the fluidized catalyst bed in the hopper and a point **29** at a lower point within the fluidized bed.

In the system of the invention the described control of valve **15** is supplemented by a separate compensating control. Thus, line **13** carrying the gaseous effluent from reactor **1** is provided with a control valve **30**. This valve is automatically controlled through a differential pressure-recorder-controller **31** which is actuated by the differential pressure across the valve **15**. Thus, the differential pressure is taken between a point just ahead of the valve and a point just beyond the valve. As this differential pressure decreases, the flow through valve **30** is caused to decrease. This, in turn, causes an increase in the pressure at point **24** in the reactor.

In the system illustrated this dual complementary control is also applied to the flow of catalyst from the hopper to the regenerator. Thus, line **17** carrying the gaseous effluent from the hopper **2** is provided with a control valve **32**. This valve is automatically controlled in the conventional way by a differential pressure-recorder-controller **33** which is actuated by changes in the differential pressure across valve **18**. Thus, as indicated, the differential pressure is measured between a point just ahead of valve **18** at a point just beyond valve **18**. As this differential pressure decreases the flow through line **17** is throttled; this in turn causes the pressure at point **28** to increase.

While the control method illustrated is particularly advantageous in the system illustrated, the principle of the control method is applicable in other systems wherein a continuously replenished bed of fluidized solid is maintained in a reactor or other vessel. This principle, it will be seen, resides in controlling the flow through an adjustable orifice (outlet valve **15** or **18**) in response to changes in the differential pressure across the valve through automatic control of the absolute pressure above the fluidized bed, as well as through adjusting the area of the orifice in response to changes in the differential pressure between a point above the fluidized bed and a point within the fluidized bed. This novel combination of controls decreases the danger of explosions and also greatly increases flexibility of the flow system.

It will be noted that in the system illustrated the combination control of the flow is applied in two instances, i. e., valves **15** and **18**. While the controls of valves **15** and **18** appear to be separate and distinct and have been separately described, the controls of these two valves are actually interconnected or interrelated in the particular system illustrated. Thus, any change in the setting of valve **32** affects the pressure in the hopper at point **28** and the pressure change is reflected by changes in the differential pressure across valves **15** and **18**. These reflected changes, in turn, affect the adjustment of both valves **30** and **32** through the differential pressure-recorder-controllers **31** and **33**.

Example

In a catalytic cracking plant of the design illustrated and using a fluidized synthetic silica-alumina composite cracking catalyst the pressure in the disengaging space in the reactor (above the fluidized catalyst bed) is normally held at 13 p. s. i. g. by the control of valve **30**. The pressure in the upper part of the hopper is normally held at 12 p. s. i. g. by valve **32**. If all factors remain steady, the plant would continue to operate evenly and at this steady condition. However, during normal operations changes occur in the amount of catalyst lost from the system, the amount of fresh catalyst added to the system for replenishment, the conditions in the fractionation system, the amount of air required in the regenerator, the density and size of the catalyst particles, etc. Some of these changes may be rather sudden and others may be rather gradual. In some cases these changes tend to cancel each other and in other cases they augment each other. These changes, especially when they augment each other, are reflected throughout the operation, for example, in the level of the catalyst in one of the vessels and/or the density of the fluidized bed of catalyst therein and this, in turn, affects the rate of catalyst flow through one or more of the control valves. If for any reason the level of the fluidized bed of catalyst in the reactor and/or the density thereof is decreased this causes the differential pressure across valve **15** to decrease; the differential pressure-recorder-controller **23** causes valve **15** to throttle the flow and differential pressure-recorder-controller **31** causes valve **30** to throttle line **7**. This causes the pressure above the fluidized bed in the reactor to increase up to, for example, 16.6 p. s. i. g. This increased pressure tends to increase the flow, to decrease the danger of blowbacks, and to compensate for over control and lag through differential pressure-recorder-controller **23**.

Similarly, the control of valve **32** through differential pressure-recorder-controller **31** cooperates with and compensates the control of valve **18** by differential pressure-recorder-controller **27**.

By using the described two interrelated controls it also becomes possible to considerably simplify and reduce the cost of such a plant. Thus when utilizing the described interrelated controls the usual standpipes may be greatly shortened without hazard. This not only decreases the problems in heat loss, erosion, etc., but allows the plant to be built much more compact and close to the ground.

We claim as our invention:

1. In a process wherein a bed of continuously replenished fluidized solid is continuously maintained in a vessel, the method of controlling the rate of withdrawal of fluidized solid from said bed through an orifice of controllable area which comprises controlling the pressure above the said fluidized bed in inverse relationship to and in response to changes in the differential pressure measured across said orifice, and controlling the area of said orifice in direct relationship to and in response to changes in the differential pressure measured between said pressure above said fluidized bed and the pressure at a point within the said fluidized bed.

2. In a process wherein a bed of continuously replenished fluidized solid is continuously maintained in a vessel, the method of controlling the rate of withdrawal of fluidized solid from said bed through an orifice of controllable area which comprises measuring the differential pressure between a point above said fluidized bed and a point within said fluidized bed, controlling the area of said orifice in direct relationship to and in response to changes in said measured differential pressure, simultaneously measuring the differential pressure across said orifice, and controlling the absolute pressure above the fluidized bed in inverse relationship to and in response to changes in said latter measured differential pressure.

3. In a process wherein a bed of continuously replenished fluidized solid is continuously maintained in a vessel, the method of controlling the rate of withdrawal of fluidized solid from said bed through an orifice of controllable area which comprises obtaining an indication of the differential pressure between a point immediately above said fluidized bed and a point within said fluidized bed, automatically adjusting the area of said orifice in direct relationship to and in response to changes in said obtained indication of said differential pressure, obtaining an indication of said differential pressure between a point immediately above and below said orifice, and automatically controlling the absolute pressure immediately above said fluidized bed in inverse relationship to and in response to changes in said obtained indication of said latter differential pressure.

4. In a system for contacting a vapor with a continuously replenished bed of fluidized solid the combination of an outlet line for fluidized solid near the bottom of a vessel containing said bed, said outlet line being provided with a control valve, an outlet line for vapors near the top of said vessel, said outlet line being provided with a control valve, a differential pressure controller instrument, means for conveying indications of the pressure near the top and bottom of said vessel to said differential pressure controller, means for actuating said valve in said bottom outlet line in response to said differential pressure controller, a second differential pressure controller, means for conveying indications of the pressures across said last mentioned valve to said second differential pressure controller, and means for actuating said control valve in said top outlet line in response to said second differential pressure controller.

5. In a system for contacting a vapor with a continuously replenished bed of fluidized solid the combination of a vessel containing said bed, an outlet conduit for fluidized solid near the bottom of said vessel, a control valve operated by a first differential pressure-recorder-controller in said conduit, an outlet conduit for vapors near the top of said vessel, a control valve operated by a second differential pressure-recorder-controller adapted to control the flow of vapors from said vessel, said first differential pressure-recorder-controller being connected between a point within said vessel near said upper (vapor) outlet and a point in said vessel near said lower (fluidized solid) outlet and said second differential pressure-recorder-controller being connected across said lower control valve.

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