This invention relates to the conversion of hydrocarbons by systems of the type which involve moving beds of granular contact material and more particularly to the use of the contact material to maintain seals between zones of different pressures. In the cracking of hydrocarbons to produce an increased yield of hydrocarbons boiling in the gasoline range it is customary to employ a continuously moving bed of granular catalyze material. Succeeding portions of this material flow through a reactor in which the conversion of the hydrocarbon material takes place. During this reaction the contact material becomes contaminated and provision is therefore made to deliver the moving bed to a generator wherein the contaminants are burned off. Succeeding portions of the regenerated contact material are then returned to the reaction or conversion zone.

It is desirable that the hydrocarbon conversion take place under pressure and that the regeneration of the contact material take place at atmospheric pressure. Accordingly, the problem is presented of continuously feeding contact material into a reaction zone while maintaining a positive pressure above atmospheric within that zone. One way to effect the seal is to use valves. These are, however, discontinuous in operation, expensive to install and maintain, and damaging to the contact material. Accordingly, resort has been had to feed legs of granular contact material which are long enough to maintain a head of contact material sufficient to keep the desired pressure level within the reactor. Recently there has been a tendency to resort to higher and higher pressures in the reaction zones and this creates a requirement for longer and longer feed legs in order to maintain the seals with an adequate degree of safety.

In an effort to overcome this problem, resort has been had to feed legs containing zones of increased cross sectional area along their length. The presence of these zones reduces the length of feed leg required to hold any given pressure. The effect of the wide zone is to increase the static pressure of the gas being held back while reducing its dynamic pressure. This prevents the gas from reaching a bed disrupting velocity at the top of the bed of contact material. The actual volume of the intermediate zone of increased cross section is, of course, dependent upon the pressure to be held and there must be maintained a sufficient amount of contact material in the place where the gas falls below bed disrupting velocity to keep the bed density constant so that flow resistance will be stable. If these conditions are met, it is found that the length of the leg necessary to hold a given pressure may be reduced.

It has been found that the length of seal leg may be further shortened if the material in the leg is compacted to increase its density. It is an object of this invention to provide an improved cyclically operable method and apparatus for compacting the feed legs of a contact material system so that a required pressure drop may be maintained with a shorter leg than in the case of uncompacted material. It is further proposed according to the present invention to effect the compressing of the contact material in a manner which avoids mechanical damage to its component granules by the use of apparatus that is external of the flow conduits and hence easy to install, to maintain and to insulate from heat.

Other objects and advantages of this invention will be apparent upon consideration of the following detailed description of a preferred embodiment thereof in conjunction with the annexed drawings wherein:

Figure 1 is a fragmentary view in elevation of a hydrocarbon conversion plant incorporating the present invention; and

Figure 2 is a view partially in elevation and partially in section of a contact material feed leg constituting a part of the system of Figure 1.

Referring now to the drawing in greater detail, the numeral 10 designates a reactor in which hydrocarbons are treated in the presence of granular contact material flowing continuously as a moving bed through a reaction zone generally designated at 11. Above the reaction zone there is a contact material receiving zone 12 which always contains enough contact material to maintain a continuously moving bed in the zone 11. The zone 12 is supplied with contact material from a series of hoppers 13, 14 and 15. The hoppers 13, 14 and 15 are supplied with contact material from hoppers 16, 17 and 18 which are located respectively therebelow. The hoppers 16 to 18, inclusive, are supplied through chutes 19, 20 and 21 from a contact material elevator 22, a fragment of which is schematically illustrated in Figure 1. The elevator 22 receives contact material from a regenerator, not shown, and it raises the material feed delivery to the chutes 19, 20 and 21. The chutes 19 to 21, inclusive, and the hopper 18 are open to atmosphere and hence atmospheric pressure prevails therein. On the other hand, the pressure within the reactor 10 is maintained at about 15 p.s.i.g. This being the case, in order to maintain the pressure within the reactor 10 against leakage, it is necessary that the flow passage between zone 12 and the hoppers which feed it be of such density as to prevent substantial escape of fluid under pressure. With this thought in mind, elongated tubular feed legs 23, 24 and 25 are connected between hoppers 13, 14 and 15, respectively, and the zone 12. Similar tubular feed legs 26, 27 and 28 connect the hoppers 16 to 18, inclusive, with the hoppers 13 to 15, inclusive.

While it is not a part of the present invention it may be useful to explain that zones 12 and 11 are separated by a plate 29 having tubes 30 which pass therethrough. The tubes serve to carry the granular contact material from the zone 12 to the zone 11. These tubes are of such size, number and distribution as to maintain a moving bed of contact material in the zone 11 at all times. The volume of the zone 12 is such that enough contact material is present to maintain the moving bed in the zone 11 during period when no flow of contact material is occurring in the feed legs 23 to 25, inclusive.

Feed legs 23 to 28, inclusive, are mounted on resilient couplings for vibration. In Figure 2, feed leg 23 is drawn to an enlarged scale and it will be described with the understanding that an identical construction is used with all the feed legs 23 to 28, inclusive.

Below the hopper 13 there is a short resilient coupling section 31 which is sufficiently flexible so that the conduit 23 can be vibrated or displaced without violation of the integrity of the conduit as a whole. A similar short section 32 is provided near the bottom of the conduit 23. About midway of the length of the conduit there is mounted a vibrator 33 which is electrically connected to
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a cycle timer 34 which is also connected to vibrators 35, 36, 37, 38 and 39 which are mounted on pipes 24 to 28 inclusive in the same manner that vibrator 33 is mounted on conduit 32. Also connected to cycle timer 34 are valves 40, 41 and 42, which are of the type to place the contents of the respective hoppers 13, 14 and 15 in communication with atmosphere through short stub pipes 43, 44 and 45 or in communication with the top of reactor 10 through conduits 46, 47 and 48. Conduit 49 leading into the top of reactor 10 is a sealing gas line.

In apparatus of the type to which the present invention relates, it is customary to introduce a sealing gas at a pressure very slightly above that prevailing in the reaction zone whereby any outward leakage of combustible hydrocarbon gases is avoided. One effect of the length or the compactness of the seal legs such as 23 is the prevention of the excessive loss of sealing gas. As a matter of fact, the loss of sealing gas along the leg can be used to determine the effectiveness of the seal maintained.

The cycle timer 34 and the vibrators 33 and 35 to 39, inclusive, per se form no part of the present invention. The vibrators are of the readily available commercial type and are attached to the conduit in a manner such that the vibrating pulsations are imparted to the conduit causing it to shake and so to shake its contents. Because the vibration is on the outside of the pipe, it has no mechanical contact with the granular material and hence does not and cannot damage it in any way. Furthermore, because the regeneration is conducted at high temperature, the contact material flowing through the various feed legs is quite hot and the necessary insulation of the vibrator is easily effected because of its external location. The cycle timer is nothing more than a clock with electric switches so arranged as to actuate the valves and vibrators in a sequence, the cycling of which will be apparent from the following description of the operation of the apparatus.

It is apparent that it is not necessary that the cyclic operation be done by an automatic machine since it can be done manually by an operator if that be desired.

The use of three sets of feed hoppers to feed a single reactor is simply for the purpose of material distribution across the cross section of the zone 13. Thus, in describing the cycling operation of the apparatus, reference will be made to the system including hopper 16, feed leg 26, hopper 13, feed leg 23 and the associated valve 40 and vibrators 33 and 37, with the understanding that the corresponding parts of the other two groups of feed hoppers and legs are actuated at the same time.

For the purpose of beginning the description, let it be assumed that a supply of contact material has just been placed in zone 12 so that that zone can for a short time provide contact material for maintaining a moving bed in zone 11. At this stage the valve 40 is in the Figure 2 position and no contact material is flowing in leg 26. Under these circumstances, the first step is to vibrate the leg 23 by actuation of the vibrator 33. This is followed by changing valve 40 from the Figure 2 full line to the Figure 2 broken line position. Once the hopper 13 has been vended through the conduit 43, material can and does flow through the leg 26 from the hopper 16 into the hopper 13. This continues until the hopper 13 is adequately filled, leg 23 having been compacted by vibration holds the pressure drop between the reactor 10 and the hopper 13. At that point, vibrator 37 is actuated to compact the material in leg 26 and thereafter valve 40 is restored to the full line position of Figure 2. This commences flow through the conduit 23 refilling the zone 12 and causes the leg 26 to hold the pressure drop while hopper 16 is being filled from the chute 19. As was said before, while hopper 13 is being filled, hoppers 14 and 15 are also being filled and, when hopper 16 is being filled, so are hoppers 17 and 18.

A full cycle of the type just described takes only about 35 seconds. The hoppers are filled and emptied in about 10 seconds each. Pressurizing and depressurizing involving operation of the valves 40, 41 and 42 takes about 3 seconds each and the vibrators are operated for about 3 seconds at a frequency of 2000 to 8000 strokes per minute. (Examples of suitable vibrators are electric vibrators as manufactured by the Sytron Co., Jeffry Mfg. Co. and Alvis Chalmers Mfg. Co. or pneumatic vibrators as manufactured by the Cleveland Vibrator Co.)

It has been found in a catalyst feed system for handling 75 tons an hour or 44.5 cubic feet at a temperature of 1000° F. that the density in the legs after vibration is 62.6 pounds per cubic foot as compared with 56.4 cubic feet in the unvibrated or loose packed leg. Fractional voids are reduced from 480 cubic feet to 360 cubic feet as a result of vibrations. The pressure at the top of the hopper is 14.7 p.s.i.a. and within the reactor it is 189.7 p.s.i.a. A seal leg such as the leg 23 shown in Figure 2 is 20 feet long and 8 inches in diameter. By the vibratory compacting herein described, the requirements are reduced with respect to a comparable system without vibration from 2800 pounds per hour to 1620 pounds per hour.

What is claimed is:

1. In apparatus for the delivery of granular contact material to a high pressure reaction zone which includes a reactor, a first hopper for feeding contact material to said reactor, a second hopper for feeding contact material to said first hopper, each hopper including a wide upper portion and a narrow leg portion and valve means movable from a first position placing the top of said first hopper in communication with said reactor to a second position placing it in communication with atmosphere, the improvement which comprises means mounting each leg portion for vibration, means on each leg to vibrate the same and means alternately to vibrate the leg of the first hopper while moving the valve means to its second position and then to vibrate the leg of the second hopper while moving the valve means to its first position.

2. In apparatus for the delivery of granular contact material to a high pressure reaction zone which includes a reactor, a first group of hoppers for feeding contact material to said reactor, valve means movable from a first position placing the top of said first group of hoppers in communication with said reactor to a second position placing them in communication with atmosphere, a second group of hoppers for feeding contact material to said first group of hoppers, the tops of said second group of hoppers being open to atmosphere, each hopper of each group including a wide upper portion and a narrow leg portion, the improvement that comprises means mounting each leg portion for vibration, a vibrator means to actuate said valve means on each leg portion, and means simultaneously to operate the vibrators on the legs of the hoppers of the first group while moving the valve actuating means to cause the valve to move to its second position and then the vibrators on the legs of the hoppers of the second group while moving the valve actuating means to cause the valve to move to its first position.

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