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[54] **MOVING BED REACTOR CONVERSION PROCESS FOR PARTICULATE CONTAINING HYDROCARBONS SUCH AS SHALE OIL AND TAR-SANDS OIL**

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[58] Field of Search **208/59, 58, 89, 251 R, 208/251 H, 253, 85, 11, 88**

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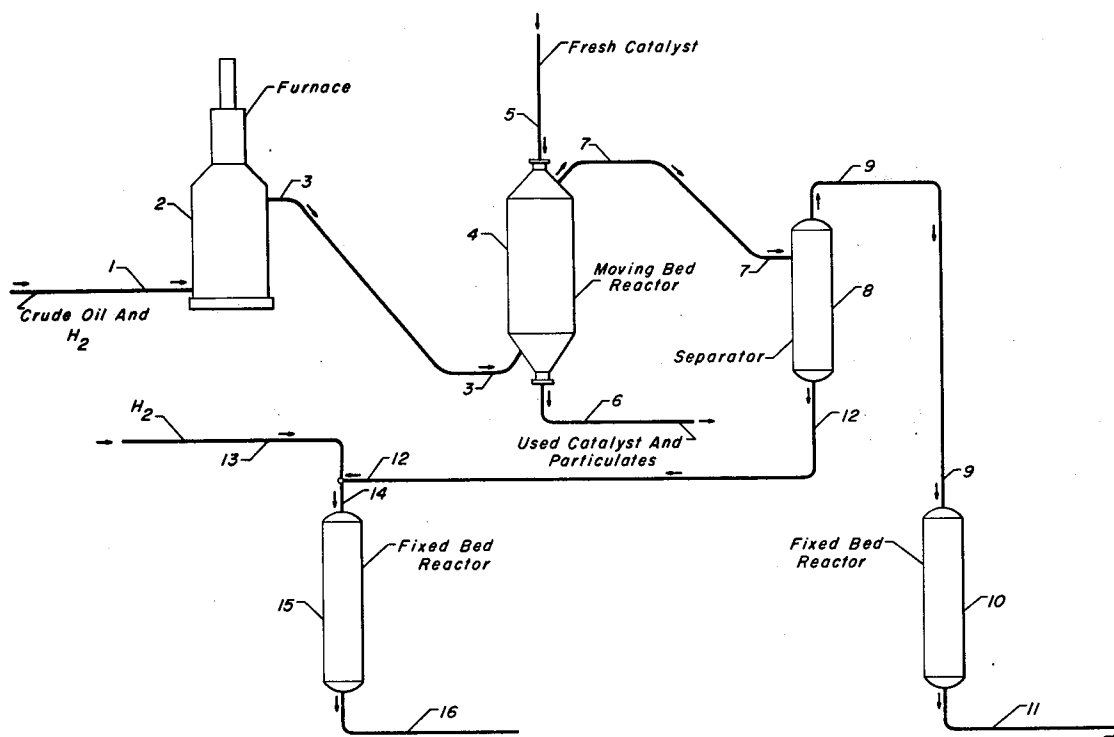
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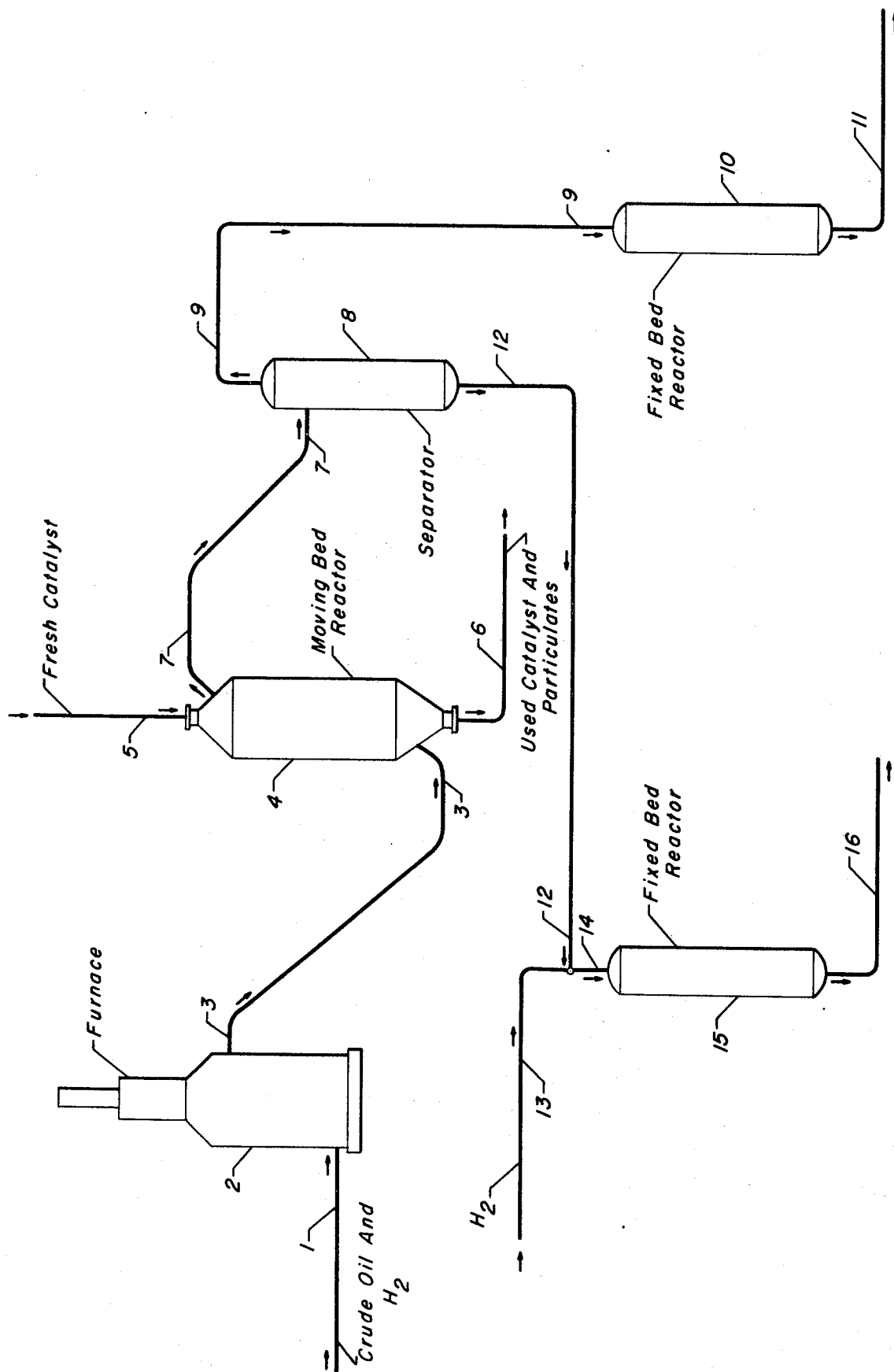
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ABSTRACT

Crude oil petroleum derived from oil shale or tar sands and containing large amounts of highly abrasive particulate matter, such as rock dust or sulfated ash, is hydroprocessed in a dual function moving bed reactor which simultaneously removes particulate matter by the filter action of the catalyst bed. The effluent from the moving bed reactor is then separated and further hydroprocessed in fixed bed reactors with fresh hydrogen added to the heavier hydrocarbon fraction to promote desulfurization.

20 Claims, 1 Drawing Figure





MOVING BED REACTOR CONVERSION PROCESS FOR PARTICULATE CONTAINING HYDROCARBONS SUCH AS SHALE OIL AND TAR-SANDS OIL

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention pertains to the hydroprocessing of petroleum feed stocks for the removal of sulfur, nitrogen and metals and the hydrocracking of heavy fractions of the petroleum. It is directly concerned with the use of a moving bed reactor for the dual-functional role of reactor and filter, particularly with feed stocks containing large amounts of abrasive or catalyst fouling material.

2. Description of the Prior Art

This invention presents a new process flow and application using a moving bed reactor in the well known field of hydroprocessing, with emphasis on the ability of the reactor to serve as a filter. The prior use of moving bed technology is shown for example in U.S. Pat. Nos. 2,303,717 and 3,211,798. Wide spread commercial application of moving bed reactors has so far been limited to reforming of naphtha as disclosed in U.S. Pat. Nos. 3,470,090 and 3,647,680. Since the naphtha is normally pretreated and the reforming is performed in a vapor phase, the problems encountered in charging heavier raw petroleum fractions have not been present.

A basic problem in fixed bed hydroprocessing is the plugging of the catalyst bed due to the accumulation of foreign matter entrained in the feed. Filtration of charge stocks for fixed bed reactors has been performed with replaceable cartridge filters in the charge lines or with dirt traps located within the reactor as described in U.S. Pat. No. 3,255,159. Other methods used inside the reactor include increasing the surface area over which the clogging occurs and impingement baffles to deflect solid material away from the catalyst bed.

The filtration of liquids in a countercurrent fashion is disclosed in several U.S. Patents of which 3,512,639 is a good example, but which is restricted to intermittent stoppages of the liquid flow during the periods of catalyst addition and withdrawal. These patents also refer to the use of this countercurrent movement in ion exchange treating and other similar applications.

Continuous countercurrent sorption operations that involve the transport of solid particles are reviewed on pages 16-20 to 16-23 of the Fourth Edition of *Chemical Engineer's Handbook* as edited by John Perry and published by McGraw-Hill, Inc. Included in this section is a rotating-disk feeder apparatus and a discussion of hydraulic-ram operations wherein a stream of liquid is charged downward from the top of a particle bed to create sufficient force to prevent fluidization of the particles contained in lower portions of the apparatus by upward moving process liquid charged from the bottom. Both streams exit at some intermediate point.

The use of a single bed of particles for both filtration of fly ash and removal of SO₂ from flue gases with panel bed filters is discussed in a series of three articles by Arthur Squires in the *Journal of the Air Pollution Control Association* starting on page 534 of Volume 20, No. 8 for August, 1970. an extensive bibliography is included which includes chemical applications disclosing bottom take-off of spent solids. Panel bed filters utilize flow of the process media horizontally through a thin layer of particles similar to radial flow reactors and include a means to remove built up filter cake either mechani-

cally or by expelling the particles horizontally through openings in the filter apparatus.

Abrasive material in oil derived from tar sands has been commercially removed by coking the heavy material.

SUMMARY OF THE INVENTION

A moving bed hydroprocessing reactor is used as a first contacting zone to remove entrained material from the charge stock by the filtration action of the catalyst. The catalyst flow through the reactor removes the accumulated material from the reactor and therefore prevents the build up of excessive pressure drops. Optimum filtration is obtained when the oil flows countercurrent to a descending catalyst bed traveling in a piston-like manner. In a specific embodiment, a broad range petroleum fraction, such as a raw tar sand origin oil containing a large amount of particulate matter, is passed through a moving bed hydroprocessing reactor in contact with hydrogen. The effluent is then separated into a light fraction which is passed through a fixed bed hydroprocessing reactor, and a heavy fraction which is comingled with fresh hydrogen and passed through a hydrotreating or hydrocracking reactor.

DESCRIPTION OF THE DRAWING

To illustrate the preferred embodiment of the invention as shown in the drawing, it will be assumed that a broad boiling range crude oil fraction is being hydroprocessed. The crude oil, which has been mixed with hydrogen, is changed through line 1 into furnace 2 which raises its temperature sufficiently to initiate a hydrotreating reaction after the crude oil and hydrogen mixture is passed through line 3 into moving bed reactor 4. The passage of the oil through the bed of catalyst results in the filtration of particulate matter from the oil and this in turn results in the build up of filter cake and an increasingly effective filter as the larger openings between the catalyst particles become clogged. Fresh catalyst is added to moving bed reactor 4 through line 5 and used catalyst is withdrawn through line 6. This results in a gradual movement of the catalyst bed in the reactor downward through the reactor and the removal of the previously entrained material with the withdrawn catalyst. The countercurrent flow of oil and catalyst aids in preventing the escape of entrained particulate matter from the reactor when the catalyst bed moves as the catalyst is transferred. Material released from the lower part of the bed must then move through the upper part and is more likely to be recaptured. The flow of oil may also be downward through the reactor in the more conventional manner. The partially hydrotreated and filtered reactor effluent leaves by lines 7 and is passed directly into separator 8. This separator may be a hot flash zone or a fractionator with a small number of trays to perform a rough split of the effluent into a heavy oil fraction and a light oil fraction. The light oil fraction including hydrogen, hydrogen sulfide, and light gases is withdrawn through line 9 for passage through fixed bed reactor 10, which due to the light character of the charged material would be operated at hydrotreating conditions to complete removal of sulfur and nitrogen before the charged material exits through line 11. The heavy hydrocarbon fraction produced in separator 8 is withdrawn through line 12 and comingled with fresh hydrogen entering the process through line 13 prior to passage by line 14 into fixed bed hydro-

cracking reactor 15. The reactor effluent leaves by line 16 for appropriate fractionation into the desired products.

This simplified flow scheme is based on the premise that all three reaction zones would be operated at approximately the same pressure. However, the use of higher pressures in the fixed bed reactors is anticipated and would be accomplished by the insertion of the appropriate compressors and pumps between separator 8 and the fixed bed reactors. It is obvious to those skilled in the art that many necessary valves, controls, temperature and pressure measurement devices, and other pieces of required process equipment are not shown on this drawing. This has been done in the interest of simplicity and clarity and is not intended to impose a limitation on the application of this invention.

DETAILED DESCRIPTION OF THE INVENTION

This invention relates to the field of hydroprocessing in general and is particularly directed to those hydroprocessing operations troubled by the accumulation on the catalyst bed of solid or semi-solid foreign material entrained in the feed stream. The invention is also concerned with the necessity of removing small highly abrasive sulfated ash from the crude oil produced from tar sands. Such foreign matter is introduced from one or more various sources and may comprise, for example, mill scale torn loose from plant equipment carrying the feed stream, corrosion products, iron sulfide, and various pieces of solid materials such as sand or oil shale particles. Build up of this solid matter develops excessive pressure drop through the catalyst bed, promotes channelling of the reactants and uneven reactant distribution through the catalyst bed and leads to an increased overall deactivation rate for the catalyst bed. This problem has prompted the development of numerous methods for alleviating the build up of this material in the catalyst bed. Examples are methods whereby the overall contact area is increased in an effort to spread out the plugging effect, the use of cartridge filters in feed lines to remove the entrained material, and mechanical apparatus inside the reactor which physically separates the solid particles from the reactants. Only the conscientious use of filters has resulted in satisfactory long term operation. Once a layer of solid material has built up on the catalyst bed, it is necessary to shut down the operation completely and physically remove this top layer of catalyst for cleaning to restore efficient operation. The increased utility cost inherent in operations having a high pressure drop through a reactor and the monetary losses incurred when the reactor is not producing provide the economic stimulus for the development of a practical and economical solution to this problem.

As the production of petroleum from new sources such as tar sand and shale oil increases due to the ever increasing demand for petroleum and the limited natural supply, this petroleum will be compounded due to large amounts of small particulate matter produced in the extraction of this hydrocarbon material. As already mentioned, a second consideration then introduced is the extreme abrasiveness of the small particles of rock and sand which are present at a relatively high concentration in these petroleum feed stocks. These particles are so exceedingly abrasive that they must be removed prior to normal processing.

A technique presently resorted to in order to avoid total shut downs of the complete process because of reactor plugging or catalyst deactivation consists of operating two or more reactors in parallel and removing one of the reactors at a time to replace or regenerate the catalyst. This method requires a higher initial capital expenditure, involves a more complicated process flow and does not provide continuously uniform products. The use of a moving bed reactor provides the means to avoid these problems encountered in the prior art. For this discussion, a moving bed reactor is defined as a reactor wherein a non-fluidized bed of catalyst is slowly transferred from one end of the reactor to the other end in a flow similar to plug flow of reactants by the intermittent addition of catalyst at the first end and removal at the second. The time between these catalyst movements will depend on process results and the amount of catalyst transferred on each occasion. Intermittent may therefore range in meaning from about every hour to about every week or two. The advantages of the moving bed system has lead to its use in the light oil process of reforming as described in U.S. Pat. Nos. 3,470,090 and 3,647,680. This application of moving bed technology is carried out at low pressures of from 100 to 300 psig. with all of the hydrocarbon maintained in a vapor phase.

The broad field of hydroprocessing is divided into three main subdivisions. The first is hydrotreating wherein material such as sulfur, nitrogen, and metals contained in various organic molecular structures are removed from the charge stock with very little molecular cracking. The second subdivision is hydrocracking, wherein a substantial part of the charge stock is cracked into smaller molecular weight components, such as in the production of a naphtha from a heavy distillate. Hydrorefining is between these two extremes and results in molecular changes to up to 10% of the feed together with impurity removal. Although there are many differences in the processing conditions, suitable catalysts and flow schemes for these different operations, they are basically alike in most aspects and may in fact be performed simultaneously in one operation using different reactors or more than one catalyst in a single reactor. In every instance, the hydrocarbon is mixed with hydrogen and raised to an elevated temperature and pressure and passed over a catalyst having a tendency to promote the desired reactions.

The manufacture and composition of these catalysts is an art in itself and is not directly relevant to the practice of the process of this invention. Catalysts used in these processes are typically composed of a base metal, which is defined to be a metal selected from the group consisting of nickel, iron and cobalt, supported on an inorganic oxide carrier. A suitable catalyst may contain from about 0.1 to 10% nickel or other metal or a combination of metals from base metal group, or other metals not in the group such as molybdenum or vanadium or oxides of these metals. The base material in the catalyst will normally be a refractory inorganic oxide such as alumina, silica, zirconia, or boria, or combinations of any of these materials, particularly alumina in combination with one or more of the other oxides. The alumina is usually the predominant component with a weight ratio in the catalyst of from 1.5:1 to about 9:1 and preferably from about 1.5:1 to about 3:1 of alumina to other support materials. Inclusion of a small amount of silica is the common method to increase the

cracking activity of the catalyst since silica is an effective cracking catalyst by itself. Details of suitable catalyst production are given in U.S. Pat. Nos. 3,525,684 and 3,471,399.

The processing conditions necessary for any hydrotreating operation are determined by the charge stock, the catalyst used and the desired result of the process. A broad range of conditions includes a temperature of from 500°F. to 1000°F., a pressure of from 300 psig. to 4000 psig., and a liquid hourly space velocity of 0.5 to about 5.0. The liquid hourly space velocity is defined as the hourly volume at 60°F. of the hydrocarbon charged to the reactor divided by the volume in the catalyst in the reactor. The exact reactor temperature required is determined by the initial activity and prior use of catalyst. As a general rule, the preferred operating pressure will increase with the boiling point of the material being processed. In all hydrotreating operations, hydrogen is circulated through the process at a rate of about 1,000 to 2,5000 scf/bbl of charge. This is to increase the vaporization of the oil, thereby resulting in better yields, and to provide hydrogen needed for the formation of ammonia and hydrogen sulfide from the nitrogen and sulfur removed from the charge stock and for the saturation of olefinic hydrocarbons formed by the cracking of large complex molecules. Hydrogen consumed in this manner must be replaced at a rate equal to its consumption, which will vary from about 10 scf/bbl to about 200 scf/bbl during hydrotreating and up to about 1,000 scf/bbl during hydrocracking. The production of hydrogen sulfide and ammonia makes it necessary to in some manner remove these compounds from the process on a continuous basis. Normal procedure to accomplish this is the injection of water into the reactor effluent to dissolve the salts formed from these impurities followed by cooling of the effluent sufficient to form a water phase which is then decanted from a separation vessel. A second method is the treatment of the recycled hydrogen gas stream with a caustic or amine solution to scrub out the H₂S. The reactor effluent is normally cooled and separated to recover the majority of the hydrogen to be recirculated, and the hydrocarbons are then fractionated into the desired products. The performance of these operations is well known to those skilled in the art and warrants no further explanation.

Canadian tar sands produce a synthetic crude oil having a composition which includes approximately 250 ppm. metals (mainly nickel and vanadium), about 5% sulfur, and from 10 ppm. to about 2,000 ppm. particulates. These crudes are very heavy in composition, have about 7° API gravity, contain approximately 11% heptane insolubles, and are only about 50% distillable. Typically, the particulate matter comprises sulfated ash which consists mostly of alumina silicate particles of 1 to 10 microns in diameter. These particles have sharp edges and are quite abrasive and must be removed early in the processing of the crude oil to prevent excessive erosion of processing equipment. Coking the oil, the simplest method to deal with this trouble, is used by the Great Canadian Tar Sand Company in the major tar sand refinery now in existence.

Shale oil compositions vary with the method of extracting the oil but will normally include a high amount of sulfur, nitrogen and metals. The amount of rock dust and particles may not be excessive if the oil is produced by retorting the shale.

The method of the present invention is to intentionally remove substantial amounts of particulate matter by the filter action of a bed of catalyst while simultaneously utilizing the catalyst to hydrotreat the charged material, and intermittently withdrawing portions of the catalyst bed and entrained particulate matter from the reactor to prevent the build up of excessive pressure drops in the reactor. Normally, it is preferred to operate a refining process of this type with the charge stock in a vaporized state, but due to the high percentage of tar sand oil which is not distillable, this could only be approached by the use of excessive amounts of recycled hydrogen. However, in the process of this invention neither long catalyst life nor highly uniform distribution patterns are the controlling criteria. The central objective is the removal of large proportions of the particulate matter and metals from the charge stock as a clean up operation prior to further processing. The flow chosen through the reactor, therefore will be that which provides the best removal of the particulate matter and still, if possible, provides a good degree of hydrotreating and may be either upflow or downflow. Upflow operation is not normally used in fixed bed operations with a charge stock as heavy as that derived from the tar sands, because the heavy liquid would not be vaporized and there would result two phase flow through the reactor. Two phase flow is thought to hinder the diffusion of hydrogen to activate catalyst sites and results in an increased carbon formation rate, quicker deactivation of the catalyst, channeling of reactants and inferior yields and operation.

Because catalyst particles are relatively large and loose fitting as compared to normal filter media, a certain degree of fine material will pass through the catalyst bed. As time progresses, the material that is removed from the liquid stream accumulates on a filter and itself acts as filter medium. With a wide particle size distribution, the coarse particles initially removed will partially plug the larger holes through the catalyst bed and increase its filtration efficiency. This natural phenomenon can be used to the best advantage with an upward flow of oil in the reactor, that is, one countercurrent to the downward moving catalyst.

When the catalyst moves during the intermittent additions and withdrawals, this built up filter structure will be partially destroyed allowing flow of some of the previously trapped particles toward the reactor exit. The large particles, however, will not be able to travel any great distance before they are again trapped and re-establish the increased filtration capability. The destruction of the accumulated filter bed by the movement of the catalyst can be lessened by designing the reactor to encourage plug flow of the catalyst through the reactor and to thereby prevent agitation of the catalyst. The most desirable situation for filtration would be for the catalyst bed to in effect slide down the reactor in a piston-like mass countercurrent to the oil.

Catalyst particles are normally about 1/16 inch to 3/8 inch extruded pellets or spheres. The use of a smaller size catalyst will increase the effectiveness of the catalyst bed as a filter medium, since it is in effect a step toward a true filter medium. The minimum size the catalyst used will be a great extent determined by the physical restraints of designing equipment to prevent the catalyst from exiting from the reactor effluent and to transport the catalyst into and out of the reactor. Other very important design considerations include the

increase in pressure drop inherent with a smaller catalyst (approximately 50 velocity heads per diameter), and the tendency of catalyst (depending on catalyst size and density and the fluid's characteristics) to become fluidized in countercurrent flow. Large pressure drops in upflow reactors can raise the catalyst bed as a whole and thereby cause difficulty in attempts to transport catalyst into and out of the reactor by gravity.

One method available for preventing the lifting or fluidization of the catalyst bed is the use of a hydraulic ram formed by material circulated downward through the top of reactor and exiting at a midpoint of the vessel. The ram exerts a downward force composed of the weight of the solids above the reactor effluent opening plus the drag of the fluid being circulated downward over these solids.

A hydraulic ram is used advantageously as a reaction zone in a specific embodiment of the present invention. A mixed phase reactant stream, such as heavy material recycled from the reactor effluent, may be used and a common effluent opening provided, or a vapor phase reactant stream may be used in conjunction with separate effluent openings for the two reactant streams to minimize mixing. The vapor phase reactant stream may be light material separated from the lower reactor zone effluent and which would be contaminated if comingled with the rising heavier reactants from the treating and filtration zone. These effluent openings could be separated by a layer of catalyst to prevent mixing rather than a physical separator, such as a conventional plate deck, which would restrict catalyst movement.

Although the moving bed reactor is intended to perform significant hydroprocessing, a specific embodiment of the present invention has the rate of catalyst addition controlled solely by the pressure drop or the filtration in the reactor rather than the rate of conversion. The pressure drop between the reactant inlet and outlet may be correlated with experimentally determined degrees of filtration to provide a means to optimize processing. A less than normally desired removal of sulfur, nitrogen and metals may be the overall optimum case.

In the preferred embodiment shown in the drawing, the moving bed reactor would hold from 10 to 25% of the total catalyst used in the process and would be operated at a liquid hourly space velocity of from 2 to 10 based on a space velocity of 0.5 to 1.0 for the process as a whole. The moving bed reactor would be operated at high severity conditions to result in approximately 50% metals removal, about 50 to 60% sulfur removal and at least 90% removal of the particulate matter. Due to the high severity operation envisioned and the inherent rapid build up of coke on the catalyst, the catalyst removed from the reactor could be substantially regenerated by contact with oxygen to burn off the carbon and reused in the reactor. The catalyst regeneration may be a two-stop operation with initial removal of entrained charge stock and particulate matter from the catalyst in a cleaning zone to form a more free flowing catalyst which in a second step would be contacted with air or some other oxygen containing gas stream. If the rate of carbon deposition is relatively low, as in the processing of a light, fully vaporized oil fraction, a portion of the catalyst may be returned to the reactor without regeneration. The high metals content of a crude tar sand derived charge stock would result in rather quick, permanent deactivation of the catalyst due to

deposition of metals on the catalyst surface. This metals poisoning of catalyst is irreversible and not affected by the removal of the carbon. Hence, there would be required a constant replacement of the used catalyst with fresh catalyst.

As shown in the drawing, the preferred embodiment utilizes a moving bed reactor followed by a fractionation step to divide the wide boiling range crude oil produced from the tar sand into two separate fractions. The lighter fraction is hydrotreated for the removal of residual metals, sulfur and nitrogen, while the heavier fraction is treated or cracked in a second fixed bed reactor operated at higher severity conditions. The hydrogen that is not consumed in the moving bed reactor is passed through to the fixed bed reactor processing the lighter fraction of the charge stock. A higher purity hydrogen stream is charged to the second moving bed reactor processing the heavy fraction of the moving bed reactor effluent to maintain a higher hydrogen partial pressure for more effective desulfurization of this heavier material. The reactors may be operated at different conditions of pressure and temperature as dictated by product slate, feed composition, and economics. The residual metals still in the effluent of the moving bed reactor will cause deactivation of the catalyst in the next reactor to which it is charged. Since the great majority of the metals and particulate matter in the reactor effluent will be in the heavier fraction leaving the separation zone, the reactor treating this fraction will have greater problems of deactivation and plugging than the reactor processing the lighter fraction. To obtain all the advantages inherent in long periods of continuous operation, a moving bed reactor may be used to process this heavier fraction. The light fraction removed from the separation zone may also be either processed in a fixed bed or moving bed reactor may be fractionated prior to any further treatment. Either of these fractions may be recycled to the initial moving bed reactor as a second stream charged to the top of the reactor to prevent fluidization or lifting of the catalyst bed by the charge stream entering the bottom of the reactor.

I claim as my invention:

1. A process for the filtration and hydroprocessing of a particulate-containing tar-sand oil or shale oil which comprises the steps of:

- a. continuously passing said oil into the bottom of a reactor in admixture with hydrogen;
- b. intermittently passing quantities of catalyst into the top of the reactor and removing quantities of catalyst and entrained particulate matter from the bottom of the reactor to effect a catalyst transfer through the reactor;
- c. measuring the pressure drop between the bottom of the reactor and the top of the reactor; and,
- d. adjusting the rate of catalyst transfer to effect an adjustment of the pressure drop to a preselected pressure drop which corresponds to a desired rate of filtration in the reactor.

2. The process of claim 1 wherein said oil charged to the process contains at least 200 ppm. of particulate matter.

3. The process of claim 1 wherein said oil charged to the process contains at least 2% sulfur (elemental weight basis) and is less than 80% distillable.

4. The process of claim 1 wherein said first hydrocarbon stream charged to the process is derived from tar sands.

5. The process of claim 1 wherein the reactor is operated at a temperature of from 500°F. to 900°F. and a pressure of 300 psig. to 2,500 psig.

6. The process of claim 1 wherein at least a portion of the catalyst removed from the reactor is passed through a cleaning zone wherein the particulate matter entrained with the catalyst is removed and the cleaned catalyst is returned to the reactor.

7. The process of claim 6 wherein at least a portion of the cleaned catalyst is contacted with an oxygen containing gas to burn off carbon deposits prior to returning the catalyst to the reactor.

8. The process of claim 1 wherein said oil charged to the process has an initial boiling point in excess of 350°F.

9. A process for the filtration and hydroprocessing of a particulate-containing tar-sand oil or shale oil which comprises the steps of:

- a. continuously passing said oil into the bottom of a reactor in admixture with hydrogen;
- b. intermittently passing quantities of catalyst into the top of the reactor and removing quantities of catalyst and entrained particulate matter from the bottom of the reactor to effect a catalyst transfer through the reactor;
- c. measuring the pressure drop between the bottom of the reactor and the top of the reactor;
- d. adjusting the rate of catalyst transfer to effect an adjustment of the pressure drop to a preselected pressure drop which corresponds to a desired rate of filtration in the reactor; and,
- e. passing effluent into the moving bed reactor through a second reactor operated at hydroprocessing conditions.

10. The process of claim 9 wherein at least a portion of the catalyst removed from the moving bed reactor is

passed through a cleaning zone wherein particulate matter entrained with the catalyst is removed and the cleaned catalyst is returned to the reactor.

11. The process of claim 10 wherein at least a portion of the cleaned catalyst is contacted with an oxygen containing gas to burn off carbon deposits prior to returning the catalyst to the moving bed reactor.

12. The process of claim 9 wherein said oil charged to the process contains at least 200 ppm. of particulate matter.

13. The process of claim 9 wherein said oil charged to the process contains at least 2% sulfur (elemental weight basis) and is less than 80% distillable.

14. The process of claim 9 wherein said second reactor is a moving bed reactor.

15. The process of claim 14 wherein catalyst removed from said second reactor is regenerated by contacting it with an oxygen-containing gas so to remove carbon deposits and is then charged to the initial moving bed reactor.

16. The process of claim 9 wherein the moving bed reactor is maintained at a pressure of 300 psig. to 500 psig. and the second reactor is maintained at a pressure of 1,000 psig. to 4,000 psig.

17. The process of claim 9 wherein the effluent from the moving bed reactor is passed into a separation zone, a light fraction of the effluent is removed, and the remaining heavy fraction of the moving bed reactor effluent is charged to the second reactor in admixture with added hydrogen.

18. The process of claim 17 wherein said oil charged to the process has an initial boiling point in excess of 350°F.

19. The process of claim 9 wherein the reactors are maintained at temperature of 500°F. to 900°F.

20. The process of claim 9 wherein said oil charged to the process is derived from tar sands.

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