

Description

The invention relates to the regeneration of coke-contaminated catalyst which has for example been employed in such hydrocarbon conversion processes as catalytic reforming, catalytic dehydrogenation and dehydrocyclodimerization. The subject invention specifically relates to the operating of moving bed regeneration systems in which used catalyst particles pass downward through a moving bed regeneration zone and are contacted with a suitable oxygen-containing combustion gas stream and heating gas stream which are circulated through the regeneration zone.

Those familiar with hydrocarbon conversion processes have long recognized that it is advantageous to perform these processes in a continuous manner. This has prompted the development of the so-called moving bed catalytic processes. In a moving bed process, the catalyst descends downward through a reaction zone in a compact, non-fluidized bed due to the action of gravity. That is, as catalyst is gradually removed from the bottom of the reactor, newly regenerated catalyst fed to the top of the reactor gradually moves downward to fill in the now available void spaces thereby providing a continuous bed of catalyst which is periodically renewed. An early example of this type of catalyst flow in a reactor is provided in Figure 3 of US-A 2 303 717, which teaches the use of a moving bed reaction zone and a moving bed regeneration zone, and the use of lockhoppers and stripping zones in catalyst treatment and transportation. Another example of a moving bed hydrocarbon conversion process is presented in US-A 3 238 122. US-A 3 725 249 teaches a moving bed reforming operation with associated regeneration equipment. US-A 3 978 150 shows a continuous or moving bed dehydrogenation process which employs moving bed catalyst regeneration. US-A 4 480 144 illustrates a carbon burnoff generation procedure for use with zeolitic catalyst.

US-A 3 652 231 shows in Figure 1 the internal structure of a catalyst regeneration zone and the gas flows employed within the regeneration zone. It illustrates the use of an oxygen-containing gas stream in a carbon burnoff zone located in an upper portion of the regeneration zone, with this oxygen-containing gas stream being circulated through external lines which include cooling and pressurization means. It also illustrates a lower chlorination section, a subsequent drying section, and the reduction of the metallic components of the regenerated catalyst prior to the return of the reconditioned catalyst to the reaction zone. It also gives generalized teaching on the operation of this regeneration procedure and the associated catalytic reforming zone.

Other arrangements for providing the necessary gas flows to moving bed regeneration zones are illustrated in US-A 3 981 824, US-A 4 094 814 and US-A 4 094 817. It is believed that heretofore it has been standard practice to remove the combustion gas from the regeneration zone and to then cool the combustion gas prior to such steps as division

of the combustion gas into various streams or pressurization of the combustion gas.

The present invention provides an improved gas circulation arrangement for use in the regeneration by carbon burnoff of used particulate catalyst in a moving bed regeneration zone. The invention is able to provide gas streams having different temperatures for use in different locations in the regeneration zone without the need for a heating means, such as was used to generate high temperature gas in prior art methods.

According to the present invention there is provided a process for regenerating particulate, coke-contaminated catalyst which comprises the steps of passing the coke-contaminated catalyst into a regeneration zone and downward through the regeneration zone as a compact bed; contacting the coke-contaminated catalyst with an oxygen-containing gas stream in a combustion zone located within the regeneration zone at conditions which result in the combustion of carbon present on the coke-contaminated catalyst and thereby producing a combustion gas stream, which is withdrawn from the regeneration zone, and low-carbon catalyst; passing the low-carbon catalyst downward through a temperature adjustment zone located within the regeneration zone and therein contacting the low-carbon catalyst with a temperature-adjusting gas stream; passing the low-carbon catalyst downward through a drying zone and/or a chlorination zone located within the regeneration zone and therein contacting the low-carbon catalyst with a drying gas stream in the case of a drying zone and with a chlorination gas stream comprising a chlorine-containing substance in the case of a chlorination zone; withdrawing resulting regenerated catalyst from the regeneration zone; compressing at least a major portion of the combustion gas stream, thereby producing a first process gas stream; passing a first aliquot portion of the first process gas stream into the temperature adjustment zone as the previously referred to temperature-adjusting gas stream; and cooling a second aliquot portion of the first process gas stream and then passing the second aliquot portion of the first process stream into the combustion zone as the previously referred to oxygen-containing gas stream.

Preferably oxygen required for the carbon combustion is added to the regeneration zone in the drying gas stream and/or the chlorination gas stream charged to a lower portion of the regeneration zone for counter-current passage to descending low-carbon catalyst.

The accompanying drawing is a schematic illustration of a moving bed catalytic reforming process according to the invention in which a particulate catalyst is regenerated in a regeneration zone 12 through the use of an oxygen-containing combustion supporting gas supplied through line 31, with the catalyst subsequently being heated by a heating gas stream supplied through line 30 prior to chlorination and drying in a lower portion of the regeneration zone.

The hydrocarbon conversion arts have for a

long time recognized benefits which may be obtained by employing a moving bed reaction zone. Among these advantages are the ability to operate at a constant set of operating conditions and to produce a relatively uniform product during the course of operations. Other advantages include an ability to operate at a higher severity than would normally be commercially practical and the avoidance of periodic shutdowns for catalyst replacement or regeneration. These advantages have prompted the development of moving bed reaction zones, catalyst handling systems, and moving bed catalyst regeneration zones. The availability of more attrition-resistant catalyst together with the improvements which have been obtained in the catalyst handling and regeneration systems have resulted in the use of moving bed reaction system being commercially viable in a large number of hydrocarbon conversion processes including catalytic reforming, catalytic dehydrogenation of acyclic hydrocarbons and dehydrocyclodimerization. The latter process is useful in the conversion of light aliphatic hydrocarbons such as propane or butylene into C_6 + product hydrocarbons such as benzene, toluene, xylene and acyclic C_6 to C_9 hydrocarbons.

In the processes to which the subject invention applies, a reactant stream comprising a feed hydrocarbon, and often also containing hydrogen, is contacted with a particulate catalyst under conditions which are effective to promote one or more desired chemical reactions. This contacting will typically cause the deposition upon the surface of the catalyst of a hydrogen deficient hydrocarbonaceous material referred to in the art as coke. The accumulation of this high carbon content material upon the catalyst will normally have deleterious effects upon the activity and/or selectivity of the catalyst. These deleterious effects are normally caused by the carbonaceous coke obscuring active catalytic sites or being deposited upon the surface or within the pores of the catalyst and thereby blocking the transportation of various reactive species throughout the catalyst or onto the catalyst surface. It is customary in the hydrocarbon conversion arts to either periodically replace the catalyst or if possible to regenerate the catalyst by the removal of the coke through combustion.

In the coke combustion regeneration procedure, a bed of deactivated or used catalyst is contacted with an oxygen-containing gas stream at an elevated temperature sufficient to initiate the combustion of the coke deposits. The oxygen-containing gas stream would normally have a minimal oxygen content and will be circulated in a manner to control the maximum temperature achieved within the bed of catalyst undergoing regeneration. This temperature control is desirable to prevent deactivation of the catalyst or damage to the regeneration equipment due to the potentially excessive temperatures which can be obtained by the combustion of the carbonaceous materials, especially in the presence of active catalytic metals which often serve to promote combustion.

In some instances, it is desirable or necessary to perform other regeneration steps subsequent to the carbon burnoff step. For instance, it is often desirable to perform a halogenation step, drying step and/or a reduction step subsequent to the carbon burnoff. These steps are normally performed using separate gas streams which are passed through catalyst having a low carbon content. These subsequent catalyst reconditioning or regeneration steps may in some instances be optimized by their performance at conditions other than the optimum conditions for the coke burnoff regeneration step. Specifically, in some instances, it is desired to perform the chlorination or drying step at a hotter temperature or at a cooler temperature than the combustion zone is operated at. It is therefore necessary to further heat or cool the catalyst after it has been withdrawn from the zone in which the coke is being combusted.

It is an objective of the subject invention to provide a method for the regeneration of particulate catalyst in a moving bed catalyst regeneration zone. It is a particular objective of the subject invention to provide process gas streams having different temperatures for use within a moving bed catalyst regeneration zone. It is another objective of the subject invention to reduce the amount of equipment required for providing various process streams employed in a moving bed catalyst regeneration zone and for providing gas streams having different temperatures for use within the regeneration zone. It is a particular objective of the subject invention to provide a relatively hot gas stream for use in heating catalyst which is being withdrawn from the combustion zone of a catalyst regeneration zone. In the subject invention these objectives are obtained by passing the combustion gas removed from the combustion zone through a pressurization means prior to any cooling step, followed by the division of the thus pressurized stream into a portion which is cooled for recycling to the combustion zone and a relatively hot portion which is used at a lower location within the regeneration zone.

In the moving bed systems which are relevant to this invention the catalyst moves downward through a reaction zone by the action of gravity in the manner previously described. It is therefore necessary to periodically transport the catalyst upward to the top of the reaction or regeneration zone. The exact transfer requirements and the number of times the catalyst must be transferred will be dependent upon layout of the individual process. For instance, if the reaction zone is mounted directly above or below the regeneration zone, it is only necessary to transport the catalyst from the bottom of the reaction zone to the top of this circuit. In an alternative arrangement the reaction zone and the regeneration zone are more normally located side-by-side such that it is necessary to transport quantities of the catalyst from the bottom of the reaction zone to the top of the regeneration zone and simultaneously transport catalyst from the bottom of the regeneration zone to the top of the reaction zone. This upward transporta-

tion of the catalyst could be obtained by various auger-type conveyers, buckets, or other mechanical contrivances. However, it is greatly preferred and it is the industry standard to transport the catalyst by means of a fluidizing gas which carries the catalyst as the gas passes upward through a conduit. In this mode of operation, the catalyst falls into a liftpot or a lift engager and is then carried upward by a gas stream charged to the lift engager. This gas stream may be hydrogen, nitrogen, methane, or one of a number of other similar gases.

It is also customary to employ various lockhoppers within catalyst transfer systems. For instance, lockhoppers provide a convenient safety measure to prevent the passage of combustible gas into the regeneration zone where it may become admixed with oxygen-containing gas. In a like manner, it is normally desired to employ some type of lockhopper or seal device between the regeneration zone and the reaction zone to prevent the passage of oxygen-containing gas into the reaction zone. Lockhoppers and other catalyst-handling zones or vessels are also employed within these processes for catalyst treating such as chlorination or metals reduction, or for pressurizing or depressurizing catalyst during the transportation of the catalyst through the overall system. Hydrogen and other gases are often used as the purge, pressurization or treating gas in these various lockhoppers and catalyst-treating zones. Descriptions of suitable catalyst transfer systems for use in the subject process are available in standard reference materials. For instance, US-A 3 839 196 and US-A 3 839 197 describe catalyst transfer systems and control techniques. An apparatus for uniform catalyst withdrawal and transfer is disclosed in US-A 3 856 662. An elutriation zone for use at the top of the regeneration zone is described in US-A 3 825 116.

The operating procedures and conditions necessary for the successful regeneration of a catalyst will be of course dependent upon the specific catalyst being regenerated. It may also be dependent upon the intended use of the catalyst. The required regeneration procedure will therefore vary. For instance, during the regeneration of a platinum-containing catalyst used in a reforming process, it is normally desired to pass the catalyst through a chlorination section after the catalyst has passed through the carbon burnoff zone of the regeneration zone. In contrast, in the now-preferred dehydrocyclodimerization process the gallium-containing catalyst does not have a halogen component and would not be subjected to a halogenation step during the regeneration procedures.

A general overview of regeneration procedures and operating conditions are presented in the previously cited US-A 3 652 231, US-A 3 981 824, US-A 4 094 814 and US-A 4 094 817. It is generally preferred that the carbon burnoff section or combustion zone of the overall unitary regeneration zone is operated at a superatmospheric pressure above about 2.0 inches of water gauge (0.5 kPa).

Pressures up to about 225 psig (1653 kPa) are suitable, with pressures below 50 psig (446 kPa) being preferred. The carbon burnoff section must be operated at a temperature sufficient to initiate and maintain the combustion of the coke deposits. The carbon burnoff section would therefore normally be operated at least above 700°F (371°C). It is preferred that the carbon burning zone of the regeneration zone is not operated at a temperature above about 1250°F (676°C) as measured at the exit screen of the catalyst bed. Inlet temperatures below about 900°F (482°C) are especially preferred. The oxygen concentration in the gas being recirculated through the carbon burnoff section of the regeneration zone is held at a reduced level compared to air as a catalyst temperature control measure. A large amount of recirculated inert gases is passed through the catalyst in admixture with the oxygen to serve as a heat sink and heat removal media. It is normally preferred that the gas passing into the carbon burnoff section of the regeneration zone will have a total oxygen content below about 2.5 mole percent. The preferred oxygen content for the gas being employed at this point in the regeneration zone is from 0.4 to 1.5 mole percent.

The conditions employed within the halogenation section will be dictated by the results of experimental regeneration of the catalyst to determine optimum regeneration conditions and to minimize the required amount of halogen charged to the regeneration zone. The halogenation operation will typically be a chlorination, but could also comprise the contacting of the low-carbon content catalyst with a different halogen such as fluorine, bromine, or iodine. In the preferred embodiment of the invention, which is the use of the regeneration zone to regenerate spherical alumina particles containing platinum and alumina used in a catalytic reforming zone, the halogenation step comprises contacting the low-carbon content catalyst with a stream comprising an admixture of chlorine containing substance and oxygen at a temperature which is somewhat elevated as compared to the preferred operating temperature of the carbon burnoff section. An organic chloride or HCl may be employed as the chlorine containing substance. More specifically, while it is preferred to operate the carbon burnoff section at an inlet temperature below about 900°F (482°C), such as 890°F (477°C), it is preferred to operate the chlorination section at a higher temperature. The temperature of 960°F (516°C) is a representative operating inlet temperature for the chlorination zone. The required temperature increase to fulfill these desired operating conditions is provided by contacting the low-carbon content catalyst withdrawn from the carbon burnoff zone with the relatively hot diverged portion of combustion gas in the heating zone located intermediate the carbon burnoff zone and the halogenation zone.

If a drying zone is employed subsequent to the halogenation zone, it is preferred that the drying zone is operated at a temperature approximately equal to the halogenation zone. Temperatures

above about 900°F (482°C) are, however, normally satisfactory for use in the drying zone with an adequate drying gas flow rate. The preferred unitary construction of the regeneration zone results in all of the catalyst treating sections or zones being at essentially the same operating pressure. The only pressure difference will be that inherent with the flow of various vapor streams through the catalyst beds and distances which separate different points within the regeneration zone. The total pressure difference between any two points in the regeneration zone should therefore be less than about 2 psi (14 kPa). The operating pressures of the chlorination, drying and heating zones are therefore set by the chosen operating pressure of the carbon burnoff section.

Referring now to the drawing, there is illustrated a reaction zone shown generally as 2. This reaction zone will normally comprise three of four individual catalyst beds with interstage heating in the case of catalytic reforming or catalytic dehydrogenation reactions. The details of these conventional interstage reactant reheating operations is not shown in the drawing for the purpose of simplicity and also since the subject process can be employed in conjunction with reaction zones in which such interstage reheating facilities are not required. The drawing has also been simplified by not showing other details not necessary for an understanding of the inventive concept. The reactant feed stream enters the reaction zone through line 1. After having contacted the catalytic particles for one or more times at reaction conditions the reactants and product compounds are removed from the reaction zone through line 3 and transferred to the appropriate product recovery facilities. The solid catalytic particles are continuously or intermittently removed from the reaction zone through conduit 5 and transferred downward into the lift engaging vessel 6. This catalyst transfer is by the action of gravity, with the removal of catalyst from the bottom part of the reaction zone allowing catalyst located above to settle downward through the reaction zone. Catalyst withdrawn from the bottom of the reaction zone is replaced by freshly regenerated catalyst supplied through conduit 4. A fluidization gas such as hydrogen or nitrogen is supplied to the lift engaging vessel 6 through line 7 in a manner which effects the transfer of used catalyst upward through conduit 8. The used catalyst then enters the elutriation and disengaging vessel 9 wherein fine catalyst particles and the lift gas from line 7 are separated into a stream which is removed from the process via conduit 10. The used, high-carbon content or spent catalyst is then transferred downward from the disengaging vessel 9 through conduit 11 into the regeneration zone shown generally as 12.

The catalyst is confined as a dense compact mass within the regeneration zone, with each catalyst particle resting upon catalyst particles below it. The catalyst particles gradually move downward through the moving bed regeneration zone and pass through a number of different zone which they are contacted with different gas

streams. In the upper portion of the regeneration zone, the catalyst is fed through distribution conduits 43 into an annular catalyst bed 15 confined between an inner cylindrical porous screen 14 and an outer cylindrical porous screen 13. These screens divide the upper portion of the regeneration zone into the annular catalyst retaining volume located between the screens and two reactant or gas transfer volumes. The outer gas transfer volume is located between the outer screen 13 and the inner surface of the cylindrical vertical wall of the regeneration zone. The inner gas transfer volume is a cylindrical volume located within the inner screen 14. The top of the cylindrical internal gas transfer volume is sealed by an imperforate round plate 16. The inner screen 14 preferably extends downward into a lower portion of the regeneration zone and at this lower point contacts a lower cylindrical bed 19 of catalyst retained within a lower portion of the regeneration zone.

In the upper portion of the regeneration zone carbon is removed from the catalyst by combustion. This combustion is supported by a relatively low concentration of oxygen present in an oxygen-containing gas stream charged to the combustion zone through line 31. The gas stream supplied by line 31 enters the annular gas transfer volume located outside of the outer screen 13 and is distributed over the outer surface of screen 13. The gas stream from conduit 31 then passes inward through the catalyst bed 15 and emerges through the porous inner screen 14 into the cylindrical gas transfer volume. This gas stream contains recycled inerts such as nitrogen and water vapor and combustion products such as water vapor and carbon dioxide. The combustion of the carbon heats the gas as it passes through the catalyst. A resultant relatively high temperature gas stream is removed from the cylindrical gas transfer volume through the conduit 17, which feeds the combustion gas stream into the conduit 26. A portion of the combustion gas stream is vented off from the process through line 28 as required to remove the net combustion products. The remaining portion of the combustion gas stream passes through line 27 and is pressurized in the fan or compressor means 29. The relatively hot combustion gas is thereby pressurized to overcome the pressure drops inherent in being recirculated through the regeneration zone.

A first portion of the thus pressurized and still relatively hot combustion gas stream is passed through line 30 at a rate controlled by valve means 34. This gas stream enters the regeneration zone through line 30 as a relatively high temperature heating stream also referred to herein as a temperature adjustment stream. This relatively high temperature gas stream passes through a small lower portion of the annular catalyst bed which functions as a heating zone and then reemerges into the cylindrical gas transfer volume located within the inner screen 14. The intermixture of this heating gas stream with the combustion gas stream supplied through line 31 to promote car-

bon burnoff is limited by the ring-shaped baffle 18 which extends into the annular gas transfer volume from the inner surface of the wall of the regeneration zone.

The remaining portion of the relatively hot and pressurized combustion gas stream of line 27 flows through line 31 and enters a cooling means 32, which preferably is an indirect heat exchange means which employs air as a cooling medium. The gas stream of line 31 will also normally flow through a heating means 33 shown as an indirect heat exchange means. The heating means 33 is not normally employed during the operation of the process but is provided for use during the start-up of the regeneration zone to heat the catalyst sufficiently to obtain self-supporting combustion conditions. The thus temperature adjusted gas is passed through line 31 and into the combustion zone of the regeneration zone to support the combustion of carbon present on catalyst which enters the regeneration zone. The oxygen required for this combustion was admixed into the gas within a cylindrical gas transfer volume located within the inner screen 14, with the oxygen being charged to a bottom portion of the regeneration zone and flowing upward through cylindrical catalyst bed and then into the bottom of the cylindrical gas transfer volume. It is preferred that all of the oxygen is added in this manner. However, some or all of the oxygen could be supplied by other methods such as by addition to line 31.

In the lower section of the regeneration zone the catalyst, after having been treated for the removal of carbon in the combustion zone and heated in a temperature adjustment (heating) zone, is passed into a chlorination zone wherein it is confined as a cylindrical catalyst bed 19 occupying the total available space within the cylindrical cross section of the portion of the catalyst regeneration zone at this point. Chlorination of the catalyst is effected by a chlorination gas stream charged to the regeneration zone through line 39 and distributed within the catalyst bed through a distribution means shown as 21, which may be perforated conduit or conduits extending into the cylindrical catalyst bed. The chlorination gas preferably also contains oxygen, with the gas rising from the distributor 21 and flowing upward into upper portions of the regeneration zone. As the catalyst passes downward from the chlorination zone, it enters a drying zone wherein the catalyst is retained as a cylindrical bed 20. Heated air from line 35 is passed into a lower portion of the drying zone through conduit 37 and distributor pipe 22. The drying air also passes upward countercurrent to the flow of very slowly descending catalyst. The oxygen present in the air from line 35 also eventually rises into the cylindrical gas transfer volume within the cylindrical inner screen 14 to join the combustion gas. A portion of the air from line 35 flows through line 36 and is admixed with chlorine or other chlorine-containing substance to provide the chlorination gas stream.

The thus low-carbon content, chlorinated and

dried catalyst is withdrawn from the regeneration zone through line 23 and transferred into a lock-hopper means 24. This transfer may be regulated by means such as positive seal valves located in lines 23 or in line 40 through which catalyst is withdrawn from lockhopper 24. The lockhopper vessel 24 basically acts as a seal device to prevent the admixture of air from the regeneration zone with hydrogen and hydrocarbon vapors present within other portions of the hydrocarbon conversion process. Nitrogen or another inert gas is therefore supplied through line 25 and will preferably flow upward through conduit 23 into the regeneration zone to purge oxygen from the descending catalyst. The regenerated catalyst is then transferred through line 40 into the lift engaging vessel 41. A stream of hydrogen gas from line 42 is preferably passed into the vessel 41 for the dual purposes of reducing the metallic components of the regenerated catalyst and for fluidizing the regenerated catalyst for transfer upward through conduit 4 and return to the reaction zone. The reducing gas is preferably hydrogen although a light hydrocarbon such as methane could also be employed. Reduction can be performed on catalyst awaiting transfer in a lift engaging vessel such as shown in the drawing or in a separate vessel. The conditions required for reduction will depend on the catalyst being employed. Superatmospheric pressure at a temperature above 750°F (399°C) in the presence of a reductant such as hydrogen or methane is required. In some instances reforming catalysts will require a temperature of about 950°F (510°C) for 60 minutes or more. This depiction of one embodiment of the invention is not intended to exclude from the scope of the invention other variations not shown on the drawing. For instance, the catalyst beds within the regeneration vessel could have different configurations, such as all cylindrical or all annular, or the regeneration zone could comprise two or more separate vessels rather than the single vessel depicted.

One embodiment of the invention may be characterized as a process for regenerating solid catalyst used in the reaction zone of a moving bed hydrocarbon conversion process which comprises the steps of passing used catalyst which has been withdrawn from the reaction zone of a hydrocarbon conversion process into a unitary catalyst regeneration zone and downward through the regeneration zone as a compact bed; contacting the used catalyst with an oxygen-containing gas stream in a combustion zone located within the regeneration zone at conditions which result in the combustion of carbon present on the used catalyst and the production of a combustion gas stream, which is withdrawn from the regeneration zone, and low-carbon catalyst; passing the low-carbon catalyst downward into and through a heating zone located within the regeneration zone, and therein contacting the low-carbon catalyst with a heating gas stream; passing the low-carbon catalyst downward into and through a chlorination zone located within the regeneration

zone, and therein contacting the low carbon catalyst with a chlorination gas stream which comprises a chlorine-containing substance; withdrawing low carbon catalyst from the regeneration zone; pressurizing at least a major portion of the combustion gas stream and producing thereby a relatively high pressure first process gas stream; passing a first aliquot portion of the first process stream into the heating zone as the previously referred to heating gas stream; and cooling a second aliquot portion of the first process stream by indirect heat exchange, and then passing the second portion of the first process stream into the combustion zone as the previously referred to oxygen-containing gas stream.

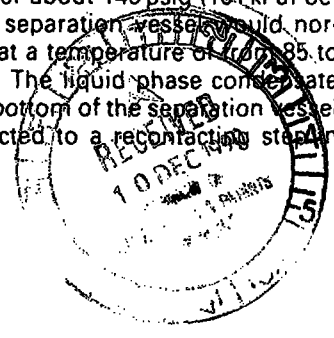
As previously mentioned, the subject method may be applied to a wide variety of processes including dehydrocyclodimerization or dehydrogenation of paraffinic hydrocarbons. The feed hydrocarbons for a dehydrogenation process employing a moving bed reactor would normally be one or more C_2 to C_8 straight chain or branched paraffinic hydrocarbons. Although it is possible to operate a dehydrogenation zone for the conversion of a mixture of two or more of such light hydrocarbons, it is preferred that the feed stream to the dehydrogenation zone is predominantly composed of a hydrocarbon(s) of a single carbon number. Catalysts and operating conditions for dehydrogenation zones may be readily found in the available literature. A preferred dehydrogenation catalyst comprises spherical particles of alumina which supports active catalytic components. The active catalytic components preferably include platinum, a halogen such as chlorine, potassium and tin. Further information on a light paraffin dehydrogenation catalyst may be obtained by reference to US-A 4 469 811. The effluent stream of a dehydrogenation reaction zone may be treated in the same manner as the effluent stream of the reforming zone to provide by partial condensation a hydrogen-rich vapor phase and a liquid phase condensate stream which is sent to fractionation or other product recovery facilities.

When the subject process is employed for the dehydrocyclodimerization of hydrocarbons, the preferred feed stock is a C_3 to C_5 straight chain paraffinic hydrocarbon. The feed stream to the dehydrocyclodimerization process may however contain significant amounts of olefins of the same carbon number. This results in the process producing an aromatic-rich product which may contain a significant amount of branch chained C_6 to C_9 hydrocarbons depending on the feed composition. Again, the product of the dehydrocyclodimerization process may be recovered in a manner similar to that employed in a reforming process, with the reaction zone effluent stream being subjected to a cooling and partial condensation to produce a vapor phase hydrogen-rich stream and a condensate stream comprised of the product and feed hydrocarbons. The liquid phase condensate would normally be transported to fractionation facilities for the separation of the remaining lighter feed hydrocarbons, which may

be recycled to the reaction zone, from the heavier product hydrocarbons. Further details on this process are available from US-A 3 756 922, US-A 4 291 182, US-A 4 157 356 and US-A 4 354 049.

As also previously mentioned, the subject methods are preferably employed in conjunction with a process for the catalytic reforming of a naphtha boiling range hydrocarbon mixture. Such a naphtha mixture is typically recovered from a crude oil but could be derived from shale oil, tar sands, or from the liquefaction of coal or other hydrocarbonaceous materials. Reforming is a vapor phase operation performed with a catalyst bed temperature in the range of 750°F to 1050°F (399 to 566°C). It is normally not desired that the catalyst temperature exceeds about 1020°F (549°C). The other reforming conditions generally include a pressure of from 20 psig to 1000 psig (239 to 6996 kPa), with pressures under about 150 psig (1136 kPa) being preferred, a liquid hourly space velocity of about 0.2 to 10.0 hr^{-1} and a hydrogen to hydrocarbon mole ratio in the range of 0.5 : 1.0 to 10.0 : 1.0. The liquid hourly space velocity is the volumes of fresh charge stock contacted per hour divided by the volume of total catalyst particles. A preferred range for liquid hourly space velocities is from 3.0 to 8.0 hr^{-1} . The inlet temperatures to the catalyst beds are normally maintained above about 950°F (510°C). Reforming catalysts typically contain one or more Group VIII noble metals (platinum, iridium, rhodium and palladium) and a halogen such as chlorine and/or fluorine. These components of a catalyst are supported on a porous refractory carrier material such as alumina. The reforming catalyst may also contain one or more additional metallic catalytic components such as rhenium, germanium, or tin with the presence of tin presently being preferred in the catalyst. Further details on catalyst suitable for catalytic reforming may be obtained by reference to US-A 3 740 328, US-A 3 745 112, US-A 3 948 804 and US-A 4 367 137. The preferred physical form of the catalyst for use in a moving bed reaction and regeneration train is in the form of hard spherical particles having a diameter of from 1/64 to 5/32 of an inch (0.4 to 4 mm).

The vapor phase effluent stream of the reforming reaction zone is preferably handled in a manner similar to that previously described. That is, the vapor phase effluent stream is subjected to heat exchange to recover useful heat and is then further cooled to effect a partial condensation and the production of the mixed phase effluent stream which is charged into a vapor-liquid separation vessel. The separation vessel would normally be operated at a pressure slightly reduced from the pressure maintained within the reaction zone. The separation vessel may therefore be operated at a pressure of from 10 to 950 psig (170 to 6652 kPa) with pressures under about 145 psig (101 kPa) being preferred. The separation vessel would normally be operated at a temperature of from 85 to 155°F (29 to 68°C). The liquid phase condensate removed from the bottom of the separation vessel is preferably subjected to a recontacting step in



which it is pressurized and combined with the compressed vapor phase material removed from the top of the separation vessel for the purposes of increasing the purity of the recovered hydrogen and increasing the liquid hydrocarbon yield. After this recontacting step, the liquid and vapor phases are once again separated with the liquid phase at this time being transported to fractionation facilities. Typically, the primary stage of the fractionation facilities consists of a debutanizer column. Suitable product recovery techniques are described in the prior art including US-A 3 882 014 and US-A 4 364 820. Dehydrogenation and dehydrocyclodimerization processes employ similar recovery schemes except they do not employ the recontacting step.

Claims

1. A process for regenerating particulate, coke-contaminated catalyst which comprises the steps of:

- a) Passing (11) the coke-contaminated catalyst into a regeneration zone (12) and downward through the regeneration zone as a compact bed (15, 19, 20);
- b) contacting the coke-contaminated catalyst (15) with an oxygen-containing gas stream (31) in a combustion zone located within the regeneration zone (12) at conditions which result in the combustion of carbon present on the coke-contaminated catalyst and thereby producing a combustion gas stream, which is withdrawn (26) from the regeneration zone, and low-carbon catalyst;
- c) passing the low-carbon catalyst (15) from the combustion zone downward through a temperature adjustment zone located within the regeneration zone (12) and therein contacting the low-carbon catalyst (15) with a temperature-adjusting gas stream (30); and
- d) passing the low-carbon catalyst from the temperature adjustment zone downward through a drying zone located within the regeneration zone (12) and therein contacting the low-carbon catalyst (20) with a drying gas stream (37) to produce regenerated particulate catalyst; characterised in that it also includes the steps of
- e) compressing (29) at least a major portion of the combustion gas stream (26) thereby producing a first process gas stream (27);
- f) passing a first aliquot portion of the first process gas stream (27) into the temperature adjusting zone as the previously referred to temperature-adjusting gas stream (30); and
- g) cooling (32) a second aliquot portion of the first process gas stream (27) and then passing the second aliquot portion of the first process gas stream into the combustion zone as the previously referred to oxygen-containing gas stream (31).

2. A process as claimed in claim 1, characterised in that the drying gas stream (37) comprises oxygen and is passed upward within the regeneration zone into the combustion zone thereby supplying oxygen consumed within the combustion zone.

3. A process as claimed in claim 1 or 2, character-

ised in that a chlorination zone is located between the temperature adjustment zone and the drying zone, and in that a chlorination gas stream (39) which comprises a chlorine-containing substance is passed into the chlorination zone.

4. A process as claimed in claim 3, characterised in that the chlorination gas stream also comprises oxygen.

5. A process as claimed in claim 4, characterised in that the chlorination gas stream is passed upward through low-carbon catalyst into the combustion zone, with the oxygen present in the chlorination gas stream being consumed in the combustion zone during the burning of carbon.

6. A process for regenerating coke-contaminated, solid particulate catalyst that has been used in the reaction zone of a moving bed hydrocarbon conversion process, which process comprises the steps of:

a) passing coke-contaminated catalyst which has been withdrawn from the reaction zone (2) of a hydrocarbon conversion process into a unitary catalyst regeneration zone (12) and downward through the regeneration zone as a compact bed (15, 19, 20);

b) contacting the coke-contaminated catalyst (15) with an oxygen-containing gas stream (31) in a combustion zone located within the regeneration zone (12) at conditions which result in the combustion of carbon present on the coke-contaminated catalyst and the production of a combustion gas stream (26), which is withdrawn from the regeneration zone, and low-carbon catalyst;

c) passing the low-carbon catalyst downward into and through a heating zone located within the regeneration zone (12), and therein contacting the low-carbon catalyst with a heating gas stream (30);

d) passing the resulting heated low-carbon catalyst (19) downward into and through a chlorination zone located within the regeneration zone (12), and therein contacting the heated low-carbon catalyst (19) with a chlorination gas stream (39) which comprises a chlorine-containing substance; and

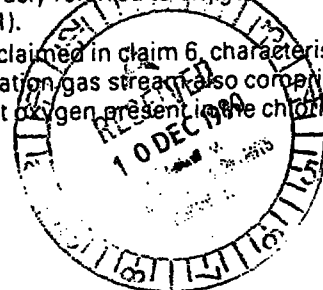
e) withdrawing (23) low-carbon catalyst from the regeneration zone (12); characterised in that the process also includes the steps of

f) pressurizing (29) at least a major portion of the combustion gas stream (26) and producing thereby a relatively high pressure first process gas stream (27);

g) passing a first aliquot portion of the first process gas stream (27) into the heating zone as the previously referred to heating gas stream (30); and

h) cooling a second aliquot portion of the first process gas stream (27) by indirect heat exchange (32), and then passing the second portion of the first process gas stream (27) into the combustion zone as the previously referred to oxygen-containing gas stream (31).

7. A process as claimed in claim 6, characterised in that the chlorination gas stream also comprises oxygen and in that oxygen present in the chlorina-



which it is pressurized and combined with the compressed vapor phase material removed from the top of the separation vessel for the purposes of increasing the purity of the recovered hydrogen and increasing the liquid hydrocarbon yield. After this recontacting step, the liquid and vapor phases are once again separated with the liquid phase at this time being transported to fractionation facilities. Typically, the primary stage of the fractionation facilities consists of a debutanizer column. Suitable product recovery techniques are described in the prior art including US-A 3 882 014 and US-A 4 364 820. Dehydrogenation and dehydrocyclodimerization processes employ similar recovery schemes except they do not employ the recontacting step.

Claims

1. A process for regenerating particulate, coke-contaminated catalyst which comprises the steps of:

- a) Passing (11) the coke-contaminated catalyst into a regeneration zone (12) and downward through the regeneration zone as a compact bed (15, 19, 20);
- b) contacting the coke-contaminated catalyst (15) with an oxygen-containing gas stream (31) in a combustion zone located within the regeneration zone (12) at conditions which result in the combustion of carbon present on the coke-contaminated catalyst and thereby producing a combustion gas stream, which is withdrawn (26) from the regeneration zone, and low-carbon catalyst;
- c) passing the low-carbon catalyst (15) from the combustion zone downward through a temperature adjustment zone located within the regeneration zone (12) and therein contacting the low-carbon catalyst (15) with a temperature-adjusting gas stream (30); and
- d) passing the low-carbon catalyst from the temperature adjustment zone downward through a drying zone located within the regeneration zone (12) and therein contacting the low-carbon catalyst (20) with a drying gas stream (37) to produce regenerated particulate catalyst; characterised in that it also includes the steps of
- e) compressing (29) at least a major portion of the combustion gas stream (26) thereby producing a first process gas stream (27);
- f) passing a first aliquot portion of the first process gas stream (27) into the temperature adjustment zone as the previously referred to temperature-adjusting gas stream (30); and
- g) cooling (32) a second aliquot portion of the first process gas stream (27) and then passing the second aliquot portion of the first process gas stream into the combustion zone as the previously referred to oxygen-containing gas stream (31).

2. A process as claimed in claim 1, characterised in that the drying gas stream (37) comprises oxygen and is passed upward within the regeneration zone into the combustion zone thereby supplying oxygen consumed within the combustion zone.

3. A process as claimed in claim 1 or 2, character-

ised in that a chlorination zone is located between the temperature adjustment zone and the drying zone, and in that a chlorination gas stream (39) which comprises a chlorine-containing substance is passed into the chlorination zone.

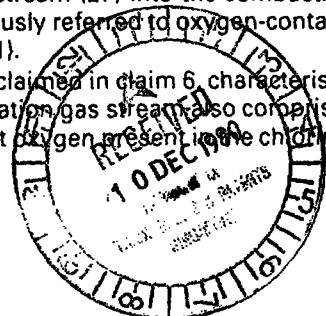
4. A process as claimed in claim 3, characterised in that the chlorination gas stream also comprises oxygen.

5. A process as claimed in claim 4, characterised in that the chlorination gas stream is passed upward through low-carbon catalyst into the combustion zone, with the oxygen present in the chlorination gas stream being consumed in the combustion zone during the burning of carbon.

6. A process for regenerating coke-contaminated, solid particulate catalyst that has been used in the reaction zone of a moving bed hydrocarbon conversion process, which process comprises the steps of:

- a) passing coke-contaminated catalyst which has been withdrawn from the reaction zone (2) of a hydrocarbon conversion process into a unitary catalyst regeneration zone (12) and downward through the regeneration zone as a compact bed (15, 19, 20);
- b) contacting the coke-contaminated catalyst (15) with an oxygen-containing gas stream (31) in a combustion zone located within the regeneration zone (12) at conditions which result in the combustion of carbon present on the coke-contaminated catalyst and the production of a combustion gas stream (26), which is withdrawn from the regeneration zone, and low-carbon catalyst;
- c) passing the low-carbon catalyst downward into and through a heating zone located within the regeneration zone (12), and therein contacting the low-carbon catalyst with a heating gas stream (30);
- d) passing the resulting heated low-carbon catalyst (19) downward into and through a chlorination zone located within the regeneration zone (12), and therein contacting the heated low-carbon catalyst (19) with a chlorination gas stream (39) which comprises a chlorine-containing substance; and
- e) withdrawing (23) low-carbon catalyst from the regeneration zone (12); characterised in that the process also includes the steps of
- f) pressurizing (29) at least a major portion of the combustion gas stream (26) and producing thereby a relatively high pressure first process gas stream (27);
- g) passing a first aliquot portion of the first process gas stream (27) into the heating zone as the previously referred to heating gas stream (30); and
- h) cooling a second aliquot portion of the first process gas stream (27) by indirect heat exchange (32), and then passing the second portion of the first process gas stream (27) into the combustion zone as the previously referred to oxygen-containing gas stream (31).

7. A process as claimed in claim 6, characterised in that the chlorination gas stream also comprises oxygen and in that oxygen present in the chlorina-



tion gas stream passes upward and is employed in the combustion zone in the combustion of carbon present on the coke-contaminated catalyst.

8. A process as claimed in claim 6 or 7, characterised in that after the heating gas stream contacts the low-carbon catalyst the heating gas stream becomes a portion of the combustion gas stream.

9. A process as claimed in any of claims 6 to 8, characterised in that the low-carbon catalyst is contacted with an oxygen-containing drying gas stream in a drying zone after it has been contacted with the chlorination gas stream but before it is withdrawn from the regeneration zone.

10. A process as claimed in any of claims 6 to 9, characterised in that regenerated catalyst withdrawn from the regeneration zone is contacted with a reducing gas in a reducing zone prior to being passed into the reaction zone of the hydrocarbon conversion process.

Patentansprüche

1. Verfahren zum Regenerieren von teilchenförmigem, koksverunreinigtem Katalysator, umfassend die Stufen:

a) Überführung (11) des koksverunreinigten Katalysators in eine Regenerationszone (12) und als kompaktes Bett (15, 19, 20) durch die Regenerationszone nach unten;

b) Kontaktierung des koksverunreinigten Katalysators (15) mit einem sauerstoffhaltigen Gasstrom (31) in einer in der Regenerationszone (12) liegenden Verbrennungszone unter Bedingungen, welche zur Verbrennung des auf dem koksverunreinigten Katalysator zugegebenen Kohlenstoffes unter Bildung eines Verbrennungsgasstromes; der aus der Regenerationszone abgezogen (26) wird, und eines kohlenstoffarmen Katalysators führen;

c) Führung des kohlenstoffarmen Katalysators (15) aus der Verbrennungszone nach unten durch eine Temperaturregelzone, die in der Regenerationszone (12) liegt, und Kontaktierung des kohlenstoffarmen Katalysators (15) in dieser mit einem Temperaturregelungs-Gasstrom (30); und
d) Führung des kohlenstoffarmen Katalysators nach unten durch eine in der Regenerationszone (12) liegende Trocknungszone und Kontaktierung des kohlenstoffarmen Katalysators (20) in dieser mit einem Trocknungsgasstrom (37), um einen regenerierten, teilchenförmigen Katalysator zu bilden; dadurch gekennzeichnet, daß es weiters folgende Stufen aufweist:

e) Verdichtung (29) wenigstens eines Großteils des Verbrennungsgasstromes (26) unter Bildung eines ersten Prozeßgasstromes (27);

f) Einführung eines ersten aliquoten Anteiles des ersten Prozeßgasstromes (27) als den vorgenannten Temperaturregelungs-Gasstrom (30) in die Temperaturregelzone; und

g) Kühlung (32) eines zweiten aliquoten Anteiles des ersten Prozeßgasstromes und darauffolgende Einführung des zweiten aliquoten Anteiles des ersten Prozeßgasstromes als den vorgenannten

sauerstoffhaltigen Gasstrom (31) in die Verbrennungszone.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß der Trocknungsgasstrom (37) aus Sauerstoff besteht und in der Regenerationszone nach oben in die Verbrennungszone zur Zufuhr von in der Verbrennungszone verbrauchtem Sauerstoff geführt wird.

3. Verfahren nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß zwischen der Temperaturregelzone und der Trocknungszone eine Chlorierungszone angeordnet ist und ein aus einer chlorhaltigen Substanz bestehender Chlorierungsgasstrom in die Chlorierungszone eingeführt wird.

4. Verfahren nach Anspruch 3, dadurch gekennzeichnet, daß der Chlorierungsgasstrom auch Sauerstoff enthält.

5. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß der Chlorierungsgasstrom nach oben durch den kohlenstoffarmen Katalysator in die Verbrennungszone geführt wird, wobei der im Chlorierungsgasstrom vorhandene Sauerstoff in der Verbrennungszone bei der Verbrennung des Kohlenstoffes verbraucht wird.

6. Verfahren zum Regenerieren von koksverunreinigtem, festem, teilchenförmigem Katalysator, der in der Reaktionszone eines Bewegtbett-Kohlenwasserstoff-Umwandlungsprozesses verwendet worden war, welches Verfahren folgende Stufen umfaßt:

a) Überführung von koksverunreinigtem Katalysator, der aus der Reaktionszone (2) eines Kohlenwasserstoff-Umwandlungsprozesses abgezogen worden war, in eine in sich geschlossene Katalysator-Regenerationszone (12) und als kompaktes Bett (15, 19, 20) durch die Regenerationszone nach unten;

b) Kontaktierung des koksverunreinigten Katalysators (15) mit einem sauerstoffhaltigen Gasstrom (31) in einer in der Regenerationszone (12) liegenden Verbrennungszone unter Bedingungen, welche zur Verbrennung des auf dem koksverunreinigten Katalysator zugegebenen Kohlenstoffes unter Bildung eines Verbrennungsgasstromes (26), der aus der Regenerationszone abgezogen wird, und von kohlenstoffarmem Katalysator führen;

c) Führung des kohlenstoffarmen Katalysators nach unten durch eine in der Regenerationszone (12) liegende Heizzone und Kontaktierung des kohlenstoffarmen Katalysators in dieser mit einem Heizgasstrom (30);

d) Führung des resultierenden erhitzten Katalysators (19) nach unten in und durch eine in der Regenerationszone (12) liegende Chlorierungszone und Kontaktierung des erhitzten kohlenstoffarmen Katalysators (19) in dieser mit einem aus einer chlorhaltigen Substanz bestehenden Chlorierungsgasstrom (39); und

e) Abziehen (23) von kohlenstoffarmem Katalysator aus der Regenerationszone (12); dadurch gekennzeichnet, daß es weiters folgende Stufen aufweist:

f) Verdichtung (29) wenigstens eines Großteils des Verbrennungsgasstromes (26) unter Bildung



eines unter relativ hohem Druck stehenden ersten Prozeßgasstromes (27);

g) Einführung eines ersten aliquoten Anteiles des ersten Prozeßgasstromes (27) als den vorgenannten Heizgasstrom (30) in die Heizzone; und

h) Kühlen eines zweiten aliquoten Anteiles des ersten Prozeßgasstromes (27) durch indirekten Wärmeaustausch (32) und darauffolgende Führung des zweiten Anteiles des ersten Prozeßgasstromes (27) als den vorgenannten sauerstoffhaltigen Gasstrom (31) in die Verbrennungszone.

7. Verfahren nach Anspruch 6, dadurch gekennzeichnet, daß der Chlorierungsgasstrom auch Sauerstoff enthält und daß der im Chlorierungsgasstrom enthaltene Sauerstoff nach oben strömt und in der Verbrennungszone bei der Verbrennung von auf dem koksverunreinigten Katalysator zugegenem Kohlenstoff verwendet wird.

8. Verfahren nach Anspruch 6 oder 7, dadurch gekennzeichnet, daß, nachdem der Heizgasstrom mit dem kohlenstoffarmen Katalysator in Berührung gelangt ist, der Heizgasstrom zu einem Teil des Verbrennungsgasstromes wird.

9. Verfahren nach einem der Ansprüche 6 bis 8, dadurch gekennzeichnet, daß der kohlenstoffarme Katalysator, nachdem er mit dem Chlorierungsgasstrom in Berührung gebracht wurde, jedoch bevor er aus der Regenerationszone abgezogen wird, mit einem sauerstoffhaltigen Trocknungsgasstrom in einer Trocknungszone kontaktiert wird.

10. Verfahren nach einem der Ansprüche 6 bis 9, dadurch gekennzeichnet, daß aus der Regenerationszone abzogener regenerierter Katalysator mit einem reduzierenden Gas in einer Reduktionszone kontaktiert wird, bevor er in die Reaktionszone des Kohlenwasserstoff-Umwandlungsprozesses eingeführt wird.

Revendications

1. Procédé pour régénérer un catalyseur en particules souillé par du coke, qui comprend les stades consistant à:

a) faire passer (11) le catalyseur souillé par du coke dans une zone de régénération (12) et le faire descendre à travers la zone de régénération sous forme d'un lit compact (15, 19, 20);

b) mettre le catalyseur (15) souillé par du coke au contact d'un courant de gaz oxygéné (31) dans une zone de combustion située dans la zone de régénération (12) dans des conditions provoquant la combustion du carbone présent sur le catalyseur souillé par du coke et produire ainsi un courant de gaz de combustion, qui est évacué (26) de la zone de régénération, et un catalyseur à faible taux de carbone;

c) faire descendre le catalyseur à faible taux de carbone (15) de la zone de combustion à travers une zone d'ajustement de la température située dans la zone de régénération (12) afin de mettre le catalyseur à faible taux de carbone (15) au contact d'un courant de gaz d'ajustement de la température (30); et

d) faire descendre le catalyseur à faible taux de

carbone de la zone d'ajustement de la température à travers une zone de séchage située dans la zone de régénération (12) pour mettre ainsi le catalyseur à faible taux de carbone (20) au contact d'un courant de gaz de séchage (37) pour produire un catalyseur en particules régénéré; caractérisé en ce qu'il comprend également les stades consistant à

e) comprimer (29) au moins une majeure partie du courant de gaz de combustion (26) afin de produire un premier courant de gaz de procédé (27);

f) faire passer une première portion du premier courant de gaz de procédé (27) dans la zone d'ajustement de la température en tant que courant de gaz d'ajustement de la température (30) précité; et

g) refroidir (32) une seconde portion du premier courant de gaz de procédé (27) puis faire passer la seconde portion du premier courant de gaz de procédé dans la zone de combustion en tant que gaz oxygéné (31) précité.

2. Procédé selon la revendication 1, caractérisé en ce que le courant de gaz de séchage (37) comprend de l'oxygène et s'élève dans la zone de régénération pour pénétrer dans la zone de combustion pour y apporter l'oxygène consommé dans la zone de combustion.

3. Procédé selon la revendication 1 ou 2, caractérisé en ce qu'une zone de chloration est située entre la zone d'ajustement de la température et la zone de séchage et en ce qu'un courant de gaz de chloration (39), qui comprend une substance chlорée, est conduit dans la zone de chloration.

4. Procédé selon la revendication 3, caractérisé en ce que le courant de gaz de chloration comprend également de l'oxygène.

5. Procédé selon la revendication 4, caractérisé en ce que le courant de gaz de chloration s'élève à travers le catalyseur à faible taux de carbone pour pénétrer dans la zone de combustion, l'oxygène présent dans le courant de gaz de chloration étant consommé dans la zone de combustion pendant la combustion du carbone.

6. Procédé pour régénérer un catalyseur solide en particules souillé par du coke, qui a été utilisé dans la zone de réaction d'un procédé de conversion d'hydrocarbures à lit mobile, qui comprend les stades consistant à:

a) faire passer un catalyseur souillé par du coke, qui a été évacué de la zone de réaction (2) d'un procédé de conversion d'hydrocarbures, dans une zone de régénération unitaire de catalyseur (12) et le faire descendre à travers la zone de régénération sous forme d'un lit compact (15, 19, 20);

b) mettre le catalyseur souillé par du coke (15) au contact d'un courant de gaz oxygéné (31) dans une zone de combustion située dans la zone de régénération (12) dans des conditions qui provoquent la combustion du carbone présent sur le catalyseur souillé par du coke et la production d'un courant de gaz de combustion (26), qui est évacué de la zone de régénération, et d'un catalyseur à faible taux de carbone;

c) faire descendre le catalyseur à faible taux de carbone dans et à travers une zone de chauffage



située dans la zone de régénération (12) et y mettre le catalyseur à faible taux de carbone au contact d'un courant de gaz de chauffage (30);

d) faire descendre le catalyseur à faible taux de carbone chauffé obtenu (19) dans et à travers une zone de chloration située dans la zone de régénération (12) et y mettre le catalyseur à faible taux de carbone chauffé (19) au contact d'un courant de gaz de chloration (39) qui comprend une substance chlorée; et

e) évacuer (23) le catalyseur à faible taux de carbone de la zone de régénération (12); caractérisé en ce qu'il comprend aussi les stades consistant à f) comprimer (29) au moins une majeure partie du courant de gaz de combustion (26) et produire ainsi un premier courant de gaz de procédé à pression relativement élevée (27);

g) faire passer une première portion du premier courant de gaz de procédé (27) dans la zone de chauffage en tant que courant de gaz de chauffage (30) précité; et

h) refroidir une seconde portion du premier courant de gaz de procédé (27) par échange indirect de chaleur (32) puis faire passer la seconde portion du premier courant de gaz de procédé (27) dans la zone de combustion en tant que courant de gaz oxygéné (31) précité.

7. Procédé selon la revendication 6, caractérisé en ce que le courant de gaz de chloration comprend également de l'oxygène et en ce que l'oxygène présent dans le courant de gaz de chloration s'élève et est utilisé dans la zone de combustion pour la combustion du carbone présent sur le catalyseur souillé par du coke.

8. Procédé selon la revendication 6 ou 7, caractérisé en ce qu'après que le courant de gaz de chauffage soit venu au contact du catalyseur à faible taux de carbone, le courant de gaz de chauffage devient une partie du courant de gaz de combustion.

9. Procédé selon l'une quelconque des revendications 6 à 8, caractérisé en ce que le catalyseur à faible taux de carbone est mis au contact d'un courant de gaz de séchage oxygéné dans une zone de séchage après avoir été mis au contact du courant de gaz de chloration, mais avant d'être évacué de la zone de régénération.

10. Procédé selon l'une quelconque des revendications 6 à 9, caractérisé en ce que le catalyseur régénéré évacué de la zone de régénération est mis au contact d'un gaz réducteur dans une zone de réduction avant d'être conduit dans la zone de réaction du procédé de conversion d'hydrocarbures.

