

- 1 -

METHOD FOR REVAMPING FIXED-BED CATALYTIC REFORMERS

FIELD OF THE INVENTION

[0001] The invention relates generally to catalytic reformers. More particularly, the invention relates to an improved method for converting or revamping high pressure, fixed-bed catalytic reformers to catalytic reformers with continuous, moving-bed reactors.

CROSS REFERENCE TO RELATED APPLICATION

[0002] This application relates to a method of converting or revamping fixed bed catalytic reformers to moving bed reactor operation and, as such, is related to US 2004/0129605 A1, published July 8, 2004, which described a different conversion scheme.

BACKGROUND OF THE INVENTION

[0003] Catalytic reforming is an established petroleum refinery process. It is used for improving the octane quality of hydrocarbon feeds. Generally, reforming refers to the total effect of molecular changes on a hydrocarbon feed, produced by a number of reactions. Typical reforming reactions include dehydrogenation of cyclohexanes, dehydroisomerization of alkylcyclopentanes, dehydrocyclization of paraffins and olefins, isomerization of substituted aromatics, and hydrocracking of paraffins. Typical reforming catalysts are multifunctional catalysts having a hydrogenation-dehydrogenation component dispersed on a porous, inorganic oxide support. The support may typically also contain an acid functionality needed to mediate the reforming reactions.

[0004] Reforming reactions are both endothermic and exothermic. Endothermic reactions are typically predominant in the early stages of reforming while exothermic reactions predominate in the later reaction stages although the

- 2 -

process as a whole is markedly endothermic. A reforming unit typically comprises a plurality of serially connected reactors with furnaces for supplying additional heat to the reaction stream as it passes from one reactor to the next in order to compensate for the heat taken up in the overall endothermic character of the process. Conventionally, reforming processes have been operated as semi-regenerative or cyclic processes using fixed bed reactors or continuous processes such as UOP CCR Platforming™ (Continuous Catalytic Regeneration Platforming™) using moving bed reactors.

[0005] Proposals have been made for combining fixed and moving bed reactors with the regeneration mode appropriate to the reactor types used in the hybrid configuration, so that the fixed bed reactors have retained the fixed bed type regeneration, usually semiregenerative, and the moving bed reactors in the unit have retained the dedicated moving bed regenerator. Units of this hybrid type are disclosed, for example, in US 5,190,638; US 5,190,639; US 5,196,110; US 5,211,838; US 5,221,463; US 5,354,451; US 5,368,720 and US 5,417,843. The unit described in US 5,417,843 uses two trains of fixed bed reactors with each train having a final moving bed reactor at the end and the moving bed reactors sharing a moving bed regenerator. The unit shown in US 5,190,639 uses two trains of fixed bed units feeding into a shared moving bed reactor with its own dedicated, fully integrated regenerator. Similar hybrid reforming units using combinations of fixed bed and moving bed reactors are described in NPRA Paper No. AM-96-50 "IFP Solutions for Revamping Catalytic Reforming Units" (1996 NPRA Annual Meeting, 17-19 March 1996). US 4,498,973 describes a moving bed reforming unit in which two moving bed reactor stacks share a common regenerator. UOP has recently announced its CycleX™ Process for increased hydrogen production from a fixed bed reforming unit by the addition of a circulating catalyst reactor as the final reactor in the reactor sequence. This reactor is provided with its own heater and regenerator as an expansion of existing assets rather than as a substitution of them: NPRA Paper AM-03-93.

- 3 -

[0006] In semiregenerative reforming, the entire reforming process unit is operated by gradually and progressively increasing the temperature to compensate for deactivation of the catalyst caused by coke deposition, until finally the entire unit is shut-down for regeneration and reactivation of the catalyst which is carried out with the catalyst remaining in the reactor cases. In cyclic reforming, the reactors are individually isolated by various piping arrangements. The catalyst is regenerated and then reactivated while the other reactors of the series remain on line. A "swing reactor" temporarily replaces the reactor which is removed from the series for regeneration and reactivation of the catalyst, which is then put back in the series. In continuous reforming, the reactors are moving-bed reactors with continuous or intermittent addition and withdrawal of catalyst through which the catalyst moves progressively before it is passed to a regeneration zone for regeneration and rejuvenation before being returned once again to the reactor. In the regenerator, at least a portion of the deposited coke is burned off and the regenerated catalyst is recycled to the reactor to continue the cycle. Commercial continuous reforming units may have the reactors arranged in a side-by-side or in a stacked configuration. Because the continuous mode of operation with its frequent regeneration can tolerate a higher degree of coke lay-down on the catalyst, it is possible to operate continuous units at lower pressures than those normally used with semi-regenerative and cyclic units in which it is important or at least desirable to extend catalyst life between successive regenerations.

[0007] Environmental concerns have driven the removal of lead from the gasoline pool and the introduction of premium grade, higher octane, lead-free gasoline in Europe and the United States. In response, petroleum refiners have changed the manner in which refinery units are run to meet the concomitant demand for higher octane, lead-free gasoline. Catalytic reforming units produce a major portion of the refinery gasoline pool and for this reason, improved

- 4 -

reforming methods and units are needed for producing lead-free fuel products with adequate octane ratings. Reforming can also be an attractive source of hydrogen in the refinery, especially when the sulfur level of fuels must be reduced to meet government regulations.

[0008] Semiregenerative reforming units may be converted to continuous moving-bed units to take advantage of the improved yield of higher octane reformat and hydrogen associated with continuous operation but the conversions which have so far been considered are essentially entire unit replacements which require replacement of all existing vessels and most of the ancillary equipment as well as installation of an integrated catalyst regenerator which is one of the most costly items in the conversion. The cost of the regenerator can be as much as about 80 percent of the total cost required for the conversion, making this option less attractive when the original fixed bed units are still capable of service.

[0009] US 2004/0129605 A1 describes an economically attractive method for converting fixed bed catalytic reforming units to continuous reactor operation while reducing the costs associated with continuous regeneration. In this conversion scheme, a fixed-bed catalytic reformer with at least one fixed-bed is converted semiregenerative to a moving-bed catalytic reformer reactor which allows continuous or intermittent addition of fresh or regenerated catalyst through suitable feed facilities to its catalyst inlet. Provision is made for continuous or intermittent removal of spent catalyst from the catalyst outlet of the reactor by way of spent catalyst recovery facilities for collecting the spent catalyst, storing it temporarily, and transferring it to a catalyst regeneration facility. The moving-bed reactor, the catalyst feeding facilities and the catalyst recovery facilities are operatively connected between themselves and to the existing facilities (piping, ancillary equipment) of the fixed-bed unit that do not require replacement.

SUMMARY OF THE INVENTION

[0010] The present invention relates to a scheme for converting fixed-bed, catalytic reformer units to units with moving bed reactors. It differs from the scheme described in US 2004/0129605 A1 in that it makes use of existing reactor vessels; in the present case, these vessels are placed into new service, this time for catalyst regeneration. Because this conversion scheme requires only new reactors, it avoids the major expense connected with the provision of a moving bed regenerator and so presents an economically favorable case for conversion to moving bed reactor operation. The costs of conversion associated with the present conversion technique will be significantly less than conversions in which both the reactors and the regenerators are converted to moving bed operation because the present conversion technique makes use of existing facilities in addition to making new use of the reactor vessels while, at the same time, not requiring dedicated onsite continuous catalyst regeneration facilities. One advantage of the present conversion scheme is that the full advantages of moving bed reactor operation are secured with the reactors operated at the lower pressures characteristic of continuous operation so as to improve reformat quality and yield.

[0011] According to the present invention, a fixed-bed catalytic reformer unit is converted to moving bed reactor/cyclic regenerator operation by re-using the fixed bed reactors of the original unit as regenerator vessels operated in cyclic regeneration mode in a converted regeneration section. A flow connection, suitably a liftpipe, is provided to convey spent catalyst from the spent catalyst outlet of a new moving bed reactor section to the converted regenerator section, together with a flow connection for regenerated catalyst from the regenerator section to the catalyst inlet of the new moving bed reactor section. A flow control distributor directs spent catalyst sequentially to each of the regenerator vessels to carry out the regeneration with regeneration gas. Each regenerator

- 6 -

vessel is cycled through a fill, regeneration, discharge sequence to maintain a continuous flow of catalyst to and from the reactor section.

[0012] In the present conversion technique and its allied operational mode, a fixed bed reformer unit with a plurality of reactor vessels is converted to a continuous reformer unit with a moving bed reactor section and a multi-vessel catalyst regeneration section operating in cyclic fashion, using the former reactor vessels for regeneration. The former reactor vessels are re-used for regeneration in the new, cyclical operation, typically on a three-vessel fill/regenerate/discharge cycle, in which one vessel receives spent catalyst, while another is in the regeneration cycle and another is discharging regenerated catalyst for recycle to the reactor stack. This conversion scheme is particularly well adapted to the conversion of cyclic reforming units where the regeneration circuit (compressor, furnace, chemical injection facilities, valving, piping and manifolding) can be used with advantage for the purposes of cyclic regeneration in the converted unit. The conversion scheme may, however, be also applied to existing semi-regenerative units although here with the marginal economic disadvantage of having to provide a new regeneration circuit.

THE DRAWING

[0013] Figure 1 shows a continuous moving-bed reforming process built from an existing cyclic reformer unit.

DETAILED DESCRIPTION

[0014] The present invention provides a substantially lower cost option for refiners to make significant improvements to the performance and service factor of existing fixed-bed reformer units. Non-continuous (or fixed-bed) catalytic reformers which can be subjected to the present conversion scheme could be semi-regenerative catalytic reformers or swing-reactor (also referred to as cyclic

- 7 -

regeneration) reformers or hybrid systems (with both fixed and moving bed sections), all of which are known.

[0015] The present conversion scheme is best adapted to the conversion of cyclic reformer units because the required catalyst regeneration equipment will already be in place and can be applied directly to the new service: the compressors, furnace, chemical injection facilities as well as piping, valving and manifolding can be used without substantial modification to the mode of cyclic regeneration used in the converted unit. Cyclic, fixed-bed reformers have been well-known. In units of this type, a plurality of reactors are used, typically from three to five, with one reactor being the so-called “swing” reactor. The actual reforming is carried out in the remaining reactors according to the normal reforming reactor sequence while the catalyst in the “swing” reactor is being regenerated by the flow of regeneration gas through the catalyst. In the normal operation sequence, the reactor with the catalyst which has aged the most, is withdrawn from the reforming sequence (taken “off-oil”): after the oil feed is cut off, the catalyst in the vessel is subjected to regeneration sequence typically with a purge of residual hydrocarbons (nitrogen purge), oxidative regeneration to burn off the accumulated coke on the catalyst, halogenative rejuvenation (usually a chlorination treatment), followed by a purge of oxides and residual occluded gases and a final hydrogen reduction, after which the reactor is returned on line by bringing it “on-oil” again while another vessel is taken off-oil for regeneration. Normally, the swing time has been about three to five days. For convenience, the term “regeneration gas” is used here to comprehend the various gases used in the regeneration sequence referred to above, including the heated purge gas (usually nitrogen), oxidative gas for coke burn-off, halogenation gas for rejuvenation, purge gas, hydrogen for reduction and, if required by the catalyst chemistry, the pre-sulfiding gas treatment.

- 8 -

[0016] It is not essential, however, that the fixed bed unit being subjected to conversion should be a cyclic unit; conversion of semi-regenerative units is feasible since these units will also provide multiple reactor vessels as assets for conversion to cyclic regeneration use. This type of conversion, however, will be accompanied by the necessity to provide additional ancillary equipment for the regeneration circuit including compressors, furnace, piping, valving and manifolding. Semi-regenerative units typically contain one or more fixed-bed reactors operating in series with inter-bed heaters to maintain operating severity as the catalyst deactivates by increasing the reaction temperature and to maintain the desired temperature profile across the unit as the ratio of endothermic to exothermic reactions increases in successive reactors. Eventually, a semi-regenerative unit is shut down for catalyst regeneration and reactivation in its original mode of operation. After conversion according to the present scheme, however, the reactor vessels are used as cyclically-operated regenerator vessels for a continuous, moving bed reactor stack.

[0017] The fixed-bed reformer unit is converted to a moving-bed reformer reactor that allows continuous addition of freshly regenerated catalyst to an inlet of the reactor and continuous removal of spent catalyst from an outlet of the reactor. Although the regeneration is carried out in a cyclical operation with the spent catalyst passing successively between the new moving bed reactor section the former reactor vessels (now functioning as regenerator vessels), the provision of suitable spent and regenerated catalyst receivers (along with an adequate catalyst inventory) will allow for continuous catalyst flow to the reactor section.

[0018] The conversion of a fixed bed (semi-regenerative or cyclic) reformer unit to operation with moving-bed reactors comprehends the replacement of the fixed bed reactors by a moving bed reactor section. Normally, since moving bed operation provides optimal reforming performance, all the former fixed-bed

- 9 -

reactors will be replaced by the moving bed reactor section but, if for some reason, it is desired to have a hybrid type unit with a fixed/moving bed configuration, some of the fixed bed reactors may be retained in the hybrid service. The reactor section will have, as is conventional, a number of moving bed reactors connected in sequence for reformer feed flow and for catalyst flow from one reactor to the next. The moving bed reactors may be disposed in a side-by-side or stacked arrangement, depending on site requirements although the stacked configuration provides for ready catalyst transfer between successive reactors by gravitational flow. The conversion does require addition of catalyst transfer facilities between the new moving bed reactor(s) and the converted, fixed bed vessels now used in the cyclic regeneration sequence but much ancillary equipment of the fixed bed unit can be retained and put to new use, especially, as noted above, the piping associated with cyclic units. Feed (oil) arrangements will need to be modified as required to suit the layout of the converted unit and its operational requirements.

[0019] As mentioned above, a former cyclic reforming unit has the necessary catalyst regeneration circuit ready for use in the new application. Since the equipment in this circuit is adapted to regenerating the catalyst in place in the reactor vessels, with the appropriate sequence of regeneration gas, this same equipment can be directly applied to the cyclic regeneration mode which is used in the converted unit. If, however, a former semi-regenerative reformer is converted to the new mode of operation, a catalyst regeneration circuit with its associated compressors, furnace, chemical injection facilities as well as valving, piping and manifolding will need to be supplied and connected appropriately to the former reactor vessels. The general form of this equipment as well as its service requirements and manner of use will follow those of conventional cyclic units and, being well known, will not be described in detail here.

- 10 -

[0020] Figure 1, given for example only, shows a continuous catalytic moving-bed reforming process unit which has been converted from a former cyclic reformer. The converted unit is composed of a moving bed reactor section 10 which is integrated with a regeneration section 11 with three regeneration vessels, 12, 13, 14 which are the former reactors of a cyclic reformer; the former reactors and regeneration system are enclosed by dashed line 15. The figure concerns itself only with the catalyst handling circuit, omitting details of the hydrocarbon feed and recovery equipment as well as furnaces and other ancillary items which are conventional for the reactor stack.

[0021] In operation, the reactor section is operated in the conventional way for a stacked reactor configuration with hydrocarbon feed being introduced into the reactor at the top of the stack and effluent removed from the last reactor at the bottom of the stack. Catalyst moves down through the reactors of the stack progressively from bed to bed, entering the catalyst inlet 10A at the top of the stack and leaving at the spent catalyst outlet 10B at the bottom of the last reactor in the stack (here, the fourth reactor). The spent catalyst passes down from the catalyst outlet through a spent catalyst removal line 20, lock valves 21 to catalyst lift pot or lift entrainer 23 in which the spent catalyst is entrained by lift gas which elevates the catalyst up liftpipe 24. The lift gas, supplied through conduit 25 under the control of differential pressure/flow controller 27, is suitably booster gas, that is, gas from the compressor of the recycle gas circuit, comprising mainly hydrogen with minor quantities of hydrocarbons, which is heated to approximately 350°C (about 700°F) in effluent heat exchanger 28.

[0022] After being conveyed upwards in liftpipe 24, the spent catalyst passes into disengager 30 and then into surge vessel/elutriator 31 in which the lift gas is separated and fines removed. The fines are recovered in the fines recovery section with filters 32A and 32B and fines collector 33; gas passes out to the gas circuit through line 34.

- 11 -

[0023] From the surge vessel/elutriator 31, the spent catalyst passes through lock 35 to flow control hopper/distributor 36. Flow control hopper/distributor 36 enables catalyst to be distributed to each of regenerator vessels 12, 13 or 14. The catalyst passes from flow control hopper/distributor in lines 37, 38, 39, through locks 40A, 40B, 40C and double block and bleed valves 41A, 41B, 41C, to regenerator vessels 12, 13 and 14. Block gas supply to the double and bleed valves is provided in conventional manner as shown with gas supplies, suitably of refinery fuel gas through lines 42A, 42B, 42C. Similar locks 43A, 43B, 43C and double block and bleed valves 44A, 44B, 44C, are provided at the catalyst outlets of vessels 12, 13 and 14. Block gas supply to the double and bleed valves on the outlets is provided in conventional manner as shown with gas supplies, suitably of refinery fuel gas through lines 45A, 45B, 45C. Make up catalyst can be admitted when required through valve 71 from catalyst drum 70.

[0024] Regenerator vessels 12, 13, 14 are the previously used axial reactors which were made redundant when they were replaced by the moving bed continuous reactors. Typically, at any point in time, one of the three regeneration vessels is in the "Spent Catalyst Fill" mode, one is in the "Regeneration" mode, and the remaining one is in the "Regenerated Catalyst Discharge" mode. The double block and bleed motor operated valves on the regenerator flow allow the reactors to be isolated from regeneration gas flow when they are in the "Spent Catalyst Fill" mode or the "Regenerated Catalyst Discharge" mode.

"Spent Catalyst Fill" Mode

[0025] When a regeneration vessel is filling it is isolated from regeneration gas flow by double block and bleed valve arrangements 41A, 41B, 41C at the inlets and 44A, 44B, 44C at the outlets of the vessels. Catalyst is flowing from the flow control hopper/distributor 36 into the selected regenerator vessel through the spent catalyst fill line that protrudes through the regeneration flow

- 12 -

inlet spool piece 12A, 13A, 14A of the selected vessel. The regenerated catalyst emptying line that protrudes through each regeneration flow outlet spool piece 12B, 13B, 14B is closed.

“Regeneration” Mode

[0026] During catalyst regeneration in one of the three regeneration vessels, the appropriate spent catalyst filling line 37, 38, 39 and the corresponding regenerated catalyst emptying line is closed. Regeneration gas flows into the regenerator vessel through the respective regeneration gas inlet spool piece 12A, 13A, 14A, and out of the vessel through the regeneration gas outlet spool piece 12B, 13B, 14B as indicated by gas flow arrows (not numbered). Regeneration off-gases are sent to the scrubber in the conventional way. The catalyst lines are isolated from the regeneration gas with the double block and bleed valve arrangements 41A, 41B, 41C, 44A, 44B, 44C on the inlet and outlet sides respectively. The regeneration circuit that was used in the cyclic unit before the conversion provides the facilities required for compression, furnace, heat exchange, and regeneration gas and chemical injection during the regeneration. These facilities will be flexible enough to meet the regeneration procedure requirements for known reforming catalysts. The regeneration sequence with its purge, coke burn-off, halogenation, purge, reduction and, if desired, pre-sulfiding, can be carried out according to conventional practice as dictated by operational requirements and catalyst chemistry in a manner comparable to that used in conventional cyclic units.

“Regenerated Catalyst Discharge” Mode

[0027] When a regenerator vessel is being emptied, it is isolated from regeneration gas flow by double block and bleed valve arrangements at the vapor inlet and outlet of the reactor. Catalyst is discharged from the regenerator vessel through the appropriate regenerated catalyst discharge line 50, 51, 52 that protrudes through the vapor outlet spool piece 12B, 13B, 14B of the respective

- 13 -

vessel and passes into a lift entrainer 60 beneath the regenerator vessel group. Recycle gas supplied through line 61 under control of differential pressure/flow controller 62 is used to entrain the regenerated catalyst in lift entrainer 60 and elevate it through liftpipe 63 up to the catalyst disengaging vessel 64 located above the reduction zone 10B at the top of moving bed reactor 10. The spent catalyst filling line that protrudes through the regeneration flow inlet spool piece 12A, 13A, 14A, respectively, is closed.

Cycle Control

[0028] The regeneration cycle operation is under the control of a sequential cycle controller (not shown) and associated control equipment, all of which is of conventional type. The controller acts to maintain the flow of spent catalyst from the flow control hopper/distributor to the selected regeneration vessel which is in the "Spent Catalyst Filling" mode while, at the same time regulating the valving to the other vessels to put the regenerator vessel in the "Regeneration" mode into the regeneration cycle and the third vessel into the "Regenerated Catalyst Emptying" mode. This involves actuation of the catalyst flow valves and the gas flow valves and blocks to obtain the required actions, all of which can be carried out by conventional controllers, control circuits, actuators and related equipment. The regeneration cycle for the catalyst will be determined by catalyst and operational requirements and may be under the control of the main cycle controller or a regeneration sub-controller operating under the overall control of the main controller. The regeneration cycle controller of either type will need mainly to control the flow of regeneration gas to the vessel which is in the "Regeneration" mode. Typically, this will include a regeneration gas sequence comprising a hydrocarbon purge (hot nitrogen), coke burn (hot oxygen-containing gas), oxy-chlorination, oxides purge (hot nitrogen), and reduction (hydrogen). The reduction step may, however, be carried out at the inlet of the reactor section, for example, above the first reactor in a stacked configuration and, if so provided, may be omitted from the sequence carried out

- 14 -

in the regeneration section. Other variations in the sequence will be dictated by catalyst requirements and can be accommodated by conventional modifications to the cycle control and appropriate provision in the regeneration system.

Unit Layout

[0029] Because this is essentially a conversion or revamp scheme, the final unit layout will normally be determined to a large degree by specific site requirements. So, the configuration and location of the reactor section may well be constrained by the site as well as the relative location of the regeneration section; normally, cost considerations will preclude relocation of the old fixed bed reactors to a new location, especially if the old unit were a cyclic unit with the associated piping in the regeneration circuit. This will often require appropriate siting of the new moving bed reactor section. With a stacked reactor configuration, the side-by-side configuration typical of old cyclic and semi-regenerative units will require the use of lift systems for the spent and regenerated catalyst flows, as described above but this is by no means inherent in the character of the conversion; if alternative arrangements are more suitable, resort may be made to them as necessary or convenient.

Reforming Catalyst

[0030] Any typical reforming catalyst suitable for moving bed operation may be used, consistent with the equipment limitations and feed and operational requirements. Suitable catalysts include those comprising one or more Group VIII noble metals on a refractory support. The catalyst will contain a hydrogenation-dehydrogenation function (hydrogen transfer) and an acid function. Examples include catalysts comprising platinum, tin, rhenium, iridium, tin or combinations of these metals. A preferred support includes substantially spherical alumina support particles. A preferred catalyst comprises platinum, platinum and tin, or platinum and rhenium on substantially spherical

- 15 -

alumina support particles. Spherical particles are preferred for movement through the moving bed reactors and other equipment with minimal attrition.

Reforming Catalyst Regeneration

[0031] A typical regeneration procedure includes a hydrocarbon purge, coke burn, halogenation (usually oxy-chlorination), oxides purge, and reduction procedure. However, depending on the type of catalyst it may also include presulfiding as part of the regeneration procedure. The oxy-chlorination procedure may vary significantly. At a minimum it may include the addition of a chloride containing agent such as Cl_2 , HCl , or a pumpable organic chloride after the coke burn to replace the chloride lost during the coke burn. However, it may also include a continuous addition of a chloride agent during the coke burn. It may also include over-chlorination after the coke burn followed by a chloride equilibration step after the platinum metal has been thoroughly redispersed. The actual regeneration procedure might include any combination of these chlorination techniques.

CLAIMS:

1. A method for the conversion of a fixed bed catalytic reformer unit having at least one fixed-bed catalytic reforming reactor to moving bed reactor/cyclic regenerator operation, the method comprising:

providing a moving bed, continuous reforming reactor section for carrying out catalytic reforming reactions on a reformer feed;

converting at least one fixed bed reforming reactor of the fixed-bed catalytic reformer unit to a catalyst regenerator vessel in a catalyst regeneration section;

providing a flow connection for spent catalyst from a spent catalyst outlet of the moving bed reactor section to the catalyst regenerator vessel and

providing a flow connection for regenerated catalyst from a regenerated catalyst outlet of the catalyst regenerator vessel to a regenerated catalyst inlet of the moving bed reactor section.
2. A method according to claim 1 in which the fixed-bed catalytic reformer unit has a plurality of fixed-bed catalytic reforming reactors which are converted to a plurality of cyclic operation catalyst regenerator vessels.
3. A method according to claim 2 which includes providing (i) a flow connection for spent catalyst from the spent catalyst outlet of the moving bed reactor section to one of the catalyst regenerator vessels and (ii) a flow connection for regenerated catalyst from the regenerated catalyst outlet of one of the catalyst regenerator vessels to the regenerated catalyst inlet of the moving bed reactor.
4. A method according to claim 3 in which the flow connection for the spent catalyst from the spent catalyst outlet of the moving bed reactor section is connected at the end remote from the reactor section to a spent catalyst

- 17 -

flow distributor for selectively directing spent catalyst to one of the plurality of catalyst regenerator vessels.

5. A method according to claim 3 in which the flow connection for the regenerated catalyst from the catalyst regenerator vessel is connected at the end remote from the catalyst regenerator vessel to a regenerated catalyst collector for directing regenerated catalyst to the catalyst inlet of the moving bed reactor section.
6. A method according to claim 4 in which each regeneration vessel has an inlet and an outlet for reforming catalyst regeneration gas.
7. A method according to claim 1 in which the moving bed, continuous reforming reactor section comprises a plurality of reforming reactors in a vertically stacked configuration and the catalyst regeneration section comprises a plurality of catalyst regeneration vessels converted from the fixed bed reactors of the fixed bed reforming unit.
8. A method according to claim 7 in which the spent catalyst outlet of the moving bed reactor section is connected for spent catalyst flow to a spent catalyst lift engager which has a spent catalyst outlet connected for spent catalyst flow to a liftpipe to convey spent catalyst to a spent catalyst flow distributor for directing spent catalyst to one of the plurality of catalyst regenerator vessels.
9. A method according to claim 8 in which each of the plurality of catalyst regenerator vessels is connected for regenerated catalyst flow to a regenerated catalyst lift engager which has an outlet for regenerated catalyst flow to a liftpipe to convey regenerated catalyst to the catalyst inlet of the moving bed reactor section.

- 18 -

10. A method according to claim 9 which includes means for selectively directing regenerated catalyst flow from each of the plurality of catalyst regenerator vessels in sequence to the regenerated catalyst lift engager.
11. A method for the conversion of a fixed-bed catalytic reformer unit having a plurality of fixed bed catalytic reforming reactors to moving bed reactor/cyclic regenerator operation and for the operation of the converted unit, the method comprising:
 - providing a fixed bed catalytic reforming unit having a plurality of fixed bed reforming reactors in which catalytic reforming reactions on a reformer feed are carried out,
 - providing a moving bed, continuous reforming reactor section for carrying out catalytic reforming reactions on a reformer feed;
 - converting a plurality of the fixed bed reforming reactors of the fixed-bed catalytic reformer unit to catalyst regenerator vessels in a catalyst regeneration section which is connected for spent and regenerated catalyst flow between the moving bed reactor section and the catalyst regeneration section;
 - providing a flow connection for spent catalyst from a spent catalyst outlet of the moving bed reforming reactor section to each catalyst regenerator vessel and
 - providing a flow connection for regenerated catalyst from a regenerated catalyst outlet of each catalyst regenerator vessel to the regenerated catalyst inlet of the moving bed reactor section,
 - providing a flow controller for selectively directing reforming catalyst regeneration gas to each catalyst regeneration vessel
 - reforming a reformer feed in the moving bed reactor section,

- 19 -

removing spent reforming catalyst from the spent catalyst outlet of the moving bed reactor section,

passing the spent reforming catalyst removed from the catalyst outlet of the moving bed reactor section to a catalyst regeneration vessel in the catalyst regeneration section

regenerating the spent reforming catalyst in the catalyst regeneration vessel by directing reforming catalyst regeneration gas through the catalyst in the regeneration vessel,

withdrawing regenerated reforming catalyst from the regeneration vessel when regeneration is complete, and

returning the regenerated reforming catalyst to the catalyst inlet of the reforming reactor section.

12. A method according to claim 11 in which the fixed-bed catalytic reformer unit includes a plurality of fixed bed reforming reactors each of which is converted to a catalyst regenerator vessel in the catalyst regeneration section, each catalyst regeneration vessel having (i) a spent catalyst inlet connectable for spent catalyst flow to the spent catalyst outlet of the moving bed reactor section and (ii) a regenerated catalyst outlet connectable for regenerated catalyst flow to the catalyst inlet of the moving bed reactor section.
13. A method according to claim 12 in which the inlets of the catalyst regenerator vessels are each sequentially connected for spent catalyst flow between the spent catalyst outlet of the moving bed reactor section and the spent catalyst inlet of the regenerator vessel to admit spent catalyst to the regenerator vessel in sequence for regeneration.
14. A method according to claim 13 in which each catalyst regenerator vessel sequentially: first, receives spent catalyst from the spent catalyst outlet of

- 20 -

the moving bed reactor section; second, receives reforming catalyst regeneration gas to regenerate the spent reforming catalyst in the regeneration vessel; third, discharges regenerated catalyst for return to the catalyst inlet of the moving bed reactor section.

15. A method according to claim 14 in which each of the catalyst regenerator vessels is sequentially connected for regenerated catalyst discharge to a regenerated catalyst lift engager which has an outlet for regenerated catalyst flow to a liftpipe to convey regenerated catalyst to the catalyst inlet of the reactor section.
16. A method according to claim 15 which includes means for selectively discharging regenerated catalyst flow from each of the plurality of catalyst regenerator vessels in sequence to the regenerated catalyst lift engager.
17. A method according to claim 13 in which the spent catalyst outlet of the reactor section is connected for spent catalyst flow to a spent catalyst lift engager which has a spent catalyst outlet connected for spent catalyst flow to a liftpipe to convey spent catalyst to a spent catalyst flow distributor for directing spent catalyst sequentially to each of the catalyst regenerator vessels.
18. A method according to claim 11 in which the fixed bed catalytic reforming unit is a cyclic reforming unit including a regeneration circuit which is incorporated into the converted unit to direct catalyst regeneration gas through the catalyst in the regeneration vessel during the regeneration step.
19. A method according to claim 18 in which the catalyst regeneration gas directed through the catalyst includes a sequence of purge gas, oxidative gas to remove coke from the catalyst and halogen-containing gas for catalyst rejuvenation.

- 21 -

20. A method according to claim 13 in which the moving bed, continuous reforming reactor section comprises a plurality of reforming reactors in a vertically stacked configuration and the catalyst regeneration section comprises a plurality of catalyst regeneration vessels converted from the fixed bed reactors of the fixed bed reforming unit.