OLEFIN UPGRADING PROCESS WITH GUARD BED REGENERATION

FIELD OF THE INVENTION

[0001] This invention relates to a method for the regeneration of guard bed sorbents and catalysts used in light olefin polymerization and alkylation processes for the production of gasoline boiling range motor fuel.

CROSS REFERENCE TO RELATED APPLICATIONS

[0002] The present application is related to the following previously filed applications which describe related catalytic processes used for making gasoline boiling range liquid hydrocarbon products:

U. S. Serial No. 11/362257, filed 27 February 2006, "Gasoline Production by Olefin Polymerization".

U. S. Serial No. 11/362,139, filed 27 February 2006, "Gasoline Production By Olefin Polymerization With Aromatics Alkylation"

U. S. Serial No. 11/362,256, filed 27 February 2006, "Process for Making High Octane Gasoline with Reduced Benzene Content"

U. S. Serial No. 11/362,255, filed 27 February 2006, "Vapor Phase Aromatics Alkylation Process"

U. S. Serial No. 11/362,139, filed 27 February 2006, "Liquid Phase Aromatics Alkylation Process"

[0003] The present rejuvenation process is intended for use with manufacturing processes such as those described in these previous applications; accordingly, reference is made to these prior application for details of the processes and of the equipment used for carrying them out.

[0004] The present application is also related to concurrently filed application Serial No. 60/ (Attorney Docket P2006EM056, PM 2006-EE-020), entitled "Rejuvenation Process for Olefin Polymerization and Alkylation Catalyst

BACKGROUND OF THE INVENTION

[0005] Following the introduction of catalytic cracking processes in petroleum refining in the early 1930s, large amounts of olefins, particularly light olefins such as ethylene, propylene, butylene, became available in copious quantities from catalytic cracking plants in refineries. While these olefins may be used as petrochemical feedstock, many conventional petroleum refineries producing petroleum fuels and lubricants are not capable of diverting these materials to petrochemical uses. Processes for producing fuels from these cracking off gases are therefore desirable and from the early days, a number of different processes evolved. The early thermal polymerization process was rapidly displaced by the superior catalytic processes of which there was a number. The first catalytic polymerization process used a sulfuric acid catalyst to polymerize isobutene selectively to dimers which could then be hydrogenated to produce a branched chain octane for blending into aviation fuels. Other processes polymerized isobutylene with normal butylene to form a co-dimer which again results in a high octane, branched chain product. An alternative process uses phosphoric acid as the catalyst, on a solid support and this process can be operated to convert all the C_3 and C_4 olefins into high octane rating, branched chain polymers. This process may also operate with a C_4 olefin feed so as to selectively convert only isobutene or both n-butene and isobutene. This process has the advantage over the sulfuric acid process in that propylene may be polymerized as well as the butenes and at the present time, the solid phosphoric acid [SPA] polymerization process remains the most important refinery polymerization process for the production of motor gasoline.

[0006] In the SPA polymerization process, feeds are pretreated to remove hydrogen sulfide and mercaptans which would otherwise enter the product and be unacceptable, both from the view point of the effect on octane and upon the ability of the product to conform to environmental regulations. Typically, a feed is washed with caustic to remove hydrogen sulfide and mercaptans, after which it is washed with water to remove organic bases and any caustic carryover. Because oxygen promotes the deposition of tarry materials on the catalyst, both the feed and wash water are maintained at a low oxygen level. Additional pre-treatments may also be used, depending upon the presence of various contaminants in the feeds. With the most common solid phosphoric acid catalyst, namely phosphoric acid on kieselguhr, the water content of the feed needs to be controlled carefully because if the water content is too high, the catalyst softens and the reactor may plug. Conversely, if the feed is too dry, coke tends to deposit on the catalyst, reducing its activity and increasing the pressure drop across the reactor. As noted by Henckstebeck, the distribution of water between the catalyst and the reactants is a function of temperature and pressure which vary from unit to unit, and for this reason different water concentrations are required in the feeds to different units. *Petroleum Processing Principles And Applications*, R. J. Hencksterbeck McGraw-Hill, 1959. As described in the prior applications cited above, there are two general types of units used for the SPA process, based on the reactor type, the unit may be classified as having chamber reactors or tubular reactors. The chamber reactor contains a series of catalyst beds with bed volume increasing from the inlet to the outlet of the reactor, with the most common commercial design having five beds. The catalyst load distribution is designed to control the heat of conversion.

[0007] For the production of motor gasoline only butene and lighter olefins are employed as feeds to polymerization processes as heavier olefins up to about C_{10} or C_{11} can be directly incorporated into the gasoline. With the SPA process,

propylene and butylene are satisfactory feedstocks and ethylene may also be included, to produce a copolymer product in the gasoline boiling range. Limited amounts of butadiene may be permissible although this diolefin is undesirable because of its tendency to produce higher molecular weight polymers and to accelerate deposition of coke on the catalyst. The process generally operates under relatively mild conditions, typically between 150° and 200°C, usually at the lower end of this range between 150° and 180°C, when all butenes are polymerized. Higher temperatures may be used when propylene is included in the feed. In a well established commercial SPA polymerization process, the olefin feed together with paraffinic diluent, is fed to the reactor after being preheated by exchange with the reaction effluent.

[0008] The solid phosphoric acid catalyst used is non-corrosive, which permits extensive use of carbon steel throughout the unit. The highest octane product is obtained by using a butene feed, with a product octane rating of [R+M]/2 of 89 to 91 being typical. With a mixed propylene/butene feed, product octane is typically about 91 and with propylene as the primary feed component, product octane drops to typically 87.

[0009] In spite of the advantages of the SPA polymerization process, which have resulted in over 200 units being built since 1935 for the production of gasoline fuel, a number of disadvantages are encountered, mainly from the nature of the catalyst. Although the catalyst is non-corrosive, so that much of the equipment may be made of carbon steel, it does lead it to a number of drawbacks in operation. First, the catalyst life is relatively short as a result of pellet disintegration which causes an increase in the reactor pressure drop. Second, the spent catalyst encounters difficulties in handling from the environmental point of view, being acidic in nature. Third, operational and quality constraints limit flexible feedstock utilization. Obviously, a catalyst

which did not have these disadvantages would offer considerable operating and economic advantages.

[0010] In application Serial No. 11/362257, we have described the production of gasoline boiling range hydrocarbons by a process using solid, non-corrosive molecular sieve catalysts to polymerize (oligomerize) light olefins in a refinery stream such as FCC off-gas; this process can be operated in an existing Polygas™ unit with relatively minor unit modifications and so, given the advantages of the molecular sieve catalysts, the new process offers and economically attractive way of improving existing refinery units for gasoline production. A related aromatics alkylation process is described in Serial Nos. 11/362,256, 11/362,255 and 11/362,139; in the process set out in these applications, a gasoline boiling range product of low benzene content is produced using light refinery olefins to alkylate reformate streams containing significant levels of benzene. Application Serial No. 11/362,139 describes a number of integrated process schemes which combine the polymerization process with the benzene alkylation process.

[0011] The gasoline manufacturing processes described in these patent application use feedstocks produced in the petroleum refinery, usually a light olefinic stream form the FCCU as a source of olefins, either alone or combined with a reformate stream in the processes using aromatics alkylation. These olefinic streams from the cracking unit usually contain significant levels of contaminants, especially sulphur compounds including mercaptans, thiophenes and substituted thiophenes, as well as compounds containing other heteroatoms such as nitrogen. Many of these contaminants will act as catalyst poisons for the molecular sieve catalysts used in the olefin upgrading process. Since poisoning of the catalyst results in decreased catalyst activity and possibly also catalyst selectivity, it is desirable to keep these contaminants from entering the catalyst bed. For this reason, guard beds are frequently used, containing either a non-

reactive sorbent for the contaminants or a reactive material which undergoes a reaction with the contaminant(s). Which ever, is used, the guard bed material eventually requires regeneration itself when loaded with the contaminant(s). Conventionally, a single guard bed is used, making it necessary either to cease operation during regeneration or to send the feed directly to the reactor without separation of the contaminant(s), so shortening catalyst life commensurately.

SUMMARY OF THE INVENTION

[0012] We have now devised a process for the regeneration of materials used in the guard beds preceding the reactors used for the light olefin conversion processes. Processes of this type include the olefin conversion processes referred to above for the manufacture of gasoline boiling range motor fuels, either using a light olefin feed on its own or with a reformate co-feed to produce a low-benzene alkylaromatic gasoline. Other olefin conversion processes using refinery light olefin streams which may use these guard bed regeneration techniques include the well-established aromatics alkylation processes for making cumene or ethylbenzene. According to the present invention, the guard bed regeneration step is integrated with the olefin conversion to ensure continuous operation of the olefin conversion without sending the feedstock containing the contaminant(s) to the reactor. The process uses reaction products from the olefin conversion process to regenerate the guard bed material and so is economically attractive since it does not require the use of separate purge, regeneration feed and separation systems.

[0013] According to the present invention, an olefin conversion process which converts olefinic refinery streams to other, higher boiling hydrocarbon products by polymerization (oligomerization) or aromatics alkylation over a molecular sieve catalyst utilizes a plurality of guard beds containing a material which removes catalyst poisons. The guard beds are operated on a swing system

in which one or more beds is kept on stream to remove the contaminant(s) while one or more of the remaining beds is being purged or regenerated. In this way, continuity of operation is assured. The regeneration medium is a product stream from the olefin conversion process.

DRAWINGS

[0014] Figure 1 shows a process schematic for the olefin polymerization unit for converting light refinery olefins to motor gasoline by the present process.

DETAILED DESCRIPTION

Olefin Conversion Process

[0015] The present process is for the conversion of light cracking olefins or the alkylation of aromatics by light cracking olefins to produce higher boiling liquid hydrocarbon products, for example, motor gasoline and other motor fuels such as road diesel blend stock as well as alkylaromatic petrochemical products such as ethylbenzene and cumene. For convenience, the present guard bed regeneration technique will be described below with reference to the olefin polymerization process and the aromatics alkylation processes described in the earlier filed applications cited above but its is more generally applicable, to other similar processes using molecular sieve catalysts and requiring a guard bed to remove contaminants form the feed stream which would otherwise deactivate the catalyst. As described in the previous applications cited above, the olefin conversion process when used to produce gasoline boiling range product, is intended to provide a replacement for the SPA polymerization process, using a molecular sieve catalyst which can be used as a direct replacement for SPA and so enables existing SPA units to be used directly with the new catalyst, so allowing the advantages of the new catalyst and process to be utilized while

retaining the economic benefit of existing refinery equipment. The aromatic alkylation process is similar in operation and again, is used to convert light refinery olefins to higher value, higher boiling liquid products.

[0016] As described in prior applications, Serial Nos. 11/362257 and 11/362,139, the gasoline boiling range products can be produced by the polymerization (oligomerization) of a light refinery olefin stream. An alternative to the straightforward polymerization process is an aromatics alkylation process of the type described in Serial Nos. 11/362,256, 11/362,255, 11/362,139, which may be combined with the polymerization process as described in Serial No. 11/362,139. Reference is made to these prior applications for descriptions of the basic olefin upgrading processes.

[0017] The present guard bed regeneration technique is, as noted, capable of use with other processes using molecular sieve catalysts which are subject to poisoning by contaminants in the feed, including processes for converting olefins into lubricants as described in U.S. Patent No. US 4956514 which describes the use of zeolite MCM-22 as an olefin oligomerization catalyst for making lube range materials by the oligomerization of low molecular weight olefins such as propylene and FCC off gas streams. Other processes to which it can be applied are the well-established processes for manufacturing aromatics such as ethylbenzene or cumene, using reactions such as alkylation and transalkylation. The cumene production (alkylation) process is described in U.S. Patent No. US 4992606 (Kushnerick et al). Ethylbenzene production processes are described in U.S. Pat. Nos. 3,751,504 (Keown); 4,547,605 (Kresge); and 4,016,218 (Haag); U.S. Pat. Nos. 4,962,256; 4,992,606; 4,954,663; 5,001,295; and 5,043,501 describe alkylation of aromatic compounds with various alkylating agents over catalysts comprising MWW zeolites such as PSH-3 or MCM-22. US Patent No. 5,334,795 describes the liquid phase synthesis of ethylbenzene with MCM-22. The processes for cumene and ethylbenzene

manufacture are well-established commercially and are available under license from vendors such as ExxnoMobil Chemical Company and Polimeri Europa.

[0018] Figure 1 shows an simplified illustrative configuration for an olefin upgrading unit operating on the principle of aromatics alkylation. Figure 1 in which the dotted lines show the needed modifications for a conventional Polygas unit. The quench circuit used in the olefins polymerization version of the process is omitted for clarity. The reactors can be tubular or chamber type. The number of reactors changes from unit to unit, in this example the configuration has three reactors and this potentially enables the rejuvenation can be practiced in one of the reactors while keeping the others in operation. The feed to be used as the rejuvenation stream is the olefin-depleted stream from the overhead of the fractionation tower. In this configuration, some piping is needed, and an additional pump to boost the recycle stream to the reactor operating pressure; this pump is needed in any event if the recycle is used as quench as described in Serial No. 11/362257.

[0019] A mixed light olefin feed from a catalytic cracking unit is introduced through line 10 and passes through guard bed 11 which operates on a swing reactor system with a matching guard bed 12. The feed then passes to feed drum 13 and on through line 14 to reactors 15A, 15B, 15C. The olefins in the feed are polymerized in reactors 15A, 15B and 15C. The effluent from the reactors passes to fractionator 20 by way of line 16. The reactor effluent is fractionated in the fractionator to produce the desired product fractions. The heavy product fraction leaves fractionator 20 through line 26 as product. A portion of the light product fraction with unreactive paraffins from the feed is removed from the top of the fractionator and passed by way of line 21, pump 22, line 23, pump 24 and line 25 to second guard bed 12 which is in the regeneration phase, desorbing the contaminants which have been removed from the feed. The guard bed vessels are switched alternately between feed treatment and regeneration by means of

conventional valving (not shown) which may also direct effluent from the guard bed during the regeneration portion of the cycle to recovery facilities by way of line 27 so as to permit removal of the desorbed contaminants. When desorption of the contaminants from the guard bed in the regeneration phase is complete, the beds can be switched so that bed 11 is in the regeneration phase, receiving product from fractionator 20 to desorb contaminants and bed 12 is put into the feed treatment phase with the feed passing from bed 12 to reactors 15A, 15B and 15C. If the reaction in reactors 15 is the olefin/aromatics alkylation reaction, using a mixed refinery olefin/reformate stream as the feed, the contaminant desorption stream will usually be a light stream with a heavier alkylaromatic fraction going to recovered product.

[0020] The guard beds may be operated on the swing cycle with two beds, 11 and 12 as described above. If desired, a purge phase may be added before a regenerated bed is returned to feed treatment although this will not always be necessary since the bed contains at that point only innocuous reaction products which can be recycled to the reaction. A three-bed guard bed system may be used with the two beds used in series for contaminant removal and the third bed on regeneration. With a three guard system used to achieve low contaminant levels by the two-stage series sorption, the beds will pass sequentially through a three-phase cycle of: regeneration, second bed sorption, first bed sorption.

[0021] The compressed fraction from pump 24 may also be sent through branch lines 29A, 29B and 29C to the reactors to rejuvenate the catalysts, as described in co-pending patent application No. 60/ , filed concurrently, (Attorney Docket P2006EM056, PM 2006EE020, entitled "Rejuvenation Process for Olefin Polymerization and Alkylation Catalyst").

Olefin and Aromatic Feeds, Reaction Conditions

[0022] The light olefins and aromatic feeds as well as the actual conditions used for converting them to gasoline boiling range products and the products themselves will be as described in the prior applications referred to above. The conditions used in other alkylaromatics processes will be those appropriate to the selected process and therefore chosen according to conventional criteria. The olefinic feeds are generally obtained from a catalytic cracking unit operating on a hydrocarbon feed such as vacuum gas oil or a resid fraction. The olefins will normally be the light olefins in the FCC off-gas in the range C2 to C4 as the higher olefins will be removed by the fractionation for separate use directly as gasoline. The aromatics will normally be derived from a reformate stream. More extended descriptions of both streams in their application to the production of olefin polymer and alkylaromatic fuels are given in the prior applications such as those described.

[0023] A light olefin stream such as ethylene, propylene, optionally with butylene and possibly other light olefins, is polymerized or reacted with an aromatic compound or compounds to form a gasoline boiling range [C_5 + - 200°C] [C_5+ - 400°F] product. The process is carried out in the presence of a molecular sieve catalyst which is usually a member of the MWW family of zeolites, a family which includes zeolites PSH 3, MCM-22, MCM-49, MCM-56, SSZ 25, ERB-1 and ITQ-1 although other sieves such as ZSM-5 or ZSM-11 may be used, especially in the vapor phase alkylation process described in Serial No. 11/362,255. The term "polymerized" is used here consistent with the petroleum refinery usage although, in fact, the process is one of oligomerization (which term will be used in this specification interchangeably with the conventional term) in which a low molecular weight polymer is the desired product. The process is carried out in a fixed bed of the catalyst, in the case of the

straightforward polymerization process, with feed dilution, normally a hydrocarbon diluent, or added quench to control the heat release which takes place.

[0024] The preferred catalysts used in the present process contain, as their essential catalytic component, a molecular sieve of the MWW type, as described in the prior applications referred to above. In addition, a matrix material or binder in order to give adequate strength to the catalyst as well as to provide the desired porosity characteristics in the catalyst. High activity catalysts may, however, be formulated in the binder-free form by the use of suitable extrusion techniques, for example, as described in U.S. 4,908,120. When used, matrix materials suitably include alumina, silica, silica alumina, titania, zirconia, and other inorganic oxide materials commonly used in the formulation of molecular sieve catalysts. For use in the present process, the level of MCM-22 in a finished matrixed catalyst of the preferred type will be typically from 20 to 70 % by weight, and in most cases from 25 to 65 % by weight. Catalyst formulation techniques are described in the prior applications, to which reference is made for a description of them.

Guard Bed

[0025] The catalyst used in the guard bed may be a reactive material, that is one, which undergoes a surface reaction with the contaminants in the feed stream so as to hold the contaminants on the exterior or interior surfaces of the material. Materials of this kind may conveniently be the same catalyst used in the polymerization or alkylation reactor as a matter of operating convenience but this is not required: if desired another catalyst or sorbent to remove contaminants from the feed may used, typically a cheaper guard bed sorbent, e.g a used catalyst from another process. Alternatively, a non-reactive sorbent such as alumina or silica-alumina may be used. The objective of the guard bed is to

remove the contaminants from the feed before the feed comes to the reaction catalyst and provided that this is achieved, there is wide variety of choice as to guard bed catalysts and conditions useful to this end. The contaminants which are normally encountered are sulfur compounds such as thiols, sulfides, thiophenes and disulfides; in processing light aromatics stream, nitrogen contaminants may also be encountered, for example, nitrogen-based organic species derived from aromatics extraction operations using solvents such as N-methylpyrrolidone (NMP), dimethylformamide (DMF), N-formyl morpholine (NFM) and similar materials. These contaminants may adversely affect catalyst performance and accordingly, should be removed from the feedstream before it encounters the catalyst in the main reactor. The volume of the guard bed will normally not exceed about 20% of the total catalyst bed volume of the unit.

Guard Bed Regeneration

[0026] The guard bed is regenerated at periodic intervals when necessary by switching the on-line bed in the feed treatment phase to regeneration. This can be done by valving in the conventional manner for swing reactor operation. Because the regeneration is carried out using a portion of the product stream, no purging of the feed is necessary before switching to the regeneration phase nor is purging of the regeneration stream necessary before reverting to the feed treatment phase although, if purging is not carried out, care should be taken to see that the contaminants are substantially completely removed from the bed prior to the bed switching.

[0027] The guard bed regeneration is carried out using product from the reactor. Normally, it will be adequate to divert only a portion of the product volume to the guard bed in order to regenerate the bed over an acceptable period of time and so the regeneration gas can be taken as a slip stream from the product stream. A fraction of the product stream will normally be used,

selecting the fraction with the most favorable desorption characteristics for the contaminants which actually become sorbed onto the guard bed material. When the reaction is one of olefin polymerization, without using a reformate co-feed, the regeneration is preferably carried out using a light paraffinic fraction (C4-C6) from the product fractionator since this fraction is reasonably inert and has good desorption characteristics for the most common contaminants sorbed onto zeolite guard beds, e.g. MCM-22 or MCM-49. If the reaction is the aromatic alkylation reaction, the regeneration can be carried out with a light alkylaromatic fraction, for example, the C8-C10 fraction.

[0028] The regeneration is carried out an elevated temperature, typically above ambient with a temperature of at least 100C being customary and usually in the range of 150-300C, preferably 150-250C. High pressures are not necessary and, in fact relatively low pressures may assist desorption. Pressure will therefore normally be in the range of 1000 kPag to 4000 kPag (about 145 to 580 psig) with pressures of 1000 to 2000 kPag (about 145 to 290 psig) being preferred, although in many cases, the pressures imposed by existing equipment will dictate as a practical matter the pressure actually used.

[0029] Space velocity through the bed is not an important factor provided that the regeneration phase is continued long enough to secure the desired degree of contaminant desorption. Normally, the space velocity of the regeneration gas will be in the range of 0.1 to 10 LHSV (hr^{-1}) relative to the volume of the guard bed material and in most cases from 0.5 to 5 LHSV, with velocities of about 0.5 to 2.0 LHSV representing typical operation.

Example

[0030] The efficacy of the contaminant desorption treatment for the guard bed material was demonstrated using a reactive guard bed contained in a 10 mm

diameter microunit containing 2g of an MCM-49 catalyst packed with sand to make up the reactor volume. A feed mixture of benzene and propylene (2.8:1 molar ration benzene: propylene) was passed through the tube held at a temperature of 120°C and a pressure of 2400 kPag (350 psig), using a space velocity of 1.25 WHSV of propylene. From day 1 until day 20, the feed included 200 ppm water and the propylene conversion was at or close to 100% during this time. At day 20, 25 ppmw sulfur was added to the feed as iso-propyl sulfide and in the course of five days, the conversion dropped to about 23-47 percent. On reverting to a clean feed (200 ppmw water), the propylene conversion reverted over about five days to essentially 100 percent. After about 32 days on stream, the feed was changed to a dry feed (less than 10 ppmw water) containing 25 ppmw sulfur as iso-propyl sulfide. The propylene conversion again decreased, to a level of about 31-50%. On removal of the sulfur from the feed at about day 43, the propylene conversion reverted once more to essentially 100 percent.

CLAIMS:

1. A process for regenerating a guard bed of porous solid material used for removing contaminants including sulfur compounds from a feed stream comprising light refinery olefins passing to a reactor containing a fixed bed of a solid, porous, molecular sieve catalyst in which the feed stream is converted to a higher boiling range hydrocarbon products, which comprises desorbing contaminants from the feed which are present on the solid material by passing a stream of hydrocarbon product from the reactor over the guard bed.

2. A process according to claim 1 in which the feed stream is a stream produced by catalytic cracking of a hydrocarbon feed and comprising C3 to C4 olefins.

3. A process according to claim 1 in which the feed stream comprises C3 to C4 olefins produced by catalytic cracking of a hydrocarbon feed and aromatic compounds including benzene.

4. A process according to claim 1 in which the feed stream is passed over a fixed bed of a catalyst comprising an MWW zeolite.

5. A process according to claim 1 in which the guard bed material comprises a molecular sieve capable of reacting with contaminants in the feed stream.

6. A process according to claim 5 in which the guard bed material comprises an MWW zeolite.

7. A process according to claim 1 in which the hydrocarbon from the reactor passed over the guard bed material comprises a light paraffinic stream.

8. A process according to claim 1 in which the hydrocarbon from the reactor passed over the guard bed material comprises alkylaromatic hydrocarbons.

9. A process according to claim 1 in which the guard bed material comprises a molecular sieve capable of reacting with contaminants in the feed stream.

10. A process according to claim 1 in which the stream of hydrocarbon product from the reactor is passed over the guard bed at a temperature of at least 100°C.

11. In a process for converting a feed stream comprising light refinery olefins and including sulfur compounds as contaminants to a gasoline boiling range hydrocarbon product, by passing the feed stream in a reactor over a fixed bed of a solid, porous, molecular sieve catalyst at an elevated temperature, the improvement which comprises the removal of contaminants from the feed stream by passing the feed stream upstream of the reactor over a fixed guard bed of solid, porous material and subsequently desorbing contaminants from the feed which are present on the solid material by passing a stream of hydrocarbon product from the reactor over the guard bed.

12. A process according to claim 1 in which the feed stream is a stream produced by catalytic cracking of a hydrocarbon feed and comprising C3 to C4 olefins.

13. A process according to claim 1 in which the feed stream comprises a stream produced by catalytic cracking of a hydrocarbon feed and comprising C3 to C4 olefins and a reformate stream comprising benzene.

14. A process according to claim 1 in which the feed stream is passed over a fixed bed of a catalyst comprising an MWW zeolite.

15. A process according to claim 1 in which the guard bed material comprises a molecular sieve capable of reacting with contaminants in the feed stream.

16. A process according to claim 5 in which the guard bed material comprises an MWW zeolite.

17. A process according to claim 1 in which the stream of hydrocarbon product from the reactor is passed over the guard bed at a temperature of at least 100°C.

18. A process according to claim 1 in which the stream of hydrocarbon product from the reactor is passed over the guard bed at a temperature of 200-300°C.

19. A process according to claim 11 in which the contaminants are removed feed stream by passing the feed stream upstream of the reactor over a fixed guard bed of the solid, porous material in the first of at least two guard bed vessels connected upstream of the reactor and to an inlet of the reactor and the contaminants are desorbed from the solid, porous material by passing a stream of hydrocarbon product from the reactor over the guard bed material contained in a second of the guard bed vessels.

20. A process according to claim 20 in which the first and second guard beds are operate in a swing system in which the first guard bed vessel is used to remove the contaminants from the feed stream while the contaminants are removed from the guard bed material in the second guard bed vessel by passing the stream of hydrocarbon product from the reactor over the guard bed material contained in the second guard bed vessel.