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HYDROCARBON FEEDSTOCKS USING
PERMUTABLE REACTORS, INCLUDING AT
LEAST ONE STEP OF SHORT-CIRCUITING A
CATALYST BED**(30) **Foreign Application Priority Data**

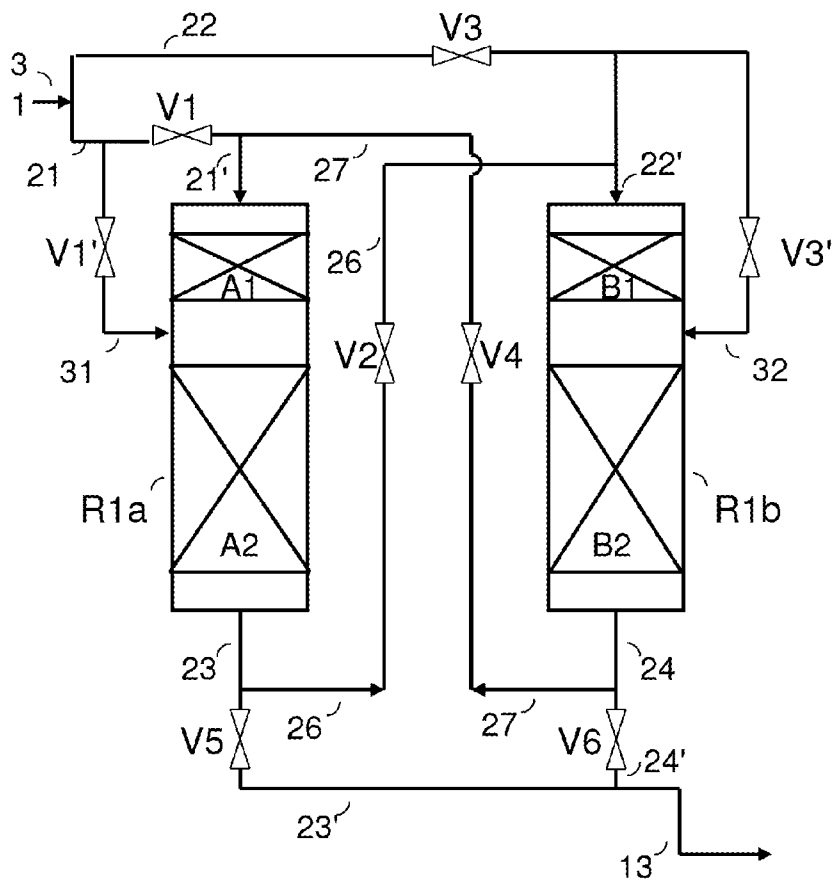
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208/89; 208/97; 422/630; 422/187(75) Inventors: **Frederic Bazer-Bachi**, Irigny (FR);
Christophe Boyer, Charly (FR);
Isabelle Guibard, St Symphorien
D'Ozon (FR); **Nicolas Marchal**, Le
Chesnay (FR); **Cecile Plain**, Saint
Germain En Laye (FR)(73) Assignee: **IFP Energies nouvelles**,
Rueil-Malmaison Cedex (FR)(21) Appl. No.: **13/978,546**(22) PCT Filed: **Dec. 20, 2011**(86) PCT No.: **PCT/FR2011/000668**

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(2), (4) Date: **Sep. 12, 2013**(57) **ABSTRACT**

Process for hydrotreating a heavy hydrocarbon fraction using a system of switchable fixed bed guard zones each containing at least two catalyst beds and in which whenever the catalyst bed that is brought initially into contact with the feed is deactivated and/or clogged during the steps in which the feed passes successively through all the guard zones, the point of introduction of the feed is shifted downstream. The present invention also relates to an installation for implementing this process.



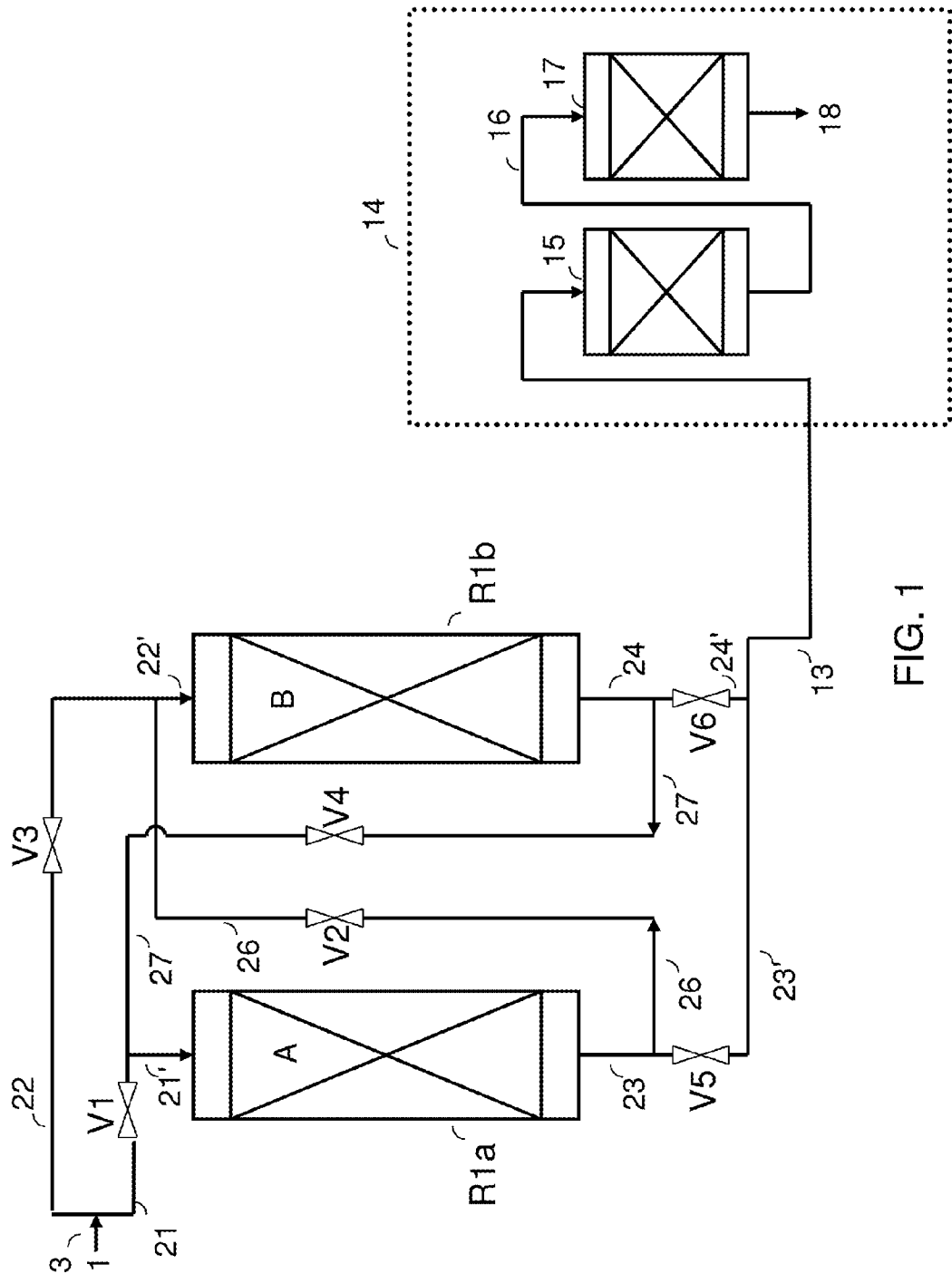


FIG. 1

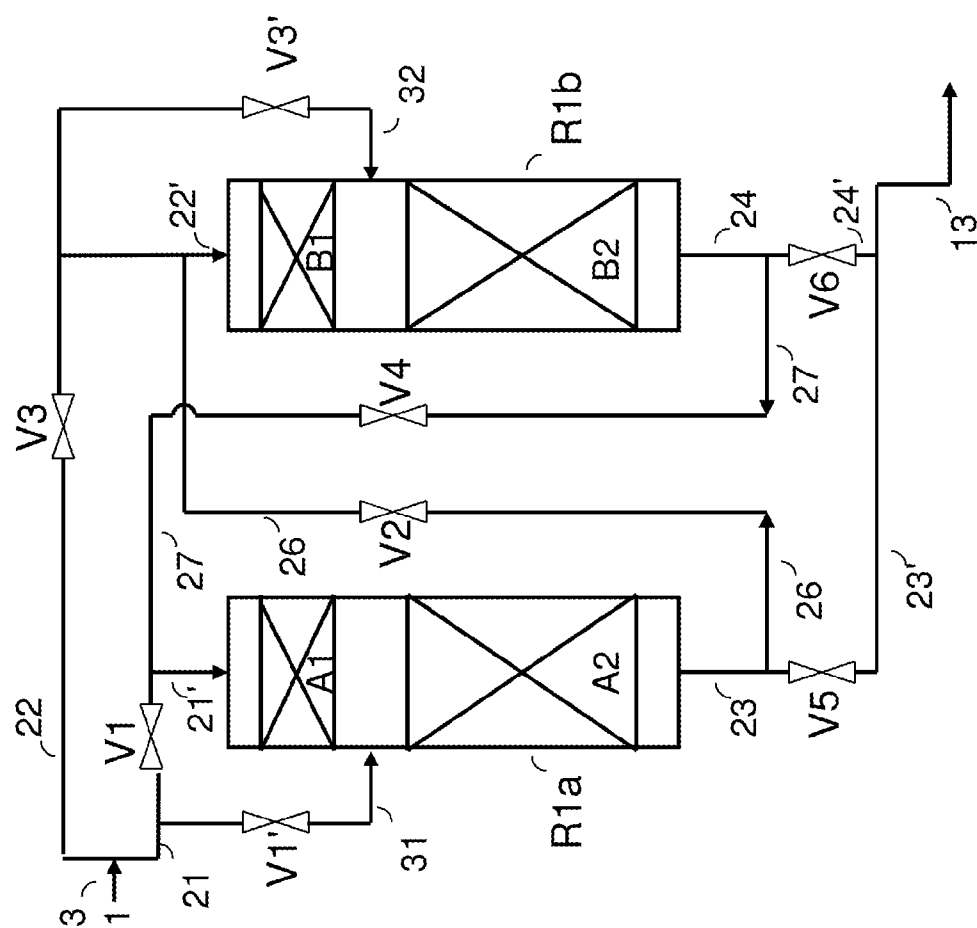


FIG. 2

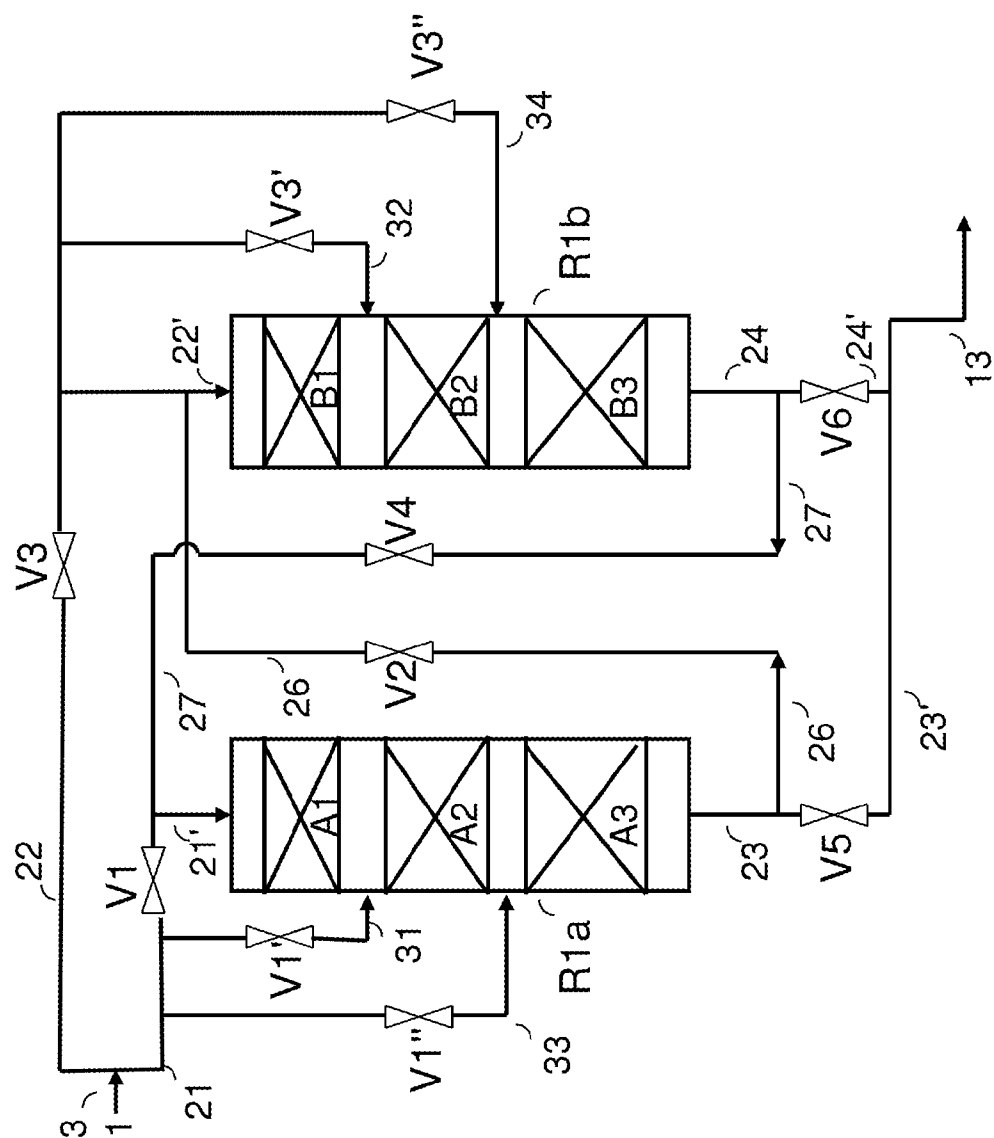


Fig. 3

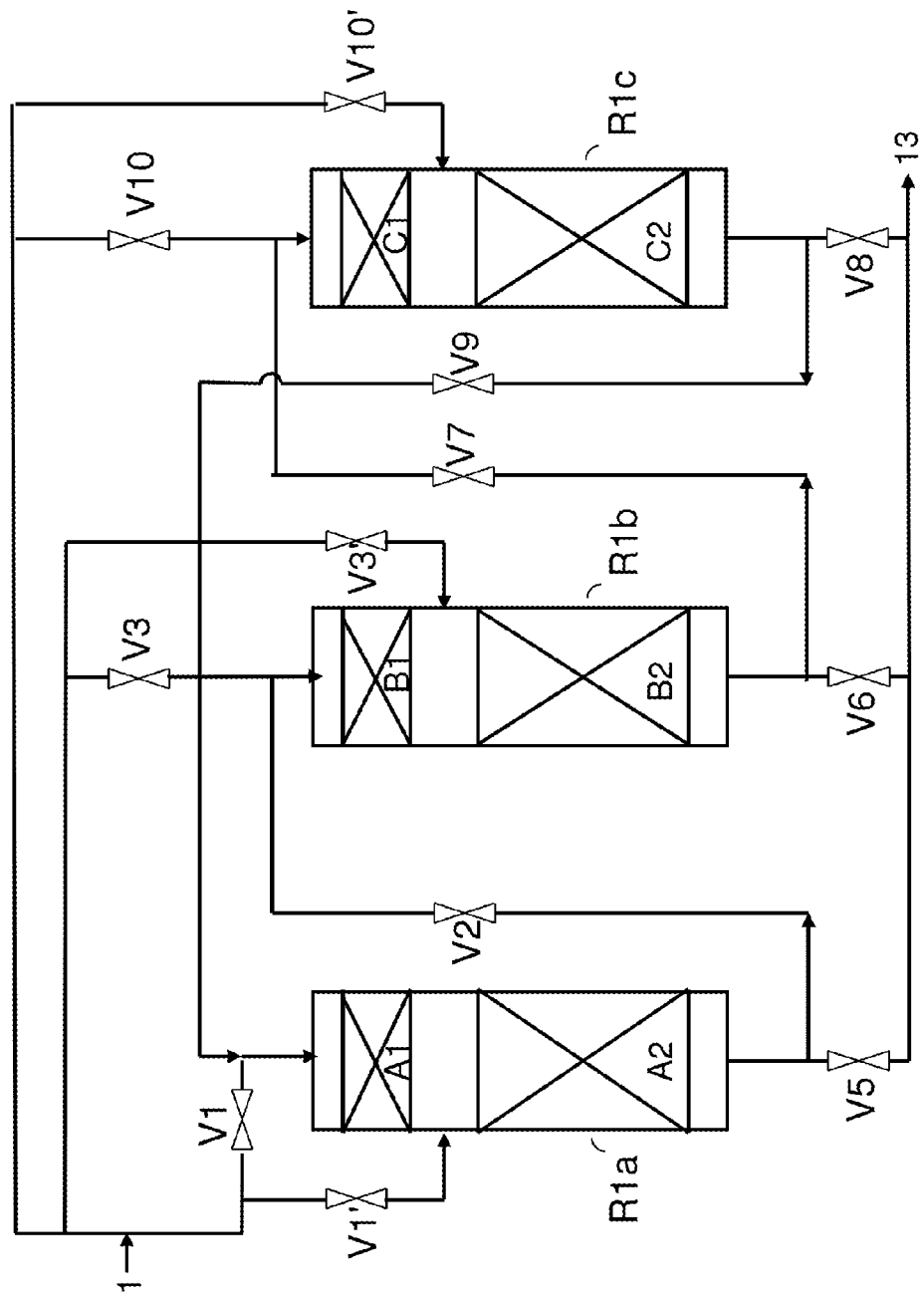


FIG. 4

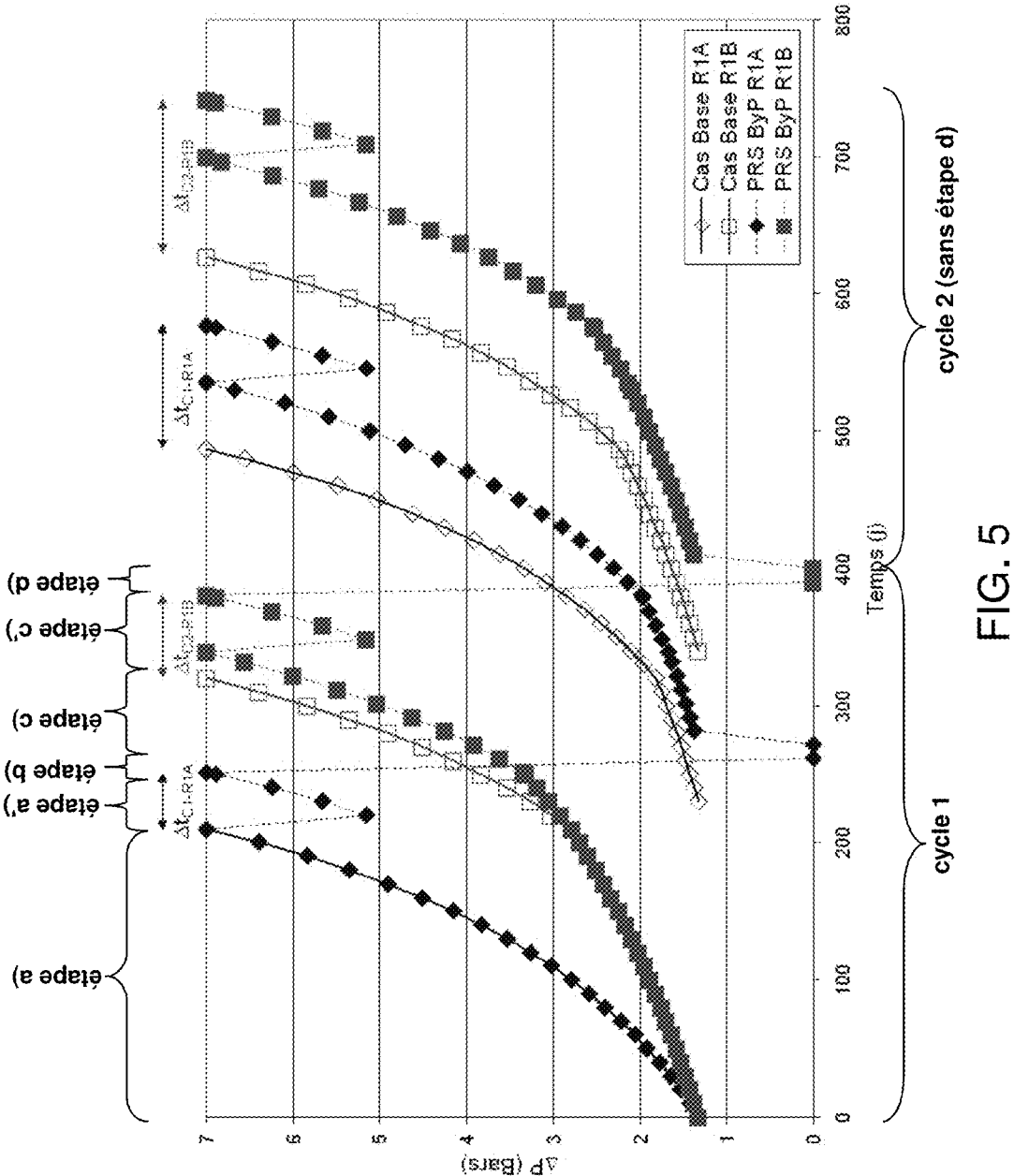


FIG. 5

**METHOD FOR HYDROTREATING HEAVY
HYDROCARBON FEEDSTOCKS USING
PERMUTABLE REACTORS, INCLUDING AT
LEAST ONE STEP OF SHORT-CIRCUITING A
CATALYST BED**

[0001] The present invention relates to a process for hydrotreating a heavy hydrocarbon fraction using a system of switchable fixed bed guard zones each containing at least two catalyst beds and in which whenever the catalyst bed that is brought initially into contact with the feed is deactivated and/or clogged during the steps in which the feed passes successively through all the guard zones, the point of introduction of the feed is shifted downstream. The present invention also relates to an installation for implementing this process.

[0002] Hydrotreating of hydrocarbon feeds is becoming increasingly important in refining practice with the increasing need to reduce the quantity of sulphur in petroleum cuts and to convert heavy fractions to lighter fractions, which can be upgraded as fuels and/or chemical products. It is in fact necessary, in view of the standard specifications imposed by each country for commercial fuels, for imported crudes, which have higher and higher contents of heavy fractions, of heteroatoms and of metals, and lower and lower hydrogen contents, to be upgraded as far as possible.

[0003] Catalytic hydrotreating makes it possible, by bringing a hydrocarbon feed into contact with a catalyst in the presence of hydrogen, to reduce its content of asphaltenes, metals, sulphur and other impurities considerably, while improving the ratio of hydrogen to carbon (H/C) and while transforming it more or less partially into lighter cuts. Thus, hydrotreating (HDT) in particular means reactions of hydrodesulphurization (HDS) by which are meant the reactions for removing sulphur from the feed with production of H_2S , reactions of hydrodenitrogenation (HDN) by which are meant the reactions for removing nitrogen from the feed with production of NH_3 , and reactions of hydrodemetallization by which are meant the reactions for removing metals from the feed by precipitation, but also hydrogenation, hydrodeoxygenation, hydrodearomatization, hydroisomerization, hydrodealkylation and hydro-deasphalting.

[0004] There are two types of hydrotreating process for treating heavy feeds such as atmospheric residues (AR) or vacuum residues (VR): fixed bed processes and ebullating bed processes. Zong et al. (Recent Patents on Chemical Engineering, 2009, 2, 22-36) summarize the various processes known in the treatment of heavy petroleum feeds.

[0005] The technology of the fixed bed processes has found the widest industrial application owing to its technical maturity, lower cost and stable and reliable performance. In these processes, the feed circulates through several fixed bed reactors arranged in series, the first reactor(s) being used in particular for performing hydrodemetallization of the feed (so-called HDM step) as well as a proportion of hydrodesulphurization, the last reactor(s) being used for performing deep refining of the feed (hydrotreating step, HDT), and in particular hydrodesulphurization (so-called HDS step). The effluents are withdrawn from the last HDT reactor.

[0006] The fixed bed processes lead to high performance in refining (production of $370^\circ C.^+$ cuts with less than 0.5 wt. % of sulphur and containing less than 20 ppm of metals) from feed containing up to 5 wt. % of sulphur and up to 300 ppm of metals, in particular nickel and vanadium). The various effluents thus obtained can serve as a basis for the production of

heavy fuel oils of good quality, of gas oil and gasoline, or feeds for other units such as catalytic cracking.

[0007] Beyond this content of metals, it is known that the first catalyst beds can quickly be deactivated because of the considerable deposit of metals that is produced. To compensate for this deactivation, the temperature of the reactor is then increased. However, this increase in temperature promotes the deposition of coke, accelerating the processes of intra-granular clogging (plugging of the catalyst pores) and extra-granular clogging (plugging of the catalyst bed). Beyond these contents of metals in the feed, ebullating bed processes are thus generally preferred. In fact, one problem posed by fixed bed catalytic hydrotreating of these feeds arises because during the hydrotreating reactions of petroleum fractions containing organometallic complexes, most of these complexes are destroyed in the presence of hydrogen, hydrogen sulphide, and a hydrotreating catalyst. The metal constituent of these complexes then precipitates in the form of a solid sulphide, which will adhere to the catalyst. This is particularly so with complexes of vanadium, nickel, iron, sodium, titanium, silicon and copper, which are naturally present in crude oils at a varying level depending on the origin of the petroleum, and which, during the operations of distillation, tend to become concentrated in high boiling point fractions and in particular in residues. In addition to these impurities, coke is also deposited, and together they then tend to deactivate and clog the catalytic system very quickly. These phenomena lead to stoppage of the hydrotreating units for replacing the solids and to an overconsumption of catalyst, which a person skilled in the art wishes to minimize.

[0008] Another problem posed by fixed bed catalytic hydrotreating of these feeds is clogging. It is known that catalyst beds, in particular the upper portions of catalyst beds, and more particularly the upper portions of the first catalyst bed in contact with the feed, are likely to clog quite quickly because of the asphaltenes and sediments contained in the feed, which is manifested firstly by an increase in head loss and sooner or later requires a stoppage of the unit for replacing the catalyst.

[0009] Therefore it becomes necessary to stop the unit in order to replace the first catalyst beds, which are deactivated and/or clogged. The hydrotreating processes for feeds of this type must therefore be designed so as to permit an operating cycle that is as long as possible without stopping the unit.

STATE OF THE ART

[0010] There have been attempts to resolve these drawbacks of the fixed bed arrangements in various ways, in particular by using guard beds installed upstream of the main reactors. The main task of the guard beds is to protect the catalysts of the main HDM and HDT reactors downstream, by performing a proportion of the demetallization and by filtering the particles contained in the feed that can lead to clogging. The guard beds are generally integrated in the HDM section in a process for hydrotreating heavy feeds generally including a first HDM section and then a second HDT section. Although the guard beds are generally used for performing a first hydrodemetallization and a filtration, other hydrotreating reactions (HDS, HDN, etc.) will inevitably take place in these reactors owing to the presence of hydrogen and a catalyst.

[0011] Thus, installation of one or more moving-bed reactors at the head of the HDM step has been considered (U.S. Pat. No. 3,910,834 or GB2124252). The operation of these moving beds can be co-current (SHELL's HYCON process

for example) or counter-current (OCR process of Chevron Lummus Global and the applicant's HYVAHL-M™ process for example).

[0012] Adding a fixed bed guard reactor in front of the HDM reactors has also been considered (U.S. Pat. No. 4,118,310 and U.S. Pat. No. 3,968,026). Most often this guard reactor can be by-passed in particular by using an isolating valve. This provides temporary protection of the main reactors against clogging.

[0013] Moreover, a system has also been described, in particular by the applicant (FR2681871 and U.S. Pat. No. 5,417,846), for combining the high performance of the fixed bed with a high operating factor for treating feeds with high contents of metals, which consists of a hydrotreating process in at least two steps for a heavy hydrocarbon fraction containing asphaltenes, sulphur-containing impurities and metallic impurities, in which, during the first so-called HDM step, the feed of hydrocarbons and hydrogen is passed, under conditions of HDM, over an HDM catalyst, then, during the next, second step, the effluent from the first step is passed, under conditions of HDT, over an HDT catalyst. The HDM step comprises one or more fixed bed HDM zones preceded by at least two guard HDM zones, also called "switchable reactors", also of fixed bed design, arranged in series to be used cyclically consisting of successive repetition of steps b) and c) defined below:

a) a step in which the guard zones are all used together for a period at most equal to the deactivation time and/or clogging time of one of them,

b) a step during which the deactivated and/or clogged guard zone is by-passed and the catalyst that it contains is regenerated and/or replaced with fresh catalyst and during which the other guard zone(s) are used,

c) a step during which the guard zones are all used together, the guard zone of which the catalyst was regenerated during the preceding step being reconnected and said step being continued for a period at most equal to the deactivation time and/or clogging time of one of the guard zones.

[0014] This process, known by the name HYVAHL-F™, can provide an overall desulphurization greater than 90% and an overall demetallization of the order of 95%. The use of switchable reactors permits continuous cyclic operation.

[0015] It has now been discovered, surprisingly, that it is possible to increase the time of use of the switchable reactors before replacement of the catalyst contained in a switchable reactor becomes necessary. The present invention thus improves the performance of switchable reactors as described by the applicant in patent FR2681871 by integrating into this process at least two catalyst beds in each switchable reactor and by integrating into certain steps of the process at least one step of by-passing deactivated and/or clogged catalyst beds, also called a by-pass step.

[0016] In the catalyst beds, clogging occurs a priori in the upper portions of the catalyst beds, and in particular in the upper portions of the first catalyst bed brought into contact with the feed in the direction of flow. The same applies to deactivation of the catalyst (deposition of metals). According to the invention, whenever a catalyst bed is deactivated and/or clogged, this catalyst bed is by-passed and the point of introduction of the feed is shifted relative to this bed downstream onto the next catalyst bed, not yet deactivated and/or clogged, of the same switchable reactor. Thus, by successive by-pass steps of the most clogged and/or deactivated portion(s) of the reactor, the volume of each switchable reactor is fully utilized

until it is exhausted (i.e. until its last catalyst bed is also deactivated and/or clogged), while maintaining the cyclic operation of the switchable reactors. Thus, the bed(s) downstream of the deactivated and/or clogged bed(s) of the same reactor are used for a longer time. This has the effect of increasing the duration of each step of the cycle of the switchable reactors during which the feed passes successively through all the reactors, which provides a longer operating cycle of the switchable reactors.

[0017] This lengthening of the cycle leads to an increase in the operating factor of the unit as well as a saving of time, a reduction of operating costs and a reduction of the consumption of fresh catalyst. The aim of the present application is thus to increase the cycle time of the switchable reactors.

DETAILED DESCRIPTION

[0018] The present invention provides an improvement of the hydrotreating process carried out using guard zones (switchable reactors) as described in patent FR2681871. The operation of the guard zones according to FR2681871 is described in FIG. 1, comprising two guard zones (or switchable reactors) R1a and R1b. This hydrotreating process comprises a series of cycles each comprising four successive steps:

[0019] a first step (called "step a" hereinafter) during which the feed passes successively through reactor R1a, then reactor R1b,

[0020] a second step (called "step b" hereinafter) during which the feed only passes through reactor R1b, reactor R1a being by-passed for catalyst regeneration and/or replacement,

[0021] a third step (called "step c" hereinafter) during which the feed passes successively through reactor R1b, then reactor R1a,

[0022] a fourth step (called "step d" hereinafter) during which the feed only passes through reactor R1a, reactor R1b being by-passed for catalyst regeneration and/or replacement.

[0023] During step a) of the process, the feed is introduced via line 3 and line 21, having an open valve V1, into line 21' and the guard reactor R1a containing a fixed catalyst bed A. During this period, valves V3, V4 and V5 are closed. The effluent from reactor R1a is sent via pipe 23, pipe 26, having an open valve V2, and pipe 22' into the guard reactor R1b containing a fixed catalyst bed B. The effluent from reactor R1b is sent via pipes 24 and 24', having an open valve V6, and pipe 13 to the main hydrotreating section 14.

[0024] During step b) of the process, valves V1, V2, V4 and V5 are closed and the feed is introduced via line 3 and line 22, having an open valve V3, into line 22' and reactor R1b. During this period the effluent from reactor R1b is sent via pipes 24 and 24', having an open valve V6, and pipe 13 to the main hydrotreating section 14.

[0025] During step c), valves V1, V2 and V6 are closed and valves V3, V4 and V5 are open. The feed is introduced via line 3 and lines 22 and 22' into reactor R1b. The effluent from reactor R1b is sent via pipe 24, pipe 27, having an open valve V4, and pipe 21' to the guard reactor R1a. The effluent from reactor R1a is sent via pipes 23 and 23', having an open valve V5, and pipe 13 to the main hydrotreating section 14.

[0026] During step d), valves V2, V3, V4 and V6 are closed and valves V1 and V5 are open. The feed is introduced via line 3 and lines 21 and 21' into reactor R1a. During this period the

effluent from reactor R1a is sent via pipes 23 and 23', having an open valve V5, and pipe 13 to the main hydrotreating section 14.

[0027] The cycle then begins again. The operations on the valves of the unit enabling the functioning of the switchable reactors according to FR2681871 are presented in Table 1.

TABLE 1

Operations on the valves around the switchable reactors according to FR2681871 (without external by-pass)							
Step in Cycle	Intervention	V1	V2	V3	V4	V5	V6
a R1A + R1B	—	O*	O	C**	C	C	O
b R1B	R1A	C	C	O	C	C	O
c R1B + R1A	—	C	C	O	O	O	C
d R1A	R1B	O	C	C	C	O	C
a R1A + R1B	—	O	O	C	C	C	O

*O = open,

**C = closed

[0028] According to the present invention, additional by-pass steps of deactivated and/or clogged catalyst beds (steps a' and c') in the steps of the cycle during which the feed passes successively through the two reactors (steps a) and c)), are added to the process steps as described above.

[0029] More particularly, the present invention relates to a process for hydrotreating a heavy hydrocarbon fraction containing asphaltenes, sediments, sulphur-containing, nitrogen-containing and metallic impurities, in which the feed of hydrocarbons and hydrogen is passed, under conditions of hydrotreating, over a hydrotreating catalyst, in at least two fixed bed hydrotreating guard zones each containing at least two catalyst beds, the guard zones being arranged in series to be used cyclically, consisting of successive repetition of steps b), c) and c') defined below:

[0030] a step a) during which the feed passes through all the catalyst beds of the guard zones for a period at most equal to the deactivation time and/or clogging time of a guard zone,

[0031] a step a') during which the feed is introduced, by-passing the deactivated and/or clogged catalyst bed, onto the next catalyst bed not yet deactivated and/or clogged of the same guard zone for a period at most equal to the deactivation time and/or clogging time of a guard zone, step a') being repeated until the feed is introduced onto the last catalyst bed not yet deactivated and/or clogged of the same guard zone for a period at most equal to the deactivation time and/or clogging time of a guard zone,

[0032] a step b) during which the deactivated and/or clogged guard zone is by-passed and the catalyst that it contains is regenerated and/or replaced with fresh catalyst and during which the other guard zone(s) are used,

[0033] a step c) during which the feed passes through all the catalyst beds of the guard zones, the guard zone of which the catalyst was regenerated during the preceding step being reconnected so as to be downstream of all the other guard zones and said step being continued for a period at most equal to the deactivation time and/or clogging time of a guard zone,

[0034] a step c') during which the feed is introduced onto the next catalyst bed not yet deactivated and/or clogged of the same guard zone for a period at most equal to the deactivation time and/or clogging time of a guard zone,

step c') being repeated until the feed is introduced onto the last catalyst bed not yet deactivated and/or clogged of the same guard zone for a period at most equal to the deactivation time and/or clogging time of a guard zone,

[0035] a step d) during which the deactivated and/or clogged guard zone is by-passed and the catalyst that it contains is regenerated and/or replaced with fresh catalyst and during which the other guard zone(s) are used.

[0036] The guard zones, in particular the first guard zone brought into contact with the feed, gradually become laden with metals, coke, sediments and various other impurities. When the catalyst or catalysts that they contain is/are practically saturated with metals and various impurities, the zones must be disconnected for carrying out replacement and/or regeneration of the catalyst(s). Preferably, the catalysts are replaced. This moment is called the deactivation time and/or clogging time. Although the deactivation time and/or clogging time varies in relation to the feed, the operating conditions and the catalyst(s) used, it is generally manifested by a drop in catalyst performance (an increase in the concentration of metals and/or other impurities in the effluent), an increase in the temperature required for maintaining constant hydrotreating or, in the specific case of clogging, by a significant increase in head loss. The head loss Δp , expressing a degree of clogging, is measured continuously throughout the cycle on each of the zones and can be defined by an increase in pressure resulting from partially blocked passage of the flow through the zone. The temperature is also measured continuously throughout the cycle on each of the two zones. In order to define a deactivation time and/or clogging time, a person skilled in the art first defines a maximum tolerable value of the head loss Δp and/or of the temperature as a function of the feed to be treated, the operating conditions and catalysts selected, and starting from which it is necessary to proceed to by-passing of a catalyst bed or to disconnection of the guard zone. The deactivation time and/or clogging time is thus defined as the time when the limit value of head loss and/or of temperature is reached. As a general rule the limit value of head loss and/or of temperature is confirmed during initial commissioning of the reactors. In the case of a process for hydrotreating heavy fractions, the limit value of head loss is generally between 0.3 and 1 MPa (3 and 10 bar), preferably between 0.5 and 0.8 MPa (5 and 8 bar). The limit value of temperature is generally between 400° C. and 430° C., the temperature corresponding, here and hereinafter, to the average measured temperature of the catalyst bed. Another limit value for the temperatures, indicating that deactivation is reached (lower level of exothermic reactions), is that the temperature difference (ΔT) on a catalyst bed becomes less than 5° C., regardless of the average temperature value.

[0037] FIG. 2 shows the hydrotreating process according to the present invention using a system of two switchable reactors each containing two catalyst beds and in which the catalyst beds can be by-passed. In the case shown in FIG. 2 the process comprises a series of cycles each having six successive steps, steps a), b), c) and d) being identical to the process described in FR2681871:

[0038] a step a) during which the feed passes successively through all the catalyst beds of reactor R1a, then all the catalyst beds of reactor R1b,

[0039] a step a') (by-pass step) during which the feed by-passes the deactivated and/or clogged catalyst bed A1 of the first reactor R1a and is introduced into the next

catalyst bed A2 downstream, then passes through all the catalyst beds of reactor R1b,

[0040] a step b), after deactivation and/or clogging of bed A2, during which the feed passes through all the catalyst beds of reactor R1b only, reactor R1a being by-passed for catalyst regeneration and/or replacement,

[0041] a step c) during which the feed passes successively through all the catalyst beds of reactor R1b, then all the catalyst beds of reactor R1a,

[0042] a step c') (by-pass step) during which the feed by-passes the deactivated and/or clogged catalyst bed B1 of reactor R1b and is introduced into the next catalyst bed B2 downstream, then passes through all the catalyst beds of reactor R1a,

[0043] a step d), after deactivation and/or clogging of bed B2, during which the feed passes through all the catalyst beds of reactor R1a only, reactor R1b being by-passed for catalyst regeneration and/or replacement.

[0044] Thus, at step a) the feed is introduced via line 3 and lines 21 and 21', having an open valve V1, into the guard reactor R1a and passes through the fixed beds A1 and A2. During this period, valves V1', V3, V3', V4 and V5 are closed. The effluent from reactor R1a is sent via pipe 23, pipe 26, having an open valve V2, and pipe 22' to the guard reactor R1b and passes through the catalyst beds B1 and B2. The effluent is removed from reactor R1b via pipes 24 and 24', having an open valve V6, and pipe 13.

[0045] Gradually, the catalyst beds, and in particular the first catalyst bed, on being brought into contact with the feed (A1 of reactor R1a), will become clogged and/or deactivated. The moment when it is considered that the first catalyst bed brought into contact with the feed is deactivated and/or clogged is measured from the head loss Δp and/or temperature of a guard zone. A maximum tolerable value for the head loss and/or temperature from which it is necessary either to by-pass the deactivated and/or clogged catalyst bed, or to proceed with replacement of the catalyst in the reactor, is defined beforehand. Each time that this limit value is reached, the catalyst bed that is clogged and/or deactivated is by-passed by introducing the feed by a by-pass device outside the reactor onto the next catalyst bed not yet deactivated and/or clogged downstream of said reactor.

[0046] Thus, according to FIG. 2, once the maximum value of head loss and/or of temperature is reached, valve V1 is closed and the feed is introduced via line 31, having an open valve V1', onto the next catalyst bed A2 in reactor R1a (step a'). The deactivated and/or clogged catalyst bed A1 is therefore by-passed. Catalyst bed A2 is much less clogged and/or deactivated than the first bed A1, permitting a considerable increase in the length of the first period, by using the lower bed A2 for a longer time.

[0047] Gradually, this next catalyst bed A2 is also clogged and/or deactivated. When the maximum value of head loss and/or of temperature is reached, step b) is then carried out, during which the feed passes through all the catalyst beds of reactor R1b only, reactor R1a being by-passed for catalyst regeneration and/or replacement. Thus, during step b), valves V1, V1', V2, V3', V4 and V5 are closed and the feed is introduced via line 3 and lines 22 and 22', having an open valve V3, into reactor R1b. During this period the effluent from reactor R1b is removed via pipes 24 and 24', having an open valve V6, and via pipe 13.

[0048] After reconnection of reactor R1a, of which the catalyst was regenerated or replaced downstream of reactor

R1b, step c) of the process is then carried out, during which the feed passes successively through reactor R1b, then reactor R1a. Thus, during step c), valves V1, V1', V2, V3' and V6 are closed and valves V3, V4 and V5 are open. The feed is introduced via line 1 and lines 22 and 22' into reactor R1b. The effluent from reactor R1b is sent via pipe 24, pipe 27, having an open valve V4, and pipe 21' to the guard reactor R1a. The effluent from reactor R1a is removed via pipes 23 and 23', having open valve V5, and via pipe 13.

[0049] Gradually, the catalyst beds, and in particular the first bed B1 of reactor R1b, will become clogged and/or deactivated. Then, just as in step a'), by-passing of the deactivated and/or clogged catalyst bed B1, called step c'), is carried out. Thus, according to FIG. 2, once the maximum value of head loss and/or of temperature is reached, valve V3 is closed and the feed is introduced into the reactor via line 32, having an open valve V3', onto the next bed B2 in reactor R1b. The deactivated and/or clogged catalyst bed B1 is therefore by-passed. The catalyst bed B2 is much less clogged and/or deactivated than the first catalyst bed B1, permitting a considerable increase in the length of the third period, by using the lower bed B2 for a longer time.

[0050] Gradually, this next catalyst bed B2 is also clogged and/or deactivated. When the maximum value of head loss and/or of temperature is reached, step d) is then carried out, during which the feed passes through all the catalyst beds of reactor R1a only, reactor R1b being by-passed for catalyst regeneration and/or replacement. During this step valves V1', V2, V3, V3', V4 and V6 are closed and valves V1 and V5 are open. The feed is introduced via line 3 and lines 21 and 21' into reactor R1a. During this period the effluent from reactor R1a is removed via pipes 23 and 23', having open valve V5, and via pipe 13.

[0051] After catalyst regeneration and/or replacement in reactor R1b, this reactor is reconnected downstream of reactor R1a and the cycle begins again.

[0052] The operations on the valves of the unit permitting functioning of the two switchable reactors having two catalyst beds that can be by-passed according to the present invention are presented in Table 2.

TABLE 2

Operations on the valves for the system of switchable reactors with external by-pass (according to the invention)										
Step in Cycle	Intervention	V1	V1'	V2	V3	V3'	V4	V5	V6	
a	R1A + R1B	—	O*	C**	O	C	C	C	C	O
a'	R1A + R1B	—	C	O	O	C	C	C	C	O
b	R1B	R1A	C	C	C	O	C	C	C	O
c	R1B + R1A	—	C	C	C	O	C	O	O	C
c'	R1B + R1A	—	C	C	C	C	O	O	O	C
d	R1A	R1B	O	C	C	C	C	C	O	C
a	R1A + R1B	—	O	C	O	C	C	C	C	O

*O = open,

**C = closed

[0053] The system of switchable reactors with external by-pass can be extended to reactors having more than two catalyst beds, for example 3, 4 or 5 catalyst beds. In this case, the external by-pass feeds, by additional lines and valves, respectively, the next catalyst bed downstream of the deactivated and/or clogged catalyst bed once the maximum value of head loss and/or of temperature is reached. Thus, step a') or c') as defined above is repeated. This by-passing of catalyst beds can continue until the last catalyst bed of the reactor in the

direction of flow is deactivated and/or clogged. It is then necessary to replace the catalyst contained in the reactor. FIG. 3 shows the hydrotreating process according to the present invention using a system of two switchable reactors each containing three catalyst beds A1, A2, A3 and B1, B2 and B3 respectively. In FIG. 3, steps a), a'), b), c) c') and d) (and reference symbols) are identical to FIG. 2, except that steps a') and c') are repeated. This repetition only will be described for this figure.

[0054] Thus, during step a'), once catalyst bed A1, and then catalyst bed A2 are deactivated and/or clogged, valve V1' is closed and the feed is introduced via line 33, having an open valve V1'', onto the next catalyst bed A3 in reactor R1a. When this third bed A3 is also clogged and/or deactivated, step b) (replacement/regeneration of reactor R1a) is then carried out. Similarly, during step c'), once catalyst bed B1, and then catalyst bed B2 are deactivated and/or clogged, valve V3' is closed and the feed is introduced via line 34, having an open valve V3'', onto the next catalyst bed B3 in reactor R1b. When this third bed B3 is also clogged and/or deactivated, step d) (replacement/regeneration of reactor R1b) is then carried out.

[0055] In a preferred embodiment, the catalyst beds contained in a guard zone can be of different or identical volumes but with the condition that the volume of the last bed is greater than each volume of the other beds. Preferably, the catalyst beds in one and the same guard zone have volumes that increase in the direction of flow. In fact, since clogging and/or deactivation occurs mainly on the first catalyst bed, it is advantageous to minimize the volume of this first bed.

[0056] The volume of each bed can be defined as follows:

[0057] Each guard zone has n beds, each bed i having a volume V_i , the total catalyst volume of the reactor V_{tot} being the sum of the volumes V_i of the n beds:

$$V_{tot} = V_1 + \dots + V_i + V_{i+1} + \dots + V_{n-1} + V_n$$

[0058] Each volume V_i of a bed i included in the n-1 first beds of the guard zone is defined between 5% of the total volume V_{tot} and the percentage resulting from the total volume V_{tot} divided by the number of beds n:

$$5\% V_{tot} \leq V_i \leq (V_{tot}/n)$$

[0059] For two consecutive beds i and i+1, the volume of the first bed V_i is less than or equal to the volume of the next bed V_{i+1} , except for the last two consecutive beds V_{n-1} and where the volume of the penultimate bed V_{n-1} is strictly less than the volume of the last bed V_n .

[0060] In the case of two catalyst beds in a guard zone, the volume V1 of the first bed is thus between 5 and 49%, the volume of the second bed is between 51 and 95%.

[0061] In the case of three catalyst beds in a guard zone, the volume V1 of the first bed is thus between 5 and 33%, the volume V2 of the second bed is between 5 and 33% and the volume V3 of the third bed is between 34 and 90%.

[0062] The maximum volume of the by-passed catalyst bed(s) in a guard zone during steps a') and c'), also called "by-passable fraction", is the sum of the volumes $V_1 + \dots + V_i + V_{i+1} + \dots + V_{n-1}$ of the n-1 beds (or the total volume minus the volume of the last bed n). This maximum volume of the by-passed catalyst bed(s) is defined as being less than the percentage expressed by the formula $((n-1) V_{tot})/n$, n being the bed number in a guard zone, V_{tot} being the total catalyst volume of the guard zone.

[0063] Starting from a certain value of by-passed fraction, generally greater than or equal to $((n-1) V_{tot})/n$, the quantity of fouling material and metals accumulated in the last bed of

the first reactor and that accumulated in the second reactor become very similar. Thus, a head loss and/or temperature increase may be observed, reaching the maximum value in the two reactors almost at the same time, and can lead to continuous malfunction of the reactors. It is thus important to have a minimum volume that cannot be by-passed in the first reactor to protect the second reactor and have time to regenerate the first reactor before there is an increase in head loss and/or temperature in the second reactor. In order to maximize the duration of a step during which the feed passes successively through all the reactors, it is therefore beneficial to by-pass a substantial quantity of the reactor, but without exceeding a limit value.

[0064] In a preferred embodiment, a catalyst conditioning section is used, allowing these guard zones to be switched while in operation, i.e. without stopping the operation of the unit: first, a system that operates at moderate pressure (from 10 to 50 bar, but preferably from 15 to 25 bar) allows the following operations to be performed on the disconnected guard reactor: washing, stripping, cooling, before discharging the used catalyst; then heating and sulphurization after loading the fresh catalyst; then another system for pressurization/depressurization, with gate valves of appropriate design, permits efficient switching of these guard zones without stopping the unit, i.e. without affecting its operating factor, since all the operations of washing, stripping, discharge of the used catalyst, loading of the fresh catalyst, heating, and sulphurization are carried out on the disconnected reactor or guard zone. Alternatively, a pre-activity catalyst can be used in the conditioning section so as to simplify the procedure for switching while in operation.

[0065] Each guard zone contains at least two catalyst beds (for example 2, 3, 4, or 5 catalyst beds). Each catalyst bed contains at least one catalyst layer containing one or more catalysts, optionally supplemented with at least one inert layer. The catalysts used in the catalyst bed(s) may be identical or different.

[0066] The hydrotreating process using switchable reactors with external by-pass can thus greatly increase the duration of a cycle. During the by-pass steps the feed has a shorter residence time in the switchable reactors because of the by-pass. In order to maintain a constant degree of hydrotreating at the outlet of the last reactor, the temperature in the guard zones is thus gradually increased. The latter is also increased overall during the cycle to counteract the catalyst deactivation. However, this temperature increase promotes the deposition of coke, accelerating the processes of clogging. Thus, to limit an excessive temperature rise, the by-passed fraction must be all the more restricted. The reactor fraction that is by-passed is thus based on optimization between the gain in cycle time and limited temperature rise.

[0067] According to a preferred variant, at the entrance of each guard zone the feed passes through a filtering distributor plate composed of a single stage or of two successive stages, said plate is situated upstream of the catalyst beds, preferably upstream of each catalyst bed. This filtering distributor plate, described in patent US2009177023, makes it possible to trap the clogging particles contained in the feed by means of a special distributor plate comprising a filtering medium. Thus, the filtering plate makes it possible to increase the gain of cycle time in the hydrotreating process using switchable guard zones. This filtering plate simultaneously provides distribution of the gas phase (hydrogen and the gaseous portion of the feed) and the liquid phase (the liquid portion of the

feed) feeding the reactor while providing a filtration function with respect to the impurities contained in the feed. Moreover, the filtering plate ensures a more uniform distribution of the mixture over the whole surface of the catalyst bed and limits the problems of poor distribution during the phase of clogging of the plate itself.

[0068] More precisely, the filtering plate is a device for filtration and distribution, said device comprising a plate situated upstream of the catalyst bed, said plate consisting of a base that is approximately horizontal and integral with the walls of the reactor and to which approximately vertical chimneys are fixed, open at the top for admission of the gas, and at the bottom for removing the gas-liquid mixture intended to feed the catalyst bed situated downstream, said chimneys being pierced over a certain fraction of their height by a continuous lateral slit or by lateral orifices for admission of liquid, said plate supporting a filtering bed surrounding the chimneys, and said filtering bed consisting of at least one layer of particles of size less than or equal to the size of the particles of the catalyst bed. The filtering bed consists of particles that are generally inert but can also comprise at least one layer of catalyst identical to or belonging to the same family as the catalyst of the catalyst bed. This last-mentioned variant makes it possible to reduce the volume of catalyst beds in the reactor.

[0069] The filtering distributor plate can also comprise two stages and be composed of two successive plates: the first plate supporting a guard bed composed of internal particles and of at least one layer of catalyst identical to or belonging to the same family as the catalyst of the catalyst bed. This plate is described in patent US2009177023. The bed is arranged on a grating, the liquid phase flows through the guard bed and the gas through the chimneys passing through the guard bed and the first plate. At the end of clogging the liquid and the gas flow simultaneously through the chimneys while allowing the second plate to continue to provide its distribution function. The second plate provides the function of distribution of the gas and liquid: it can be composed of chimneys with lateral perforations for passage of the liquid or be composed of bubble-caps or vapour-lift.

[0070] According to another variant, the hydrotreating process according to the present invention can comprise more than two switchable reactors (for example 3, 4 or 5) functioning according to the same principle of switching and by-pass, each switchable reactor having at least two catalyst beds.

[0071] FIG. 4 shows the case of three guard zones each having two catalyst beds. The process will comprise, in its preferred embodiment, a series of cycles each having nine successive steps:

[0072] a step a) during which the feed passes successively through all the catalyst beds of reactor R1a, then all the catalyst beds of reactor R1b and finally all the catalyst beds of reactor R1c,

[0073] a step a') (by-pass step) during which the feed by-passes the deactivated and/or clogged catalyst bed A1 of the first reactor R1a and is introduced into the next catalyst bed A2 downstream of reactor R1a, then passes through all the catalyst beds of reactor R1b and finally all the catalyst beds of reactor R1c,

[0074] a step b) during which the feed passes through all the catalyst beds of reactor R1b, then all the catalyst beds of reactor R1c, reactor R1a being by-passed for catalyst regeneration and/or replacement,

[0075] a step c) during which the feed passes successively through all the catalyst beds of reactor R1b then all the catalyst beds of reactor R1c and finally all the catalyst beds of reactor R1a,

[0076] a step c') (by-pass step) during which the feed by-passes the deactivated and/or clogged catalyst bed B1 of the second reactor R1b and is introduced into the next catalyst bed B2 downstream of reactor R1b, then passes through all the catalyst beds of reactor R1c, and finally all the catalyst beds of reactor R1a,

[0077] a step d) during which the feed passes through all the catalyst beds of reactor R1c, then all the catalyst beds of reactor R1a, reactor R1b being by-passed for catalyst regeneration and/or replacement,

[0078] a step e) during which the feed passes successively through all the catalyst beds of reactor R1c then all the catalyst beds of reactor R1a and finally all the catalyst beds of reactor R1b,

[0079] a step e') (by-pass step) during which the feed by-passes the deactivated and/or clogged catalyst bed C1 of third reactor R1c and is introduced into the next catalyst bed C2 downstream of reactor R1c, then passes through all the catalyst beds of reactor R1a, and finally all the catalyst beds of reactor R1b,

[0080] a step f) during which the feed passes through all the catalyst beds of reactor R1a, then all the catalyst beds of reactor R1b, reactor R1c being by-passed for catalyst regeneration and/or replacement.

[0081] In the case shown schematically in FIG. 4 the process functions in an equivalent manner to that described in connection with FIG. 2 (the reference symbols for the lines have been omitted for reasons of legibility).

[0082] During step a), valves V1, V2, V7 and V8 are open and valves V1', V3, V3', V5, V6, V9, V10 and V10' are closed.

[0083] During step a'), valves V1', V2, V7, V8 are open and valves V1, V3, V3', V5, V6, V9, V10 and V10' are closed.

[0084] During step b), valves V3, V7 and V8 are open and valves V1, V1', V2, V3', V5, V6, V9, V10 and V10' are closed.

[0085] During step c), valves V3, V7, V9 and V5 are open and valves V1, V1', V2, V3', V6, V8, V10 and V10' are closed.

[0086] During step c'), valves V3', V7, V9 and V5 are open and valves V1, V1', V2, V3, V6, V8, V10 and V10' are closed.

[0087] During step d), valves V10, V9 and V5 are open and valves V1, V1', V2, V3, V3', V6, V7, V8 and V10' are closed.

[0088] During step e), valves V10, V9, V2 and V6 are open and valves V1, V1', V3, V3', V5, V7, V8 and V10' are closed.

[0089] During step e'), valves V10', V9, V2 and V6 are open and valves V1, V1', V3, V3', V5, V7, V8 and V10 are closed.

[0090] During step f), valves V1, V2 and V6 are open and valves V1', V3, V3', V5, V7, V8, V9, V10 and V10' are closed.

[0091] The different variants of the process described above for a system of two switchable reactors having two catalyst beds also apply to a system having more than two switchable reactors. These different variants are in particular: the conditioning system, the possibility of having more than two catalyst beds per reactor, the possibility of having beds with different volumes as defined above, the volume of the by-passed catalyst bed(s) in one guard zone being less than $((n-1)V_{tot})/n$, maintaining the degree of hydrotreating by raising the temperature, integration of a filtering plate at the entrance of each reactor upstream of the first catalyst bed, preferably upstream of each catalyst bed.

[0092] The process according to the invention can advantageously be carried out at a temperature between 320° C. and

430° C., preferably 350° C. to 410° C., at a hydrogen partial pressure advantageously between 3 MPa and 30 MPa, preferably between 10 and 20 MPa, at a space velocity (HSV) advantageously between 0.05 and 5 volumes of feed per volume of catalyst and per hour, and with a ratio of hydrogen gas to liquid hydrocarbon feed advantageously between 200 and 5000 normal cubic metres per cubic metre, preferably 500 to 1500 normal cubic metres per cubic metre. The value of HSV of each switchable reactor in operation is preferably from about 0.5 to 4 h⁻¹ and most often from about 1 to 2 h⁻¹. The overall value of HSV of the switchable reactors and that of each reactor is selected so as to achieve maximum HDM while controlling the reaction temperature (limiting the exothermic effect).

[0093] The hydrotreating catalysts used are preferably known catalysts and are generally granular catalysts comprising, on a support, at least one metal or metal compound having a hydro-dehydrogenating function. These catalysts are advantageously catalysts comprising at least one group VIII metal, generally selected from the group comprising nickel and/or cobalt, and/or at least one group VIB metal, preferably molybdenum and/or tungsten. The support used is generally selected from the group comprising alumina, silica, silica-aluminas, magnesia, clays and mixtures of at least two of these minerals.

[0094] Prior to injection of the feed, the catalysts used in the process according to the present invention are preferably subjected to a sulphurization treatment for transforming, at least partly, the metallic species to sulphide before they are brought into contact with the feed to be treated. This treatment of activation by sulphurization is well known to a person skilled in the art and can be carried out by any method already described in the literature, either in situ, i.e. in the reactor, or ex situ.

[0095] The feeds treated in the process according to the invention are advantageously selected from atmospheric residues, vacuum residues from direct distillation, crude oils, topped crude oils, deasphalted oils, residues from conversion processes such as for example those originating from coking, from fixed-bed, ebullating-bed, or moving-bed hydroconversion, heavy oils of any origin and in particular those obtained from oil sands or oil shale, used alone or mixed. These feeds can advantageously be used as they are or diluted with a hydrocarbon fraction or a mixture of hydrocarbon fractions that can be selected from the products obtained from a fluid catalytic cracking (FCC) process, a light cut of oil (Light Cycle Oil, LCO), a heavy cut of oil (Heavy Cycle Oil, HCO), a decanted oil (DO), a residue from FCC, or that can be obtained from distillation, the gas oil fractions, in particular those obtained by vacuum distillation (Vacuum Gas Oil, VGO). The heavy feeds can also advantageously comprise cuts obtained from the coal liquefaction process, aromatic extracts, or any other hydrocarbon cuts or also non-petroleum feeds such as gaseous and/or liquid derivatives (containing little if any solids) from thermal conversion (with or without catalyst and with or without hydrogen) of coal, biomass or industrial waste, such as for example recycled polymers.

[0096] Said heavy feeds generally have more than 1 wt. % of molecules having a boiling point above 500° C., a content of metals Ni+V above 1 ppm by weight, preferably above 20 ppm by weight, a content of asphaltenes, precipitated in heptane, above 0.05 wt. %, preferably, above 1 wt. %.

[0097] The hydrotreating process according to the invention makes it possible to effect 50% or more of HDM of the

feed at the outlet of the switchable reactors (and more precisely from 50 to 95% of HDM) owing to the HSV selected and the efficiency of the HDM catalyst.

[0098] The hydrotreating process according to the invention using the system of switchable guard zones including at least one by-pass step advantageously precedes a fixed bed or ebullating bed process for hydrotreating heavy hydrocarbon feeds.

[0099] Preferably, it precedes the applicant's Hyvahl-FTTM process comprising at least one hydrodemetallization step and at least one hydrodesulphurization step. The process according to the invention is preferably integrated upstream of the HDM section, the switchable reactors being used as guard beds. In the case shown in FIG. 1, the feed 1 enters the switchable guard reactor(s) via pipe 1 and leaves said reactor (s) via pipe 13. The feed leaving the guard reactor(s) enters, via pipe 13, the hydrotreating section 14 and more precisely the HDM section 15 comprising one or more reactors. The effluent from the HDM section 15 is withdrawn via pipe 16, and then sent to the HDT section 17 comprising one or more reactors. The final effluent is withdrawn via pipe 18.

[0100] The present invention also relates to an installation (FIG. 2) for implementing the process according to the invention comprising at least two fixed bed reactors (R1a, R1b) arranged in series and each containing at least two catalyst beds (A1,A2; B1,B2), the first bed of each reactor having at least one inlet pipe for a gas (not shown) and an inlet pipe for a hydrocarbon feed (21, 22), said inlet pipes for the feed each containing a valve (V1, V3) and being connected by a common pipe (3), each reactor having at least one outlet pipe (23, 24) each containing a valve (V5, V6) for removal of the effluent, the outlet pipe of each reactor (23, 24) being connected by an additional pipe (26, 27) having a valve (V2, V4) to the inlet pipe (22, 21) of the feed of the reactor downstream, characterized in that the installation further comprises, for each reactor, a feed inlet pipe for each catalyst bed (31, 32), said pipes each having a valve (V1', V3') and being connected to said inlet pipe for the hydrocarbon feed of the first bed (21, 22), and each valve of the installation being able to be opened or closed separately.

[0101] According to a preferred variant, the installation comprises a filtering distributor plate composed of a single stage or of two successive stages at the entrance of each reactor, situated upstream of the catalyst beds, preferably upstream of each catalyst bed.

Example 1

Not According to the Invention

[0102] The feed consists of a mixture (70/30 wt. %) of atmospheric residue (AR) of Middle East origin (Arabian Medium) and of a vacuum residue (VR) of Middle East origin (Arabian Light). This mixture is characterized by a high viscosity (0.91 cP) at ambient temperature, a density of 994 kg/m³, high contents of Conradson carbon (14 wt. %) and asphaltenes (6 wt. %) and a high level of nickel (22 ppm by weight), vanadium (99 ppm by weight) and sulphur (4.3 wt. %).

[0103] The hydrotreating process is carried out according to the process described in FR2681871 and comprises the use of two switchable reactors. The two reactors are loaded with a CoMoNi/alumina hydrodemetallization catalyst. A cycle is defined as integrating the steps from a) to d). The deactivation time and/or clogging time is reached when the head loss

reaches 0.7 MPa (7 bar) and/or the average temperature of a bed reaches 405° C. and/or when the temperature difference on a catalyst bed becomes less than 5° C.

[0104] The process is carried out at a pressure of 19 MPa, a temperature at reactor inlet at the start of the cycle of 360° C. and at the end of the cycle of 400° C., and an HSV=2h⁻¹ per reactor, allowing a degree of demetallization close to 60% to be maintained.

[0105] Table 3 and FIG. 5 show the operating time (in days) for the process according to FR 2681871 (without by-pass). Thus, according to FIG. 5, the curve of reactor R1a according to the state of the art (base case R1a) shows, at the start of the cycle, an increase of head loss in the first reactor R1a up to its maximum tolerable value ($\Delta p=0.7$ MPa or 7 bar), after which catalyst replacement is required. In the case of the state of the art (FR268187), the operating time of reactor R1a is therefore 210 days. At the time of replacement of the catalyst of reactor R1a, the head loss in reactor R1b reached about 3 bar. During the next phase in which the feed passes through reactor R1b and then reactor R1a containing fresh catalyst, the head loss of reactor R1b increases up to the maximum tolerable value, which is reached after 320 days of operation. A second cycle can be envisaged on these switchable reactors, replacing the catalyst of reactor R1b.

[0106] The deactivation time and/or clogging time (or the operating time) of the first zone is therefore 210 days. Overall, a cycle time of 320 days for the first cycle and of 627 days for two cycles is observed.

Example 2

According to the Invention

[0107] The hydrotreating process is repeated with the same feed and under the same operating conditions and with the same catalyst according to example 1, except that the process comprises the use of two switchable reactors, each reactor containing two catalyst beds, the first catalyst bed representing a volume of 20%, and the second representing a volume of 80% (by-pass of 20%), and the process according to the invention is carried out. A cycle is defined as integrating the steps from a) to d). The deactivation time and/or clogging time is reached when the head loss reaches 0.7 MPa (7 bar) and/or the average temperature of a bed reaches 405° C. and/or when the temperature difference on a catalyst bed becomes less than 5° C. The degree of HDM is maintained at 60%.

[0108] Table 3 and FIG. 5 show the gain in operating time (in days) for the process according to the invention with a by-passed fraction of 20% in each reactor.

TABLE 3

Gain in operating time (days) without external by-pass (according to FR2681871) and with a by-pass of 20% in each reactor.		
Case	Base (by-pass 0%) (not according to the invention)	By-Pass 20% (according to the invention)
Duration R1-A Cycle 1	210 d	252 d
Duration R1-B Cycle 1	320 d	380 d
Total gain End 1 cycle	—	60 d
Duration R1-A Cycle 2	487 d	577 d
Duration R1-B Cycle 2	627 d	741 d
Total gain End 2 cycles	—	114 d

[0109] It can therefore be seen that the hydrotreating process integrating a by-passed fraction of 20% makes it possible

to increase the duration of a first cycle by 60 days (i.e. by 18.75%) and by 114 days for two cycles (i.e. by 18.2%) while maintaining a degree of HDM of 75%, equivalent to the degree of HDM according to the process without external by-pass.

[0110] FIG. 5 shows the variation of head loss during the time measured in reactors R1a and R1b without external by-pass (according to FR2681871, curves for the Base Cases R1a and R1b) and in reactors R1a and R1b with an external by-pass of 20% (according to the invention, curves PRS ByP R1a and R1b).

[0111] Thus, according to FIG. 5, the curve of reactor R1a (curve PRS ByP R1a) shows, at the start of the cycle, an increase of head loss in the first reactor R1a up to its maximum tolerable value ($\Delta p=0.07$ MPa or 7 bar). When this value is reached, the first bed is by-passed and the feed is introduced onto the second bed A2 of reactor R1a. The head loss in the reactor then drops suddenly (hook in curve PRS ByP R1a), without returning to the initial head loss, to gradually increase again up to the point where the next (second) bed is clogged and the limit value of the head loss is reached again. The gain in time obtained at the end of step a') is then Δt_{C1-R1a} (32 days). The head loss of reactor R1a then drops abruptly because the system passes to step b), during which the catalyst of reactor R1a is replaced. The feed then only passes through reactor R1b, and then R1b and R1a after replacement.

[0112] Curve R1b (curve PRS ByP R1b) shows the head loss of the second reactor R1b as a function of time. The same phenomenon of gain of time by external by-pass is observed at the end of step c'): Δt_{C2-R1b} (60 days).

[0113] FIG. 2 also shows a second cycle of switchable reactors. The gain of time after 2 successive cycles is then Δt_{C2-R1b} (114 days). It can be seen that the more cycles there are, the larger the gain of time.

1. Process for hydrotreating a heavy hydrocarbon fraction containing asphaltenes, sediments, sulphur-containing, nitrogen-containing and metallic impurities, in which the feed of hydrocarbons and hydrogen is passed, under conditions of hydrotreating, over a hydrotreating catalyst, in at least two fixed bed hydrotreating guard zones each containing at least two catalyst beds, the guard zones being arranged in series to be used cyclically, consisting of successive repetition of steps b), c) and c') defined below:

- a step a) during which the feed passes through all the catalyst beds of the guard zones for a period at most equal to the deactivation time and/or clogging time of a guard zone,
- a step a') during which the feed is introduced, by-passing the deactivated and/or clogged catalyst bed, onto the next catalyst bed not yet deactivated and/or clogged of the same guard zone for a period at most equal to the deactivation time and/or clogging time of a guard zone, step a') being repeated until the feed is introduced onto the last catalyst bed not yet deactivated and/or clogged of the same guard zone for a period at most equal to the deactivation time and/or clogging time,
- a step b) during which the deactivated and/or clogged guard zone is by-passed and the catalyst that it contains is regenerated and/or replaced with fresh catalyst and during which the other guard zone(s) are used,
- a step c) during which the feed passes through all the catalyst beds of the guard zones, the guard zone of which the catalyst was regenerated during the preceding step

being reconnected so as to be downstream of all the other guard zones and said step being continued for a period at most equal to the deactivation time and/or clogging time of a guard zone,

a step c') during which the feed is introduced onto the next catalyst bed not yet deactivated and/or clogged of the same guard zone for a period at most equal to the deactivation time and/or clogging time of a guard zone, step c') being repeated until the feed is introduced onto the last catalyst bed not yet deactivated and/or clogged of the same guard zone for a period at most equal to the deactivation time and/or clogging time of a guard zone.

2. Process according to claim 1 in which each guard zone has n beds, each bed i having a volume V_i , the total catalyst volume of the guard zone V_{tot} being the sum of the volumes V_i of the n beds; each volume V_i of a bed i included in the $n-1$ first beds of the guard zone has a volume V_i defined between 5% of the total volume V_{tot} and the percentage resulting from the total volume V_{tot} divided by the number of beds n ; and in which for two consecutive beds i and $i+1$, the volume of the first bed V_i is less than or equal to the volume of the next bed V_{i+1} , except for the last two consecutive beds V_{n-1} and V_n where the volume of the penultimate bed V_{n-1} is strictly less than the volume of the last bed V_n .

3. Process according to claim 1 in which during steps a') and c') the maximum volume of the by-passed catalyst bed(s) in a guard zone is defined as less than the volume given by the formula $((n-1) V_{tot})/n$, n being the total number of catalyst beds, V_{tot} being the total catalyst volume of the guard zone which is defined by the sum of the volumes of the n catalyst beds of the guard zone.

4. Process according to claim 1 in which the degree of hydrotreating is maintained by a temperature increase.

5. Process according to claim 1 in which, at the entrance of each guard zone, the feed passes through a filtering distributor

plate composed of a single stage or of two successive stages, said plate is situated upstream of the catalyst beds.

6. Process according to claim 1 in which the feed passes through a filtering distributor plate upstream of each catalyst bed of a guard zone.

7. Process according to claim 1, characterized in that it precedes a fixed bed or ebullating bed hydrotreating process.

8. Installation for implementing the process according to claim 1 comprising at least two fixed bed reactors (R1a, R1b) arranged in series and each containing at least two catalyst beds (A1, A2; B1, B2), the first bed of each reactor having at least one inlet pipe for a gas and an inlet pipe for a hydrocarbon feed (21, 22), said feed inlet pipes each containing a valve (V1, V3) and being connected by a common pipe (3), each reactor having at least one outlet pipe (23, 24) each containing a valve (V5, V6) for removal of the effluent, the outlet pipe of each reactor (23, 24) being connected by an additional pipe (26, 27) having a valve (V2, V4) to the feed inlet pipe (22, 21) of the reactor downstream, characterized in that the installation further comprises, for each reactor, a feed inlet pipe for each catalyst bed (31, 32), said pipes each having a valve (V1', V3') and being connected to said inlet pipe for the hydrocarbon feed of the first bed (21, 22), each valve of the installation being able to be opened or closed separately.

9. Installation according to claim 8, characterized in that it comprises a filtering distributor plate composed of a single stage or of two successive stages at the entrance of each reactor, said plate is situated upstream of the catalyst beds.

10. Installation according to claim 8, characterized in that it comprises a filtering distributor plate composed of a single stage or of two successive stages upstream of each catalyst bed.

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