VERIFICATION OF TRANSLATION

I, Dr Lesley Margaret Stone, of Silver Creek House, Lhergy Cripperty, Union Mills, Isle of Man IM4 4NJ, British Isles, hereby declare as follows:

1. I am a translator and am familiar with both the French and English languages.

2. I am the translator of the documents attached hereto and certify that the following is a true translation to the best of my knowledge and belief of the Official Copy dated 2nd November 2012 of French patent application number 12/01009 filed on 4th April 2012.

Dated this 20th day of March, 2013

Signature of translator

CATALYTIC REACTOR WITH QUENCH DEVICE PROVIDED WITH TANGENTIAL INJECTION OF A QUENCH FLUID

The present invention relates to the field of fixed bed type catalytic reactors, which are used in hydrocarbon feed hydrotreatment operations. The invention describes a system for injection of a quench fluid into the reactor.

Catalytic reactors are used in particular in the oil and petrochemicals industry to treat hydrocarbon effluents by hydrotreatment. Such reactions react carbon-containing compounds with hydrogen in hydrogenation, hydrodesulphurization, hydrodenitrogenation, hydrocracking or hydrodearomatization reactions.

A catalytic reactor is generally composed of a cylindrically-shaped enclosure comprising one or more catalytic beds, i.e. a bed of solids, for example with extruded or spherical shapes, which act to catalyze the hydrotreatment reaction. The reactor is supplied overhead with a reaction fluid composed of hydrocarbon effluent and hydrogen.

The exothermic nature of the hydrotreatment reactions carried out in refining and petrochemicals processing necessitates dividing the volume of solid catalyst into several beds, and of injecting cold fluid in order to cool the reaction medium and supply the reactor with reactants. The injected fluid may be a liquid, in general a hydrocarbon cut, or a gas, for example hydrogen, depending on the application. The cold fluid is introduced into the reactor at a device termed a quench box. Quench box technology is principally aimed at mixing hot fluids coming from the upper bed with injected cold fluid. Once the fluids have been mixed, they are redistributed over the section of the reactor by a distribution device before penetrating into the catalytic bed located underneath the distribution plate.

Documents US 5 837 208 and WO 2004/041426 supply examples of quench devices based on collecting hot fluids, injecting cold fluid via a straight injection pipe into the collecting region

located immediately above the collector plate, passing fluids into a quench box, and discharging fluids directly above a distribution plate.

Documents US 2002/0039547, FR 2 824 495, US 6 180 068 and US 2004/0037759 describe quench boxes in which a rotational flow is generated in order to promote mixing. The rotational flow is frequently conditioned by the manner in which the collected fluids enter the quench device.

Documents US 5 403 560 and US 2010/0303685 propose causing rotational flow of a fluid over the collector plate, upstream of passing into the quench box. In those examples, the rotational flow is generated by a particular geometry of the collector plates, for example by means of spiral-shaped elements positioned to force the flow to turn over the collector plate before returning to the quench box. However, positioning inserts or baffles in a spiral turns out to be voluminous and bulky in the reactor.

Document US 2004/0234434 presents a quench device in which a rotational flow is generated over the collector plate. The flow is generated by injecting cold fluid by means of a circular injection pipe in the form of a torus comprising a plurality of outlet conduits. The jets of cold fluid are directed outwardly with respect to the axis of the reactor in order to induce a rotational flow. However, the injection pipe is bulky and mechanically difficult to install and maintain in a reactor.

Document US 2011/0123410 describes a quench device in which a rotational flow is generated downstream of the quench box. The outlet from the quench box is positioned above a perforated plate so as to generate a rotational flow.

The aim of the invention is to improve mixing of quench fluid with the hot fluids by positioning the fluid injection pipe at the periphery of the reactor at the level of the collector plate so as to generate a rotational flow over the plate. The present invention proposes using a bent injection pipe discharging above the collector plate close to the reactor enclosure and producing a jet the direction of which is substantially tangential to the enclosure of the reactor in order to produce a rotational movement of fluid over the collector plate in a simple, effective manner.

The present invention describes a catalytic reactor comprising an enclosure comprising at least two beds of solid catalyst separated by an intermediate zone comprising a collector plate cooperating with a quench box disposed below the collector plate. The reactor comprises a nozzle for injecting a quench fluid, the nozzle being disposed in a collecting region located in the intermediate zone above the collector plate. The reactor is characterized in that the end of the injection nozzle comprises a tubular portion configured so as to inject the quench fluid into the collecting region in a substantially horizontal direction and forming an angle in the range -10° to +10° with respect to the direction tangential to the wall of the enclosure at the level of said tubular portion.

In accordance with the invention, the nozzle may comprise a single orifice discharging into the collecting region, the orifice being located at the end of the nozzle.

The nozzle may discharge at the wall of the enclosure so as to inject a fluid in a direction forming an angle in the range -10° to +10° with respect to the horizontal direction.

The end of the injection nozzle may be composed of a straight tubular portion forming an angle in the range -10° to +10° with respect to the direction tangential to the wall of the enclosure at the level of the nozzle orifice.

The straight tubular portion may form an angle in the range -10° to +10° with respect to the horizontal direction.

The nozzle may form a tube with a length in the range 5 cm to 50 cm, measured in the collecting region.

The nozzle may be disposed at a distance of less than 40 cm from the enclosure and at a distance of less than 20 cm from the collector plate.

The reactor may comprise a distributor plate for gas and liquid disposed beneath the quench box.

The reactor may comprise a perforated plate disposed between the quench box and the distributor plate.

The invention also describes the use of a reactor in accordance with the invention, in which a fluid can be injected via said nozzle comprising at least 70% by volume of liquid. In addition, a fluid can be injected via said nozzle at a rate in the range 1 to 15 m/s.

The invention also describes a method for obtaining a reactor in accordance with the invention, in which an existing reactor is revamped by replacing the old nozzle with an injection nozzle the end of which comprises a tubular portion configured so as to inject the fluid into the collecting region in a substantially horizontal direction and forming an angle in the range -10° to +10° with respect to the direction tangential to the wall of the enclosure at said tubular portion.

The device of the invention can be used to obtain excellent performances for the mixture, as will be illustrated below in the examples.

Further, the injection pipe of the invention has reduced bulk compared with prior art solutions, in particular compared with the device described in document US 2004/0234434. Thus, mechanical assembly of the injection pipe on the plate is easy, and costs are moderate. In addition, the height of the collecting region above the collector plate may be reduced as a result. As a consequence, for the same internal volume of a reactor, implementing the present invention means that the volume of solid catalyst can be increased.

Further, the present invention may be deployed in existing facilities. In particular, the present invention can advantageously be used to replace a straight injection pipe quench device in order to improve its quench performance. In addition, by modifying the position of the screen supporting the bed of solid catalyst, it is possible to reduce the collecting region and thus gain volume, which can then be utilized in carrying out the reaction.

Further characteristics and advantages of the invention will be better understood and will become clear from the following description made with reference to the accompanying drawings in which:

- Figures 1, 2, 2A and 2B illustrate a quench device in a reactor in accordance with the invention;

- Figures 3 and 4 show two quench devices in accordance with the prior art;
- Figure 5 represents the performance graphs of a quench device of the invention and two prior art quench devices.

Figure 1 represents a portion of a reactor in which a hydrotreatment reaction is carried out. The reactor is composed of an enclosure 1 comprising at least one bed of solid catalyst 2. The enclosure 1 may be in the shape of a cylinder closed at its ends. In general, the axis of the cylinder is orientated in the vertical direction. As an example, the cylinder may have a diameter in the range 1 to 10 metres and a height in the range 3 to 20 metres. The upper portion of the reactor is supplied with reaction fluid composed of a gas and a liquid, for example a feed of liquid hydrocarbons and gaseous hydrogen. The reaction fluid flows in a downward vertical direction in enclosure 1, in particular under gravity. In other words, the gas and the liquid flow as a co-current from the top to the bottom of the reactor. The reaction between the reactants is catalyzed by a solid catalyst which may be in the form of extrudates or beads disposed between two screens in order to form a bed which extends in general over the whole horizontal section of the internal volume of the enclosure. Because the reaction is exothermic, the volume of solid catalyst is divided into a plurality of beds. In Figure 1, two beds 2 and 11 of solid catalysts are shown.

The bed 2 of solid catalyst is placed on a layer 3 of inert solid grains usually known as grading. The layer 3 is supported by a screen. An empty region 4 is located between the screen supporting the layer 3 and the collector plate 6. The gas and the liquid flowing through the bed 2 discharge into the empty region 4 which will hereinafter be known as the collecting region. The collector plate 6 can be used to collect the liquid and gas coming into the collecting region 4. As an example, the collector plate is a horizontal disk which covers the internal section of the enclosure 1.

In accordance with the invention, an injection pipe 5, also known as an injection nozzle, can be used to introduce cold fluid from the outside of the reactor into the collecting region 4. The pipe 5 is composed of a portion of tube which opens into the collecting region 4. Preferably, the tube

comprises a single outlet orifice in the region 4, this orifice being located at the level of the end of the tube.

Figure 2 represents a view of the reactor of Figure 1 in the section AA'. The shape and possibly the dimensions of the tube forming the pipe 5 are selected such that the direction of the jet of fluid at the outlet from the pipe is in a substantially horizontal direction substantially tangential to the wall of the enclosure 1. Figures 2A and 2B represent two forms of pipe 5 in accordance with the invention. As an example, referring to Figure 2A, the end of the pipe is in the shape of a tube, for example a straight tube, i.e. extending in a straight direction. As an example, the pipe may be in the form of a cylinder with a circular section or in the form of a truncated cone. As an example, the end of the pipe 5 may be a cylinder with a circular section with a diameter D. Alternatively, referring to Figure 2B, the pipe 5 may be in the form of a tube the axis of which is curved. As an example, the pipe 5 is a tube with a circular section with a constant diameter D, the axis 16 of the tube forming a circular arc which is concentric with the circular described by the enclosure 1 in a horizontal plane.

The pipe 5 is dimensioned so as to direct the cold fluid in a direction substantially tangential to the wall of the enclosure 1. Referring now to Figures 2A and 2B, the end of the pipe 5 is formed by a tube portion which extends in the straight line 14. The direction tangential to the wall of the enclosure 1 at the level of the outlet orifice from the pipe 5 is represented by the straight line 15. As an example, in accordance with the invention, the direction of the jet of fluid obtained from the pipe is substantially tangential to the inner surface of the wall of the enclosure 1 at the outlet, i.e. the direction of the jet forms an angle θ in the range -10° to +10°, preferably in the range -5° to +5° with respect to the tangent to the inner surface of the enclosure 1 at the outlet from the pipe 5, i.e. with respect to the straight line 15.

In addition, the pipe 5 is dimensioned in order to direct the cold fluid in a substantially horizontal direction. As an example, the direction of the jet of fluid obtained from the pipe, i.e. the direction in which the tube forming the end of the pipe at the outlet extends, may be substantially

horizontal. As an example, the direction of the jet forms an angle in the range -10° to +10°, preferably in the range -5° to +5°, with respect to a horizontal direction.

The pipe is positioned close to the wall of the enclosure 1 and close to the collector plate 6. As an example, the maximum distance between the wall of the enclosure 1 and the pipe is in the range 0 to 30 cm and the maximum distance between the surface of the collector plate and the pipe is in the range 0 to 10 cm. Preferably, the length of the pipe 5 in the collecting region 4 is reduced, for example in the range 5 to 50 cm, preferably in the range 5 to 20 cm.

The simplicity of the shape of the pipe 5 and the reduced dimensions of the pipe 5 with respect to the reactor size means that an injection system in accordance with the invention can be used in the context of a remodelling, usually termed revamping, of a facility. In fact, it is possible to install the pipe 5 in the place of a pipe in an existing reactor, for example a reactor as described in documents US 7 314 602 or US 2004/0234434.

Referring now to Figure 1, the collector plate 6 communicates with a quench box 7 which acts to mix the liquid and the gas collected on the plate 6. The box 7 may have a variety of geometries. Referring now to Figure 2, the quench box comprises two inlet orifices 12 communicating with the collecting region 4 through the plate 6. Thus, the fluids recovered on the plate 6 flow into the quench box 7 via the orifices 12. The gaseous and liquid fluids are mixed in the box 7 which may have a variety of different internal configurations. As an example, the mixing box 7 may be produced in accordance with the teaching of document FR 2 824 495. In addition, the quench box 7 comprises two outlet orifices 13 communicating with the space located beneath the box 7. As an example, the orifices are located on the bottom of the box 7, staggered with respect to the inlet orifices 12.

The horizontal and tangential injection of cold fluid via the pipe 5 onto the plate 6 means that a rotational flow can be generated over the plate 6. Because of the position of the pipe close to the enclosure 1 and the central position of the orifices 12, the rotational flow follows a spiral shape from the exterior towards the interior of the plate 6. This rotational flow effectively improves

mixing and homogenization of the temperatures of the hot fluids obtained from bed 2 and the cold fluid injected via the pipe 5. Preferably, a fluid is injected comprising at least 70%, or even 80% by volume of liquid, such that the inertia of the injected liquid causes a better rotational movement of the fluid over the plate 6. In addition, in order to provide the rotational movement, the cold fluid may be injected via the pipe 5 at a speed which is preferably in the range 1 to 15 m/s. As an example, the shape and dimensions may be adapted as a function of the pressure at which the cold fluid is available for injecting the fluid into the collecting region 4 at a rate in the range 1 to 15 m/s.

Referring now to Figure 1, below the quench box 7 is a distribution plate 9. Document US 6 093 373 describes an example of a distributor plate. The plate 9 can be used to distribute the fluids obtained from the box 7 over the bed of catalyst 11. The plate 9 is provided with distribution elements, for example tray risers, in order to distribute the gas and the liquid over the whole of the surface of the reactor section. A pre-distributor plate 8 may optionally be disposed between the plate 9 and the box 7 so as to break the jets of fluids leaving the box 7 in order not to disturb the function of the distributor plate 9. As an example, the plate 8 is composed of a perforated plate. In order to improve the homogeneity of the fluid flow in bed 2, a layer 10 of inert solid grains usually known as grading may be disposed above the bed 11.

The examples presented below serve to compare the performances of injecting a quench fluid into a reactor in accordance with the invention, compared with the prior art.

The efficiency of the proposed system of the invention was compared with that of a straight pipe device described in Figure 3 and that of a circular pipe device described in Figure 4.

Figure 3 presents a straight pipe quench device similar to that disclosed in document US 7 314 602. References in Figure 3 which are identical to those in Figure 1 denote the same elements. With reference to Figure 3, the injection pipe 5A is a perforated straight tube which distributes cold fluid to various parts of the collector plate 6.

Figure 4 presents a quench device with a circular injection pipe 5B, similar to that disclosed in document US 2004/0234434.

A cold mock-up was used to compare the mixing performances between three distinct quench configurations in accordance with Figure 2, Figure 3 and Figure 4.

The mock-up was composed of a vertically positioned straight cylinder with a 0.48 m diameter section. The mock-up comprised a bed of catalyst 1 m in height. The empty region 4 where fluid collection was carried out above the collector plate 6 was 20 cm in height.

The cylinder was supplied overhead with a mixture of water and air at 1 bar and at 50°C. Tests were carried out at various gas surface velocities (gsv) and liquid surface velocities (lsv) at the inlet to the upper bed.

The cold quench fluid was either liquid (water) or gas (air). It was injected at a flow rate equal to half the flow rate of the same phase entering the upper bed. When the liquid surface velocity (lsv) entering the upper bed was less than 1 cm/s, the quench fluid was gaseous. When the liquid surface velocity (lsv) entering the upper bed was more than 1 cm/s, the quench fluid was liquid. For the three configurations, the tests conducted at 0.002 m/s, 0.005 m/s and 0.008 m/s were carried out with injection of a gas (air), and the tests conducted at 0.015 m/s and 0.02 m/s were carried out with an injection of a liquid (water).

In the three configurations studied, the same quench box was used - only the shape of the quench fluid injection pipe differed from one configuration to the next.

For the three configurations, the quench box was identical to the box 7 shown diagrammatically in Figures 1 and 2. The orifices 12 and 13 were circular, with a diameter of 3 cm.

In configuration 1 in accordance with Figures 1 and 2A corresponding to the configuration of the invention, the injection pipe was a bent tube, with a diameter D equal to 2 cm, stuck to the wall of the column and to the collector plate. The end of the pipe 5 was a straight cylinder the axis of which was orientated purely tangentially to the cylindrical partition of the mock-up.

In configuration 2 in Figure 3, not in accordance with the invention, the pipe 5A was a straight cylinder with a 3 cm internal diameter comprising six 1 cm diameter holes.

In configuration 3 of Figure 4, not in accordance with the invention, the pipe 5B was circular and formed a 20 cm diameter torus with a 3 cm internal diameter. The torus was provided with seven outlet holes 1 cm in diameter orientated at 45° with respect to the tangential direction.

For each test configuration, six thermocouples were positioned at the inlet to the lower bed and in the grading layer. The maximum temperature difference measured by these thermocouples defined the residual temperature difference, denoted ΔT, and was used to compare the configurations.

The results are shown in Figure 5 which shows the change in lsv in m/s as a function of ΔT in °C. The results are shown as a function of the liquid surface velocity lsv, as they proved to be less sensitive to the gas surface velocity, gsv. The crosses indicate the results for configuration 1, the roundels indicate the results for configuration 3, and the triangles represent the results for configuration 2.

Several important facts may be noted regarding the results given in Figure 5:

- the best performances were obtained with the bent tube injection pipe of configuration 1 in accordance with the invention;
- the performances obtained with the bent pipe of configuration 1 were better with a liquid quench fluid (lsv > 1 cm/s) than with a gaseous quench fluid. This is linked to the inertia of cold liquid, which is higher than that of a cold gas, which means that liquid can be made to rotate more easily over the collector plate;
- the performances obtained with the toroidal pipe of configuration 3 were close to the results obtained with the bent tube pipe of configuration 1 in accordance with the invention, with a gaseous quench fluid, and slightly poorer with a liquid quench fluid.

As a consequence, configuration 1 in accordance with the invention provides better results than the cans of configurations 2 and 3, while being lighter, easier to assemble and less bulky. The benefits of a device in accordance with the invention are thus very high.

CLAIMS

1. A catalytic reactor comprising an enclosure (1) comprising at least two beds of solid catalyst (2; 11) separated by an intermediate zone comprising a collector plate (6) cooperating with a quench box (7) disposed below the collector plate (6), the reactor comprising a nozzle (5) for injecting a quench fluid, the nozzle being disposed in a collecting region (4) located in the intermediate zone above the collector plate (6), characterized in that the end of the injection nozzle (5) comprises a tubular portion configured so as to inject the quench fluid into the collecting region (4) in a substantially horizontal direction and forming an angle in the range -10° to +10° with respect to the direction tangential to the wall of the enclosure (1) at the level of said tubular portion.

2. A reactor according to claim 1, characterized in that the nozzle (5) comprises a single orifice discharging into the collecting region, the orifice being located at the end of the nozzle.

3. A reactor according to claim 1 or claim 2, characterized in that the nozzle (5) discharges at the wall of the enclosure (1) so as to inject a fluid in a direction forming an angle in the range -10° to +10° with respect to the horizontal direction.

4. A reactor according to one of the preceding claims, characterized in that the end of the injection nozzle (5) is composed of a straight tubular portion forming an angle (θ) in the range -10° to +10° with respect to the direction tangential to the wall of the enclosure (1) at the level of the nozzle orifice.

5. A reactor according to claim 4, characterized in that the straight tubular portion forms an angle in the range -10° to +10° with respect to the horizontal direction.

6. A reactor according to one of the preceding claims, characterized in that the nozzle (5) forms a tube with a length in the range 5 cm to 50 cm, measured in the collecting region (4).

7. A reactor according to one of the preceding claims, characterized in that the nozzle (5) is disposed at a distance of less than 40 cm from the enclosure and at a distance of less than 20 cm from the collector plate (6).

8. A reactor according to one of the preceding claims, comprising a distributor plate (9) for gas and liquid disposed beneath the quench box (7).

9. A reactor according to claim 8, comprising a perforated plate (8) disposed between the quench box (7) and the distributor plate (9).

10. A method for deploying a reactor according to one of claims 1 to 9, characterized in that a fluid comprising at least 70% by volume of liquid is injected via said nozzle (5).

11. A method according to claim 10, in which a fluid is injected via said nozzle (5) at a rate in the range 1 to 15 m/s.

12. A method of obtaining a reactor according to one of claims 1 to 9, in which an existing reactor is revamped by replacing the old nozzle with an injection nozzle (5) the end of which comprises a tubular portion configured so as to inject the fluid into the collecting region in a substantially horizontal direction and forming an angle in the range -10° to +10° with respect to the direction tangential to the wall of the enclosure at said tubular portion.