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Burroughs et al.

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[54] **HYDROGENATION REACTOR WITH IMPROVED FLOW DISTRIBUTION**

[75] Inventors: **James W. Burroughs**, Beaumont; **Robert L. Herbst**, Groves; **William C. Moyer**, Port Arthur; **Jesse M. Gray, Jr.**, Houston, all of Tex.

[73] Assignee: **Texaco Inc.**, New York, N.Y.

[22] Filed: **Nov. 14, 1973**

[21] Appl. No.: **415,718**

Related U.S. Application Data

[62] Division of Ser. No. 186,638, Oct. 5, 1971, abandoned.

[52] **U.S. Cl.** ..... **23/288 R**; 23/288 A; 208/57; 208/146

[51] **Int. Cl.** **B01j 9/04**; C10g 23/16

[58] **Field of Search** ..... 23/288 R, 288 A, 288 E; 208/57, 146

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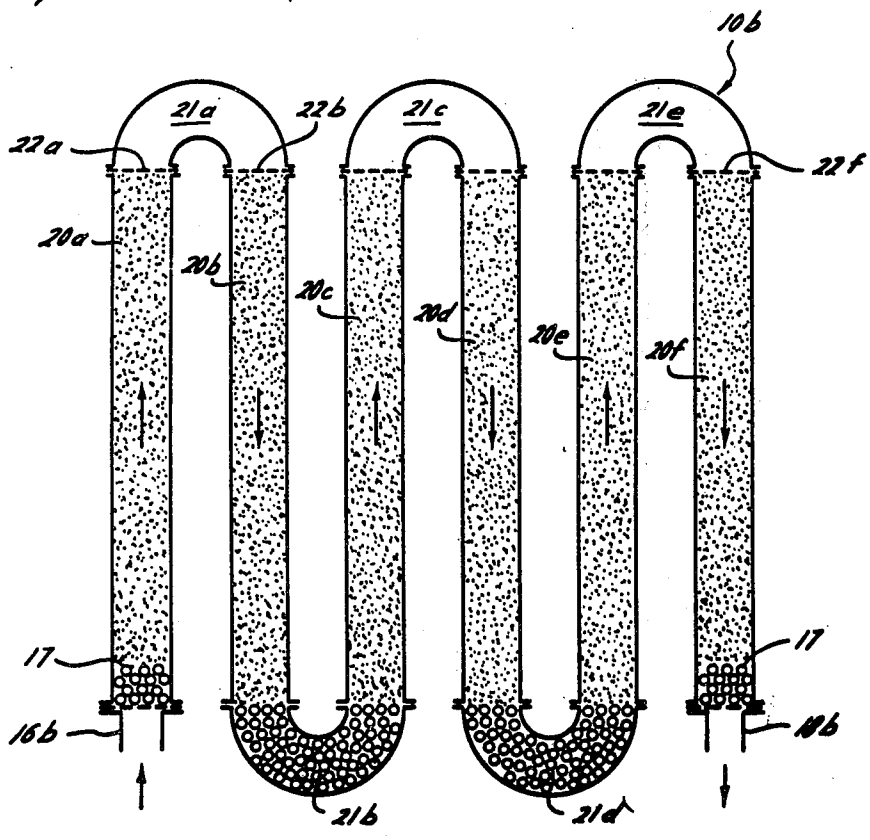
Primary Examiner—Barry S. Richman

Attorney, Agent, or Firm—T. H. Whaley; C. G. Ries; Theron H. Nichols

[57] **ABSTRACT**

A hydrogenation reactor comprises an elongated vertical container with a height greater than twice the width and divided into a plurality of tall slender chambers, either as a new reactor or as a modified existing reactor, having greatly increased distribution of a fluid reactant mixture flowing through a solid catalyst. Vertical baffles divide the container into various novel configurations having an increased height-to-width ratio giving increased linear velocity of the flowing reactants to several times that of the single pass reactor while maintaining the space velocity constant, the baffles further providing high strength-to-weight ratio and greater distribution while still permitting easy loading, regeneration, and dumping of the catalyst. With the last chamber being a downflow chamber in all modifications, catalyst "carry over" is minimized. Most of the modifications have an even number of chambers with inlet and exit nozzles at the bottoms of both the first chamber and last chamber insuring more efficient reverse flow at any time.

1 Claim, 14 Drawing Figures



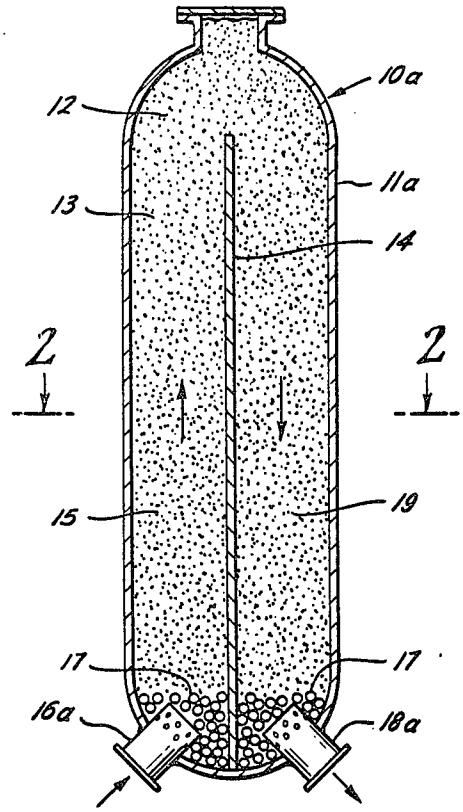


Fig. 1

Fig. 2

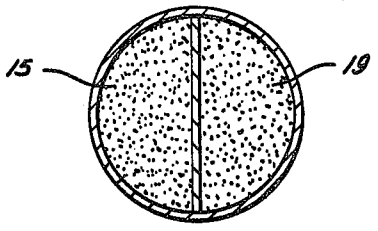
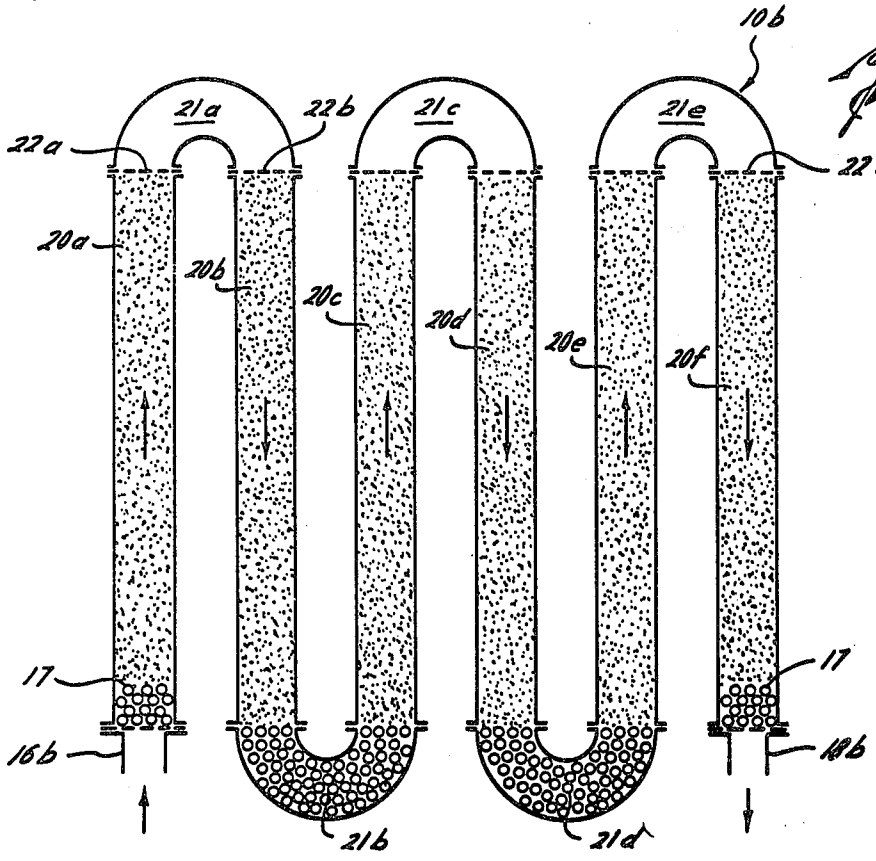


Fig. 3



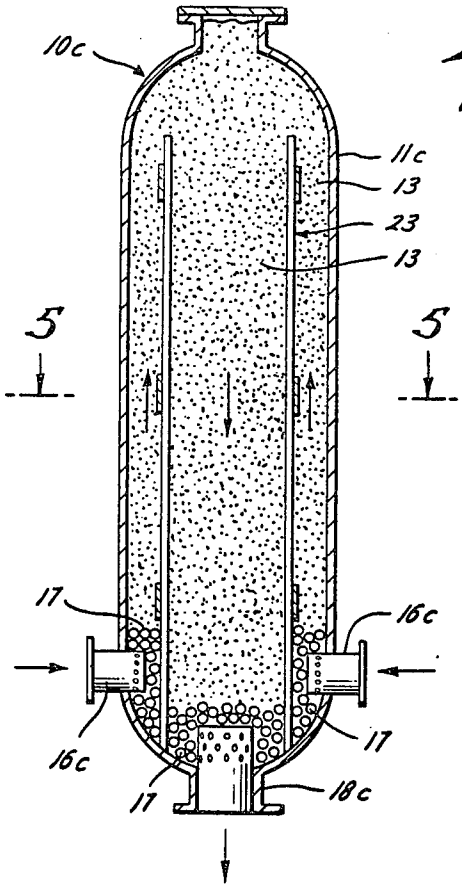


Fig. 4

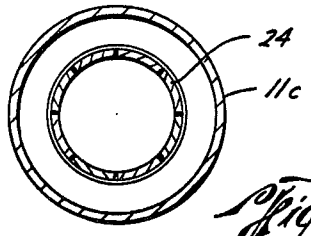


Fig. 5

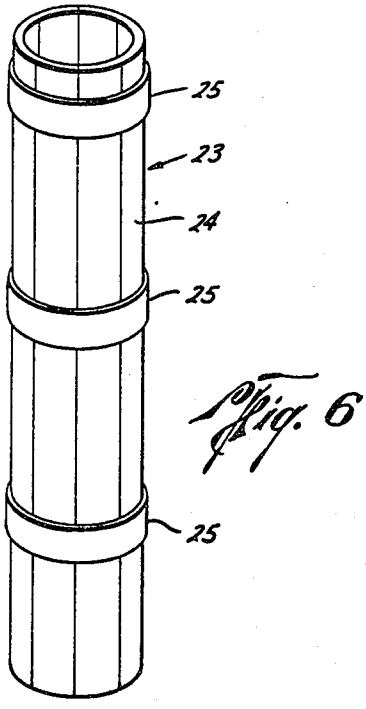


Fig. 6

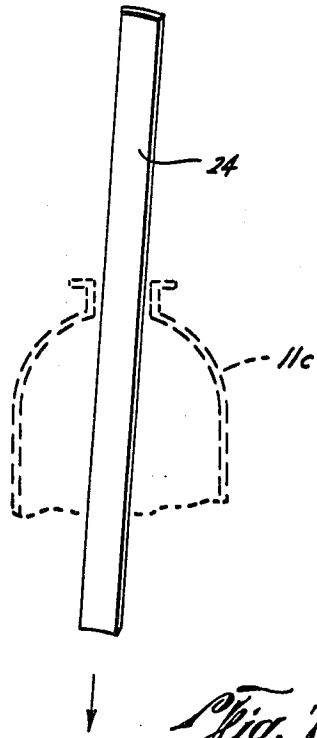


Fig. 7

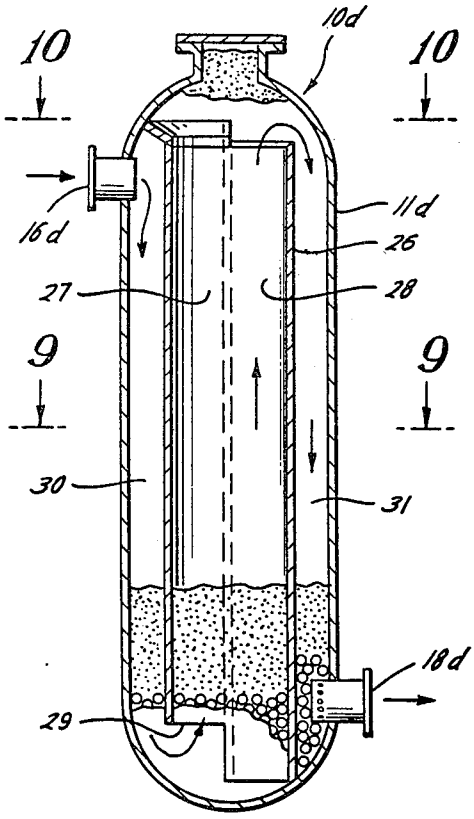


Fig. 8

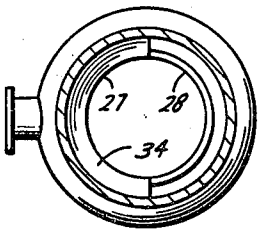


Fig. 10

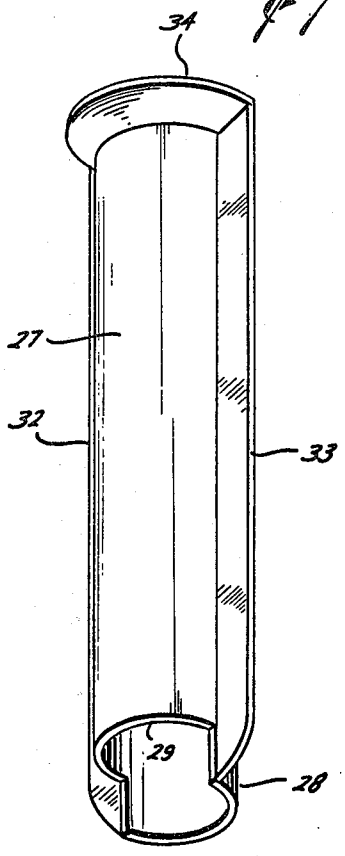


Fig. 11

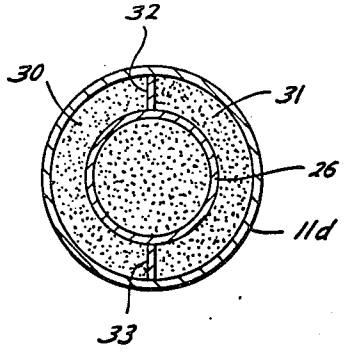


Fig. 9

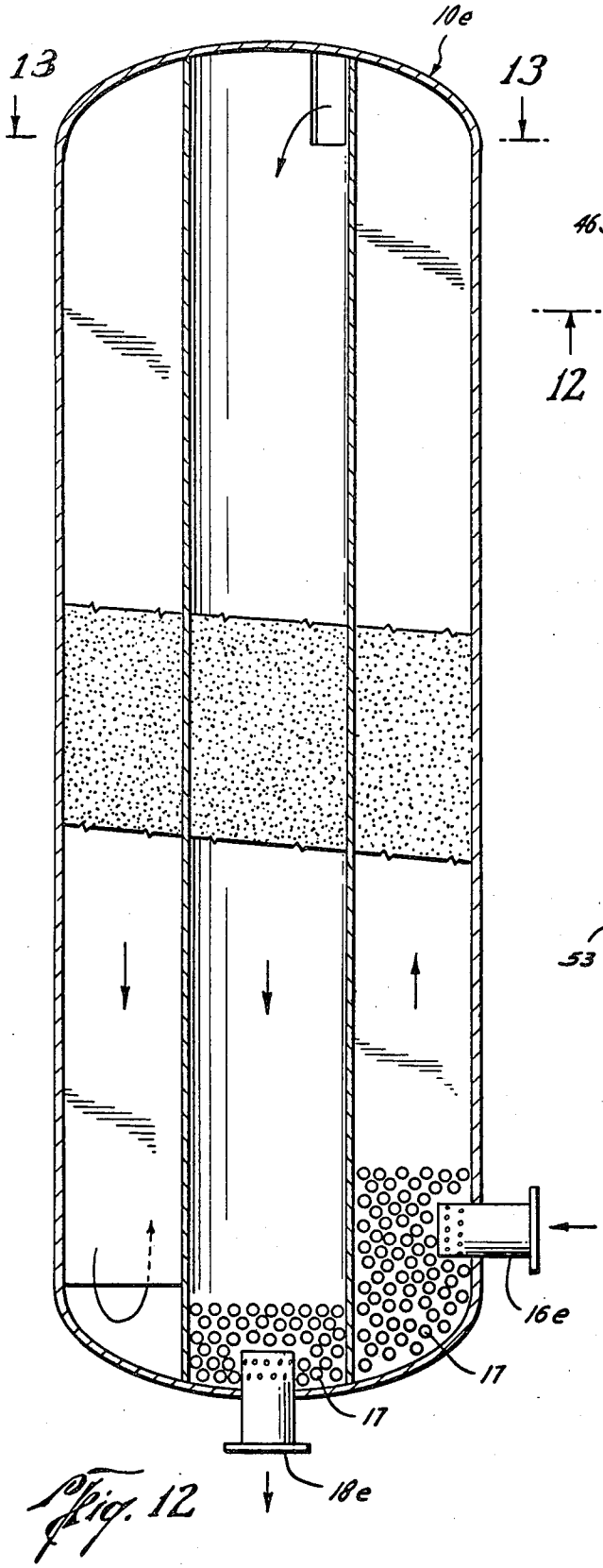


Fig. 12

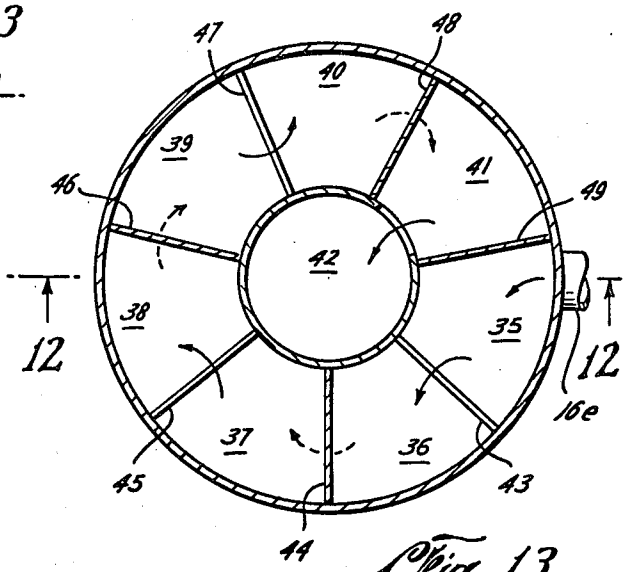


Fig. 13

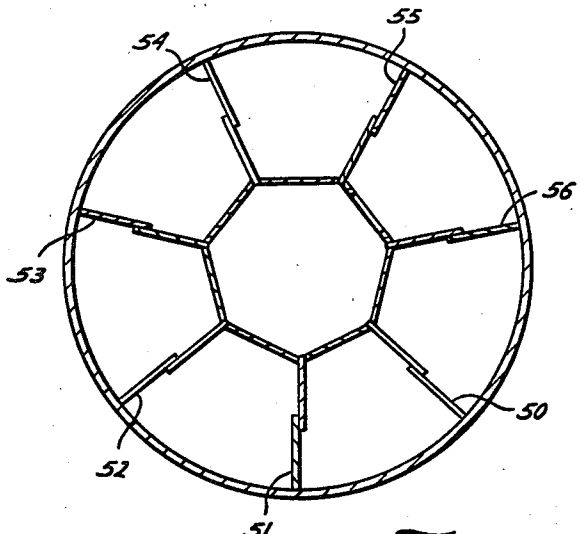


Fig. 14

HYDROGENATION REACTOR WITH IMPROVED FLOW DISTRIBUTION

This is a division of application Ser. No. 186,638, filed Oct. 5, 1971 and now abandoned.

OBJECTS OF THE INVENTION

A primary object of this invention is to provide a hydrogenation reactor having a fluid reactant mixture with a solid catalyst that provides increased distribution of the fluid reactant mixture flowing through the solid catalyst.

Another primary object of this invention is to provide a hydrogenation reactor that has a height of over twice the width resulting in greatly increased distribution of a solid catalyst in a liquid reactant, produces greater contact between the liquid reactant and the catalyst, and channelizing is prevented.

Another object of this invention is to provide a hydrogenation reactor which has increased distribution while still permitting easy loading, regeneration, and dumping of the catalyst.

A further object of this invention is to provide a hydrogenation reactor which may be modified with baffles for increasing the distribution of the fluid reactant mixture and yet increase the strength-to-weight ratio.

A still further object of this invention is to provide a hydrogenation reactor which has an efficient reverse flow operation at any time.

Another object of this invention is to provide a hydrogenation reactor that provides increased linear velocity while maintaining a constant space velocity.

Yet another object of this invention is to provide a hydrogenation reactor that is easy to operate and is of simple configuration and economical to form and assemble.

Other objects and various advantages of the disclosed hydrogenation reactor with improved flow distribution will be apparent from the following detailed description together with the accompanying drawings, submitted for purposes of illustration only and not intended to define the scope of invention, reference being had for that purpose to the subjoined claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings diagrammatically illustrate by way of example, not by way of limitation, several forms of the invention wherein like reference numerals designate corresponding parts in the several views in which:

FIG. **1** illustrates schematically one modification of the invention, with parts in section for clarity of disclosure, comprising a vertical elongated container having one baffle therein;

FIG. **2** is a section at **2—2** on FIG. **1**;

FIG. **3** is a schematic sectional view of another elongated vertical chambered hydrogenation reactor;

FIG. **4** illustrates schematically a sectional view of another modification of the reactor of FIG. **1**;

FIG. **5** is a section at **5—5** of FIG. **4**;

FIG. **6** is a perspective view, schematically illustrated, of the inner chamber of the reactor of FIG. **4**;

FIG. **7** is a schematic view showing the assembly of the cylindrical chamber of FIG. **6**;

FIG. **8** illustrates schematically a view of another modification of the reactor of FIG. **1** with another cylindrical baffle positioned inside an elongated cylindrical container, with parts illustrated in section;

FIG. **9** is a sectional view at **9—9** on FIG. **8**;

FIG. **10** is a sectional view at **10—10** on FIG. **8**;

FIG. **11** is a perspective view of the inner cylindrical chamber of FIG. **8** with parts removed for clarity of disclosure;

FIG. **12** is a schematic sectional view of another modification of the hydrogenation reactor of FIG. **1**;

FIG. **13** is a sectional view at **13—13** on FIG. **12**; and

FIG. **14** is a modification of FIG. **13**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention disclosed herein the scope of which being defined in the appended claims is not limited in its application to the details of construction and arrangement of parts shown and described, since the invention is capable of other embodiments and of being practiced or carried out in various other ways. Also it is to be understood that the phraseology and terminology employed herein is for the purpose of description and not of limitation.

FIG. **1** shows an improved liquid distribution in a hydrogenation reactor **10***a*, the reactor container configuration **11***a* which allows a combination of upflow and downflow operation of a fluid reactant mixture **12**, as a charge oil and hydrogen flowing through a mass of solid catalyst pellets **13** as illustrated. These pellets may be of any shape and size, such as but not limited to, cylindrical pellets from 1/16 inch to 1 inch in length. This reactor **10** is bisected with an elongated vertical baffle **14**. The baffle has a fluid tight connection with the bottom of the container **11***a* forming a first elongated vertical chamber **15** with an inlet nozzle **16***a* in the bottom and to one side of the baffle, the nozzle having a perforated cover or a screen (not shown) and being covered with a layer of mullite balls **17** or slag which acts as a filter and retains the catalyst in the reactor. The fluid reactant **12** comprising hydrogen with components in oil and catalyst **13** mixture fill the cylindrical container **11** on both sides of the baffle **14**. An outlet nozzle **18***a* is positioned on the other side of the baffle from the inlet nozzle **16***a* at the bottom of the second chamber **19** formed by dividing vertical baffle. Likewise, outlet nozzle **18***a* is covered with a perforated cover or screen (not shown) and a layer of mullite balls **17** or slag that acts as a filter or catalyst retainer. While only one baffle is illustrated and described in this embodiment, a plurality of baffles may be utilized if so required for increased distribution of the fluid reactants. This baffle or these baffles provide at least two-pass flow, or more, in the reactor.

Another critical feature of this reactor is that the height of the total container **11** is over twice the width or diameter of the container. Thus, in operation charge oil and hydrogen enter at the bottom of the first chamber **15** of the reactor flow upward and over the baffle **14** and then downward to the outlet **18** on the opposite side of the baffle. This results in greatly increased distribution of the catalyst in the reactants, provides greater contact between the liquid reactant and the solid catalyst, and prevents channelizing.

This modification of the reactor improves liquid distribution in two ways: (1) the liquid distribution is optimum on the upflow side, since this side of the reactor should have a continuous liquid phase with a minimum of channelizing, and (2) liquid distribution is improved on the downflow side since the cross section flow area is one-half or more that of the normal reactor.

The catalyst **13** is filled to the top of the reactor to minimize agitation due to upflow operation. Some catalyst attrition is inherent in upflow operation and can result in excessive catalyst "carry over"; however, the novel configuration of the modified reactor provides upflow followed by downflow operation which permits the catalyst in the downflow side to act as a filter for the catalyst from the upflow chamber. Accordingly an optimum liquid distribution results in the upflow chamber with less catalyst "carry over" from the reactor than from a reactor with only upflow operation.

The symmetrical design of the reactor permits efficient reverse flow operation at any time. This feature allows efficient operations to be quickly restored in the event of pressure drop buildup or channelizing in the downflow chamber.

Preferably, the vertical elongated container and baffle are formed of an alloy or is alloy-lined to protect them from hydrogen attack.

In addition to the above advantages, contacting in the reactor bed is improved, since linear velocity in the bed is doubled, at least, and catalyst carry over is no greater than for normal downflow of reactors.

FIG. **2**, a sectional view of FIG. **1**, illustrates how the baffle divides the overall container into two chambers **15** and **19.**

FIG. **3** illustrates another embodiment **10***b* comprising an even number of elongated vertical chambers **20***a* to **20***f*. These chambers are serially interconnected with passage means **21***a* to **21***e* for each respective pair of adjacent chambers. The first chamber **20***a* has its inlet nozzle **16***b* at the bottom of chamber **20***a* and the last chamber **20***f* has its exit nozzle **18***b* at the bottom of chamber **20***f* which like most of the other modifications disclosed provides efficient reverse flow at any time. The first chamber **20***a* has a passage **21***a* at the top thereof turning through 180° to connect to the top of the second chamber **20***b*. The second chamber **20***b* has a passage **21***b* at its bottom to connect, after turning 180°, to the third slender elongated vertical chamber **20***c*. Chambers **20***c* and **20***d* are interconnected at the tops of each with a passage **21***c* and chambers **20***d* and **20***e* are interconnected at their bottoms with a 180° angled passage **21***d*. The last two chambers illustrated, chambers **20***e* and **20***f*, are interconnected at the tops of each with a passage **21***e* thereby allowing outflow at the exit nozzle **18***b* at the bottom of the last passage **21***f*. The number of elongated vertical passages is preferably an even number in order to provide an upflow chamber as the first chamber and a downflow chamber as the last chamber to insure efficient reverse flow at any time without loss of catalyst. As clearly shown in FIG. **3**, the chambers have equal cross-sectional areas and each of the U-bend angles has a cross-sectional area equal to that of the chambers.

Filter-screens **22***a* and **22***f* are provided at the top of each U-bend angle to prevent catalyst movement or carry over from one vertical chamber to the next. Catalyst fills all the vertical chambers. Filters such as ceramic balls **17** are positioned at the inlet and outlet and in angled passages **21***b* and **21***d* for forming filter-screens and for improved flow distribution in the hydrogenation reactor. Each of the elongated serially interconnected vertical chambers is spaced from the others for increased cooling therebetween.

FIGS. **4–7** illustrate another modification of the invention. FIG. **5**, a cross sectional view of the modified reactor **10***c* of FIG. **4**, illustrates an elongated vertical outer housing forming a container **11***c* with an elongated vertical tube inside thereof forming inner chamber **23** which is coaxial and concentric therewith outer annular chamber **11***c*. The inner chamber **23** is connected at the bottom to the outer container **11***c*, and secured around the periphery thereof are one or more inlet nozzles **16***c*. Likewise, filters **17** are positioned around the inlets. A catalyst **13** fills the two containers. An exit nozzle **18***c* is positioned in the bottom of inner container **23** with filter **17** thereover for preventing outflow of the catalyst with the reactants. In the center of this modified reactor at the bottom is the exit nozzle **18***c* with filter **17** therewith.

In operation, fluid reactants enter at the bottom and flow around the outer peripheral annular chamber **11***c*, over the top of the inner chamber, and down the inside cylindrical chamber **23** to flow out the exit nozzle **18***c*. This inner chamber **23** may be a prefabricated cylinder formed of staves **24** which may be dismantled, and then reassembled inside the reactor and pulled together with circumscribing straps **25.** While only two inlet nozzles are illustrated, a multiplicity of inlet nozzles may be positioned around the peripheral of the outer annular chamber. The plurality of inlet nozzles provides uniform distribution of the charge entry. For reverse flow operation the feed is introduced into the bottom of the central chamber so that flow would be upward through the cylindrical chamber and downward through the annular outer chamber. While the cross sectional area of the outer and inner chambers may be equal, likewise they may also be varied to optimize flow distribution.

Catalyst is filled to the top of the reactor to minimize agitation of catalyst due to upflow operations.

FIG. **5** a sectional view of FIG. **4** illustrates the relative area of the two chambers.

FIG. **6** illustrates the inner cylindrical chamber **23** as being formed of staves **24** which are reassembled and secured with the straps **25** inside the outer chamber.

FIG. **7** illustrates the assembly of the inner cylindrical chamber comprising the insertion of staves **24** internally of the outer chamber **11***c*.

FIGS. **8–11** illustrate another modification of the reactor **10***d* which provides the advantages of increasing the linear velocity of the flowing medium in the reactor to several times that of the single pass reactor of a given diameter. Space velocity (volume of oil per hour per volume of linear catalyst) would remain unchanged. In this reactor, formed basically of an elongated vertical container **11***d* having a height greater than twice the width or diameter includes an inner cylinder **26,** for forming a cylindrical inner chamber, the cylinder being attached to the bottom of the outer container **11***d*. The inner cylinder **26** as shown in FIGS. **8, 10** and **11,** comprises two semicylindrical walls **27** and **28,** and has an opening **29** in wall **27.**

With cylinder **26** concentrically positioned inside of container **11***d*, FIG. **8,** an annulus is formed therebetween. This annulus is cut into two semiannular chambers **30** and **31** by vertical plates **32** and **33,** FIG. **11,** extending from cylinder **26** at the joint between walls **27** and **28** to the walls of the container **11***d*, FIG. **10,** and by arcuate plate **34,** FIG. **11,** extending from the top edges of wall **27** and the flat plates **32** and **33** to the container **11***d*, FIG. **8.** A suitable catalyst fills all chambers.

Thus in operation, flow of the reactant passes from inlet **16***d* down through semiannular chamber **30**, through opening **29**, up through cylinder **26** and over into the semi-annular chamber **31**, down the chamber and out the bottom exit nozzle **18***d*.

The embodiment of FIG. **9** is easy to design and install. In this modification which comprises only three chambers, the inner sectional area of the cylindrical chamber is one-third the total area whereby the other two semiannular chambers are one-third each in area. The advantages of this modification are: (1) vertical baffling is relatively simple and inexpensive in increasing the height-to-diameter ratio of the reactor; (2) the flat plates support the inner cylindrical section and thereby strengthen the overall structure of the reactor; (3) the flow of oil and hydrogen through the reactor can be reversed during the operation at any time; (4) all sections can be regenerated in the regular manner and the catalyst may be dumped through nozzles in the bottom; and (5) the internal baffles may be made from low alloy steel and accordingly would not need to be alloy clad.

FIGS. **12** to **14** disclose another embodiment of the hydrogenation reactor **10***e*, FIG. **12**, which like all embodiments except that of FIG. **8**, includes an even number of chambers. These chambers are elongated and vertical, and like all other modifications, have a height over twice the width. This reactor **10***e* comprises an odd number of chambers around a central cylindrical chamber. In the exemplementary illustration seven chambers **35** to **41**, FIG. **13**, are formed around one cylindrical chamber **42** whereby the inlet nozzle **16***e* is formed in the bottom of the first chamber **35** which is one of seven around the periphery of the inner chamber **42**. Each pair of adjacent chambers is interconnected with the passages. The first chamber **35** being an upflow chamber has its outlet and passage at the top which connects with its adjacent chamber **36** at its top, this second chamber being a downflow chamber. The second and third adjacent chambers **36** and **37**, respectively, are interconnected at the bottoms thereof. The next two chambers, **37** and **38**, the third and fourth chambers, are interconnected at the top thereof whereby with an odd number of peripheral chambers around the periphery of inner chamber **42** the last or add numbered chamber, the seventh or chamber **41** in this case is an upflow chamber. This last upflow chamber **41** is connected with a passage at its top to the top of the center and last downflow chamber **42**, whereby flow passes out of the bottom of the chamber and out of the exit nozzle **18***e* therein. Both entrance and exit nozzles have a filter **17** thereover as illustrated by the mullite balls.

While the chambers illustrated in FIG. **13** have straight solid adjacent walls **43** to **49** therebetween, the walls **50** to **56** illustrated in the FIG. **14** embodiment are made up of two walls each joined at their adjacent edges. In this arrangement the seven elongated vertical chambers form the annular space around the center heptagonal chamber. All chambers have an equal cross sectional area. With the first and last chamber being formed as an upflow and downflow chamber, respectively, reverse flow through the reactor may be efficiently accomplished and whenever desired catalyst carry over is minimized since the last chamber is always a downfall chamber. The baffles are either welded or bolted into position.

Likewise, these modifications provide increased linear velocity with improved distribution of the flowing stream throughout the reactor catalyst bed and therefore provide an improved and more efficient reactor in terms of oil throughput, i.e., throughput rate and total throughput (barrels of oil per pound of catalyst). Likewise the quality of the hydrogen treated oil is improved with respect to initial color, color stability, thermal, and oxidation stability.

While only a few embodiments of the invention have been shown in the accompanying drawings, it will be evident that various other modifications are possible in the arrangement and construction of the hydrogenation reactor with improved fluid distribution, without departing from the scope of the invention.

We claim:

1. A hydrogenation reactor for catalytically hydrogenating a reactant mixture with a catalyst comprising,

a. elongated means forming a plurality of an even number and of at least six separate elongated vertical chambers, each said chamber having upper and lower ends and the cross-sectional areas of all of said vertical chambers being equal,

b. a first filter means in said upper end of each elongated vertical chamber and a second filter means in said lower end of each elongated vertical chamber, each said second filter means comprising a bed of ceramic balls, for preventing carryover of the catalysts,

c. a bed of particulate catalyst at least partially filling each of said chambers, each said bed of catalyst being supported on each respective bed of ceramic balls within said chamber,

d. detachable first U-shaped passage means serially interconnecting said upper ends of consecutive separate chambers comprising the first and second chambers, the third and fourth chambers and the fifth and sixth chambers and subsequent odd-numbered and adjacent downstream even-numbered chambers for passing all of the fluid reactant mixture through each of said separate chambers,

e. detachable second U-shaped passage means serially interconnecting said lower ends of consecutive pairs of separate chambers comprising the second and third chambers and the fourth and fifth chambers and subsequent even-numbered and adjacent downstream odd-numbered chambers for passing all of the fluid reactant mixture through each of said separate chambers,

f. all of said detachable U-shaped passage means having cross-sectional areas equal to the cross-sectional area of said chambers,

g. inlet means in the lower end of the first of said elongated vertical chambers for injecting a fluid reactant mixture into said reactor, said inlet means including a first ceramic ball bed retaining means for supporting said bed of ceramic balls in said first chamber and preventing the passage of said ceramic balls and said particulate catalyst supported thereon out of said reactor and

h. outlet means in the lower end of the last of said elongated vertical chambers for removing reaction products from said reactor, said outlet means including a second ceramic ball bed retaining means for supporting said bed of ceramic balls in said last of said chambers and preventing the passage of said

ceramic balls and said particulate catalyst supported thereon out of said reactor,

i. whereby said serially interconnected configuration forms an improved reactor having simplicity of construction, simplicity of maintenance by easy replacement of individual vertical chambers, ease of increasing and decreasing of size, ease of catalyst loading and unloading, improved and infinite contact between the fluid reactant mixture and the particulate catalyst, and insurance of efficient reverse flow capabilities at any time without loss of catalyst by carryover.

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