

DISTRIBUTOR ASSEMBLY**I. FIELD OF THE INVENTION**

This invention relates to a distributor assembly for multi-bed, down-flow catalytic reactors, that is, reactors which include vertically superimposed packed beds of particulate catalytic material and where a liquid or liquid and gas mixture is processed as it flows down through the packed beds. This type of reactor is used in the petroleum and chemical processing industries for carrying out various catalytic reactions, such as hydrotreating, hydrofinishing, hydrocracking, and dewaxing.

II. BACKGROUND OF THE INVENTION

Multi-bed, down-flow catalytic reactors are used in the petroleum and chemical industries for a variety of processes. In the petroleum refining industry, multi-bed, down-flow reactors are used in processes for hydrotreating, hydrodesulfurization, hydrofinishing, hydrocracking, and dewaxing. In these processes, the process liquid is mixed with a gas or vapor and this multiple phase mixture is passed through the packed catalyst beds. In exothermic reactions, large amounts of heat may be generated in the catalyst beds. Quench media may be added to regulate the temperature in the reactor. Typically, the quench media is also a reactant, e.g., hydrogen. As the liquid and gas mixture flows through a catalyst bed, some maldistribution of temperature and reactant concentration often develops across each bed. Unless this is mitigated, the reactor operation would be inefficient and hot spots may develop that could potentially shorten catalyst life and force premature reactor shutdown and therefore plant shutdown. It is, therefore, necessary to provide reactor internals for collecting and mixing the liquid and gas exiting from one bed before distribution to the next bed, so that

1 any such maldistribution is not propagated from one catalyst bed to the next.
2 To accomplish this, distributor assemblies are used between the catalyst
3 beds to ensure that the distribution of the liquid and gas mixture (and as the
4 case may be, the vaporous reactant or quench gas) across each bed is as
5 uniform as possible in both composition and temperature. To make the
6 corrections of temperature and concentration maldistributions, the distributor
7 assembly should provide for good liquid-liquid, gas-gas, and gas-liquid
8 mixing. In addition to providing good mixing, it is desirable that the distributor
9 assembly be compact and impose only a low pressure drop.

10 By providing such uniform distribution, each bed will be efficiently utilized and
11 the desired catalytic reactions will take place in a more predictable manner.
12 Numerous types of distributor assemblies for multi-bed, down-flow reactors
13 are known in the prior art. One example is shown in U.S. Pat. No. 4,836,989,
14 in which the distributor assembly includes a collector tray arranged below a
15 catalyst bed and a distributor tray is mounted under the collector tray. The
16 distributor tray is fed by spillways which provide passageways for the liquid
17 collected on the collector tray, as well as quench gas injected between the
18 distributor tray and the catalyst bed. The spillways have outlets below the
19 collector tray which face sideways and tangentially into an annular second
20 mixing zone located under the collector tray. This second mixing zone has a
21 high liquid holdup. The outlets are described as imparting a swirling motion to
22 the liquid in the annular second mixing zone that promotes good mixing and
23 temperature equilibrium. Further mixing and redistribution apparatus is
24 provided below the second mixing zone to collect and distribute liquid over
25 the underlying catalyst bed. The design also requires a high pressure drop to
26 be effective.

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28 Another type of a distributor assembly, as shown in U.S. Pat. No. 4,960,571,
29 includes a collector plate that has a central opening therein. A quench mixing
30 zone is provided under the collector plate, in which a second plate having

1 openings formed in an annular outer portion thereof is mounted under the
2 collector plate, with the annular portion thereof being situated radially
3 outwardly of the central opening in the collector plate. Baffles are affixed to
4 the annular portion and arranged at a tangential angles and in concentric
5 rings to induce current eddies in the liquid and gas flowing through the
6 annular portion. The design does not provide as extensive radial mixing as is
7 usually desirable.

8 Another distributor assembly for multi-bed, down-flow reactors is described in
9 U.S. Pat. No. 5,690,896 ('896 patent). The '896 patent teaches a mixing box
10 arrangement where all fluid collected on a tray flow in a spiral pattern to a
11 single mixing zone leading to a single outlet. This design has drawbacks in
12 that the degree of correction of temperature and composition distributions
13 may depend upon the origin of the distribution relative to the single opening to
14 the mixing zone. Also, because of the single opening and mixing zone, the
15 required height of the assembly could be high in order to accommodate a
16 sufficient liquid throughput. The design also requires a high pressure drop to
17 be effective.

18 Examples of other types of distributor assemblies for multi-bed, down-flow
19 reactors are described in U.S. Pat. Nos. 3,705,016, 3,977,834, and
20 4,182,741. It would be advantageous to have a distribution assembly that
21 overcame the deficiencies of known designs. The distributor assembly of the
22 invention provides this improved design.

23 III. SUMMARY OF THE INVENTION

24 The invention, in one embodiment, is a distributor assembly for a multi-bed,
25 downflow catalytic reactor including: a collection plate configured for
26 substantially horizontally disposed between the walls of a cylindrical reactor,
27 configured for collecting liquid flowing down from a higher catalyst bed
28 contained in the reactor. The collection plate having of an outlet in a center

1 portion thereof configured for allowing a passageway for liquid and gas from
2 the higher catalyst bed to flow toward a lower catalyst bed contained in the
3 reactor.

4 A plurality of generally arc-shaped elongated baffles: disposed in a staggered,
5 substantially symmetrical pattern about the collection plate, each baffle
6 having a bottom edge portion fixably attached to the collection plate and a top
7 edge portion extending substantially vertically upward to a height sufficient to
8 substantially prevent liquid flowing over the top edge portion. Each baffle
9 having a head portion proximal to perimeter portions of the collection plate
10 and having an opposite tail portion proximal to a center portion of the
11 collection plate, wherein the head portion of each of the elongated baffles
12 overlaps a tail portion of another of the elongated baffles.

13 The elongated baffles configured for directing the liquid from an outer portion
14 of the collection plate toward a center portion of the collection plate and
15 configured to cause mixing between liquid passing out of the tail portion of
16 each elongated baffle with the liquid passing into the head portion of the
17 adjacent overlapping elongated baffle. A first mixing zone configured to be
18 bounded on the bottom by the collection plate, on one side by a wall of the
19 cylindrical reactor, on the opposite side by the outer surface of the elongated
20 baffles.

21 A cylindrical weir fixably attached to the collection plate about the outlet,
22 configured for causing the liquid and gas to rise up and over the first
23 cylindrical weir before flowing through the outlet toward the lower catalyst
24 bed. A second mixing zone: bounded on the bottom by the collection plate,
25 on one side by the outer surface of the cap and the first cylindrical weir, and
26 on the opposite side by the inner surface of the elongated baffles; having a
27 plurality of entrances bound on one side by the interior surface of a head
28 portion of one elongated baffle and on an opposite side by the outer surface

1 of a tail portion of an overlapping elongated baffle. Optionally, a plurality of
2 quench gas ports is disposed in the second mixing zone; each port having an
3 outlet disposed proximal to the collecting collection plate and configured for
4 ejecting a quench gas beneath the surface of a liquid collected in the second
5 mixing zone and towards the tail portion of each of the generally arc-shaped
6 elongated baffles. The entrances to the second mixing zone form
7 passageways configured to permit the liquid to flow from the first mixing zone
8 to the second mixing zone.

9 A cap, typically cylindrical, having a diameter larger than the first cylindrical
10 weir, is disposed over and about the first cylindrical weir, disposed so the top
11 of the cap is above the top edge of the first cylindrical weir, thus providing a
12 passage way, and the bottom edge of the cap is above the collection plate,
13 thus providing a passageway: thereby forming a third mixing zone, including
14 an annular passageway between the outer surface of the first cylindrical weir
15 and the inner surface of the cap. The cap having a plurality of slots
16 substantially symmetrically disposed about the circumference of its open end;
17 beginning at a lower extremity and disposed substantially vertically up a
18 portion of the cap; configured for allowing passage of gas and liquid from the
19 second mixing zone to the third mixing zone.

20 A plurality of semi-spiral-shaped baffles are optionally fixably disposed in the
21 third mixing zone, the semi-spiral-shaped baffles having an elongated shape.
22 Each semi-spiral-shaped baffle optionally has one lateral edge fixed to an
23 inner surface of the cap, or alternatively an opposite lateral edge fixed to an
24 outer surface of the first cylindrical weir, or utilizes any other conventional
25 attachment method, and having one longitudinal end disposed proximal to a
26 bottom portion of the first cylindrical weir but above a top portion of the slots
27 in the cap; and having an opposite longitudinal end disposed proximal to a
28 top portion of the first cylindrical weir, configured for causing the liquid and

1 gas in the third mixing zone to move laterally and for causing further mixing of
2 the liquid and gas.

3 A substantially doughnut-shaped screen member, typically a thin or flattened
4 shape as to thickness but maintaining roundness along the inner and outer
5 circumferences, disposed over a top portion of the cylindrical weir, configured
6 for causing further liquid-liquid mixing and for causing separation of the liquid
7 and the gas. A fourth mixing zone has an annular shape and is bounded on
8 the top by the inner top surface of the cap, on the bottom by the substantially
9 doughnut-shaped screen member, and has the width of the inner and outer
10 diameters of the doughnut-shaped screen member. A plurality of baffles
11 ("fourth-mixing-zone baffles") are optionally fixably attached to a top surface
12 of the doughnut-shaped screen member, configured for diverting the liquid
13 and the gas, and for causing further mixing of the liquid and gas.

14 The distributor assembly is configured for disposal and fixable attachment
15 between inner surfaces of the walls of a multi-bed down-flow cylindrical
16 reactor wall and for disposal between vertically stacked catalyst beds within
17 the reactor. These and other features of the present invention will be more
18 readily understood upon reading the following "Detailed Description of the
19 Preferred Embodiment" in conjunction with the accompanying drawings.

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21 IV. BRIEF DESCRIPTION OF THE DRAWINGS

22

23 FIG. 1 is a schematic, perspective isometric view of a preferred embodiment
24 of the distributor assembly in the context of a reactor vessel according to the
25 present invention.

26

27 FIG. 2 is a schematic, perspective isometric cut-away view of a preferred
28 embodiment of the distributor assembly according to the present invention.

1 FIG. 3 is a top plan view of the preferred embodiment of the distributor
2 assembly according to the present invention.

3 Fig. 4 is a top plan view of a preferred embodiment of the cap and weir
4 portions of the distributor assembly according to the present invention.

5 FIG. 5 depicts the performance of the invention in correcting liquid
6 concentration maldistributions by showing the concentrations of a tracer liquid
7 in various zones of the effluent from the distributor assembly.

8 V. DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

9 A. Elements

10 The elements for the assembly and corresponding reference numbers as
11 used in the figures are listed in Table 1 below. In the section following this
12 one, each element and how it relates to the other elements is described in
13 detail with reference to the figures.

TABLE 1	
<u>Element Name</u>	<u>Element Number Used In Figures</u>
Reactor	1100
Reactor Side Wall	1105
First Mounting Means	1106
Catalyst Beds	1107, 1108
Bubble Cap Tray Assembly	1110
Perforated Plate	1115
Second Mounting Means	1117
Distributor Assembly	1120
Collection plate	1125
Generally Arc-Shaped Elongated Baffles	1130
Quench Gas Ports	1140
Cap	1150
Semi-Spiral-Shaped Baffles	1155
Fourth-mixing-zone baffles	1160
First Cylindrical Weir	1165
Doughnut-shaped Screen Member	1170
Second Cylindrical Weir	1175
First Mixing Zone	1180
Second Mixing Zone	1185
Third Mixing Zone	1187
Fourth Mixing Zone	1188
Fifth Mixing Zone	1189
Inlet Passage Ways	1195

1 **B. Organization Of Elements Of The Distributor Assembly For A Catalytic**
2 **Reactor**

3 FIG. 1 depicts an overview schematic cut-away view of a multi-bed,
4 down-flow reactor 1100 with the distributor assembly of the invention included
5 therein. It has a cylindrical reactor wall 1105 and a first mounting means
6 1106 fixably attached to the cylindrical reactor wall 1105. Reactor 1100 is
7 configured for supporting catalyst beds 1107-1108 containing packed
8 particulate catalytic material (not shown) in vertically superimposed relation to
9 each other to permit liquid and gas to flow from a higher catalyst bed 1107 to
10 a lower catalyst bed 1108. A typical first mounting means 1106 optionally
11 includes a strut member fixably attached to the reactor wall 1105, typically
12 welded, and optionally a grid screen assembly (not shown) including a
13 support grid, space cloth and wire screen, all of which are well known in the
14 art, for supporting the catalyst in the higher catalyst bed. The grid screen
15 assembly is typically mounted on parallel cross beams (not shown) or other
16 strut members that are horizontally mounted to the reactor wall 1105.
17 Mounting means 1106 supports the higher catalyst bed from the bottom of the
18 bed 1107. Distributor assembly 1120 is optionally supported in a "basket"
19 hanging from and below the same mounting means 1106. Lower catalyst bed
20 1108 is below the distributor assembly 1120 and is supported by additional
21 mounting means 1117.

22 The distributor assembly 1120 of the present invention is mounted to the
23 reactor wall 1105 under the grid screen assembly (not shown) to receive
24 liquid and gas flowing down from the entire bottom surface of the
25 overlying/higher catalyst bed 1107 and to mix the liquid and gas. Two or
26 more catalyst beds fixably attached to the first mounting means and disposed
27 between inner surfaces of the cylindrical reactor wall.

1 An optional second mounting means 1117 is fixably attached to the cylindrical
2 reactor wall and configured for supporting distributor assembly 1120. Any
3 other conventional mounting/support means may be used for positioning the
4 catalyst beds and distributor assemblies in the reactor. For example, a
5 catalyst bed can be supported from the bottom by mounting means attached
6 to the bottom of the catalyst bed and the reactor. The distributor assembly
7 below that catalyst bed can rest in a "basket" hanging down from the same
8 mounting means. Generally, it is desirable to have fewer weld points to the
9 reactor wall. Distributor assembly 1120 is fixably attached to either the first or
10 second mounting means, 1106 or 1117, respectively, and disposed between
11 inner surfaces of the cylindrical reactor wall 1105 and between the catalyst
12 beds 1107-1108.

13 The section shown in FIG. 2 is an isometric detail view of the distributor
14 assembly 1120. The distributor assembly 1120 distributes the mixture of
15 liquid and gas received from higher catalyst bed 1107 to a perforated plate
16 1115. Perforated plate 1115 mounted below the distributor assembly 1120, in
17 turn, distributes the liquid and gas, as well as quench gas, over the cross
18 section of the reactor to a bubble cap tray assembly 1110 which is mounted
19 under the perforated plate 1115. A conventional bubble cap tray assembly
20 1110 is mounted below a conventional perforated plate 1115 and is
21 configured to further mix the liquid and gas, as well as any quench gas, and
22 to distribute the resultant liquid-gas mixture across the upper surface of an
23 underlying/lower catalyst bed 1108.

24 The distributor assembly 1120 includes a collection plate 1125 disposed
25 substantially horizontally between the cylindrical reactor wall 1105. It is
26 configured for collecting liquid flowing down from the higher catalyst bed
27 1107. The collection plate 1125 has an outlet in a center portion thereof
28 configured for allowing a passageway for liquid and gas from the higher
29 catalyst bed 1107 to flow toward the lower catalyst bed 1108.

1 A key element of the distributor assembly is a plurality of generally
2 arc-shaped elongated baffles 1130. They are disposed in a staggered,
3 substantially symmetrical pattern about the collection plate. The number of
4 baffles is sufficient to increase mixing in mixing zone 1 and zone 2 and aid
5 flow from mixing zone 1 to mixing zone 2. In one embodiment, the number is
6 from about 2 to about 6. Each baffle 1130 has a bottom edge portion fixably
7 attached to the collection plate 1125 and a top edge portion extending
8 substantially vertically upward to a height sufficient to substantially prevent
9 liquid flowing over the top edge portion, but sufficiently short to minimize
10 overall height of the distributor assembly.

11 Each baffle 1130 has a head portion proximal to the cylindrical reactor wall
12 1105 and has and an opposite tail portion proximal to a center portion of the
13 collection plate 1125. The baffles 1130 are thus configured so the head
14 portion of each of the elongated baffles overlaps a tail portion of another of
15 the elongated baffles. The head portion is sufficiently close to the perimeter
16 and sufficiently far from the perimeter to increase mixing in mixing zone 1 and
17 mixing zone 2. In one embodiment, the head portion of each baffle proximal
18 to perimeter portions of the collection plate is a distance of from about 5% to
19 about 40% of the radius of the collection plate to the perimeter of the
20 collection plate. The tail portion is sufficiently close to the center and
21 sufficiently far from the center to increase mixing in mixing zone 2 and mixing
22 zone 3 and flow through mixing zone 3. In one embodiment, the opposite tail
23 portion proximal to a center portion of the collection plate is a distance of from
24 about 5% to about 40% of the radius of the collection plate to the center of
25 the collection plate.

26 The elongated baffles 1130 are configured for directing the liquid from an
27 outer portion of the collection plate 1125 toward a center portion of the
28 collection plate 1125 and configured to cause mixing between liquid passing

1 out of the tail portion of each elongated baffle with the liquid passing into the
2 head portion of the adjacent overlapping elongated baffle.

3 There is a first mixing zone 1180 having a bottom wall formed by a flat
4 circular bottom wall or collection plate 1125, defined on one side by an
5 upright, cylindrical, peripheral reactor wall 1105, defined on the opposite side
6 by the outer surface of the generally arc-shaped elongated baffles 1130. The
7 first mixing zone 1180 is configured to collect liquid flowing down from the
8 overlying catalyst bed 1107 and mix the liquid prior to reaching the inlet
9 passageways 1195 of second mixing zone 1185, described below.

10 A first cylindrical weir 1165 is fixably attached to the collection plate 1125
11 about the outlet and is configured for causing the liquid and gas to rise up and
12 over the first cylindrical weir before flowing through the outlet toward the lower
13 catalyst bed.

14 The distributor assembly 1120 further includes a second mixing zone 1185
15 bounded on the bottom by the collection plate 1125, on one side by the outer
16 surface of the cap 1150 and, optionally, the first cylindrical weir 1165, and on
17 the opposite side by the inner surface of the elongated baffles 1130, typically
18 mounted in substantially fluid-tight relation to the upper surface of the
19 collection plate. That is, the bottom wall of the first mixing zone 1180 and the
20 bottom wall of second mixing zone 1185 are both formed by the collection
21 plate 1125, and thus both lay in the same horizontal plane. A plurality of
22 quench gas ports 1140 are disposed in the second mixing zone; each port
23 1140 having an outlet (not shown separately) disposed proximal to the
24 collecting collection plate 1125 and configured for ejecting a quench gas
25 beneath the surface of a liquid collected in the second mixing zone 1185 and
26 towards the tail portion of each of the generally arc-shaped elongated baffles
27 1130. The number of quench gas ports is sufficient to increase mixing in

1 mixing zone 2 and flow from mixing zone 2 to mixing zone 3. In one
2 embodiment, the number is from about 2 to about 6.

3 The second mixing zone 1185 has a plurality of entrances 1195 bound on
4 one side by the interior surface of a head portion of one elongated baffle and
5 on an opposite side by the outer surface of a tail portion of an overlapping
6 elongated baffle 1130. The entrances form a passageways configured to
7 permit the liquid to flow from the first mixing zone 1180 to the second mixing
8 zone 1185. The entrances form a passageways configured to permit the
9 liquid to flow from the first mixing zone to the second mixing zone.

10 A cap 1150 is disposed over and about the first cylindrical weir 1165 thereby
11 forming a third mixing zone 1187. The third mixing zone 1187, including an
12 annular passageway between the outer surface of the first cylindrical weir
13 1165 and the inner surface of the cap 1150. Cap 1150 has a plurality of slots
14 (or other shaped openings) substantially symmetrically disposed about the
15 circumference of its open end. The slots begin at a lower extremity and are
16 disposed substantially vertically up a portion of the cap 1150. The slots are
17 configured for allowing passage of gas from the second mixing zone to the
18 third mixing zone 1187.

19 The distributor assembly 1120 includes a plurality of semi-spiral-shaped
20 baffles 1155 fixably disposed in the third mixing zone. The semi-spiral-
21 shaped baffles 1155 having an elongated shape, are fixably disposed as such
22 by any conventional method, e.g., having one lateral edge fixed to an inner
23 surface of the cap 1150 or having an opposite lateral edge fixed to an outer
24 surface of the first cylindrical weir 1165. They also have one longitudinal end
25 disposed proximal to a bottom portion of the first cylindrical weir 1165 but
26 above a top portion of the slots in the cap 1150. Semi-spiral-shaped baffles
27 1155 have an opposite longitudinal end disposed proximal to a top portion of
28 the first cylindrical weir 1165. They are configured for causing the liquid and

1 gas in the third mixing zone to move laterally and for causing further mixing of
2 the liquid and gas.

3 A substantially doughnut-shaped screen member 1170 is disposed over a top
4 portion of the first cylindrical weir 1165 and is configured for causing further
5 liquid-liquid mixing and for causing separation of the liquid and the gas as
6 fluid leaves the fourth mixing zone. A fourth mixing zone 1188 is thus formed
7 having an annular shape and bounded on the top by the inner top surface of
8 the cap 1150, on the bottom by the substantially doughnut-shaped screen
9 member 1170, and has the width of the inner and outer diameters of the
10 doughnut-shaped screen member 1170. The inner diameter of said
11 substantially doughnut-shaped screen member is sufficient to achieve
12 significant gas/liquid separation. In one embodiment, that inner diameter is
13 from about 10% to about 75% of the diameter of said first cylindrical weir.
14 Other variations on the figurations of the screen member are included in the
15 invention.

16 There is optionally a plurality of fourth-mixing-zone baffles 1160 fixably
17 attached to a top surface of the doughnut-shaped screen member 1170. The
18 fourth-mixing-zone baffles 1160 are configured for diverting the liquid and the
19 gas, and for causing further mixing of the liquid and gas.

20 An optional second cylindrical weir 1175 is centrally disposed about the outlet
21 in the collection plate 1125 and disposed within the first cylindrical weir 1165
22 and having a smaller diameter and smaller height than the first cylindrical weir
23 1165, thereby forming a fifth mixing zone 1189. Fifth mixing zone 1189 has
24 an annular shape bounded on the bottom optionally by the collection plate
25 1125, on an outer side by an inner surface of the first cylindrical weir 1165,
26 and on the inner side by an outer surface of the second cylindrical weir 1175.
27 The fifth mixing zone 1189 is configured to receive liquid from the fourth
28 mixing zone 1188 for causing the liquid from the fourth mixing zone 1188 to

1 further mix before the liquid flows over the top edge of the second cylindrical
2 weir 1175 towards the lower catalyst bed 1108. Alternatively to being
3 bounded on the bottom by the collection plate 1125, fifth mixing zone is
4 bounded optionally on the bottom by a doughnut-shaped bottom panel
5 elevated above the collection plate 1125, thus forming a annular basket
6 shape.

7 Given the elements and arrangement of the elements as disclosed herein,
8 one skilled in the art is capable of choosing the dimensions for each element
9 appropriate for the internal diameter of the reactor for which any particular
10 embodiment of the invention is intended. Figure 3 is a top view schematic
11 perspective of distributor assembly 1120. The above description for Figure 2
12 also describes the elements in Figure 3. Figure 4 is top cut-away view of the
13 cap 1150, first cylindrical weir 1165, and second cylindrical weir 1175. As
14 shown, each of those three elements, respectively, has a progressively
15 smaller diameter. Figure 5 depicts experimental results and is discussed in
16 that section below.

17 C. Advantages of the Invention

18 The benefits of the invention include, but are not limited to, low liquid holdup;
19 good mixing, especially gas-liquid mixing, on the collection plate; low
20 pressure drop, and relatively short overall height. The space-saving compact
21 design is a major benefit since some conventional designs require as much
22 as 4-5 ft. between the catalyst beds to install the conventional distributor
23 assemblies (including conventional bubble cap tray and perforated plate).
24 The invention only requires less than about 4 ft., preferably less than about
25 3 ft., and more preferably less than about 2 ft. between the catalyst beds to
26 install the distributor assembly of the invention. Such space saving translates
27 to large cost savings since the overall reactor height can be shorter and in

1 retrofits of existing reactors, the catalyst beds need not be made smaller to
2 make room for the distributor assembly.

3 VI. PREFERRED EMBODIMENTS AND EXAMPLES OF USE OF THE
4 INVENTION

5 As liquid rains down from higher catalyst bed 1107 at various locations into
6 the first mixing zone 1180, see, e.g., Figure 2, the circular flow pattern in the
7 horizontal plane of the first mixing zone 1180 induces mixing of the liquid in
8 the pool with that liquid raining down. Thus, the liquid entering the second
9 mixing zone 1185 has a relatively improved uniformity of temperature and
10 composition distribution.

11 The size of the inlet passageways 1195, particularly, the width and height of
12 the downstream end thereof is selected in view of the operating range of flow
13 rate of liquid through the reactor 1100. Passageways 1195 optionally are
14 constricted for restricting the flow of liquid from the first mixing zone to toward
15 the second mixing zone 1185. This is to cause liquid to accumulate in the
16 first mixing zone 1180 and that also, by virtue of the constriction of the flow
17 and expansion downstream thereof imparts some turbulence to the liquid and
18 gas stream exiting therefrom. The restriction should not be too great,
19 however, lest the liquid overflow the baffles 1130.

20 As may be seen in Figures 2 and 3, the inlet passageways 1195 to the
21 second mixing zone 1185 extend along a path that is radially offset from the
22 axis of the reactor wall 1105 and that is also tangential to the circular outlet in
23 the collection plate 1125. This orientation relative to the outlet, together with
24 the annular shape of the flow passageway within the second mixing zone
25 1185, optionally imparts a rotating or spiraling flow pattern to the liquid that is
26 additive to the rotating or circular flow pattern generated within the first mixing
27 zone 1180. Also, the inlet passageways 1195 is optionally tapered or
28 converges in the direction of flow of liquid from the first mixing zone into the

1 second mixing zone 1185, to thereby induce some turbulence in the flow as
2 the liquid flows through the constricted downstream end of the inlet
3 passageway into the second mixing zone 1185. The restriction should not be
4 too great, however, lest the liquid overflow the baffles 1130.

5 In certain hydrocarbon processing applications (for example,
6 hydrodesulfurization), quench gas is injected through quench gas ports into
7 the liquid and gas being processed. Quench gas may be injected to control
8 the temperature and also the composition of the liquid and gas mixture (e.g.,
9 to provide hydrogen excess) that is distributed across the underlying catalyst
10 bed. In the preferred embodiment shown in Figures 1 through 5, quench fluid
11 or gas (for example, hydrogen) is injected at a plurality of points into the liquid
12 by, e.g., quench gas ports 1140. A plurality of quench gas ports 1140 are
13 optionally disposed in the second mixing zone. Each quench gas port 1140
14 has an outlet disposed proximal to the collection plate and configured for
15 ejecting a quench gas beneath the surface of the liquid in the second mixing
16 zone 1185 and towards the tail portion of each of the generally arc-shaped
17 elongated baffles 1130.

18 The operating liquid level is lower than the height of the baffles 1130.
19 Quench gas injection at such locations along the circular flow path in the
20 second mixing zone 1185 causes agitation of the pool of liquid at each
21 location, to thereby enhance the mixing of liquid falling into and flowing
22 through the second mixing zone 1185.

23 Gas passes through the slots in cap 1150 at high velocity. The gas carries
24 entrained liquid upward toward the top of first cylindrical weir 1165. The path
25 of the upward flowing liquid and gas is redirected laterally by semi-spiral-
26 shaped baffles 1155. Upon reaching the top of first cylindrical weir 1150, the
27 liquid and gas moves toward the center of collection plate 1125. There is at
28 least some gas-liquid separation due to the density difference between the

1 phases. The fallen liquid passes through doughnut-shaped screen member
2 1170 and into fifth mixing zone 1189. The gas continues and passes through
3 the outlet in the collection plate 1125. The liquid in fifth mixing zone 1189
4 eventually rises up and over the top edge of second cylindrical weir 1175 and
5 also passes through outlet in the collection plate 1125.

6 In the preferred embodiment, the liquid and gas, as well as quench gas,
7 exiting from the outlet of the collection plate 1125 is directed to the center of a
8 perforated, flat, perforated plate 1115 that is mounted below the collection
9 plate 1125. The plate 1115 has a large number of apertures therein (only
10 some of which are shown for sake of clarity). A bubble cap assembly 1110 is
11 mounted under the plate 1115 to receive liquid and gas from the perforated
12 collector plate and distribute the liquid and gas mixture across the underlying
13 catalyst bed.

14 Further liquid mixing and liquid-gas entrainment is provided by the
15 combination of the perforated plate and bubble cap assembly. Such bubble
16 cap assembly 1110 may be of the type generally described in U.S. Pat.
17 No. 4,836,989, the contents of which is incorporated by reference. The
18 assembly includes a plate mounted under plate 1115 and a large number of
19 tubes which project upwardly from the plate and cap mounted at the upper
20 ends of the tubes. Slots are formed at the lower ends of the caps to provide
21 passageways for gas and liquid. The distribution of the tubes over the cross
22 section of the plate provides for even distribution of the liquid and gas mixture
23 over the underlying catalyst bed. It is preferred that the several distributor
24 assemblies 1120 be oriented within the reactor 1100, one between each two
25 catalyst beds.

26 The distributor assembly of the invention provides for substantial liquid-liquid,
27 gas-liquid, and gas-gas mixing directly on the collection plate 1125. This
28 provides better mixing than the staged approach used in some known devices

1 of first having only liquid-liquid and gas-gas mixing on the collection tray, then
2 having gas-liquid mixing on the bubble cap assembly below. The semi-spiral-
3 shaped baffles also contribute to substantial gas-liquid and gas-gas mixing.
4 This mixing occurs in mixing zone 3, the annular space between the cap and
5 the first cylindrical weir. The quench gas ports additionally contribute to
6 substantial gas-liquid mixing.

7 Obtaining good mixing characteristics requires taking into account the
8 following parameters, among others: intensity of local turbulence, length of
9 flow path, and overall contact time. The distributor assembly 1120 of the
10 invention addresses each of these parameters in a unique way which obtains
11 synergistic results. Intense local mixing on the collection plate 1125 is
12 provided by the gas as it lifts the liquid up the first cylindrical weir 1165 and by
13 the jetting quench gas in the vicinity of the cap 1150 and first cylindrical weir
14 1165. The length of the flow path is increased by the baffle arrangement of
15 generally arc-shaped elongated baffles 1130 on the collection plate 1125 and
16 by the circulatory motion of the liquid phase caused by the quench gas ports
17 1140. The overall contact time is augmented in this invention by addition of
18 the optional second cylindrical weir 1175.

19 The previous description of a preferred embodiment of the present invention
20 is primarily for illustrative purposes, it being recognized that a number of
21 variations might be used which would still incorporate the essence of the
22 invention. Accordingly, reference should be made to the claims below in
23 determining the scope of the invention.

24 VII. EXPERIMENTAL RESULTS

25 A. Configuration

26 A large scale size model of the distributor assembly of the invention was
27 constructed and its performance for correcting gas and liquid maldistributions

- 1 was tested. It was fixably attached to a cylindrical large scale model of a
 2 section of a catalytic reactor having a diameter of 6 ft. and a height of 7 ft.
 3 The approximate dimensions of the tested embodiment of the invention were
 4 as shown in Table 3 which follows:

5

TABLE 3		
<u>Element Name</u>	<u>Element Number Used In Figures</u>	<u>Approx. Dimensions Used in Experiment</u>
Reactor	1100	6 ft. O.D.
Reactor Side Wall	1105	7 ft. Height
First Mounting Means	1106	Grid Bars
Catalyst Beds	1107, 1108	6 in. Height
Bubble Cap Tray Assembly	1110	6 ft. Diameter
Perforated Plate	1115	6 ft. Diameter
Second Mounting Means	1117	None
Distributor Assembly	1120	18 in. Height
Distance from bottom of Collection plate 1125 to top of Cap 1150		8 in. Height
Generally Arc-Shaped Elongated Baffles	1130	62 in. Length
Quench Gas Ports	1140	0.5 in. Diameter
Cap	1150	24 in. Diameter
Semi-Spiral-Shaped Baffles	1155	11 in. Length
Fourth-mixing-zone baffles	1160	6 in. Total Length
First Cylindrical Weir	1165	18 in. Diameter
Doughnut-shaped Screen Member	1170	176 in. ² Area
Second Cylindrical Weir	1175	5 in. Diameter

1 **B. Methodology**

2 In one test, a non-reactive liquid tracer was injected in one of four test ports
3 on the perimeter of the simulated catalyst bed above the distributor assembly.
4 The tracer element acted as a simulated temperature and concentration
5 variation. Water was the diluent acting as simulated reactor primary feed.

6 The water and tracer passed through the distributor assembly. The effluent
7 was collected below the distributor assembly, then through conventional
8 perforated tray and then through a bubble cap distribution tray. The effluent
9 from the bubble cap distribution tray was collected in 16 equally-sized
10 geometrically divided zones. The concentration of the tracer in each zone
11 was determined using electroconductivity measurements.

12 **C. Results**

13 Figure 5 depicts the performance of the invention in correcting liquid
14 concentration maldistributions by showing the concentrations of a tracer liquid
15 in various zones of the effluent from the distributor assembly. The numbers
16 shown in each zone in Figure 5 indicate the standard deviation from the mean
17 concentration of the tracer across zones. The results show the deviations are
18 random and small thus indicating good liquid/liquid mixing.

VIII. CLAIMS

2 WHAT IS CLAIMED IS:

- 3 1. A distributor assembly for a multi-bed, downflow catalytic reactor
4 comprising:
- 5 (a) a cylindrical reactor wall;
- 6 (b) at least one mounting means fixably attached to said cylindrical
7 reactor wall;
- 8 (c) two or more catalyst beds fixably attached to said mounting
9 means and disposed between inner surfaces of said cylindrical
10 reactor wall, said catalyst beds being vertically superimposed in
11 relation to each other to permit liquid and gas to flow from a
12 higher catalyst bed to a lower catalyst bed;
- 13 (d) a distributor assembly fixably attached to said mounting means
14 and disposed between inner surfaces of said cylindrical reactor
15 wall and between said catalyst beds and comprising:
- 16 (1) a collection plate disposed substantially horizontally
17 between said cylindrical reactor wall, configured for
18 collecting liquid flowing down from said higher catalyst
19 bed; said collection plate having of an outlet in a center
20 portion thereof configured for allowing a passageway for
21 liquid and gas from said higher catalyst bed to flow
22 toward said lower catalyst bed;
- 23 (2) from about 2 to about 6 generally arc-shaped elongated
24 baffles:



- 1 (a) disposed in a staggered, substantially symmetrical
2 pattern about said collection plate,
- 3 (b) each baffle having a bottom edge portion fixably
4 attached to said collection plate and a top edge
5 portion extending substantially vertically upward to
6 a height sufficient to substantially prevent liquid
7 flowing over said top edge portion;
- 8 (c) each baffle having a head portion proximal to said
9 cylindrical reactor wall and having and an opposite
10 tail portion proximal to a center portion of said
11 collection plate, wherein said head portion of each
12 baffle proximal to perimeter portions of said
13 collection plate is a distance of from about 5% to
14 about 40% of the radius of said collection plate to
15 the perimeter of said collection plate; and said
16 opposite tail portion proximal to a center portion of
17 said collection plate is a distance of from about 5%
18 to about 40% of the radius of said collection plate
19 to the center of said collection plate;
- 20 (d) wherein said head portion of each of said
21 elongated baffles overlaps a tail portion of another
22 of said elongated baffles, and
- 23 (e) said elongated baffles configured for directing said
24 liquid from an outer portion of said collection plate
25 toward a center portion of said collection plate and
26 configured to cause mixing between liquid passing
27 out of the tail portion of each elongated baffle with



- 1 the liquid passing into the head portion of the
2 adjacent overlapping elongated baffle;
- 3 (3) a first mixing zone bounded on the bottom by said
4 collection plate, on one side by said cylindrical reactor
5 wall, on the opposite side by the outer surface of said
6 elongated baffles;
- 7 (4) a first cylindrical weir fixably attached to said collection
8 plate about said outlet, configured for causing said liquid
9 and gas to rise up and over said first cylindrical weir
10 before flowing through said outlet toward the lower
11 catalyst bed;
- 12 (5) a second mixing zone:
- 13 (a) bounded on the bottom by said collection plate, on
14 one side by the outer surface of said cap and said
15 first cylindrical weir, and on the opposite side by
16 the inner surface of said elongated baffles;
- 17 (b) having a plurality of entrances bound on one side
18 by the interior surface of a head portion of one
19 elongated baffle and on an opposite side by the
20 outer surface of a tail portion of an overlapping
21 elongated baffle; and
- 22 (c) wherein said entrances form passageways
23 configured to permit said liquid to flow from said
24 first mixing zone to said second mixing zone;
- 25 (6) a cap disposed over and about said first cylindrical weir.



- 1 (a) thereby forming a third mixing zone, comprising an
2 annular passageway between the outer surface of
3 said first cylindrical weir and the inner surface of
4 said cap; and
- 5 (b) said cap having a plurality of slots substantially
6 symmetrically disposed about the circumference of
7 its open end; beginning at a lower extremity and
8 disposed substantially vertically up a portion of
9 said cap; configured for allowing passage of gas
10 and liquid from said second mixing zone to said
11 third mixing zone;
- 12 (7) from about 2 to about 6 semi-spiral-shaped baffles fixably
13 disposed in said third mixing zone, said semi-spiral-
14 shaped baffles having an elongated shape, having one
15 lateral edge fixed to an inner surface of said cap or an
16 opposite lateral edge fixed to an outer surface of said first
17 cylindrical weir, and having one longitudinal end disposed
18 proximal to said a bottom portion of said first cylindrical
19 weir but above a top portion of said slots in said cap; and
20 having an opposite longitudinal end disposed proximal to
21 a top portion of said first cylindrical weir, configured for
22 causing said liquid and gas in said third mixing zone to
23 move laterally and for causing further mixing of said liquid
24 and gas;
- 25 (8) a substantially doughnut-shaped screen member
26 disposed over a top portion of said first cylindrical weir,
27 thereby forming a fourth mixing zone bounded on the top
28 by the cap, on the bottom by the substantially doughnut-



- 1 shaped screen member, an having the width of the inner
2 and outer diameter of the doughnut-shaped screen
3 member, said fourth mixing zone configured for causing
4 further liquid-liquid mixing and for causing separation of
5 said liquid and said gas, and wherein the inner diameter
6 of said substantially doughnut-shaped screen member is
7 from about 10% to about 75% of the diameter of said first
8 cylindrical weir;
- 9 (9) from about 2 to about 6 fourth-mixing-zone baffles fixably
10 attached to a top surface of said doughnut-shaped
11 screen member, configured for diverting said liquid and
12 said gas, and for causing further mixing of said liquid and
13 gas;
- 14 (10) a second cylindrical weir centrally disposed about said
15 outlet in said collection plate and disposed within said
16 first cylindrical weir and having a smaller diameter and
17 smaller height than said first cylindrical weir, thereby
18 forming a fifth mixing zone having an annular shape
19 bounded on the bottom by said collection plate, on an
20 outer side by an inner surface of said first cylindrical weir,
21 and on the inner side by an outer surface of said second
22 cylindrical weir, said fifth mixing zone configured to
23 receive liquid from said fourth mixing zone for causing
24 said liquid from said third mixing zone to further mix
25 before said liquid flows over the top edge of said second
26 cylindrical weir towards the lower catalyst bed; and
- 27 (11) from about 2 to about 6 quench gas ports disposed in
28 said second mixing zone; each port having an outlet



1 disposed proximal to said collecting collection plate and
2 configured for ejecting a quench gas beneath the surface
3 of said liquid in said second mixing zone and towards
4 said tail portion of each of said generally arc-shaped
5 elongated baffles.

6 2. A distributor assembly for a multi-bed, downflow catalytic reactor
7 comprising:

- 8 (a) a collection plate configured for substantially horizontally
9 disposal between the walls of a cylindrical reactor, configured
10 for collecting liquid flowing down from a higher catalyst bed
11 contained in said reactor; said collection plate having of an
12 outlet in a center portion thereof configured for allowing a
13 passageway for liquid and gas from said higher catalyst bed to
14 flow toward a lower catalyst bed contained in said reactor;
- 15 (b) a plurality of generally arc-shaped elongated baffles:
- 16 (1) disposed in a staggered, substantially symmetrical
17 pattern about said collection plate;
- 18 (2) each baffle having a bottom edge portion fixably attached
19 to said collection plate and a top edge portion extending
20 substantially vertically upward to a height sufficient to
21 substantially prevent liquid flowing over said top edge
22 portion;
- 23 (3) each baffle having a head portion proximal to perimeter
24 portions of said collection plate and having and an
25 opposite tail portion proximal to a center portion of said
26 collection plate;



- 1 (4) wherein said head portion of each of said elongated
2 baffles overlaps a tail portion of another of said elongated
3 baffles; and
- 4 (5) said elongated baffles configured for directing said liquid
5 from an outer portion of said collection plate toward a
6 center portion of said collection plate and configured to
7 cause mixing between liquid passing out of the tail
8 portion of each elongated baffle with the liquid passing
9 into the head portion of the adjacent overlapping
10 elongated baffle;
- 11 (c) a first mixing zone configured to be bounded on the bottom by
12 said collection plate, on one side by a wall of said cylindrical
13 reactor, on the opposite side by the outer surface of said
14 elongated baffles;
- 15 (d) a cylindrical weir fixably attached to said collection plate about
16 said outlet, configured for causing said liquid and gas to rise up
17 and over said first cylindrical weir before flowing through said
18 outlet toward the lower catalyst bed;
- 19 (e) a second mixing zone:
- 20 (1) bounded on the bottom by said collection plate, on one
21 side by the outer surface of said cap and said first
22 cylindrical weir, and on the opposite side by the inner
23 surface of said elongated baffles;
- 24 (2) having a plurality of entrances bound on one side by the
25 interior surface of a head portion of one elongated baffle
26 and on an opposite side by the outer surface of a tail
27 portion of an overlapping elongated baffle; and



- 1 (3) wherein said entrances form a passageways configured
2 to permit said liquid to flow from said first mixing zone to
3 said second mixing zone;
- 4 (f) a cap disposed over and about said first cylindrical weir:
- 5 (1) thereby forming a third mixing zone, comprising an
6 annular passageway between the outer surface of said
7 first cylindrical weir and the inner surface of said cap; and
- 8 (2) said cap having a plurality of slots substantially
9 symmetrically disposed about the circumference of its
10 open end; beginning at a lower extremity and disposed
11 substantially vertically up a portion of said cap;
12 configured for allowing passage of gas from said second
13 mixing zone to said third mixing zone;
- 14 (g) a substantially doughnut-shaped screen member disposed over
15 a top portion of said cylindrical weir, configured for causing
16 further liquid-liquid mixing and for causing separation of said
17 liquid and said gas;
- 18 (h) a plurality of fourth-mixing-zone baffles fixably attached to a top
19 surface of said doughnut-shaped screen member, configured for
20 diverting said liquid and said gas, and for causing further mixing
21 of said liquid and gas; and
- 22 (i) said distributor assembly configured for disposal and fixable
23 attachment between inner surfaces of the walls of a multi-bed
24 downflow cylindrical reactor wall and for disposal between
25 vertically stacked catalyst beds within said reactor.



- 1 3. The distributor assembly of claim 2, further comprising a plurality of
2 semi-spiral-shaped baffles fixably disposed in said third mixing zone,
3 said semi-spiral-shaped baffles having an elongated shape, having one
4 lateral edge fixed to an inner surface of said cap or an opposite lateral
5 edge fixed to an outer surface of said first cylindrical weir, and having
6 one longitudinal end disposed proximal to said a bottom portion of said
7 first cylindrical weir but above a top portion of said slots in said cap;
8 and having an opposite longitudinal end disposed proximal to a top
9 portion of said first cylindrical weir, configured for causing said liquid
10 and gas in said third mixing zone to move laterally and for causing
11 further mixing of said liquid and gas.
- 12 4. The distributor assembly of claim 2, further comprising a second
13 cylindrical weir centrally disposed about said outlet in said collection
14 plate and disposed within said first cylindrical weir and having a smaller
15 diameter and smaller height than said first cylindrical weir, thereby
16 forming a fifth mixing zone having an annular shape bounded on the
17 bottom by said collection plate, on an outer side by an inner surface of
18 said first cylindrical weir, and on the inner side by an outer surface of
19 said second cylindrical weir, said fifth mixing zone configured to
20 receive liquid from said fourth mixing zone for causing said liquid from
21 said third mixing zone to further mix before said liquid flows over the
22 top edge of said second cylindrical weir towards the lower catalyst bed.
- 23 5. The distributor assembly of claim 4, wherein said second cylindrical
24 weir is fixably attached to the same mounting means as the higher
25 catalyst bed.
- 26 6. The distributor assembly of claim 2, further comprising a plurality of
27 quench gas ports disposed in said second mixing zone; each port
28 having an outlet disposed proximal to said collection plate and



- 1 configured for ejecting a quench gas beneath the surface of said liquid
2 in said second mixing zone and towards said tail portion of each of
3 said generally arc-shaped elongated baffles.
- 4 7. The distributor assembly of claim 2 wherein said plurality of generally
5 arc-shaped elongated baffles is from about 2 to about 6.
- 6 8. The distributor assembly of claim 2 wherein:
- 7 (a) said head portion of each baffle proximal to perimeter portions
8 of said collection plate is a distance of from about 5% to about
9 40% of the radius of said collection plate to the perimeter of said
10 collection plate; and
- 11 (b) and said opposite tail portion proximal to a center portion of said
12 collection plate is a distance of from about 5% to about 40% of
13 the radius of said collection plate to the center of said collection
14 plate.
- 15 9. The distributor assembly of claim 2 wherein said plurality of fourth-
16 mixing-zone baffles is from about 2 to about 6.
- 17 10. The distributor assembly of claim 2, wherein said plurality semi-spiral-
18 shaped baffles is from about 2 to about 6.
- 19 11. The distributor assembly of claim 2 wherein the inner diameter of said
20 substantially doughnut-shaped screen member is from about 10% to
21 about 75% of the diameter of said first cylindrical weir.
- 22 12. The distributor assembly of claim 2, further comprising a perforated
23 plate disposed beneath said collection plate, and comprising a bubble
24 cap tray assembly disposed beneath said perforated plate.



- 1 13. The distributor assembly of claim 12, wherein the distance from the
2 bottom of said bubble cap tray assembly to the top of said cap of
3 claim 2 subpart (f) is not greater than about 4 ft.
- 4 14. The distributor assembly of claim 12, wherein the distance from the
5 bottom of said bubble cap tray assembly to the top of said cap of
6 claim 2 subpart (f) is not greater than about 3 ft.
- 7 15. The distributor assembly of claim 12, wherein the distance from the
8 bottom of said bubble cap tray assembly to the top of said cap of
9 claim 2 subpart (f) is not greater than about 2 ft.
- 10 16. A distributor assembly for a multi-bed, downflow catalytic reactor
11 comprising:
- 12 (a) a cylindrical reactor wall;
- 13 (b) at least one mounting means fixably attached to said cylindrical
14 reactor wall;
- 15 (c) two or more catalyst beds fixably attached to said mounting
16 means and disposed between inner surfaces of said cylindrical
17 reactor wall, said catalyst beds being vertically superimposed in
18 relation to each other to permit liquid and gas to flow from a
19 higher catalyst bed to a lower catalyst bed; and
- 20 (d) a distributor assembly fixably attached to said mounting means
21 and disposed between inner surfaces of said cylindrical reactor
22 wall and between said catalyst beds and comprising:
- 23 (1) a collection plate disposed substantially horizontally
24 between said cylindrical reactor wall, configured for
25 collecting liquid flowing down from said higher catalyst
26 bed; said collection plate having of an outlet in a center



- 1 portion thereof configured for allowing a passageway for
2 liquid and gas from said higher catalyst bed to flow
3 toward said lower catalyst bed;
- 4 (2) a plurality of generally arc-shaped elongated baffles:
- 5 (a) disposed in a staggered, substantially symmetrical
6 pattern about said collection plate;
- 7 (b) each baffle having a bottom edge portion fixably
8 attached to said collection plate and a top edge
9 portion extending substantially vertically upward to
10 a height sufficient to substantially prevent liquid
11 flowing over said top edge portion;
- 12 (c) each baffle having a head portion proximal to said
13 cylindrical reactor wall and having and an opposite
14 tail portion proximal to a center portion of said
15 collection plate;
- 16 (d) wherein said head portion of each of said
17 elongated baffles overlaps a tail portion of another
18 of said elongated baffles; and
- 19 (e) said elongated baffles configured for directing said
20 liquid from an outer portion of said collection plate
21 toward a center portion of said collection plate and
22 configured to cause mixing between liquid passing
23 out of the tail portion of each elongated baffle with
24 the liquid passing into the head portion of the
25 adjacent overlapping elongated baffle;



- 1 (3) a first mixing zone bounded on the bottom by said
2 collection plate, on one side by said cylindrical reactor
3 wall, on the opposite side by the outer surface of said
4 elongated baffles;
- 5 (4) a first cylindrical weir fixably attached to said collection
6 plate about said outlet, configured for causing said liquid
7 and gas to rise up and over said first cylindrical weir
8 before flowing through said outlet toward the lower
9 catalyst bed;
- 10 (5) a second mixing zone:
- 11 (a) bounded on the bottom by said collection plate, on
12 one side by the outer surface of said cap and said
13 first cylindrical weir, and on the opposite side by
14 the inner surface of said elongated baffles;
- 15 (b) having a plurality of entrances bound on one side
16 by the interior surface of a head portion of one
17 elongated baffle and on an opposite side by the
18 outer surface of a tail portion of an overlapping
19 elongated baffle; and
- 20 (c) wherein said entrances form passageways
21 configured to permit said liquid to flow from said
22 first mixing zone to said second mixing zone;
- 23 (6) a cap disposed over and about said first cylindrical weir:
- 24 (a) thereby forming a third mixing zone, comprising an
25 annular passageway between the outer surface of



- 1 said first cylindrical weir and the inner surface of
2 said cap; and
- 3 (b) said cap having a plurality of slots substantially
4 symmetrically disposed about the circumference of
5 its open end; beginning at a lower extremity and
6 disposed substantially vertically up a portion of
7 said cap; configured for allowing passage of gas
8 and liquid from said second mixing zone to said
9 third mixing zone;
- 10 (7) a plurality of semi-spiral-shaped baffles fixably disposed
11 in said third mixing zone, said semi-spiral-shaped baffles
12 having a elongated shape, having one lateral edge fixed
13 to an inner surface of said cap or an opposite lateral
14 edge fixed to an outer surface of said first cylindrical weir,
15 and having one longitudinal end disposed proximal to
16 said a bottom portion of said first cylindrical weir but
17 above a top portion of said slots in said cap; and having
18 an opposite longitudinal end disposed proximal to a top
19 portion of said first cylindrical weir, configured for causing
20 said liquid and gas in said third mixing zone to move
21 laterally and for causing further mixing of said liquid and
22 gas;
- 23 (8) a substantially doughnut-shaped screen member
24 disposed over a top portion of said first cylindrical weir,
25 thereby forming a fourth mixing zone bounded on the top
26 by the cap, on the bottom by the substantially doughnut-
27 shaped screen member, an having the width of the inner
28 and outer diameter of the doughnut-shaped screen



- 1 member, said fourth mixing zone configured for causing
2 further liquid-liquid mixing and for causing separation of
3 said liquid and said gas;
- 4 (9) a plurality of fourth-mixing-zone baffles fixably attached to
5 a top surface of said doughnut-shaped screen member,
6 configured for diverting said liquid and said gas, and for
7 causing further mixing of said liquid and gas;
- 8 (10) a second cylindrical weir centrally disposed about said
9 outlet in said collection plate and disposed within said
10 first cylindrical weir and having a smaller diameter and
11 smaller height than said first cylindrical weir, thereby
12 forming a fifth mixing zone having an annular shape
13 bounded on the bottom by said collection plate, on an
14 outer side by an inner surface of said first cylindrical weir,
15 and on the inner side by an outer surface of said second
16 cylindrical weir, said fifth mixing zone configured to
17 receive liquid from said fourth mixing zone for causing
18 said liquid from said third mixing zone to further mix
19 before said liquid flows over the top edge of said second
20 cylindrical weir towards the lower catalyst bed; and
- 21 (11) a plurality of quench gas ports disposed in said second
22 mixing zone; each port having an outlet disposed
23 proximal to said collecting collection plate and configured
24 for ejecting a quench gas beneath the surface of said
25 liquid in said second mixing zone and towards said tail
26 portion of each of said generally arc-shaped elongated
27 baffles.



- 1 17. The distributor assembly of claim 16, further comprising a perforated
2 plate disposed beneath said collection plate, and comprising a bubble
3 cap tray assembly disposed beneath said perforated plate.
- 4 18. The distributor assembly of claim 17, wherein the distance from the
5 bottom of said bubble cap tray assembly to the top of said cap of
6 claim 16 subpart (d)(6) is not greater than about 4 ft.
- 7 19. The distributor assembly of claim 17, wherein the distance from the
8 bottom of said bubble cap tray assembly to the top of said cap of
9 claim 16 subpart (d)(6) is not greater than about 3 ft.
- 10 20. The distributor assembly of claim 17, wherein the distance from the
11 bottom of said bubble cap tray assembly to the top of said cap of
12 claim 16 subpart (d)(6) is not greater than about 2 ft.
- 13 21. The distributor assembly of claim 16, wherein said second cylindrical
14 weir is fixably attached to the same mounting means as the higher
15 catalyst bed.
- 16 22. The distributor assembly of claim 16, further comprising a plurality of
17 quench gas ports disposed in said second mixing zone; each port
18 having an outlet disposed proximal to said collection plate and
19 configured for ejecting a quench gas beneath the surface of said liquid
20 in said second mixing zone and towards said tail portion of each of
21 said generally arc-shaped elongated baffles.
- 22 23. The distributor assembly of claim 16, wherein said plurality of generally
23 arc-shaped elongated baffles is from about 2 to about 6.
- 24 24. The distributor assembly of claim 16, wherein:
- 25 (a) said head portion of each baffle proximal to perimeter portions
26 of said collection plate is a distance of from about 5% to about



1 40% of the radius of said collection plate to the perimeter of said
2 collection plate; and

3 (b) and said opposite tail portion proximal to a center portion of said
4 collection plate is a distance of from about 5% to about 40% of
5 the radius of said collection plate to the center of said collection
6 plate.

7 25. The distributor assembly of claim 16, wherein said plurality of fourth-
8 mixing-zone baffles is from about 2 to about 6.

9 26. The distributor assembly of claim 16, wherein said plurality semi-spiral-
10 shaped baffles is from about 2 to about 6.

11 27. The distributor assembly of claim 16, wherein the inner diameter of
12 said substantially doughnut-shaped screen member is from about 10%
13 to about 75% of the diameter of said first cylindrical weir.