

WHAT IS CLAIMED IS:

1. A nozzle for the distribution of a gas-liquid fluid mixture in a down-flow reactor comprising
a nozzle body having a top, a bottom, a length, a width or a diameter, and a wall having
an interior and exterior surface, the nozzle body comprising a gas inlet zone body portion, a
liquid inlet zone body portion, and an exit zone body portion, wherein
the gas inlet zone body portion defines a gas inlet zone volume and has at least two
offset gas inlets for the passage of gas therethrough into the gas inlet zone volume and
the liquid inlet zone body portion defines a liquid inlet zone volume and has at least
one liquid inlet for the passage of liquid therethrough into the liquid inlet zone volume, the
gas and liquid inlet zone volumes being in fluid communication;
a nozzle cap located at the top of the nozzle body enclosing the top of the gas inlet zone
body portion; and
a converging-diverging nozzle restrictor located in the exit zone at the bottom of the
nozzle body, the nozzle restrictor having a frustoconical converging zone and a
frustoconical diverging zone in fluid communication with the liquid inlet zone.
2. The nozzle of claim 1, wherein the gas inlet and liquid inlet zones are in fluid
communication and are arranged such that during operation gas flows into the gas
inlet zone and therefrom into the liquid inlet zone, and liquid flows into the liquid
inlet zone, wherein the gas and liquid mix and flow into the exit zone.
3. The nozzle of claim 1 or 2, wherein one or more of the nozzle body, the gas inlet zone body
portion, the liquid inlet zone body portion, and the exit zone body portion is substantially
cylindrical.
4. The nozzle of any one of claims 1-3, wherein at least two gas inlets are located at differing
lengths along the length of the nozzle body from the top of the nozzle body.
5. The nozzle of any one of claims 1-4, wherein one or more gas inlets are configured to
produce a tangential flow of inlet gas around the interior of the gas inlet zone and to
thereby provide a gas phase spiral flow.

6. The nozzle of any one of claims 1-5, wherein the gas inlets are laterally spaced around the gas inlet zone body portion at about equal angles relative to the centerline of the nozzle body.
7. The nozzle of any one of claims 1-6, wherein the gas inlet body portion has two gas inlets spaced at about 180 degrees apart, or three gas inlets spaced at about 120 degrees apart, or four gas inlets spaced at about 90 degrees apart.
8. The nozzle of any one of claims 1-7, wherein the gas inlet body portion has two gas inlets.
9. The nozzle of any one of claims 1-8, wherein one or more liquid inlets are configured to produce a tangential flow of liquid around the interior of the liquid inlet zone and to thereby provide a liquid phase spiral flow.
10. The nozzle according to any one of claims 1-9, wherein one or more of the liquid inlets is configured to provide the spiral flow of liquid in the liquid inlet zone volume, wherein the flow of liquid is from the liquid inlets to the exit zone body portion.
11. The nozzle of any one of claims 1-10, wherein the liquid inlets are laterally spaced around the liquid inlet zone body portion at about equal angles relative to the centerline of the nozzle body.
12. The nozzle of any one of claims 1-11, wherein the liquid inlet body portion has two liquid inlets spaced at about 180 degrees apart, or three liquid inlets spaced at about 120 degrees apart, or four liquid inlets spaced at about 90 degrees apart.
13. The nozzle of any one of claims 1-12, wherein the liquid inlet body portion has two liquid inlets.
14. The nozzle of claim 5 or 9, wherein the gas phase spiral flow and the liquid phase spiral flow are in the same rotational direction.
15. A hydroprocessing system comprising the nozzle of any one of claims 1-14.
16. Use of the nozzle of any one of claims 1-14 in a hydroprocessing system.
17. Use of the nozzle of any one of claims 1-14 in a hydroprocessing down-flow reactor.

18. A method for making a nozzle for the distribution of a gas-liquid fluid mixture in a down-flow reactor comprising
- providing a standard size pipe having a defined length and width or diameter to form a nozzle body having a top, a bottom, a length, a width or a diameter, and a wall having an interior and exterior surface;
 - forming a gas inlet zone body portion in the nozzle body comprising forming at least two offset gas inlets through the wall of the gas inlet zone body portion;
 - forming a liquid inlet zone body portion in the nozzle body comprising forming at least one liquid inlet through the wall of the liquid inlet zone body portion;
 - forming an exit zone body portion in the nozzle comprising adapting or configuring the bottom of the nozzle body to include a nozzle restrictor;
 - forming a nozzle cap configured to enclose the top of the gas inlet zone body portion as an integral part of the top of the nozzle body or from a separate material;
 - forming a nozzle restrictor comprising a frustoconical converging zone and a frustoconical diverging zone as an integral part of the bottom of the nozzle body or from a separate material;
 - affixing the nozzle cap to the top of the nozzle body to enclose the top of the gas inlet zone body portion when formed from the separate material; and
 - inserting or attaching the nozzle restrictor when formed from the separate material.
19. The method of claim 18, wherein the gas inlet and liquid inlet zones are in fluid communication and are arranged such that during operation gas flows into the gas inlet zone and therefrom into the liquid inlet zone, and liquid flows into the liquid inlet zone, wherein the gas and liquid mix and flow into the exit zone.
20. The method of claim 18 or 19, wherein any of the nozzle body, the gas inlet zone body portion, the liquid inlet zone body portion, and the exit zone body portion is substantially cylindrical.
21. The method of any one of claims 18-20, wherein at least two gas inlets are located at differing lengths along the length of the nozzle body from the top of the nozzle body.
22. The method of any one of claims 18-21, wherein one or more gas inlets are configured to produce a tangential flow of inlet gas around the interior of the gas inlet zone and to thereby provide a gas phase spiral flow.

23. The method of any one of claims 18-22, wherein the gas inlets are laterally spaced around the gas inlet zone body portion at about equal angles relative to the centerline of the nozzle body.
24. The method of any one of claims 18-23, wherein the gas inlet body portion has two gas inlets spaced at about 180 degrees apart, or three gas inlets spaced at about 120 degrees apart, or four gas inlets spaced at about 90 degrees apart.
25. The method of any one of claims 18-24, wherein the gas inlet body portion has two gas inlets.
26. The method of any one of claims 18-25, wherein one or more liquid inlets are configured to produce a tangential flow of liquid around the interior of the liquid inlet zone and to thereby provide a liquid phase spiral flow.
27. The method according to any one of claims 18-26, wherein one or more of the liquid inlets is configured to provide a spiral flow of liquid in the liquid inlet zone volume, wherein the flow of liquid is from the liquid inlets to the exit zone body portion.
28. The method of any one of claims 18-27, wherein the liquid inlets are laterally spaced around the liquid inlet zone body portion at about equal angles relative to the centerline of the nozzle body.
29. The method of any one of claims 18-28, wherein the liquid inlet body portion has two liquid inlets spaced at about 180 degrees apart, or three liquid inlets spaced at about 120 degrees apart, or four liquid inlets spaced at about 90 degrees apart.
30. The method of any one of claims 18-29, wherein the liquid inlet body portion has two liquid inlets.
31. The method of claim 22 or 26, wherein the gas phase spiral flow and the liquid phase spiral flow are in the same rotational direction.
32. A nozzle for the distribution of a gas-liquid fluid mixture in a down-flow reactor made according to the method of any one of claims 18-31.