off-specification. Also, if the temperature at any point exceeds a certain value (typically 800 to 850°F), the exothermic reactions may become self-accelerating leading to a runaway event, which can damage the catalyst, the vessel, or downstream equipment.

[0005] Due to these hazards, refiners operating with poor reactor internal hardware must sacrifice yield and/or throughput to avoid the deleterious effects of poor interbed fluid mixing. Reactor temperature maldistribution and hot spots can be minimized through mixing and equilibration of reactants between catalyst beds, correcting any temperature and flow maldistributions, and minimizing pressure drops. The mixing of fluids between catalyst beds can be accomplished through the use of distributer assemblies, including nozzles incorporated on distributor trays. With present-day refinery economics dictating that hydroprocessing units operate at feed rates far exceeding design, optimum interbed fluid mixing is a valuable low-cost debottleneck.

[0006] Distributor assemblies, including distributor trays with nozzles, can be used to collect, mix, and distribute fluids in the interbed region of multi-bed catalyst reactors. Various types of nozzle and mixing devices are described in a number of patents and publications. The present invention provides certain improvements over prior art nozzle devices, such as those described in WO 2012/011989 A1 and WO 2012/011990 A1.

[0007] Due to the need for sufficient interbed fluid mixing and distribution to provide for good catalyst lifetimes, high throughput, long cycle length, and overall reactor performance, improved mixing and distribution devices are needed. A continuing need therefore exists for nozzle devices in down-flow reactors.

SUMMARY OF THE INVENTION

[0007a] According to a first aspect of the present invention, there is provided a nozzle for the distribution of a gas-liquid fluid mixture in a down-flow reactor including 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.

[0007b] According to a second aspect of the present invention, there is provided a hydroprocessing system comprising the above nozzle.

[0007c] According to a third aspect of the present invention, there is provided a use of the above nozzle in a hydroprocessing system.

[0007d] According to a fourth aspect of the present invention, there is provided a use of the above nozzle in a hydroprocessing down-flow reactor.

[0007e] According to a fifth aspect of the present invention, there is provided a method for making a nozzle for the distribution of a gas-liquid fluid mixture in a down-flow reactor including 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.

[0007f] According to a sixth aspect of the present invention, there is provided a nozzle for the distribution of a gas-liquid fluid mixture in a down-flow reactor made according to the above method.

[0008] Embodiments of the present invention are directed to a nozzle device for a down-flow hydroprocessing reactor. The nozzle provides effective mixing and distribution of gas and liquid to a catalyst bed in a hydroprocessing reactor. The nozzle provides effective mixing of an existing mixing volume in mixing the gas and liquid phases of two-phase systems, while providing for a reduced pressure drop through the nozzle as compared with other nozzles. The nozzle is well-suited for retrofit applications and can be used for new reactor designs to achieve efficient fluid mixing and distribution to a reactor catalyst bed. In conjunction with additional mixing and distribution

components of a multi-bed down-flow reactor, including, e.g., mixing boxes and distribution trays, the nozzle provides effective mixing and distribution of the liquid and gas phases in a reactor.

[0009] The nozzle generally includes a nozzle body having a top, bottom, length, width or diameter, and a wall having an interior and exterior surface. The nozzle is characterized by having at least three zones: a gas inlet zone body portion, a liquid inlet zone body portion, and an exit zone body portion. The gas and liquid inlet zones have respective volumes for the introduction of gas and liquid into the nozzle through the inlets. The nozzle also includes a cap or other closure at the top of the nozzle body and a nozzle flow restrictor located at the bottom of the nozzle. The nozzle restrictor is generally referred to as a converging-diverging nozzle restrictor since it includes a converging zone and a diverging zone, each zone having a frustoconical shape.

[0010] Embodiments of the invention also relate to hydroprocessing system comprising the nozzle and the use of the nozzle in a hydroprocessing system, including, e.g., in a distributor tray apparatus for the interbed distribution of gas and liquid to a catalyst bed.

[0011] Embodiments of the invention further relate to a method for making a nozzle for the distribution of a gas-liquid fluid mixture in a down-flow reactor. For example, in an embodiment of the invention, the nozzle body may be formed from a standard size pipe of a pre-determined length and width or diameter to form a nozzle body having a top, bottom, length, width or diameter, and a wall having an interior and exterior surface. The method includes 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 and 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. An exit zone body portion is formed in the nozzle comprising adapting or configuring the bottom of the nozzle body to include a nozzle restrictor. A nozzle restrictor comprising a frustoconical converging zone and a frustoconical diverging zone is formed as an integral part of the bottom of the nozzle body or from a separate material. When formed from a separate material, the nozzle restrictor is inserted or attached to the bottom of the nozzle body. A nozzle cap configured to enclose the top of the gas inlet zone body portion may also be formed as an integral part of the top of the nozzle body or from a separate material. When formed from a separate material, the nozzle cap is affixed to the top of the nozzle body to enclose the top of the gas inlet zone body portion.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG's 1-3 provide representative views of a nozzle device according to an embodiment of the invention. The scope of the invention is not limited by these representative figures and is to be understood to be defined by the claims of the application.

[0013] FIG. 1 shows a schematic view of an embodiment of the nozzle device of the invention, including side view 1 and cross-sectional views 1A, 1B, and 1C.