[0317] Using one dimensional models for mass, energy and momentum, the coolant stream distribution, temperature profile and pressure drop during reactor operation were described for the application of partial boiling of water to control the reaction temperature for Fischer-Tropsch synthesis.

[0318] A cooling channel and manifold system were design based on the heat flux profile from the F-T reaction when operated at a contact time of 350 ms. The reactor productivity is estimated at 0.08 barrels of FT liquid per day. The FT reactor also contained a mixture of catalyst and high thermal conductivity inert material in part of the reactor. The results show that at a pump rate of 3.0 liters per minute (LPM) at 20° C., the wall temperature across the coolant section is predicted to be controlled to a 224.2° C. to 225° C. range, surprisingly a range of less than 1° C., assuming 355 psig and 224° C. header inlet conditions, insulated perimeters and 0.2794 cm (0.011 inches) ID half circle orifices in each channel opening to the 0.05588 (0.022 inches)×0.254 cm (0.10 inches) array of parallel microchannels where boiling occurs adjacent to the FT reaction in interleaved microchannels.

[0319] Flow rates lower than 3.0 LPM result in higher outlet quality in the footer that lowers the footer overall density, making the pressure increase from the top of the footer manifold to the bottom less than in the all liquid header. Lower total flows into the header also result in lower orifice pressure losses in entering sections in the "step" have more flow than in the upstream section in a monotonic change driven by differences in the local hydrostatic pressure difference between the header and footer. That distribution bias coupled with constant heat input gives rise to higher quality in channels of the upper sections, further adding flow resistance and maldistribution. The model predicts backflow for pumping rates below 1.0 LPM, which has a predicted exit mass quality of 5%, so the recommendation is to operate at 3.0 LPM with an approach temperature to saturation down to 1° C.

[0320] **FIG. 36** illustrates reactor geometry, where coolant is cross flow in microchannels and process flow is from top to bottom (aligned with gravity). The process channels are narrower at the top of the reactor and become wider near the bottom of the reactor. There are more cooling channels near the top of the reactor than near the bottom of the reactor. This design requires a horizontal manifolding system for the coolant stream, in this case water that partially boils in the coolant channels.

Assumptions and References

Model Geometry

[0321] **FIG. 37** shows a schematic of the channels and the important dimensions.

[0322] The coolant manifold has one hundred and seventy (170) 0.05588 cm (0.022 inches) wide by 0.254 cm (0.100 inches) tall coolant channels for the end channel columns and 83 channels in the "Step" channel column. There are 0.030" tall ribs separating the channels. The total modeled height of the header and footer column is 170×(0.100"+0.030")=22.100".

[0323] The orifice opening is a 0.011" diameter half circle, which has been experimentally tested in the single channel boiling device. The purpose of the orifice is to create a higher pressure drop in the orifice at the inlet to the cooling channel than the pressure drop through the channel during partial boiling operation. By this manner, the flow is controlled to each of the hundreds of cooling channels. This orifice channel extends 0.050" in length and opens up to the main channel cross-section described in the preceding paragraph. The upstream section of the channel before the main heat exchanger section is 0.700" in length. The heat exchanger section then extends 11.500" in length. The downstream. section of the channel is 0.750" in. length prior to the footer.

[0324] The header and footer cross-sectional area sections are taken as a 0.925" diameter half circle extending from a 0.75" long by 0.925" wide rectangle, which interfaces the coolant channels.

[0325] The goal is to obtain constant wall temperature, high heat removal and robust flow (i.e. stable operation) for a coolant loop. A model based upon experimental findings allows the design for operation to be made to remove a heat load of 2750 W/m2 in the top half of the manifold and 6500 W/m2 in the bottom half. Sub-cooled water enters the header from its top and leaves the footer out the bottom.

[0326] This coolant loop has a number of heat removal channels arranged vertically with a header and footer of 0.56 meters in height arranged vertically to gravity. The fluid was brought in at high pressure (355 psig) and 224° C., just below the saturation temperature of 225° C. By using 0.02794 cm (0.011 inches) diameter half circular orifices in each channel and an average outlet mass quality of 0.02, the channel to channel quality index factor was 9%. The exit temperatures were all 224.8° C. **FIG. 38** shows the average channel mass flux rate (bottom axis) and average exit temperatures of the manifold (top axis) plotted versus the section number, ordered with the first set of seventeen channels as section **1** and the last set of 17 channels in section **10**. There is a tendency for the flow to bias toward the bottom sets of channels which is driven by the lower hydrostatic pressures difference from the top to the bottom in the vapor containing footer compared to the header.

[0327] This design can have a good flow distribution due to the pressure losses in the orifice add sufficient flow resistance. This was necessary, as the pressure drop losses for the 29.21 cm (11.5 inches) long channel is fairly small at this pressure. **FIG. 39** shows the Lockhart-Martenelli constant C versus mass quality fraction, and the constant drops from 8 at X=0.01 to zero by X=0.3, with the pressure drop best described by single phase gas pressure drops for mass quality fractions greater than 0.6.

[0328] The manifold can maintain a 225° C. wall temperature well because the convective heat transfer coefficient sees a substantial increase in just a small outlet mass quality fraction. **FIG. 40** shows the ratio of the experimentally obtained heat transfer coefficient to that of the single phase liquid heat transfer coefficient at the inlet temperature. The ratio increases quickly from unity at mass quality fraction of 0.01 to almost 5 by X=0.2. Thus the advantages of the convective boiling heat transfer can be obtained at low mass quality fractions.