aligned features. A feature is a cut-out in the shim that include shapes such as, but not limited to: circles, squares, rectangles, parallelograms, waves, irregular shapes, shapes with rounded corners, triangles and combinations thereof.

[0095] The basic design of the ortho-style integrated endothermic and exothermic reactor is shown in **FIG. 7***a*. The features cut in this shim are slots and holes. After alignment of 230 shims each 0.02 inch (0.05 cm) thick, five slots are formed for the endothermic reaction chamber. Some of these shims are used outside the reaction section to manifold and align flow stream. Each reaction slot is 1.5 inches (3.8 cm) wide and 2 inches (5 cm) long. Within this slot, a catalyst in inserted from the side after machining open access slots. Also formed after alignment and joining of the shims, are 5.1 cm long holes for the exothermic reaction. This geometry is selected to allow for an interstream pressure differential where the exothermic reaction, such as combustion, operates at lower pressure in the holes than the endothermic reaction in the slots. One example of an endothermic reaction for use in this design is methane steam reforming. A combustion catalyst may be optionally inserted or coated on the walls of the holes. Alternate designs could allow for catalyst insertion after bonding. Only one shim design is required to create the core of the reactor. Additional shims manifold and connect the flows from inlet pipes to the slots or holes within the reactor. The shims and corresponding features and flows are described starting from the connection to inlet pipes.

[0096] The cover shim **302** has separate openings for both reactants of the exothermic reaction, such as a fuel and air. The cover shim also contains an opening for the endothermic reaction mixture. The left most opening is for the fuel. Moving to the right, the next two openings **306** are for the air. The two openings **308** on the right hand side of the cover shim are for the endothermic reaction mixture. Tubing connections for each of the three streams may be welded on this cover shim. The thickness of this shim or cover plate is 0.25 inches (0.64 cm).

[0097] The next shim **310** is used for flow distribution. The shim **310** is composed of 20 shims of 0.02 inch (0.05 cm) thickness each. The fuel passes through this shim to the next adjacent shim. Both the air and endothermic reaction mixture flow laterally within this grouping of like shims to spread the flow evenly across the shim face. Air and an endothermic reaction mixture flow through alternating channels **312**, **314**.

[0098] Shim **320** is used for flow distribution. The shim **320** is composed of 1 shim of 0.02 inch (0.05 cm) thickness. The fuel passes through this shim to the next adjacent shim. The small holes **322** represent an orifice plate to provide sufficient back pressure to evenly distribute the fluids in the adjoining shims

[0099] Shim **330** comprises slots **332**, **334** for both the air and endothermic reaction mixture. The flow is now more evenly distributed across each slot. Also contained in this shim is a through hole for the combustion fuel. The shim **330** is composed of 1 shim of 0.02 inch (0.05 cm) thickness.

[0100] Shim **340** contains holes and slots. The endothermic reaction mixture flows from slots **332** in shim **330** into holes **342** in this shim. Holes are used to better contain the high pressure stream. The combustion air continues to flow in slots **344**. The combustion fuel continues to flow through the through holes **346** in the right hand side of the shim. The shim **340** is composed of 1 shim of 0.02 inch (0.05 cm) thickness.

[0101] Shim **350** is used to distribute fuel across the face of the shim. Fuel flows from the opening **352** on the right side of the shim and distributes through the slots **354** that are adjacent to the air slots **355**. The endothermic reaction mixture continues to flow through holes **352**. The shim **350** is composed of 20 shims of 0.02 inch (0.05 cm) thickness each.

[0102] Shim **360** is used for mixing the fuel and combustion air. Mixing occurs in the oblong short slots **362** that overlay the fuel slot **354** and air slot **355**. The endothermic reaction mixture continues to flow through holes **366**. The shim **360** is composed of 1 shim of 0.02 inch (0.05 cm) thickness.

[0103] Shim **370** is used to reduce the flow opening of the combustion stream to near or below the quench diameter to minimize homogeneous flame combustion. The shim **370** is composed of 20 shims of 0.02 inch (0.05 cm) thickness each.

[0104] Shim **380** is identical in design to shim **360**. The shim **380** is composed of 1 shim of 0.02 inch (0.05 cm) thickness.

[0105] The endothermic reaction mixture expands from the holes to the slots within the reactor section **390**. Slots **392** are preferred for ease of insertion of the reaction catalyst. After bonding the block, side grooves are machined to open up each of the reaction slots. The catalyst is then inserted from either side and the slots are resealed with a side plate to create a hermetic seal to the environment on the side of the device. The combustion reaction occurs in the double row of holes **394** that are interspersed between endothermic reaction slots. Holes are selected to minimize metal stresses from a high pressure differential between the streams. This pressure differential may, for example, range from 0.1 to 900 atm. A preferred range is 2-100 atm. Double rows of combustion holes are used to create more flow and reaction area for the combustion stream. This acts to give more time for reaction and reduce the combustion stream pressure drop. The reactor **390** is composed of 100 shims of 0.02 inch (0.05 cm) thickness each to create a 2 inch (5 cm) reactor flow length.

[0106] The size of the reactor shim holes were 0.04" (0.1 cm) in diameter and the slot gap was 0.035" (0.089 cm) through which the catalyst is inserted or coated and reacting flow is converted to products. The width of the slot is 1.5" (3.8 cm), although it can be any width in this design.

[0107] Shim **400** is the same as shim **380**. The reactor effluent, or product, flows from the slots into the holes. The combustion effluent flows from the double row of holes into oblong slots. The same shim design was used here to minimize the number of unique shim designs.

[0108] Shim **410** is the same as shim **370**. A different shim design could have been used to improve the performance of the device, such as pressure drop, however symmetric shims