

Channel Plate Heat Transfer System

The present invention relates to a flow-plate, an assembled flow-plate section, a flow module comprising the flow-plate, use of the flow module as a plate
5 reactor.

Background

The heat transfer to or from a process flow in a channel of a continuous plate
10 reactor or a continuous flow module is usually carried out on both sides of the channel plate by heat transfer plates, which work as barriers between process and utility fluids. When scaling up, i.e. increasing the cross section of the process flow channels, the heat transfer surface to volume ratio decreases, this could result in insufficient heat transfer capacity. Insufficient cooling may result
15 in producing more bi-products etc. which should be avoided.

The Invention

Accordingly, the present invention finds a solution to the above mentioned technical problem by providing a new flow-plate concept. Thus, the present
20 invention relates to a flow-plate heat transfer system, said flow-plate heat transfer system comprise a plate which is dividable into two parts in mid plane, i.e. two channel sides and two utility sides of the channel plate. The two parts of the flow-plate heat transfer system, i.e. the flow-plate, are complement of each other and put together form a process channel between the two channel sides.
25 The channel sides of the flow-plate comprise curved channel formed obstacles, side walls and process channel walls. The obstacles, i.e. the curved channel formed obstacles, are lined up in rows separated by the side walls, and the backside of the rows of obstacles are deep machined with grooves making the obstacles hollow for heat transfer fluids on the utility sides.

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Thus, one aspect of the invention relates to a flow-plate, which is dividable in mid plane, said flow-plate comprises two parts, each part comprises a channel

side and a utility side. The two parts of the flow plate are counter parts and complementing each other. Each channel side comprises parallel rows of obstacles, sidewalls and parallel rows of channel floors. Said sidewalls are separating said parallel rows of curved obstacles, and said sidewalls are also
5 separating said parallel rows of channel floors. The rows of curved obstacles are complementing said rows of channel floors to form a channel between the two channel sides of said flow plate. The utility sides of the rows of curved obstacles have deep machined grooves. Said deep machined grooves are lined up in parallel rows on the utility sides of the flow-plate, and the rows of deep
10 machined grooves are perpendicular to the channel. The rows of deep machined grooves are for flow of heat transfer fluids on the utility sides.

The channel has a serpentine type of pass through the plate and the channel is formed between a first sidewall and a second sidewall, and so on. The channel
15 is also formed between the curved obstacles, and the channel floors. The pass between curved obstacles and channel floors enhances the mixing of the process flow in the channel.

The flow-plate may be divided into two parts by parting the plate in its mid
20 plane, and that the complex structure of the channel could be simplified and thus easier to manufacture. Between the two parts may a gasket seal the process channel of the flow-plate when the flow-plate is mounted within the flow module or the plate reactor.

25 The flow-plate may further comprise two turbulator plates, said turbulator plates may be designed to cower the rows of deep machined grooves formed on the backside of the rows of lined up obstacles. Each one of the turbulator plates may have two sets of holes, each set of holes in a separate row on each end of the turbulator plate. The sets of holes may be communicating with the rows of
30 deep machined grooves on the backside of the obstacles. In each row of the deep machined grooves may bars be fitted corresponding to the sidewalls, which are separating the rows of the formed process channel within the flow-

plate. The side walls are passing the rows of obstacles, and are thus forming the bars within the deep machined grooves. The bars promote mixing of the heat transfer fluids and increase the heat transfer surface of the flow-plate, which also enhance heat transfer to and from the fluids flowing within the process channel. The two counter parts of the flow-plate could be moulded, could be machined, or could be combinations of moulded and machined.

Clearance slots between the sidewalls and the bars may be for small bypass of process fluids, which bypass fluids could keep the flow-plate clean during operation, and could improve the handling of the flow plates during assembling and during dissembling.

The deep machined grooves of the flow-plate may have inserted turbulators. The turbulators may be selected from metallic foam, offset strip fin turbulators, or turbulator wings arranged on strips connected to the turbulators on the utility side, preferably the inserted turbulators may be turbulator wings arranged on strips connected to the turbulators. The turbulators are for enhancing turbulence within the grooves and thus the heat transfer to and from process flow within the channel.

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Two barrier plates may be closing the flow-plate, one barrier plate on each utility side of the flow-plate. Inlets and outlets for heat transfer fluids may be arranged on each barrier plate.

The formed channel in the flow-plate may have at least one turning box, which turning box may be a space or a room between two adjacent rows of obstacles in the flow-plate. The turning boxes enables communication between two adjacent rows of obstacles, i.e. two channel rows, such that fluids may flow from one row to the other in the space of the turning box. Each turning box comprises two compartments divided by a wall. In each compartment of the turning box is one mini-obstacle arranged for creating a three dimensional flow and enhanced mixing of the process flow in the channel. The flow of fluids flow

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from a first channel row to a second channel row in the turning box. By use turning boxes it is possible to create a true three dimensional flow to give an enhanced mixing of the process flow. One or more access ports or one or more port holes, or combinations thereof may provide access to the process channel preferably access to the turning boxes. At both ends of the process channel may at least one inlet be connected, and at least one outlet may be connected to the other end of the process channel. Nozzles, which may be inserted in the access ports or the inlets, can be selected from any suitable nozzle and examples of nozzles are injection nozzles, dispersion nozzles, re-dispersion nozzles, re-mixing nozzles, coaxial nozzles, tube nozzles etc. A coaxial nozzle could be selected for the inlet port and be defined as a nozzle with two or more tubes arranged within each other, that a larger tube having a large radius is surrounding a smaller tube having a smaller radius. When such a nozzle is used two or more fluids can be mixed or form dispersions. A re-mixing nozzle could be a tube nozzle having a hole with a nozzle head and the hole has a smaller radius than the tube. The nozzle may be a dispersion nozzle which can have one or more holes at the outlet of the dispersion nozzle and the holes can be arranged in concentric circles or the holes can be arranged in other suitable patterns.

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The access ports or the port holes may have inserted port-fittings. The port-fitting may comprise fastening element and a seal arranged either externally on said shaft or the seal may be arranged at the second end portion facing away from the head, or the seal may be arranged in the short side of said second end portion. The seal may seal the port hole together with port-fitting from the fluids flowing in process channel. The port-fitting may also be a plug which closes the port hole or access port. The port-fitting may be equipped with an inlet, an outlet, a nozzle, a sensor unit, a thermo couple, a spring-loaded sensor or a resistance thermometer. Any kind of equipment which would monitor the flow of fluids within the process channel may be arranged within the port-fitting.

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The present invention relates also to an assembled flow-plate section, which flow plate section comprises a flow-plate according to the invention. In the assembled flow section is the flow-plate arranged as a core. The flow plate is dividable in mid plane and comprises two channel sides and two utility sides.

- 5 Between the two channel sides is a channel formed by curved sides of obstacles. The channel is sealed by a gasket between the two counter parting channel sides. Two utility sides are lined up by the backsides of the rows of curved obstacles and the backsides have deep grooves for heat transfer fluids. On each side of the two utility sides are a frame plate, an O-ring, a turbulator
10 plate, and also a barrier plate arranged. The two barrier plates are closing the assembled flow-plate section which comprises the flow plate.

- The assembled flow-plate section comprises also that each barrier plate have cut-open parts for distribution of heat transfer fluids into grooves on the
15 backsides of the obstacles and into utility channels which are formed by turbulator plates and barrier plates. In the cut-open parts of the barrier plates are inlets or outlets respectively arranged for heat transfer fluids.

- The utility flow or the heat transfer fluid could be divided to flow through the two
20 utility plates, i.e. one stream on each side of the flow-plate, and could be collected at the outlet. Process and utility sides could thus be totally separated, and there would be no interfaces with seals between the fluids. Therefore, all seals would be towards atmosphere.

- 25 The present invention relates also to a flow module, preferably a continuous plate reactor, which flow module comprises one or more flow-plate systems of the invention and a clamping device. The clamping device comprises a frame, two end plates, disc springs, and tension rods. The piles of disc springs could be arranged as a grid of springs supported on the end plates to distribute
30 clamping forces on flow-plates, which flow-plates are placed between the two end plates.

The flow module may also comprise that the clamping device comprises two U-formed end sections, end plates, two beam webs at each end plate. Each long sides of beam webs has at least one notch in which at least one tongue of the end plate is fitted, in such a way that an U-formed end section is formed.

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The flow module could also comprise other types of plates with different functions one example of such plates is a residence time plate. The flow module is not limited to the example, other types of plates are also possible.

10 The residence time plate may be for example completing a reaction and thus providing longer residence time in the flow module. Thus, the flow module also comprises one or more residence time plates. The residence time plates may comprise two or more chambers connected in series, and the chambers are separated by parallel walls, each wall has a hole or a passage, which hole or passage is a communication between two chambers. The holes or the passages
15 in the walls may be alternating on the right hand side or the left hand side of residence time plate, and residence time plate has at least one inlet and at least one outlet. The chambers may be equipped with inserts selected from the group consisting of folded sheet inserts, baffle ladder sheet inserts, stacked sheets inserts, metallic foam, offset strip fin turbulators or combinations thereof.
20 Preferably the flow module may have inserted folded sheet inserts, which folded sheet inserts comprises baffles which may be shifting place in each folds in an alternating fashion that they form a zigzag pattern with alternating heights of the baffles.

25 The present invention relates also to the use of the flow module as a plate reactor. Further embodiments and aspects of the invention are defined by the independent claims and the dependents claims.

Other aspects and advantages of the invention will, with reference to the
30 accompanying drawings, be presented in the following detailed description of embodiments of the invention. The below figures are intended to illustrate the

invention and are only examples of the invention, and as such not to limit the scope of the invention.

Brief description of the drawings

- 5 Figure 1 is showing a principal layout of one of the parts of a flow plate, which flow plate is divided in mid plane.
- Figure 2 is showing two connected counter parts of the flow plate.
- Figure 3 is showing utility grooves of the flow plate.
- Figure 4 is showing how a gasket is sealing the channel.
- 10 Figure 5 is showing the parallel grooves for heat transfer fluids seen from the utility side of the flow plate.
- Figure 6 is showing how the grooves are covered by the turbulators on the utility side of the flow plate.
- Figure 7 is showing how two barrier plates are arranged on top of the two utility sides.
- 15 Figure 8 is showing a port hole which has access to the channel.
- Figure 9 is showing a cross view of a flow plate with the heat transfer system.
- Figure 10 is showing a blown apart part view of a flow plate from the utility side.
- 20 Figure 11 is showing a blown apart part view of a flow plate seen from the channel side.
- Figure 12 is showing flow plates within a frame or a clamping device.
- Figure 13 is showing a U-formed end plate section.
- 25 Figure 14 is showing a sectioned part of a flow-plate having turning boxes.
- Figure 15 is showing turbulator wings inserted into the grooves.
- Figure 16 is showing the turbulator wings in an assembled flow plate.
- Figure 17 is showing a residence time plate.

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Detailed description

Figure 1 is disclosing a principal layout of one of the parts of a flow plate 1, which flow plate 1 is divided in mid plane into two mirroring counter parts. The

counter parts have each a channel side 2 and a utility side 3. On the channel side there are curved obstacles 4, sidewalls 5 and channel floors 6.

5 In Figure 2 the two parts of the flow plate are put together and the parts are counter parts and mirroring each other. When the flow parts are connected they form a channel 7 between the two counter parting channel sides. Channel 7 is limited by curved obstacles 4, sidewalls 5 and channel floors 6, and each obstacle 4 is arranged opposite channel floor 6, and channel 7 is divided by sidewalls 5 on each side of channel 7. Channel 7 will have a serpentine type of
10 direction within the space created by obstacles 4, channel floors 6 and side walls 5, and the direction of the channel will thus going up, going down and going forward. Said curved obstacles 4 on each flow part are lined up in rows separated by sidewalls 5, said lined up rows of curved obstacles 4 have deep grooves 8 which make obstacles 4 and part of sidewalls 5 hollow for heat
15 transfer fluids on utility sides 3. Grooves 8 are lined up parallel to each other on the flow plate, and grooves 8 are perpendicular to channel 7.

Figure 3 is showing how sidewalls 5 are passing grooves 8 and may constitute bars 9 within grooves 8. Bars 9 promote mixing of heat transfer fluids and
20 increase the heat transfer surface of the flow plate, which also enhance heat transfer to and from the fluids flowing within channel 7. Between sidewalls 5 and bars 9 are clearance slots 10 for small bypass flow to keep clean during operation of the flow module. Clearance slots 10 improve also the handling of the flow plates during assembling and during disassembling.

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Figure 4 is disclosing how a gasket 11 is placed on one channel side 2 for sealing the two channel sides to each other, and thus channel 7. Gasket 11 is arranged on sidewalls 5. Figure 5 is showing flow-plate 1 seen from utility side 3. From this view can parallel grooves 8 for heat transfer fluids be seen.
30 Sidewalls 5 may constitute bars 9 in grooves 8, this can also be seen in Figure 5. Bars 9 promote turbulence of the flow of heat transfer fluids and thus heat to and from channel 7.

Figure 6 discloses how grooves 8 are covered by turbulator(s) 12 on utility side 3. Turbulator 12 can have fins 13, but other alternatives are also possible. The heat transfer fluids are flowing both in grooves 8 in obstacles 4 on utility side 3, and on the utility side passing turbulator 12 with the mixing promoting fins 13, which turbulator is constructed to provide the desired turbulence of the flow of heat transfer fluids. The process fluid within channel 7 is heated or cooled along the channel rows from utility sides 3 and from grooves 8 within curved obstacles 4.

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In Figure 7 two barrier plates 14 are arranged on top of the two utility sides 3 and cover the opposite side of the created utility channels 15 enabling heat transfer fluids to flow in created utility channels 15 and in deep grooves 8. By passing the flow of utility fluids in utility channels 15 and in deep grooves 8 it is possible to enhance transfer of heat to and from the process flow in channel 7.

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Figure 8 shows how one or more access ports 16 or one or more port holes 16, or combinations thereof are providing access to channel 7. At least one of ports 16, i.e. the access ports or the port holes, is an inlet connected to channel 7, and at least one of the ports 16, i.e. the access ports or the port holes an outlet from channel 7. Figure 8 shows also an obstacle 4 with deep groove 8.

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Figure 9 is showing a cross view of flow plate 1 and a barrier plate 14 which barrier plate has a cut-open part 17 which is seen in Figure 9. Barrier plate 14 is sectioned lengthwise that it is possible to see cut-open part 17 in Figure 9 and to see part of turbulator plate 12. Cut-open part 17 makes it also possible to distribute utility fluids to utility channels 15 and to deep grooves 8. Each turbulator plate 12 has two sets of holes 18 on each end of turbulator plate 12. Holes 18 are lined up in rows one row on each end of turbulator plate 12. Holes 18 together with utility channels 15 are for distributing heat transfer fluids to the deep grooves 8 and to utility sides 3 for heat transfer to or from channel 7. An

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inlet 19 or an outlet 19 is distributing heat transfer fluids to or from utility sides 3. Figure 9 shows also one port 16 which communicates with channel 7.

Figure 10 is showing a blown apart part view of flow plate 1 seen from utility side 3, and Figure 11 is showing a blown apart part view of flow plate 1 seen from channel side 2. Figure 10 is showing how grooves 8 are arranged in parallel rows, the rows are perpendicular to channel 7 of flow plate 1, channel 7 is not seen in Figure 10. Turbulator plate 12 could be sealed with an O-ring 20 against a frame plate 21 between utility side 3 of flow plate 1 and barrier plate 14. Two sets of holes 18 are provided in turbulator plate 12 for communication and transport of heat transfer fluids to grooves 8. Frame plate 21 may be integrated with utility side 3 of flow plate 1 as one alternative or frame plate 21 could be integrated with barrier plate 14 as another alternative, but frame plate 21 could also be a separate plate as shown in Figure 10. In Figure 10 cut-open part 17 can not be seen since barrier plate 14 is not sectioned in this figure and the view of barrier plate 14 is from the outside.

Figure 11 is showing a blown apart part view of flow plate 1 together with a turbulator plate 12 and a barrier plate 14 seen from channel side 2 and Figure 11 is disclosing that flow plate 1 comprises channel 7 which could change direction in at least one turning box, not seen in Figure 11 or Figure 10. A turning box, which can be seen in Figure 14, could be arranged between two adjacent channel rows 22 forming two compartments in a space between two adjacent channel rows 22 in flow plate 1 and one inner side of the flow plate. The compartments could be divided by a wall to create a three dimensional flow resulting in an enhanced mixing, and that fluids may flow from a first channel row to a second row in the turning box. Grooves 8 are arranged in rows perpendicular to channel rows 22 of the flow plate. Cut-open part 17 can be seen in Figure 11 since barrier plate 14 is seen from channel side 2. Inlet 19 or outlet 19 can also be seen in Figure 11.

Figure 12 is showing a clamping device which comprises flow plates 1, frame 23, grids of springs 24 and end plates 25 forming when assembled a flow module. Flow plates 1 are assembled within frame 23. Frame 23 is holding flow plates 1 into place between two distribution plates 26, together with two pressure plates 27 between two end plates 25. Flow plates 1 could be put into place and compressed by aid of hydraulic cylinders tensioning the tension rods. Flow plates 1 are kept in place by the force from grids of springs 24 and end plates 25, nuts 28 could be tightened and the force from hydraulic cylinders could be released. The two end plates 25 are positioned so that the intended number of flow plates 1 can be entered between them when in open position. The distance between end plates 25 may be adjusted by choosing the number of sleeves 29 and tightening of nuts 28 on one end of each tension rod 30.

Distribution plates 26 distribute the force contributions from the grids of springs 24 and end plates 25. The force on flow plates 1 can be measured by measuring the distance between one end plate 25 and how far indicator pins 31 have reached outside end plate 25. The flow module could be a plate reactor.

Figure 13 is showing U-formed end sections 32 which could be assembled with frame 23. Each U-formed end sections 32 comprise an end plate 25 and two elongated beam webs 33. The two elongated beam webs 33 could be arranged on each side of end plate 25 forming a U-shape beam construction. Each edge of the long side of end plates 25 may be stepped, i.e. the edge has a tongue 34 of about half the thickness of the edge. Each beam web 33 has a notch 35 along an edge of its long side 36. To fix beam webs 33 and end plates 25 together bolts 37 are arranged in through holes 38 along the edge of beam webs 33 and fastened in corresponding holes in end plates 25 and tongue 34 is fitted into the notches 35 of the beam webs 33. To further fix the position of the beam webs 33 in relation to end plates 25 and strengthen the design, notches 35 may have bridges 39 i.e. interruptions in notches 35 at strategic positions, which bridges 39 correspond to interruptions in tongues 34 at the same positions.

Figure 14 is showing a part of a flow-plate having turning boxes 39. The flow-plate of Figure 14 is sectioned that it is possible to see the top part of obstacles 4 and turning boxes 39. Turning boxes 39 have two compartments 40
5 corresponding to the space between two adjacent channel rows. The two compartments 40 are divided by wall 41 which is an elongation of sidewall 5 but has a different height for providing contact between the two compartments. Two mini-obstacles 42 one in each compartment have also a different height compared to obstacles 4. The height of mini-obstacles 42 correspond with the
10 height of wall 41 and provide a three dimensional flow in channel 7 resulting in an enhanced mixing, and that fluids may flow from a first channel row to a second row in turning boxes 39.

Figure 15 is showing turbulator wings 43 which can be inserted into the
15 grooves. Wings 43 are arranged on strips 44 which are connected to turbulator 12. Figure 16 is showing turbulator wings 43 inserted into grooves 8 in an assembled flow plate. The addition of turbulator wings 43 will enhance turbulence within the grooves and thus heat transfer. Other types of turbulators which can be inserted into grooves 8 could be metallic foam, or offset strip fin
20 turbulators.

Figure 17 is showing a residence time plate 45, residence time plate 45 comprises two or more chambers connected in series, the chambers are separated by parallel walls, each wall has a hole or a passage, which hole or
25 passage is a communication between two chambers, the holes or the passages are alternating on the right hand side or the left hand side of residence time plate 45. Residence time plate 45 has at least one inlet and at least one outlet. The chambers could be equipped with inserts selected from the group consisting of folded sheet inserts 46, baffle ladder sheet inserts, stacked sheets
30 inserts, metallic foam, offset strip fin turbulators or combinations thereof.

Preferably the inserts are folded sheet inserts 46, which comprise baffles which are shifting place in each fold in an alternating fashion that they form a zigzag pattern with alternating heights of the baffles.

- 5 On each side of residence time plate 45 is a gasket 47 for sealing the residence time plate. Residence time plate 45 and gaskets 47 are placed within at least one utility plate 48 when the flow module is assembled.

10 The flow module of the present invention is useful when undertaking the following process operations; manufacturing, reactions, mixing, blending, doing cryogenic operations, washing, extractions and purifications, pH adjustment, solvent exchanges, manufacturing of chemicals, manufacturing of intermediate chemicals, manufacturing API (active pharmaceutical ingredients) when
15 working with low temperature operations, manufacturing of pharmaceutical intermediates, scale-up and scale-down developments, precipitation or crystallisations, performing multiple injections or multiple additions or multiple measurements or multiple samplings, working with multistep reactions, pre-cooling operations, preheating operations, post-heating and post-cooling operations, processes for converting batch processes to continuous processes,
20 and operations for dividing and recombining flows.

Reaction types which can be preformed in the present invention include addition reactions, substitution reactions, elimination reactions, exchange reactions, quenching reactions, reductions, neutralisations, decompositions,
25 replacement or displacement reactions, disproportionation reactions, catalytic reactions, cleaving reactions, oxidations, ring closures and ring openings, aromatization and dearomatization reactions, protection and deprotection reactions, phase transfer and phase transfer catalysis, photochemical reactions, reactions involving gas phases, liquid phases and solid phases, and which may
30 involve free radicals, electrophiles, nucleophiles, ions, neutral molecules, etc.

Synthesis such as amino acid synthesis, asymmetric synthesis, chiral synthesis, liquid phase peptide synthesis, olefin metathesis, peptide synthesis, etc. can also be carried out with the flow module. Other types of synthesis in which the flow module can be used are reactions within carbohydrate chemistry, carbon disulfide chemistry, cyanide chemistry, diborane chemistry, epichlorohydrin chemistry, hydrazine chemistry, nitromethane chemistry, etc. or synthesis of heterocyclic compounds, of acetylenic compounds, of acid chlorides, of catalysts, of cytotoxic compounds, of steroid intermediates, of ionic liquids, of pyridine chemicals, of polymers, of monomers, of carbohydrates, of nitrones etc.

The flow module is suitable for name reactions such as Aldol condensations, Birch reductions, Baeyer-Villiger oxidations, Curtius rearrangements, Dieckmann condensations, Diels-Alder reactions, Doebner-Knoevenagel condensations, Friedel-Crafts reactions, Fries rearrangements, Gabriel synthesis, Gomberg-Bachmann reactions, Grignard reactions, Heck reactions, Hofmann rearrangements, Japp-Klingemann reactions, Leimgruber-Batcho indole synthesis, Mannich reactions, Michael additions, Michaelis-Arbuzov reactions, Mitsunobu reactions, Miyaura-Suzuki reactions, Reformatsky reactions, Ritter reactions, Rosenmund reductions, Sandmeyer reactions, Schiff base reductions, Schotten-Baumann reactions, Sharpless epoxidations, Skraup synthesis, Sonogashira couplings, Strecker amino acid synthesis, Swern oxidations, Ullmann reactions, Willgerodt rearrangements, Vilsmeier-Haack reactions, Williamson ether synthesis, Wittig reactions etc.

Further reactions which the flow module is suitable for are condensation reactions, coupling reactions, saponifications, ozonolysis, cyclization reactions, cyclopolymerization reactions, dehalogenations, dehydrocyclizations, dehydrogenations, dehydrohalogenations, diazotizations, dimethyl sulphate reactions, halide exchanges, hydrogen cyanide reactions, hydrogen fluoride reactions, hydrogenation reactions, iodination reactions, isocyanate reactions, ketene reactions, liquid ammonia reactions, methylation reactions, coupling,

organometallic reactions, metalation, oxidation reactions, oxidative couplings, oxo reactions, polycondensations, polyesterifications, polymerization reactions, other reaction such as acetylations, arylations, acrylations, alkoxylation, ammonolysis, alkylations, allylic brominations, amidations, aminations, 5 azidations, benzoylations, brominations, butylations, carbonylations, carboxylations, chlorinations, chloromethylations, chlorosulfonations, cyanations, cyanoethylations, cyano-methylations, cyanurations, epoxidations, esterifications, etherifications, halogenations, hydroformylations, hydro-silylations, hydroxylations, ketalizations, nitrations, nitro-methylations, 10 nitrosations, peroxidations, phosgenations, quaternizations, silylations, sulfochlorinations, sulfonations, sulfoxidations, thiocarbonylations, thiophosgenations, tosylations, transaminations, transesterifications, etc.

The present invention is further defined by the independent claims and the 15 dependent claims.

Claims

1. A flow-plate (1) which is dividable in mid plane, comprises two parts, each part comprises a channel side (2) and a utility side (3), the two parts of the flow plate are counter parts and complementing each other, each channel side (2) comprises parallel rows of obstacles (4), sidewalls (5) and parallel rows of channel floors (6), said sidewalls (5) are separating said parallel rows of curved obstacles (4), and said sidewalls (5) are separating said parallel rows of channel floors (6), and said rows of curved obstacles (4) are complementing said rows of channel floors (6) to form a channel (7) between the two channel sides (2) of said flow plate (1), the utility sides (3) of the rows of curved obstacles (4) have deep machined grooves (8), said deep machined grooves (8) are lined up in parallel rows on the utility sides (3) of flow-plate (1), and the rows of deep machined grooves (8) are perpendicular to the channel (7), and the rows of deep machined grooves (8) are for flow of heat transfer fluids on the utility sides (3).
2. A flow-plate according to claim 1, wherein flow-plate (1) further comprises two barrier plates (14) and two turbulator plates (12) said turbulator plates (12) are designed to cover the deep machined grooves (8), and the two barrier plates (14) are closing the utility sides (3), one barrier plate on each utility side (3) opposite utility sides (3) creating utility channels (15), each barrier plate have cut-open parts (17) for distribution of heat transfer fluids, and arranged in the cut-open parts are inlets (19) or outlets (19) respectively for heat transfer fluids.
3. A flow-plate according to claim 1 or 2, wherein each turbulator plate (12) has two sets of holes (18) lined up in rows one row on each end of turbulator plate (12), said sets of holes (18) together with cut-open parts (17) are for distributing heat transfer fluids to the deep machined grooves (8) and to utility channels (15) for heat transfer to or from channel (7).

4. A flow-plate according to any one of claim 1, 2 or 3, wherein one or more access ports (16) or one or more port holes (16), or combinations thereof are providing access to channel (7), at least one of access ports (16) or one port holes (16), or combinations thereof, is an inlet connected to channel (7), and at
5 least one of access ports (16) or one port holes (16), or combinations thereof, is an outlet connected to channel (7).

5. A flow-plate according to any one of the preceding claims, wherein
10 sidewalls (5) are fitted in bars (9) in the deep machined grooves (8).

6. A flow-plate according to any one of the preceding claims, wherein the two counter parts of flow plate (1) are moulded, are machined or are combinations of moulded and machined.

15 7. A flow-plate according to any one of the preceding claims, wherein clearance slots (10) between sidewalls (5) and bars (9) are for small bypass to keep clean during operation and for improving handling of flow plates (1) during assembling and during disassembling.

20 8. A flow-plate according to any one of the preceding claims, wherein the flow-plate also have turning boxes (39), which turning box comprises two compartments (40) divided by a wall (41), in each compartment is one mini-obstacle (42) arranged for creating a three dimensional flow and enhanced mixing in channel (7), and that fluids flow from a first channel row to a second
25 channel row in turning box (39).

9. A flow-plate according to any one of the preceding claims, wherein the deep machined grooves (8) have inserted turbulators selected from metallic foam, offset strip fin turbulators, or turbulator wings (43) arranged on strips (44)
30 connected to turbulator (12), preferably the inserted turbulators are turbulator wings (43) arranged on strips (44) connected to turbulator (12), and wherein the turbulators are for enhancing turbulence within the deep machined grooves.

10. An assembled flow-plate section comprising a flow-plate (1) said flow-plate (1) is dividable in mid plane and is the core of the flow-plate section, which flow-plate (1) comprises two channel sides (2) and two utility sides (3), between the
5 two channel sides (2) is channel (7) formed by curved sides of obstacles (4), channel (7) is sealed by gasket (11) between the two counter parting channel sides (2), the two utility sides (3) are lined up by the backsides of the rows of curved obstacles (4), the backsides have deep machined grooves (8) for heat transfer fluids and on each utility side (3) is a frame plate (21), an O-ring (20), a
10 turbulator plate (12), and also a barrier plate (14) arranged, the two barrier plates (14) are closing the assembled flow-plate section.

11. An assembled flow-plate section according to claim 10, wherein the flow-plate is according to any one of claims 1 to 9.

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12. An assembled flow-plate section according to claim 10 or 11, wherein each barrier plate have cut-open parts (17) for distribution of heat transfer fluids into the deep machined grooves (8) and into utility channels (15) formed by turbulator plates (12) and barrier plate (14), and arranged in the cut-open parts
20 are inlets (19) or outlets (19) respectively for heat transfer fluids.

13. A flow module, preferably a plate reactor, comprising one or more assembled flow plate sections, according to claim 10, 11, or 12, and a clamping device, which clamping device comprises a frame (23), two end plates (25),
25 disc springs (24), and tension rods (30), wherein piles of disc springs (24) are arranged as a grid of springs supported on end plates (25) to distribute clamping forces on flow plates (1), which flow plates are placed between the two end plates (25).

30 14. A flow module according to claim 13, wherein the clamping device comprises two U-formed end sections (32) comprising end plates (25), two beam webs (33) at each end plate (25), wherein each long sides of beam webs

(33) has at least one notch (35) in which at least one tongue (34) of end plate (25) is fitted, in such a way that an U-formed end section (32) is formed.

15. A flow module according to claim 13 or 14, wherein the flow module also
5 comprises one or more residence time plates comprising two or more chambers connected in series, the chambers are separated by parallel walls, each wall has a hole or a passage, which hole or passage is a communication between two chambers, the holes or the passages are alternating on the right hand side or the left hand side of residence time plate (45), and residence time plate (45)
10 has at least one inlet and at least one outlet, the chambers are equipped with inserts selected from the group consisting of folded sheet inserts (46), baffle ladder sheet inserts, stacked sheets inserts, metallic foam, offset strip fin turbulators or combinations thereof.
- 15 16. A flow module according to claim 15, wherein the inserts are folded sheet inserts (46), comprising baffles which are shifting place in each fold in an alternating fashion that they form a zigzag pattern with alternating heights of the baffles.
- 20 17. Use of a flow module according to any one of claims 13 to 16 as a reactor for chemical reactions.