filtration unit to the second filtration unit and for controlling the ultrafiltration and/or diafiltration process.

US 2015/000777 A1 shows a modular fluid control system comprised of a plurality of fluid control modules, each including a manifold portion. The modules are mechanically fixed to a support element. Each module is in close proximity with an adjacent module, but not mechanically fastened. Due the close proximity between the modules, a seal at a first open end of a manifold passage seals against the second open end of a neighboring module, so as to form a through passage between modules. The modules can be removed from within an array without disturbing neighboring units.

Summary

It is an object of the invention to overcome the limitations of the device arrangements known from the prior art and to make it possible to easily provide individually configured bioprocess device assemblies with great flexibility.

The above problem is solved by a modular system according to the present disclosure. Advantageous and expedient embodiments of the invention are apparent from the present disclosure.

In an aspect, the present disclosure refers to a modular system for providing a bioprocess device assembly, the modular system comprising:

- a rigid skid, and

- a plurality of grid-modules;

the skid including a plurality of identical plug-in structures, the plurality of plug-in structures being arranged in a regular two-dimensional grid, the grid arrangement of the plug-in structures defining two-dimensional plug-in fields of an identical standard shape and size,

at least some of the grid-modules having a matching counterpart plug-in structure adapted to fix the respective grid-module to any of the plug-in structures of the skid,

at least some of the grid-modules, in an installed state when fixed to a plug-in structure of the skid and/or to a neighboring grid-module, having a two-dimensional extension in the plane of the grid that is not greater than the standard size of the plug-in fields,

at least some of the grid-modules including at least one connection port adapted to receive a rigid universal flow connector of standard shape and size in a standard position and orientation, the universal flow connector establishing a flow connection between two neighboring grid-modules,

the connection port of each grid-module defining the standard position and orientation of the universal flow connector such that, in its installed state, the grid-module can be connected via the universal flow connector either directly to the connection port or to another universal flow connector received in the connection port of an opposing grid-module fixed to the grid-module and/or to a neighboring plug-in structure,

at least some of the grid-modules having at least one integrated fluid line through, or into, which a medium to be processed or analyzed can flow, the integrated fluid line being in flow communication with the connection port of the grid-module;

the plurality of grid-modules including:

- at least one flow control grid-module having means for actively changing flow properties of the medium, and/or

- at least one interaction grid-module having means for sensing, detecting or measuring a property of the medium.

In another aspect, the present disclosure refers to a computer program including an algorithm for creating a digital simulation of a bioprocess device assembly configured by a user based on the modular system according to the above aspect, the computer program providing digital counterparts of the grid-modules and a digital interface, enabling a user to configure a digital version of a bioprocess device assembly based on the digital counterparts of the grid-modules, the computer program providing a simulation of the functionality of the bioprocess device assembly.

The present disclosure provides in an example a modular system for providing a bioprocess device assembly and comprises a rigid skid and a plurality of grid-modules. The skid includes a plurality of identical plug-in structures being arranged in a regular two-dimensional grid. The grid arrangement of the plug-in structures defines two-dimensional plug-in fields of an identical standard shape and size. At least some of the grid-modules have a matching counterpart plug-in structure adapted to fix the respective grid-module to any of the plug-in structures of the skid. At least some of the grid-modules, in an installed state when fixed to a plug-in structure of the skid and/or to a neighboring grid-module, have a two-dimensional extension in the plane of the grid that is not greater than the standard size of the plug-in fields. At least some of the grid-modules include at least one connection port adapted to receive a rigid universal flow connector of standard shape and size in a standard position and orientation. The connection port of each grid-module defines the standard position and orientation of the universal flow connector such that, in its installed state, the grid-module can be connected via the universal flow connector directly to the connection port of an opposing grid-module fixed to the grid-module or to a neighboring plug-in structure. As an alternative, the grid-module can be

connected via the universal flow connector to another universal flow connector received in the connection port of an opposing grid-module fixed to a neighboring plug-in structure. At least some of the grid-modules have at least one integrated fluid line through, or into, which a medium to be processed or analyzed can flow. The integrated fluid line is in flow communication with the connection port of the grid-module. The plurality of grid-modules includes at least one flow control grid-module having means for actively changing flow properties of the medium, and/or at least one interaction grid-module having means for sensing, detecting or measuring a property of the medium.

The modular system allows a plurality of interacting grid-modules to be detachably fixed in any of a plurality of defined positions on a skid to create individually configured bioprocess device assemblies. Due to the direct flow connection between neighboring grid-modules, compact tubeless setups can be realized. A great flexibility is achieved because the grid-modules can be replaced or exchanged easily. The invention allows to create a flexible trial kit in process development on the one hand, and a fully self-contained, preassembled GMP (good manufacturing practice) ready production assembly on the other hand.

In the given context, a rigid skid is to be understood as a stiff frame, plate or any other support structure providing a plurality of regularly arranged plug-in structures, preferably on a generally flat surface, for carrying a plurality of grid-modules. The skid can be part of a work platform or a control tower or a similar system for assisting the performance of unit operations.

According to the disclosure, the plug-in structures of the skid are arranged in a regular two-dimensional grid. This means that the plug-in fields defined by the positions of the regularly arranged plug-in structures are all of identical shape and size. In particular, the shape is that of a rectangle (e.g. a square) or a regular polygon (equiangular and equilateral), resulting in a regular tessellation of the skid. For example, the regular two-dimensional grid can be a rectilinear cartesian grid or a honeycomb grid.

The grid-modules are individual units providing functions that are typically required in a bioprocess device assembly. The various types of grid-modules can be assigned to different groups or categories. According to the disclosure, the plurality of grid-modules includes at least one flow control grid-module having

means for actively changing flow properties of the medium, and/or at least one interaction grid-module having means for sensing, detecting or measuring a property of the medium. A control grid-module can include a valve or a pump, for example, whereas an interaction grid-module can include a sensor or a probe head, for example. Of course, other types of grid-modules can be employed as well, as will be explained later.

The grid-modules typically have a counterpart plug-in structure matching the plug-in structures of the skid. However, it is to be noted that not all of the grid-modules need to have such a counterpart plug-in structure. Some of the grid-modules may be held by one or more of their neighboring grid-modules which, in turn, are fixed to the skid via their counterpart plug-in structures.

Further, some of the grid-modules may have a two-dimensional extension that is greater than the standard size of a regular plug-in field. In particular, the dimension of a grid-module in one of the directions in the plane of the grid can be greater than the corresponding dimension(s) of the standard size plug-in field. However, according to the disclosure, the dimensions of such a larger grid-module are such that it is ensured that the larger grid-module could be connected to a neighboring grid-module of standard size via a universal flow connector. In simple terms, the dimension of a larger grid-module can be an integer multiple of the corresponding dimension of the plug-in field.

Fluid connection between any neighboring grid-modules having a fluid-related function is provided via universal flow connectors having a standard shape and a standard size. This means that the connectors are not specific to the respective grid-module (type), but common to all grid-modules. Since all grid-modules that need fluid connection are adapted to receive such a universal flow connector in a standard position and orientation, only one type of flow connectors needs to be provided for the whole modular system. According to the disclosure, the connection port of each grid-module defines the standard position and orientation (relative to the plane of the grid) of the universal flow connector such that, in its installed state, the respective grid-module can be connected via the universal flow connector to the connection port or to a universal flow connector of an opposing grid-module fixed to a neighboring plug-in structure, irrespective of the actual type of the grid-module (as long as it has a fluid connection).

The modular concept of the invention is most effective in practice with grid-modules whose maximum extensions in the plane of the grid are equal to the corresponding extensions of the plug-in fields. Irrespective of the actual shape of the plug-in fields (e.q. squares or regular hexagons), this allows the greatest flexibility for setting up clear individual configurations which can be easily assembled and changed, if necessary, by the user.

According to a preferred example, at least one of the grid-modules includes four connection ports in a right-angle arrangement. This allows maximum flexibility since such a grid-module can establish flow connections in all orthogonal directions in the plane of the grid.

The arrangement of grid-modules can even be expanded in a further direction, thus allowing even more complex three-dimensional configurations. To this end, at least one of the grid-modules includes a further plug-in structure allowing another grid-module to be connected in a direction perpendicular to the plane of the grid. According to this concept, grid-modules can be stacked on one another to overcome the limitations of two-dimensional grid-module patterns.

In order to provide a flow connection between stacked grid-modules, at least one grid-module includes a universal flow connector that, in the installed state of the grid-module, is oriented in a direction perpendicular to the plane of the grid.

Apart from flow connections, it is useful to also standardize any electrical and/or optical connections that are necessary in the final bioprocess device assembly. Therefore, at least some of the grid-modules can include at least one universal electrical and/or optical connector adapted to be connected to a universal electrical and/or optical connector of a neighboring grid-module or to an electrical and/or optical interface of a neighboring grid-module.

According to a further development, the modular system is not limited to fluid-related grid-modules, but further comprises at least one non-fluid grid-module without any fluid connection to a neighboring grid-module, but having at least one universal mechanical and/or electrical and/or optical connector adapted to be connected to a universal mechanical and/or electrical and/or optical connector of a neighboring grid-module.

Some of the grid-modules that are typically used in certain arrangements can be preassembled to form a structural unit before they are fixed to the skid.

In particular, the preassembled group of grid-modules can be held together in an installation box or by an installation frame for easier shipment and installation. According to a variant, the box or frame itself includes flow and/or electrical and/or optical connectors.

The installation box or installation frame itself can also be a skid in the sense of the invention. This means that the installation box or installation frame functions as a support structure and provides a number of regularly arranged plug-in structures for carrying a corresponding number of grid-modules. In this case the installation box or installation frame and the grid-modules fixed therein can constitute an independent (autarchic) bioprocess device assembly in the sense of the invention.

To help the user in setting up a configuration with the modular system and to avoid confusion, at least some of the grid-modules can be provided with a schematic graphical representation of a function associated to the respective grid-module on an outer surface thereof. This allows the user to easily identify the function of a grid-module at any time.

Schematic graphical representations can also be provided in at least some of the plug-in fields of the skid. Especially when certain plug-in fields are reserved for specific grid-modules, such schematic graphical representations of the functions associated to those grid-modules show the user where to place them. According to a further development, schematic graphical representations can be visualized in the plug-in fields according to a predefined (part of a) configuration scheme or according to a digital configuration scheme created with a computer program. While permanent graphical representations can be realized as printings, etched structures etc., variable graphical representations would require the skid to include one or more displays or illumination means, or the graphical representations are projected on the skid by a projector, or the graphical representations are presented to the user via AR (augmented reality).

To avoid the hassle of cables related to power supply and data/signal transfer, the grid-modules can include a wireless communication module and/or a wireless power receiver.

A major example is the integration of functional components, especially sensors, in some of the grid-modules. Such sensors are used to monitor certain characteristics of the medium flowing through the respective module. To facilitate placing and mounting such functional components, universal receptacles can be used which are adapted to receive universal functional components. “Universal” means that different types of functional components have a design matching a standard design of a receptacle, so that the receptacle is capable of receiving different types of functional components.

Preferably, the universal receptacle is integrated into a fluid line or into a flow connector of the grid-module. It is to be understood that the fluid line or the flow connector itself can be designed such that no additional part is required to receive a functional component, i.e. the fluid line or the flow connector itself can be the universal receptacle.

As already indicated before, at least one of the grid-modules can include several functional components. For example, a flow control grid-module including a valve can further include a sensor or a flow cell, or a grid-module including crossing fluid lines can further include several sensors accommodated in some of the fluid line portions.

One or more of the grid-modules may include a securing mechanism with extendable hooks in order to secure the grid-module to the skid via the hooks.

A grid-module may include a mounting structure for fixing a component having a structure matching the mounting structure. The mounting structure of the grid-module thus serves as an adapter for fixing, for example, a probe head, or other components.

As mentioned in the beginning, especially in the pharmaceutical production of high-quality active ingredients single-use equipment is used to an increasing extent due to the high flexibility achievable therewith as well as the saving of time, investments and operating expenditure such as the cleaning, validation and examination of such equipment. Single use equipment is not only used in the field

of product and process development anymore, but also in the field of clinical trial manufacturing (CTM) for the approval procedure and even in the commercial good manufacturing practice (GMP) in the production of drugs. Therefore, it is preferred that the grid-modules of the modular system according to the disclosure are single-use grid-modules made from materials whose properties are not significantly deteriorated when sterilized by ionizing radiation, such as gamma rays or beta rays or X-rays, or by chemicals or by steam. This means that basic characteristics of such materials, like mechanical stability, toughness (opposite of brittleness) etc. and the dimensions of components made from such materials, are not significantly affected by a sterilization process.

According to a preferred example, the materials used for the grid-modules can be further distinguished as follows: Any components that come into contact with fluid during use are made from a group of first materials to fulfill the high safety and regulatory requirements for materials in contact with pharmaceutical products and intermediates, and any structural components that do not come into contact with fluid during use are made from a group of second materials which are different from the first materials. The first materials can be certified with respect to at least one of the following criteria: bio-safety, chemical compatibility and robustness, extractables and/or leachables, TSE/BSE regulations; whereas the second materials are selected from at least one of the following: recycled plastic, renewable materials. This distinction of materials allows to use highly regulated materials only where needed and therefore to reduce the CO_2 footprint and to save resources and costs.

Moreover, according to a special example, the distinction of components made from first and second materials allows easy separation and appropriate further processing of the components after use. The fluid-contacting components can be separated from the rest of the grid-module after use without opening the fluid-contacting components so that any residual fluid does not come into contact with the rest of the grid-module. This allows a separation into contaminated / non-contaminated components, a separation into different types of unmixed/homogeneous plastics (recycling), or separation into a recycling portion (reusable returnable packaging) and a disposable portion.

The disclosure also provides in an example a computer program including an algorithm for creating a digital simulation of a bioprocess device assembly configured by a user based on the modular system described above. The computer program provides digital counterparts of the grid-modules and a digital interface, enabling a user to configure a digital version of a bioprocess device assembly based on the digital counterparts of the grid-modules. The computer program then provides a simulation of the functionality of the bioprocess device assembly as configured by the user. Thus the computer program allows a user to create a digital version of a bioprocess device assembly – based on a drag & drop functionality of the program, for example – before it is built in the real world. The computer program assists the user in setting up the configuration, and the functionality of the configuration can be tested and simulated, so that costly errors in the real configuration can be avoided.

To assist the user in creating a fully functional bioprocess device assembly, the computer program can include templates for standard configurations, a trouble solver algorithm and an optimization proposal algorithm which could be based on artificial intelligence.

Moreover, the digital version created by the computer program can work as a digital twin of the real bioprocess device assembly for controlling the process performed by the device assembly (especially controlling the pumps, valves etc.) and/or for detection (via the sensors etc.) and correction (adjusting process parameters etc.) of deviations.

Further features and advantages of the invention will become apparent from the following description and from the accompanying drawings to which reference is made. In the drawings:

- Figure 1 shows a top view of a skid for a modular system according to the invention with a plurality of plug-in fields arranged in a two-dimensional grid of a first kind;

- Figure 2 shows a top view of three plug-in structures of the skid;

- Figure 3 shows a top view of a skid with a plurality of plug-in fields arranged in a two-dimensional grid of a second kind;