drying chamber, an unloading chamber adjacent the drying chamber and a third vacuum pump in communication with the unloading chamber, a third door separating the drying chamber from the unloading chamber, a fourth door separating the unloading chamber from the external environment, and a microwave chamber having a plurality of magnetrons, the microwave chamber positioned on a different plane from the loading and unloading chambers and adjacent the drying chamber.

In another example of the disclosure is a microwave vacuum dryer in accordance with the foregoing, wherein the microwave chamber is positioned underneath the drying chamber.

In another example of the disclosure is a microwave vacuum dryer in accordance with the foregoing, wherein the drying chamber has at least two walls and a floor that define two inner parallel edges, the two edges comprising removable tray guidance rails.

In another example of the disclosure is a microwave vacuum dryer in accordance with the foregoing, wherein the loading chamber, the drying chamber and the unloading chamber are each aligned along a central axis.

In another example of the disclosure is a microwave vacuum dryer in accordance with the foregoing, wherein the first door and the fourth door are manually operable.

In another example of the disclosure is a microwave vacuum dryer in accordance with the foregoing, wherein the second door and the third door are automatically operable and allow for simultaneous movement of the second and third doors.

In another example of the disclosure is a microwave vacuum dryer in accordance with the foregoing, wherein the plurality of magnetrons is arranged in an array along a length of the drying chamber between the second and third doors.

In another example of the disclosure is a microwave vacuum dryer in accordance with the foregoing, wherein the array of magnetrons is arranged in banks.

In another example of the disclosure is a microwave vacuum dryer in accordance with the foregoing, wherein the banks comprise six banks of magnetrons.

In another example of the disclosure is a microwave vacuum dryer in accordance with the foregoing, wherein each of the six banks of magnetrons includes three individual magnetrons.

In another example of the disclosure is a microwave vacuum dryer in accordance with the foregoing, wherein each of the plurality of magnetrons has a predetermined power setting based on a location along the length of the drying chamber.

In another example of the disclosure is a microwave vacuum dryer in accordance with the foregoing, wherein the drying chamber comprises a plurality of ports for monitoring the drying

of containers of frozen solution. In some examples, the plurality of ports comprise a thermal imaging or fiber optic probe.

In another example of the disclosure is a microwave vacuum dryer in accordance with the foregoing, wherein at least one of the unloading, drying and loading chambers comprises an outer gasket to act as a microwave seal when one of the doors to the chamber is closed, and an inner gasket adjacent the outer gasket, the inner gasket to provide a sterile boundary when one of the doors to the chamber is closed.

In another example of the disclosure is a microwave vacuum dryer in accordance with the foregoing, wherein each of the unloading, drying and loading chambers comprises an outer gasket to act as a microwave seal when one of the doors to the chamber is closed, and an inner gasket adjacent the outer gasket, the inner gasket to provide a sterile boundary when one of the doors to the chamber is closed.

In another example of the disclosure is a microwave vacuum dryer in accordance with the foregoing, further comprising a tray unloader housed within the unloading chamber, and a tray loader housed within the loading chamber.

In another example of the disclosure is a microwave vacuum dryer in accordance with the foregoing, wherein the unloading chamber comprises a closeable valve for partially backfilling the unloading chamber with an inert gas, and a stoppering mechanism to close partially-stoppered containers.

In another aspect of the disclosure a method of drying a product comprises providing a microwave vacuum dryer having a loading chamber and a first vacuum pump in communication with the loading chamber, a first door separating the loading chamber from an external environment, a drying chamber adjacent the loading chamber, a second vacuum pump in communication with the drying chamber, and a condenser in vapor communication with the drying chamber, a second door separating the loading chamber and the drying chamber, an unloading chamber adjacent the drying chamber and a third vacuum pump in communication with the unloading chamber, a third door separating the drying chamber from the unloading chamber, a fourth door separating the unloading chamber from the external environment, a microwave chamber having a plurality of magnetrons, the microwave chamber positioned on a different plane from the loading and unloading chambers and adjacent the drying chamber, evacuating air from the drying chamber using the second vacuum pump, and activating at least one of the plurality of magnetrons to generate a microwave field within the drying chamber. The product may include but not limited to a pharmaceutical product that reflects GMP requirements.

In another example of the disclosure is a method of drying a product in accordance with the foregoing, further comprising the step of recirculating water adjacent to the drying chamber to remove excess microwaves from the drying chamber.

In another example of the disclosure is a method of drying a product in accordance with the foregoing, further comprising the steps of opening the first door, loading a first tray holding one or more containers having frozen solution into the loading chamber, closing the first door, and evacuating air from the loading chamber to equilibrate the environment of the loading chamber with the environment of the drying chamber.

In another example of the disclosure is a method of drying a product in accordance with the foregoing, further comprising the steps of opening the second door, advancing the first tray of containers into the drying chamber using a tray loader housed within the loading chamber, and closing the second door.

In another example of the disclosure is a method of drying a product in accordance with the foregoing, further comprising the steps of loading an additional tray into the loading chamber, closing the first door, and evacuating air from the loading chamber to equilibrate the environment of the loading chamber with the environment of the drying chamber.

In another example of the disclosure is a method of drying a product in accordance with the foregoing, wherein the additional tray holds one or more containers having frozen solution, or wherein the additional tray is empty.

In another example of the disclosure is a method of drying a product in accordance with the foregoing, further comprising the steps of pushing the additional tray into the drying chamber using a tray loader housed within the loading chamber, thereby pushing the first tray further into the drying chamber with the additional tray.

In another example of the disclosure is a method of drying a product in accordance with the foregoing, further comprising repeating the step of loading additional trays into the loading chamber and pushing the tray ahead of it through the drying chamber, until the drying chamber is filled with trays.

In another example of the disclosure is a method of drying a product in accordance with the foregoing, wherein the plurality of magnetrons is arranged in an array along a length of the drying chamber between the second and third doors, and wherein the magnetrons in different parts of the array are activated at different power levels before the first tray of containers is pushed into the drying chamber.

In another example of the disclosure is a method of drying a product in accordance with the foregoing, wherein the plurality of magnetrons is arranged in an array along a length of the drying chamber between the second and third doors, and wherein the plurality of magnetrons are activated to one or more predetermined power levels, and wherein the plurality of magnetrons is activated after the drying chamber is filled with trays.

In another example of the disclosure is a method of drying a product in accordance with the foregoing, further comprising the step of opening the third door, and advancing the first tray into the unloading chamber using a tray unloader housed within the unloading chamber.

In another example of the disclosure is a method of drying a product in accordance with the foregoing, further comprising the step of advancing all of the trays from the drying chamber to the unloading chamber in a sequential manner.

In another example of the disclosure is a method of drying a product in accordance with the foregoing, further comprising the step of removing the first tray from the unloading chamber.

In another example of the disclosure is a method of drying a product in accordance with the foregoing, wherein the drying chamber has at least two walls and a floor that define two inner parallel edges, the two edges comprising removable tray guidance rails.

In another example of the disclosure is a method of drying a product in accordance with the foregoing, further comprising the steps of operating the microwave vacuum dryer in a semi-continuous mode by performing the following steps sequentially: (i) evacuating air from the drying chamber with the second vacuum pump, (ii) recirculating water in a water chamber above the drying chamber, (iii) generating the microwave field within the drying chamber, (iv) loading a first tray of containers having frozen solution into the loading chamber and closing the first door, (v) evacuating air from the loading chamber to equilibrate the environment of the loading chamber with the environment of the drying chamber, and (vi) drying the frozen solution in the containers of the first tray within the drying chamber.

In another example of the disclosure is a method of drying a product in accordance with the foregoing, further comprising the steps of operating the microwave vacuum dryer in a batch mode by performing the following steps sequentially: (i) evacuating air from the drying chamber with the second vacuum pump, (ii) loading a plurality of trays of containers containing frozen solution into the drying chamber via the loading chamber, (iii) recirculating water in a water chamber above the drying chamber, (iv) generating the microwave field within the drying chamber, and (v) drying the frozen solution in the containers within the drying chamber.

In another example of the disclosure is a method of drying a product in accordance with the foregoing, wherein the unloading chamber comprises a closeable valve for partially backfilling the unloading chamber with an inert gas, and a stoppering mechanism to close partially-stoppered containers.

BRIEF DESCRIPTION OF THE DISCLOSURE

Various embodiments of the presently disclosed devices and methods are disclosed herein with reference to the drawings, wherein:

FIGS. 1-5 are schematic perspective, back, front, top and exploded perspective views of a microwave vacuum dryer;

FIGS. 6-7 are schematic back and side views showing the microwave vacuum dryer of FIGS. 1-5 with a lid in an open condition;

FIG. 8 is a photograph showing gaskets of a chamber;

FIG. 9 is a photograph of a removable microwave barrier that can be detached for cleaning;

FIGS. 10-11 are photographs showing a channel inside a drying chamber; and

FIG. 12 is a schematic perspective view of a room having a microwave vacuum dryer.

Various embodiments will now be described with reference to the appended drawings. It is to be appreciated that these drawings depict only some embodiments of the disclosure and are therefore not to be considered limiting of its scope.

DETAILED DESCRIPTION

Despite the various improvements that have been made to microwave vacuum drying, conventional devices and methods suffer from some shortcomings.

Therefore, there is a need for further improvements to the devices and methods used for microwave vacuum drying, and especially for devices and methods that allow for more efficient manufacturing and permit, for example, continuous or semi-continuous manufacturing of live virus vaccines. Among other advantages, the present disclosure may address one or more of these needs.

FIGS. 1-5 illustrate one example of a microwave vacuum dryer 100 according to one embodiment of the present disclosure. Vacuum dryer 100 generally extends between a first end (or entrance) 102 and a second end (or exit) 104, and includes a plurality of chambers arranged adjacent one another. Beginning at the first end 102 and proceeding toward the second end 104, vacuum dryer 100 includes a loading chamber 110, a drying chamber 112, and an unloading