

SUMMARY OF INVENTION

[0009] The present disclosure enables particulate material, such as used catalyst particles, to be removed from reactor tubes in a labor and time efficient manner.

[0010] A device is proposed in the present disclosure for unloading particulate material from a reactor tube of a catalytic reactor. The catalytic reactor typically comprises an array of substantially vertically aligned reactor tubes. The device can comprise an air lance for loosening the particulate material inside the reactor tube using pressurized air. The device can further comprise an air lance unit for feeding the air lance in and out of the reactor tube. The device can further comprise a flexible guide tube that is on one end connectable to the air lance unit and on the other end to a first cleaned reactor tube. The flexible guide tube is arranged for guiding the air lance from the reactor tube to the first cleaned reactor tube thereby enabling a part of the air lance that has not been fed into the reactor tube to be stored within the first cleaned reactor tube. The cleaned reactor tube is a reactor tube that has been unloaded and/or cleaned prior to the unloading of the reactor tube 6, possibly using any known unloading and/or cleaning method.

[0010a] In one aspect, the present disclosure provides a device for unloading particulate material from a reactor tube (6) of a catalytic reactor (1) comprising an array of substantially vertically aligned reactor tubes, the device comprising: a flexible air lance (11, 111-113) for loosening the particulate material inside the reactor tube (6) using pressurized air; an air lance unit (10) for feeding the flexible air lance (11, 111-113) in and out of the reactor tube (6); and a flexible guide tube (12, 121-123) on one end connectable to the air lance unit (10) and on the other end connectable to a first cleaned reactor tube (7, 71-73) for guiding the flexible air lance (11, 111-113) from the reactor tube (6) via the air lance unit (10) to the first cleaned reactor tube (7, 71-73) for storing a part of the air lance that has not been fed into the reactor tube (6) within the first cleaned reactor tube (7, 71-73), wherein the first cleaned reactor tube (7, 71-73) is a reactor tube that has been unloaded and/or cleaned prior to unloading the particulate material from the reactor tube (6); and the flexibility of the guide tube allows the guide tube to bend when the air lance unit is moved.

[0011] Advantageously, the air lance unit can be used for feeding the air lance in and out of the reactor tube, thereby eliminating the need for trained personnel to do this job.

The air lance unit may detect obstructions in the reactor tube from detected resistance when feeding the air lance into the reactor tube, allowing the air lance unit to adjust the feeding force, adjust the air pressure of the pressurized air (including the possibility of stopping the air flow), adjust the vacuuming force (including the possibility of shutting
5 down the vacuum system) and/or stop the unloading for one or more of the reactor tubes. Thus, the unloading procedure can be further automated. The part of the air lance that has not been fed into the reactor tube is advantageously stored in an already cleaned reactor tube, resulting, together with the flexible guide tube, in the tube sheet to be free from air lance parts. As a result multiple sections of the tube sheet may be processed at once by
10 multiple air lance units for cleaning even more reactor tubes simultaneously. Also, a tube sheet clean of air lance parts may be subjected to other activities, such as cleaning or inspecting of tubes, while reactor tubes are being unloaded.

[0012] The embodiment of claim 2 advantageously enables the loosened particles to be vacuumed away using the same air lance unit as used for feeding the air lance. As a

result the space needed on the tube sheet for unloading the particulate material can be minimized.

[0013] The embodiment of claim 3 advantageously enables one or more flexible guide tubes to be connected to the cleaned reactor tubes more easily. The first connector
5 device may be adapted to the specific dimensions and connection possibilities of the reactor tubes, while the part connecting to the flexible guide tube is always the same. This allows the flexible guide tube to be the same for all catalytic reactors.

[0014] The embodiment of claim 5 advantageously increases the safety of the device by securing e.g. the pressurized parts of the device at the cleaned reactor tubes in case
10 parts break loose.

[0015] The embodiment of claim 6 advantageously enables the air lance to be provided with pressurized air via the cleaned reactor tube, thereby eliminating the need for a pump at the top sheet and thus saving space at the top sheet for unloading or other activities.

15 [0016] The embodiment of claim 7 advantageously enables multiple reactor tubes to be cleaned simultaneously, thereby saving time to unload the reactor tubes. Moreover, the air lance unit can be operated by a single person, resulting in multiple reactor tubes to be unloadable simultaneously by a single person. The number of personnel required for unloading the reactor tubes is therefore minimized as well.

20 [0017] The embodiment of claim 8 advantageously enables the air lance unit and first connector device to be compact and thus easier to handle.

[0018] The embodiment of claim 9 advantageously enables the air lance unit to be held in place by gravity, i.e. without or with limited fixation to the tube sheet or reactor tubes.

25 [0019] An air lance unit is proposed in the present disclosure having one or more of the above mentioned features and advantages.

[0019a] In another aspect, the present disclosure provides an air lance unit (10) for use in a device as disclosed herein, wherein the air lance unit (10) is arranged for: feeding one
30 end of a flexible air lance (11, 111-113) in and out of a reactor tube (6); and feeding the other end of the air lance unit (11, 111-113) in and out of a cleaned reactor tube (7, 71-73) via a flexible guide tube (12, 121-123) that is on one end connectable to the air lance unit (10) and on the other end connectable to the cleaned reactor tube (7, 71-73) for

guiding the flexible air lance (11, 111-113) from the reactor tube (6) via the air lance unit (10) to the first cleaned reactor tube (7, 71-73).

[0020] A method is proposed in the present disclosure for unloading particulate material from a reactor tube of a catalytic reactor using a device having one or more of the above mentioned features and advantages. The method can comprise feeding the air lance from the first cleaned reactor tube into the reactor tube while the air lance unit is placed over the reactor tube. The method can further comprise feeding the air lance from the reactor tube to the first cleaned reactor tube while the air lance unit is placed over the reactor tube. The method can further comprise moving the air lance unit

resulting in the air lance unit to be placed over a further reactor tube from which particulate material is to be unloaded. The method can further comprise feeding the air lance from the first cleaned reactor tube into the further reactor tube while the air lance unit is placed over the further reactor tube. The method can further comprise feeding the
5 air lance from the further reactor tube to the first cleaned reactor tube while the air lance unit is placed over the further reactor tube. The cleaned reactor tube is a reactor tube that has been unloaded and/or cleaned prior to the unloading of the reactor tube 6, possibly using any known unloading and/or cleaning method.

[0020a] In another aspect, the present disclosure provides a method for unloading
10 particulate material from a reactor tube (6) of a catalytic reactor (1) using a device as disclosed herein, the method comprising: feeding the flexible air lance (11, 111-113) from the first cleaned reactor tube (7, 71-73) into the reactor tube (6) while the air lance unit (10) is placed over the reactor tube (6); feeding the flexible air lance (11, 111-113) from the reactor tube (6) to the first cleaned reactor tube (7, 71-73) while the air
15 lance unit is placed over the reactor tube (6); moving the air lance unit (10) resulting in the air lance unit (10) to be placed over a further reactor tube from which particulate material is to be unloaded, wherein the flexibility of the guide tube allows the guide tube to bend when the air lance unit is moved; feeding the flexible air lance (11- 111-113) from the first cleaned reactor tube (7, 71-73) into the further reactor tube while the air
20 lance unit (10) is placed over the further reactor tube; and feeding the flexible air lance (11, 111-113) from the further reactor tube to the first cleaned reactor tube (7, 71-73) while the air lance unit (10) is placed over the further reactor tube, wherein the first cleaned reactor tube (7, 71-73) is a reactor tube that has been unloaded and/or cleaned prior to unloading the particulate material from the reactor tube (6).

25 [0021] Advantageously, the method can be used for subsequently unloading reactor tubes at different locations on the tube sheet using the same air lance unit. Because the same cleaned reactor tubes can be used for storing the air lances, minimal personnel involvement is required when moving the air lance unit, i.e. the main task to be performed is moving the air lance unit.

30 [0022] The embodiment of claim 12 advantageously enables the reactor tubes to be unloaded and the cleaned reactor tubes to be located at an optimal distance allowing the flexible guide tube to remain connected to the cleaned tubes while the air lance unit is movable to most or all reactor tubes to be cleaned in its section.

[0023] The embodiment of claim 13 advantageously enables reactor tubes in a substantially circular tube sheets to be unloaded in an efficient way.

[0024] The embodiment of claim 14 advantageously enables application of multiple air lance units simultaneously for quicker unloading of all of the reactor tubes in the tube
5 sheet.

[0025] Hereinafter, embodiments of the present disclosure will be described in further detail. It should be appreciated, however, that these embodiments may not be construed as limiting the scope of protection for the present disclosure.

BRIEF DESCRIPTION OF DRAWINGS

10 [0026] Embodiments will now be described, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, and in which:

[0027] Figs. 1 and 2 show a side view of a catalytic reactor;

[0028] Figs. 3 and 4 show a perspective view of a section of a top part of a catalytic
15 reactor;

[0029] Fig. 5 shows a top view of a section of a tube sheet of a catalytic reactor;

CLAIMS

1. A device for unloading particulate material from a reactor tube (6) of a catalytic reactor (1) comprising an array of substantially vertically aligned reactor tubes, the device comprising:
 - a flexible air lance (11, 111-113) for loosening the particulate material inside the reactor tube (6) using pressurized air;
 - an air lance unit (10) for feeding the flexible air lance (11, 111-113) in and out of the reactor tube (6); and
 - a flexible guide tube (12, 121-123) on one end connectable to the air lance unit (10) and on the other end connectable to a first cleaned reactor tube (7, 71-73) for guiding the flexible air lance (11, 111-113) from the reactor tube (6) via the air lance unit (10) to the first cleaned reactor tube (7, 71-73) for storing a part of the air lance that has not been fed into the reactor tube (6) within the first cleaned reactor tube (7, 71-73),
 - wherein the first cleaned reactor tube (7, 71-73) is a reactor tube that has been unloaded and/or cleaned prior to unloading the particulate material from the reactor tube (6); and the flexibility of the guide tube allows the guide tube to bend when the air lance unit is moved.
2. The device according to claim 1, further comprising a vacuum system connectable via a vacuum hose (13) to the air lance unit (10) for vacuuming the particulate material from the reactor tube (6).
3. The device according to claim 1 or 2, further comprising a first connector device (14) fixable to one end of the first cleaned reactor tube (7, 71-73), and wherein the flexible guide tube (12, 121-123) is connectable to the first cleaned reactor tube (7, 71-73) via the first connector device (14).
4. The device according to claim 3, further comprising a second connector device (15) fixable to the other end of the first cleaned reactor tube (7, 71-73), the second connector device (15) comprising a valve (151-153) for providing the pressurized air to the flexible air lance (11, 111-113) via the first cleaned reactor tube (7, 71-73).

5. The device according to claim 4, further comprising a security cable (16) for connecting the first connector device (14) with the second connector device (15) via a second cleaned reactor tube (75).

5

6. The device according to any one of the claims 3-5, further comprising a control conduit (17, 171-173) between the valve (151-153) and the air lance unit (10) for controlling the valve (151,153), wherein the first connector device (14) and the second connector device (15) are arranged to guide the control conduit (17, 171-173) through a
10 third cleaned reactor tube (74).

7. The device according to any one of the preceding claims, comprising:

a plurality of flexible air lances (111-113) for simultaneously loosening particulate material inside a plurality of reactor tubes (6) using pressurized air, wherein said air lance
15 unit (10) is arranged for feeding the plurality of flexible air lances (111-113) in and out of the plurality of reactor tubes (6), respectively; and

a plurality of flexible guide tubes (121-123) on one end connectable to said air lance unit (10) and on the other end connectable to a plurality of cleaned reactor tubes (71-73) for guiding the plurality of flexible air lances (111-113) from the plurality of
20 reactor tubes (6) to the plurality of cleaned reactor tubes (71-73), respectively, for storing respective parts of the plurality of flexible air lances that have not been fed into the plurality of reactor tubes (6) within the plurality of cleaned reactor tubes (71-73).

8. The device according to claim 7, wherein the plurality of reactor tubes (6) are
25 adjacent reactor tubes and wherein the plurality of cleaned reactor tubes (71-73) are adjacent reactor tubes.

9. The device according to any one of the preceding claims, wherein the air lance unit (10) and the flexible guide tube (12, 121-124) are arranged to be used on a upper tube
30 sheet (4) of the catalytic reactor (1).

10. An air lance unit (10) for use in a device according to any one of the claims 1-9, wherein the air lance unit (10) is arranged for:

5 feeding one end of a flexible air lance (11, 111-113) in and out of a reactor tube (6); and

feeding the other end of the air lance unit (11, 111-113) in and out of a cleaned reactor tube (7, 71-73) via a flexible guide tube (12, 121-123) that is on one end connectable to the air lance unit (10) and on the other end connectable to the cleaned reactor tube (7, 71-73) for guiding the flexible air lance (11, 111-113) from the reactor tube (6) via the air lance unit (10) to the first cleaned reactor tube (7, 71-73).

11. The air lance unit (10) according to claim 10, arranged to detect obstructions in the reactor tube from a detected resistance when feeding the flexible air lance into the reactor tube, and in response adjust a feeding force, adjust an air pressure of the pressurized air, adjust a vacuuming force and/or stop the unloading for one or more of the reactor tubes.

12. The air lance unit (10) according to claim 10 or 11, further comprising a laser guide system for projecting a laser line onto further reactor tubes laterally located on two opposite sides of the air lance unit and aligned with reactor tubes (6) to be unloaded by the air lance unit (10).

13. A method for unloading particulate material from a reactor tube (6) of a catalytic reactor (1) using a device according to any one of the claims 1-9, the method comprising: feeding the flexible air lance (11, 111-113) from the first cleaned reactor tube (7, 71-73) into the reactor tube (6) while the air lance unit (10) is placed over the reactor tube (6);

feeding the flexible air lance (11, 111-113) from the reactor tube (6) to the first cleaned reactor tube (7, 71-73) while the air lance unit is placed over the reactor tube (6); moving the air lance unit (10) resulting in the air lance unit (10) to be placed over a further reactor tube from which particulate material is to be unloaded, wherein the flexibility of the guide tube allows the guide tube to bend when the air lance unit is moved;

feeding the flexible air lance (11- 111-113) from the first cleaned reactor tube (7, 71-73) into the further reactor tube while the air lance unit (10) is placed over the further reactor tube; and

- 5 feeding the flexible air lance (11, 111-113) from the further reactor tube to the first cleaned reactor tube (7, 71-73) while the air lance unit (10) is placed over the further reactor tube,
wherein the first cleaned reactor tube (7, 71-73) is a reactor tube that has been unloaded and/or cleaned prior to unloading the particulate material from the reactor tube (6).

10

14. The method according to claim 13, wherein the array of substantially vertically aligned reactor tubes is divided into two or more sections, wherein the reactor tube (6) and the further reactor tube are located in a first of the two or more sections, and wherein the first cleaned reactor tube (7, 71-73) is located in a second of the two or more sections.

15

15. The method according to claim 14, wherein the two or more sections are four quadrants.

16. The method according to claim 14 or 15, wherein two or more sections are
20 processed simultaneously using two or more air lance units.