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GB-A- 2 266 951
US-A- 1 616 893
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DESCRIPTION

DESCRIPTION

Background of the invention

[0001] The present invention refers to an anti-erosion device for a shell-and-tube equipment and, more specifically, to an anti-erosion device for the tube-sheet of a shell-and-tube equipment.

[0002] Inlet tube-sheets of shell-and-tube equipment, like heat exchangers and chemical reactors, may be subjected to damages and early wear and tear when the tube-side fluid is characterized by high velocity and two-phases, as a fluid laden of solid particles or bubbles. Such a fluid can entail local erosion on inlet tube-sheet. Gases coming from steam cracking furnaces for ethylene production are an example of harmful fluid: cracked gas at high temperature and velocity, laden of coke particles, is often cooled by means of shell-and-tube heat exchangers (also called "transfer-line exchangers" or TLE) which inlet tube-sheet and tube-to-tube-sheet joints frequently suffer from significant wear and tear.

[0003] In order to eliminate or mitigate wear and tear of the inlet tube-sheet of a shell-and-tube equipment handling an erosive tube-side fluid, several solutions are available: among them, use of ferrules or sleeves represents a major solution. Ferrules or sleeves are short tubes or pipes, often provided with entry and exit ends of specific shape, that can be installed either outside or, partially or totally, inside inlet tube-sheet bores and tubes. Many types of ferrules or sleeves for facing erosion problems are known in the state of the art: few of them are here recalled.

[0004] Documents US 1 616 893 and US 2 445 273 disclose tubes provided with joints to an inlet tube-sheet at respective tube-sheet bores.

[0005] For example, document FR 2508156 describes a tubular device that is an extension of the exchanging tube, fixed at the tube itself, which suffers from erosion in place of the exchanging tube.

[0006] Document US 4103738 describes a perforated plate placed above the inlet tube-sheet and sleeves connected to the inlet tube-sheet. Sacrificial replaceable tubes, kept in place by both the perforated plate and the sleeves, are mounted so to abut with the exchanging tubes.

[0007] Document US 4585057 describes a tube inlet guide with funnel shaped extensions which lower ends extend into the exchanging tubes. The tube inlet guide is kept in place by specific supports.

[0008] For the specific application on transfer-line exchangers (TLE), ferrules or sleeves design for facing erosion on tube-side inlet parts are as well known in the state of the art. For example, document US 3707186 describes a ferrule which has the entry with a flared shape, which extends beyond the tube-sheet and which is partially embedded into a refractory lining installed on the tube-side face of the tube-sheet. The remaining portion of the ferrule is inserted into the respective exchanging tube. The exit of the ferrule has an internal diameter which is larger than the internal diameter of the central portion of the ferrule.

[0009] Document US 2008/202732 describes a tubular sleeve and a plate joined together, forming a sleeve with a plate. The tubular portion of the sleeve is inserted into the tube-sheet bore and into a respective exchanging tube, and it is expanded against the tube by rolling or hydraulic expansion. The end of the sleeve not inserted into the tube is provided with a plate, positioned at an angle of 90° with regard to the sleeve axis, covering the tube-side face of the tube-sheet.

[0010] From a general standpoint, many other design of ferrules or sleeves for protecting the inlet tube-sheet of a shell-and-tube equipment from other phenomena than erosion, like overheating and corrosion, have been disclosed. Some major examples are described in the following documents. Document US 2001/0040024 discloses a number of ferrules, or sleeves, of several shape and materials, to be installed on tube-side of inlet tube-sheets of shell-and-tube equipment operating under carburizing, nitriding or reducing environment, where the ferrules rest in a refractory layer.

[0011] Document DE 3022480 describes a device for protecting the tube-sheet of a heat exchanger for an ammonia converter effluent gas. The device is composed of two sleeves, one inserted into the other, where the outer sleeve is welded by one end to the tube-side face of the inlet tube-sheet and by the other end to a chamber wall of a bucket, and the inner sleeve, fixed to the outer sleeve, goes through the tube-sheet and through a first portion of the tubes.

[0012] Anchoring or holding ferrules or sleeves in place is generally a design issue. This is particularly critical when:

- the tube-side fluid flows at high velocity and is erosive, or
- the ferrules are installed in the outlet end of the exchanging tubes, or
- the shell-and-tube equipment is in vertical position and the tube-sheet equipped with ferrules is at the bottom.

[0013] In the first case, the ferrules or sleeves can vibrate or be subjected to a significant impinging action. In the second case, ferrules can be expelled from tubes, whereas, in the third case, ferrules may fall down. Ferrules or sleeves can be held in place by embedding the portion protruding outside the tube-side face of the tube-sheet into a refractory layer, as reported in documents US 3707186 and US 2001/0040024 mentioned above. Ferrules or

sleeves can also be fixed by rolling or hydraulically expanding the ferrule body against the exchanging tube, as reported in document US 2008/202732 mentioned above, or can be kept in place by means of a third element, like a supporting tube-sheet (as disclosed in document US 4103738) or a sleeve (as disclosed in document DE 3022480).

[0014] The aforementioned documents, describing ferrules or sleeves for tube-sheet and tubes protection, include both advantages and disadvantages. For instance, a potential disadvantage for ferrules or sleeves simply abutted to exchanging tubes is given by misalignment or different tolerances about relevant internal diameters, which may represent an obstacle to tube-side flow and therefore a source of erosion and turbulence. Moreover, merely abutted devices can be used for upper tube-sheets only.

[0015] A potential disadvantage for ferrules or sleeves embedded into refractory is given by difficult maintenance in case of ferrules replacement. Moreover, the embedded ferrules and refractory system may suffer from thermal chocks.

[0016] Finally, ferrules or sleeves expanded against the exchanging tubes can engender damages on tubes during ferrules installation and removal for maintenance, and also during operations due to different thermal elongation between pressure parts and ferrules and local overheating.

Summary of the invention

[0017] One object of the present invention is therefore to provide an anti-erosion device for a shell-and-tube equipment which is capable of resolving the drawbacks of the prior art in a simple, inexpensive and particularly functional manner.

[0018] In detail, one object of the present invention is to provide an anti-erosion device for a shell-and-tube equipment that is capable of minimizing, or avoiding, the above-mentioned drawbacks without making difficult the inspection, removal and, in case, replacement of the device itself.

[0019] Another object of the present invention is to provide an anti-erosion device for a shell-and-tube equipment having a robust and simple innovative design.

[0020] These objects are achieved according to the present invention by providing an anti-erosion device for a shell-and-tube equipment as set forth in the attached claims.

[0021] In particular, these objects are achieved by a shell-and-tube equipment comprising a shell that surrounds a tube bundle. Said tube bundle comprises a plurality of tubes, wherein at least one end of each tube is provided with a joint to an inlet tube-sheet at respective tube-sheet bores for inletting a fluid in the shell-and-tube equipment. The inlet tube-sheet is provided with a first side, which receives the fluid from an inlet channel located upstream of

said inlet tube-sheet, and with a second side, which is opposite to said first side and on which the tubes are joined. The inlet tube-sheet is connected to each tube of the tube bundle on said second side. Said shell-and-tube equipment comprises an anti-erosion device comprising a first outer tubular element and a second inner tubular element for at least a corresponding tube. Both the outer tubular element and the inner tubular element have a respective longitudinal axis that is parallel to the longitudinal axis of the corresponding tube. A first tubular end of said outer tubular element is connected to the first side of the inlet tube-sheet, whereas a second free tubular end of said outer tubular element extends in the inlet channel. Said inner tubular element is inserted into said outer tubular element, so as to substantially cover the entire internal surface of said outer tubular element, and into at least a portion of the corresponding tube to a point which is beyond said joint or the second side of the inlet tube-sheet whichever is farer from said outer tubular element. Said inner tubular element is joined to said outer tubular element by means of mechanical or hydraulic expansion of at least a first tubular portion of said inner tubular element against the internal surface of said outer tubular element. The inlet tube-sheet is connected to each tube of the tube bundle on said second side preferably such that each tube is either not inserted into the respective tube-sheet bore or partially inserted into the respective tube-sheet bore.

[0022] Further characteristics of the invention are underlined by the dependent claims, which are an integral part of the present description.

[0023] The anti-erosion device according to the present invention is designed for being installed in shell-and-tube equipment, like heat exchangers and chemical reactors, for protecting the inlet tube-sheet, the relevant tube-to-tube-sheet joints and the first portion of tubes from erosive action of the tube-side fluid. The anti-erosion device can also be of help in reducing the overheating in case the tube-side fluid is at high temperature. This anti-erosion device is characterized by robustness suitable to withstand severe operating conditions and simple design for easy maintenance.

[0024] The anti-erosion device according to the present invention is of interest for transfer-line exchangers (TLE). The process gas coming from a hydrocarbon steam cracking furnace is typically at 750-850°C, enters into the TLE inlet channel typically at 100-150 m/s and is laden of carbonaceous sub-products coming from cracking of hydrocarbons. Often such sub-products are constituted of hard particles which are potential source of erosion for the gas-side face of the inlet tube-sheet, for the inlet tube-to-tube-sheet joint and for the first portion of tubes. Yet, the anti-erosion device according to the present invention can also be used for other services than TLE, where a two-phase fluid at high velocity must be processed in a shell-and-tube equipment, as a slurry or gas from fluidized beds and combustors.

Brief description of the drawings

[0025] The characteristics and advantages of an anti-erosion device for a shell-and-tube equipment according to the present invention will be clearer from the following exemplifying

and non-limiting description, with reference to the enclosed schematic drawings, in which:

figure 1 is a schematic view of a shell-and-tube equipment with horizontally arranged tube bundle;

figure 2A is a partial sectional view of a first embodiment of a tube-to-tube-sheet joint in a shell-and-tube equipment according to the prior art;

figure 2B is a partial sectional view of a second embodiment of a tube-to-tube-sheet joint in a shell-and-tube equipment according to the prior art;

figures 3A-3C are respective partial sectional views that show the main features of an anti-erosion device for a shell-and-tube equipment according to the present invention;

figures 4A and 4B are respective partial sectional views of an embodiment of the anti-erosion device for a shell-and-tube equipment according to the present invention;

figure 5 is a partial sectional view of another embodiment of the anti-erosion device for a shell-and-tube equipment according to the present invention; and

figure 6 is a partial sectional view of a further embodiment of the anti-erosion device for a shell-and-tube equipment according to the present invention.

Detailed description of the preferred embodiments

[0026] With reference to figure 1, a shell-and-tube equipment 10, more specifically a shell-and-tube heat exchanger 10, is shown. The shell-and-tube equipment 10 is of the type comprising a shell 12 that surrounds a tube bundle 14. Although the shell-and-tube equipment 10 is shown in a horizontal orientation, it may also be oriented vertically or at any angle with respect to a horizontal surface.

[0027] The tube bundle 14 comprises a plurality of tubes 16. The tubes 16 can be of any shape, like U-shaped or straight. At least one end of each tube 16 is joined to an inlet tube-sheet 18 provided with respective tube-sheet bores 20 for inletting a fluid F in the shell-and-tube equipment 10. Said at least one end of each tube 16 is provided with a joint 26 to the inlet tube-sheet 18 at the respective tube-sheet bores 20. The shell-and-tube equipment 10 further comprises an inlet channel connected to the inlet tube-sheet 18 on the opposite side of the shell 12 and in fluid communication with the tubes 16.

[0028] With reference to figure 2A, a first embodiment of a tube-to-tube-sheet joint according to the prior art is shown. This tube-to-tube-sheet joint can be obtained, for example, in a shell-and-tube equipment 10 of the type shown in figure 1. The inlet tube-sheet 18 is provided with a tube-side face 22, facing the inlet channel. The tube-side face 22 of the inlet tube-sheet 18

thus receives the fluid F from the inlet channel, that is located upstream of said inlet tube-sheet 18. The inlet tube-sheet 18 is further provided with a shell-side face 24, jointed to each tube 16 by a weld 26 of butt-end type. This weld 26 is also called "inner bore weld" since it is generally made from the tube-sheet bore 20.

[0029] In this embodiment each tube 16 is not inserted into the respective tube-sheet bore 20 and usually has substantially the same internal diameter D3 of the diameter D4 of the tube-sheet bore 20. Each tube 16 is welded on the shell-side face 24 of the inlet tube-sheet 18. The inlet tube-sheet 18 may be preferably provided with a hub 28 on the shell-side face 24 and therefore the tube-to-tube-sheet joint 26 is a butt-end to butt-end weld.

[0030] Figure 2B shows a second embodiment of a tube-to-tube-sheet joint according to the prior art. The joint is of fillet type, where the tube 16 is either not inserted into the tube-sheet bore 20, or partially inserted into the tube-sheet bore 20, i.e. inserted into the tube-sheet bore 20 for a partial length of the tube-sheet bore 20. The external diameter D5 of each tube 16 is substantially identical or smaller than the internal diameter D4 of the respective tube-sheet bore 20. The joint 26 is made either between the butt-end of the tube 16 and the surface of the tube-sheet bore 20, or between the external surface of the tube 16 and the surface of the tube-sheet bore 20. The joint 26 is made from the tube-sheet bore 20, and is located in proximity of the shell-side face 24 of the inlet tube-sheet 18.

[0031] Figures 3A-3C show a generic embodiment of an anti-erosion device for a shell-and-tube equipment according to the present invention. By way of example, this anti-erosion device is applied to a tube-to-tube-sheet weld 26 as per figure 2B. However, it should be pointed out that the anti-erosion device according to the present invention can be adopted to different tube-to-tube-sheet joint types where the tube 16 is joined to the inlet tube-sheet 18 on the shell-side 24 of the tube-sheet 18. For example, the anti-erosion device according to the present invention can be installed in a shell-and-tube equipment 10 provided with any of the two joints represented in figures 2A and 2B, or at any other tube-to-tube-sheet joint known in the state of the art where the tube is joined to the inlet tube-sheet on the shell-side of the tube-sheet. For the sake of simplicity, the following description refers to the tube-to-tube-sheet joint 26 of figure 2B, without limiting the conceptual application of the anti-erosion device according to the present invention to other tube-to-tube-sheet joints.

[0032] The tube-sheet 18 is provided with a tube-side face 22, which also is denoted first side 22. The first side 22 receives a fluid F from an inlet channel located upstream of the inlet tube-sheet 18. The tube-sheet 18 is also provided with a shell-side face 24, which also is denoted second side 24. The second side 24 of the inlet tube-sheet 18 is opposite to the first side 22, i.e. the second side 24 is the opposite side of the inlet tube-sheet 18 in relation to the first side 22 of the inlet tube sheet 18. The tubes 16 are joined to the inlet tube-sheet 18 on the second side 24. The inlet tube-sheet 18 is connected to each tube 16 of the tube bundle 14 on the second side 24. The tube 16 is either not inserted into the tube-sheet bore 20 or partially inserted into the tube-sheet bore 20. Thereby, the tube 16 does not extend through the tube-sheet bore 20. The inlet tube-sheet 18 is then connected to each tube 16 of the tube bundle 14

on said second side 24 such that each tube 16 is either not inserted into the respective tube-sheet bore 20 or partially inserted into the respective tube-sheet bore 20.

[0033] In some embodiments, the tubes 16 are not inserted into the tube-sheet bores 20. In other words, the tubes 16 do not extend into the tube-sheet bores 20. Thereby, the tubes 16 are located outside the tube-sheet bores 20. The inlet tube-sheet 18 is then connected to each tube 16 of the tube bundle 14 on said second side 24 such that each tube 16 is not inserted into the respective tube-sheet bore 20.

[0034] The joint between the tube 16 and the inlet tube-sheet 18 in form of a weld 26 may be located outside the tube-sheet bore 20 as in figures 2A and 6 or may be located inside the tube-sheet bore 20 as in figures 2B, 3A, 3C, 4A, 4B and 5.

[0035] With reference to figures 3A-3C, the anti-erosion device according to the present invention comprises two tubular elements or ferrules, i.e. a first ferrule 30, or the outer ferrule, and a second ferrule 32, or the inner ferrule. In particular, figure 3A shows only the outer ferrule 30, figure 3B shows only the inner ferrule 32 and figure 3C shows both the inner ferrule 32 and the outer ferrule 30. Both the outer ferrule 30 and the inner ferrule 32 have a respective longitudinal axis that is parallel to the longitudinal axis of a corresponding tube 16.

[0036] The outer ferrule 30 is connected by a first tubular end 34 to the tube-side face 22 of the inlet tube-sheet 18. The connection at said first tubular end 34 is preferably made by a weld, i.e. the outer ferrule 30 is preferably connected to the first side 22 of the inlet tube-sheet 18 by a weld. Yet, the outer ferrule 30 can also be integral with the inlet tube-sheet 18, that is the outer ferrule 30 is obtained by machining the inlet tube-sheet 18. For TLE application, the tube-side face 22 of the inlet tube-sheet 18 is preferably solidly layered by a special material which is erosion-proof. With such a design, the outer ferrule 30 results connected to such a layer by weld. Since the outer ferrule 30, also denoted outer tubular element 30, is connected to the tube-side face 22, i.e. the first side 22, of the inlet tube-sheet 18, the outer ferrule 30 (the outer tubular element 30) is located outside the tube-sheet bore 20. The outer ferrule 30 (the outer tubular element 30) is not inserted into the tube-sheet bore 20. In other words, the outer ferrule 30 (the outer tubular element 30) does not extend into the tube-sheet bore 20.

[0037] The second tubular end 36 of the outer ferrule 30 is free to extend in the inlet channel of the shell-and-tube equipment 10 and can have any shape. Preferably, this second free tubular end 36 is beveled or provided with a funnel shape, so as to minimize the impact of the tube-side fluid F and to convey the fluid F in a more regular way. The internal diameter D6 of the outer ferrule 30 can be either substantially identical or larger than the diameter D4 of the tube-sheet bore 20. In case of different tube-to-tube-sheet welds, the internal diameter D6 of the outer ferrule 30 could be either substantially identical or larger than the external diameter D5 of the tube 16.

[0038] The outer ferrule 30 is robust, with a thickness T1 which can be substantially identical to the thickness of the tube 16. Any material of construction can be used for the outer ferrule 30,

such as any metallic material. In a preferred design, such material shall be carbon steel, low alloy steel or nickel-alloy. In other words, the outer tubular element (30) may be manufactured with a material chosen in the group consisting of carbon steel, low alloy steel and nickel alloy. The outer ferrule 30 can have an axial length L5, excluding the second free tubular end 36, ranging from 50 mm to 200 mm approx.

[0039] The inner ferrule 32 has an overall axial length L1, including the respective tubular ends 38 and 40, so that the inner ferrule 32 extends, at a first side corresponding to a first tubular end 38 thereof, into the tube 16 to a point which is beyond at least the tube-to-tube-sheet joint 26. Preferably, the inner ferrule 32 extends into the tube 16 to a point which is beyond either the tube-to-tube-sheet joint 26 or the shell-side face 24 of the inlet tube-sheet 18, depending on which of the joint 26 and the shell-side face 24 is farer from the outer ferrule 30. Thus, preferably the inner ferrule 32 extends into the tube 16 to a point which is beyond both the tube-to-tube-sheet joint 26 and the shell-side face 24 of the inlet tube-sheet 18. At the opposite side, corresponding to a second tubular end 40 thereof, the inner ferrule 32 extends either until to the second free tubular end 36 or beyond said second free tubular end 36 of the outer ferrule 30.

[0040] The inner ferrule 32 is characterized by two external diameters. A first external diameter D7 refers to a first tubular portion 42 of the inner ferrule 32 that is inserted for total or most length into the outer ferrule 30, whereas a second external diameter D8 refers to a second tubular portion 44 of the inner ferrule 32 that is inserted for total or most length into the tube 16. The first external diameter D7 and the second external diameter D8 can be substantially identical or different, depending on the tube-to-tube-sheet joint 26 and on the final design of the inner ferrule 32. In case the first external diameter D7 and the second external diameter D8 are different, the second external diameter D8 is smaller than the first external diameter D7, and the first tubular portion 42 is connected to the second tubular portion 44 preferably by means of a conical or pseudo-conical transition portion 46 of the inner ferrule 32. The transition portion 46, if any, is designed to minimize turbulence and impingement of the fluid F. In case the first external diameter D7 and the second external diameter D8 are substantially identical, like for example in the embodiment of the anti-erosion device shown in figure 6, the transition portion 46 is not present and the first 42 and second 44 tubular portions are directly connected, forming a single straight tubular portion. The second external diameter D8 of the second tubular portion 44 of the inner ferrule 32 is smaller than or substantially equal to the internal diameter D3 of the tube 16. The second external diameter D8 of the second tubular portion 44 is preferably as close to said internal diameter D3 of the tube 16 as possible, depending on the mechanical tolerances.

[0041] The second tubular end 40 of the inner ferrule 32, placed closer to the second free tubular end 36 of the outer ferrule 30, can have any shape. Preferably, the second tubular end 40 of the inner ferrule 32 is beveled or have a funnel shape, so as to minimize turbulence and impingement of the fluid F. The first tubular end 38 of the inner ferrule 32, placed farer from the second free tubular end 36 of the outer ferrule 30, can have any shape too. Preferably, the first tubular end 38 of the inner ferrule 32 is beveled or have a funnel shape, so as to minimize

turbulence of the fluid F. The inner ferrule 32 is made of a metallic material. The inner ferrule 32 is preferably made of erosion resistant material, such as a high-content nickel alloy. Alternatively, the inner ferrule 32 can be made of a common carbon steel or low alloy steel and consequently the inner ferrule 32 acts as a sacrificial element to be replaced along time. In other words, inner tubular element 32 may be manufactured with a material chosen in the group consisting of carbon steel, low alloy steel and high-content nickel alloy.

[0042] As shown in figure 3C, the inner ferrule 32 is inserted into the outer ferrule 30, so as to substantially cover the entire internal surface thereof, and into at least a portion of the tube 16. The inner ferrule 32 is joined to the outer ferrule 30 by means of mechanical or hydraulic expansion of its first tubular portion 42, or of a major slice of said first tubular portion 42, against the internal surface of the outer ferrule 30. Practically, the inner ferrule 32 is expanded against the outer ferrule 30 for a length L2 which is preferably shorter than the axial length L5 of the outer ferrule 30. The length L2 is also preferably shorter than the overall axial length of the first tubular portion 42.

[0043] According to a preferred design, the second tubular end 40 of the inner ferrule 32 follows the shape of the second free tubular end 36 of the outer ferrule 30 in order to cover the portion of the outer ferrule 30 where the fluid F can impinge. Figure 3C shows a transition portion 46 of the inner ferrule 32. As any person skilled in the art can realize, such a transition portion 46 is necessary when the tube-sheet bore diameter D4 is larger than the internal diameter D3 of the tube 16. The length L4 of the transition portion 46 is determined by the designer according to the dimensions of the inlet tube-sheet 18 and the respective tubes 16. The length L4 of the transition portion 46 is also determined in order to reduce the induced turbulence. It is also to be noted that, even if the transition portion 46 is present, the second tubular portion 44 and the first tubular portion 42 can have a substantially identical internal diameter due to a larger thickness of the second tubular portion 44 with regard to the thickness of the first tubular portion 42. The length L3 of the second tubular portion 44 inserted for total or most length into the tube 16 is determined by the designer according to the risk of erosion inside the tube 16. The length L3 of the second tubular portion 44 is also determined in order to smooth the turbulence of the fluid F.

[0044] As shown in figure 4A, the outer ferrule 30 can be provided, on the internal surface thereof, with one or more grooves or hollows 48 designed to get a stronger fixing of the inner ferrule 32. According to such a design, the first tubular portion 42 of the inner ferrule 32 is expanded against the internal surface of the outer ferrule 30 for a length L2 and, at the grooves or hollows 48, the inner ferrule 32 is forced to penetrate into the grooves or hollows 48.

[0045] The inner ferrule 32, besides the expansion against the outer ferrule 30, can also be welded to the outer ferrule 30 by a welding 50 between the second free tubular end 36 of the outer ferrule 30 and the second tubular end 40 of the inner ferrule 32, as shown in figure 4B. Accordingly, the material of the welding 50 is erosion resistant.

[0046] According to another embodiment of the anti-erosion device, the inner ferrule 32, besides the expansion against the outer ferrule 30, can also be expanded against the tube 16. Practically, a slice of length L3 of the second tubular portion 44 inserted for total or most length into the tube 16 is mechanically or hydraulically expanded. In case of such a design, shown in figure 5, the outer ferrule 30 is preferably provided with slots or holes 52 made in a portion of the outer ferrule 30, where the inner ferrule 32 is not expanded against the outer ferrule 30 in order to vent the space between the inner ferrule 32 and the outer ferrule 30, the tube-sheet bore 20 and the tube 16. The outer ferrule 30 may be provided with the slots or holes 52 in a portion of the outer ferrule 30, in proximity of the tube-side face 22 of the inlet tube-sheet 18.

[0047] According to the above description, the erosive fluid F, to be processed by the shell-and-tube equipment 10, is conveyed by the anti-erosion device, comprising the outer ferrule 30 and the inner ferrule 32. The anti-erosion device collects the fluid F far from the inlet tube-sheet 18 and therefore reduces the impingement of the fluid F on the tube-side face 22 of the inlet tube-sheet 18. Moreover, in case the outer ferrule 30, or the inner ferrule 32, is provided with a funnel shaped second tubular end 40, the impingement of the fluid F on the inlet tube-sheet 18 can be further reduced or even eliminated. The outer ferrule 30 has also the important function, depending on the respective axial length L5, to reduce the turbulence of the flow before reaching the inlet tube-sheet 18 and the tubes 16.

[0048] The inner ferrule 32 protects the outer ferrule 30, the tube-sheet bore 20, the tube-to-tube-sheet joint 26 and the first portion of the tube 16 from direct impingement of fluid F and therefore from erosion. Since the fluid F is gently canalized and conveyed along the outer ferrule 30 and the inner ferrule 32 so to reduce turbulence, the erosive action of gas is also reduced. In case the fluid F is at high temperature, also the tube-side heat transfer coefficient is reduced and risk of local overheating is reduced as well.

[0049] The outer ferrule 30 can be considered to be a non-pressure part from construction codes standpoint. As a consequence, the outer ferrule 30 can be repaired or replaced without specific procedures. Such outer ferrule 30 is robust and can withstand high shear stresses or loads coming from the fluid F or from expansion of the inner ferrule 32. The inner ferrule 32 is not a pressure parts as well. Therefore, the inner ferrule 32 can be easily removed and, in case, replaced without affecting the inlet tube-sheet 18.

[0050] The space left in between the inner ferrule 32 and the tube-sheet bore 20 or the tube 16 is beneficial from a heat transfer standpoint, since it acts as a thermal barrier. Such a space may be filled in by a heat insulating material if necessary. Alternatively or additionally, also the external surface of the inner ferrule 32 may be coated with a heat insulating material if necessary.

[0051] It is thus seen that the anti-erosion device for a shell-and-tube equipment according to the present invention achieves the previously outlined objects.

[0052] The anti-erosion device for a shell-and-tube equipment of the present invention thus

conceived is susceptible in any case of numerous modifications and variants, all falling within the same inventive concept; in addition, all the details can be substituted by technically equivalent elements. In practice, the materials used, as well as the shapes and size, can be of any type according to the technical requirements.

[0053] The scope of protection of the invention is therefore defined by the enclosed claims.

REFERENCES CITED IN THE DESCRIPTION

Cited references

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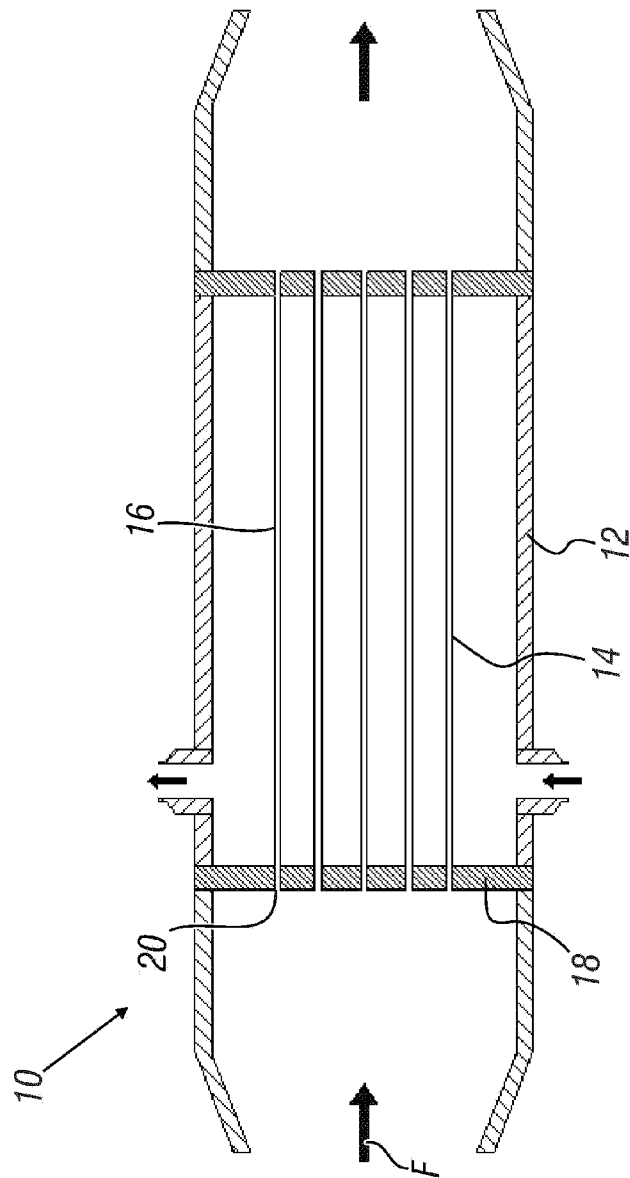
ANTIEROSIONSANORDNING TIL ET SKAL-OG-RØR-UDSTYR

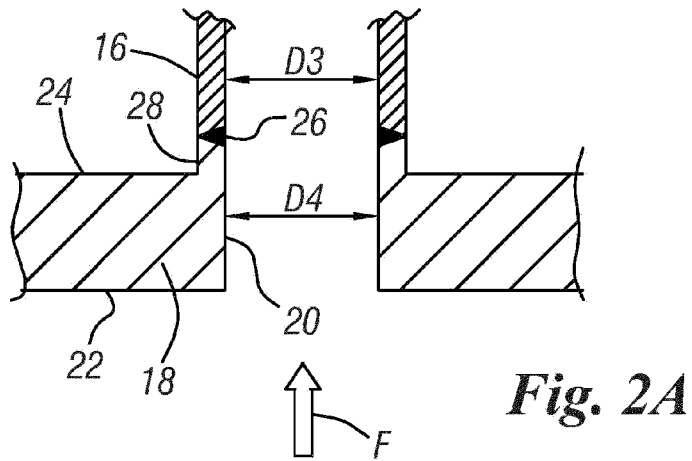
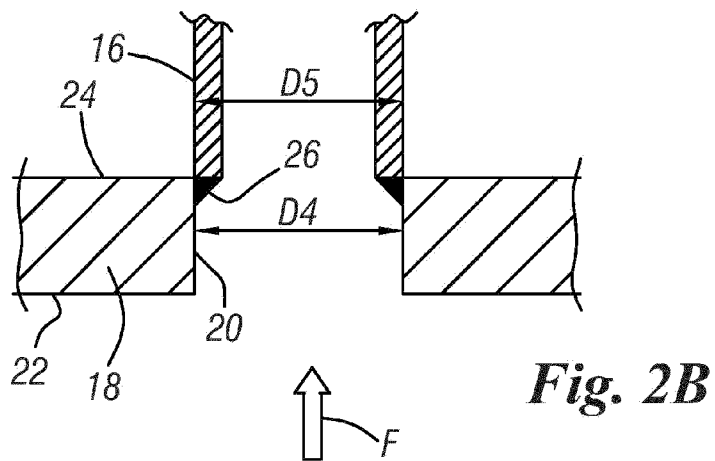
PATENTKRAV

1. Skal-og-rør-udstyr (10) omfattende en skal (12), der omgiver et rørbundt (14), hvor rørbundtet (14) omfatter en flerhed af rør (16), hvor mindst én ende af hvert rør (16) er forsynet med en samling (26) til en
5 indløbsrørplade (18) ved tilsvarende rørpladeboringer (20) til at lade et fluid (F) trænge ind i skal-og-rør-udstyret (10), hvor indløbsrørpladen (18) er forsynet med en første side (22), der modtager fluidet (F) fra en indløbskanal placeret opstrøms for indløbsrørpladen (18), og med en anden side (24), der er modsat den første side (22), og hvorpå rørene (16) er samlet, og hvor indløbsrørpladen (18) er forbundet med hvert rør (16) af rørbundtet (14) på den anden side (24), således at hvert rør (16) enten ikke er indført i den
10 tilsvarende rørpladeboring (20) eller delvist indført i den tilsvarende rørpladeboring (20), hvilket skal-og-rør-udstyr (10) er kendetegnet ved, at det omfatter en antierosionsanordning, der omfatter et første udvendigt rørelement (30) og et andet indvendigt rørelement (32) til mindst et tilsvarende rør (16), hvor både det udvendige rørelement (30) og det indvendige rørelement (32) har en tilsvarende længdeakse, der er parallel med længdeaksen af det tilsvarende rør (16), hvor en første rørende (34) af det udvendige
15 rørelement (30) er forbundet med den første side (22) af indløbsrørpladen (18), mens en anden fri rørende (36) af det udvendige rørelement (30) strækker sig i indløbskanalen, hvor det indvendige rørelement (32) indføres i det udvendige rørelement (30), for således i alt væsentligt at dække hele den indvendige overflade af det udvendige rørelement (30), og i mindst en del af det tilsvarende rør (16) til et punkt, der er ud over samlingen (26) eller den anden side (24) af indløbsrørpladen (18), alt efter hvad der er længst væk fra det
20 udvendige rørelement (30), og hvor det indvendige rørelement (32) er samlet med det udvendige rørelement (30) ved hjælp af mekanisk eller hydraulisk ekspansion af mindst en første rørdel (42) af det indvendige rørelement (32) mod den indvendige overflade af det udvendige rørelement (30).
2. Skal-og-rør-udstyr (10) ifølge krav 1, kendetegnet ved, at den anden frie rørende (36) af det udvendige rørelement (30) har en skrå form eller tragtform.
- 25 3. Skal-og-rør-udstyr (10) ifølge krav 1 eller 2, kendetegnet ved, at det indvendige rørelement (32) har en første rørende (38), der indføres i det tilsvarende rør (16), og en anden rørende (40), der strækker sig enten til den anden frie rørende (36) af det udvendige rørelement (30) eller ud over den anden frie rørende (36) af det udvendige rørelement (30).
4. Skal-og-rør-udstyr (10) ifølge krav 3, kendetegnet ved, at mindst én af den første rørende (38) af
30 det indvendige rørelement (32) eller den anden rørende (40) af det indvendige rørelement (32) har en skrå form eller tragtform.
5. Skal-og-rør-udstyr (10) ifølge krav 3 eller 4, kendetegnet ved, at den anden rørende (40) af det indvendige rørelement (32) følger formen af den anden frie rørende (36) af det udvendige rørelement (30) for at dække den del af det udvendige rørelement (30), som fluidet (F) kan støde mod.
- 35 6. Skal-og-rør-udstyr (10) ifølge et hvilket som helst af kravene 3 til 5, kendetegnet ved, at det indvendige rørelement (32) er svejset til det udvendige rørelement (30) ved hjælp af en svejsning (50) mellem den anden frie rørende (36) af det udvendige rørelement (30) og den anden rørende (40) af det indvendige rørelement (32), hvor svejsningen (50) er erosionsbestandig.

7. Skal-og-rør-udstyr (10) ifølge et hvilket som helst af kravene 3 til 6, kendetegnet ved, at det indvendige rørelement (32) har en første udvendig diameter (D7), der svarer til den første rørdel (42), der er indført i det udvendige rørelement (30), og en anden udvendig diameter (D8), der svarer til en anden rørdel (44) af det indvendige rørelement (32), der er indført i hele eller næsten hele længden deraf i det tilsvarende rør (16).
8. Skal-og-rør-udstyr (10) ifølge krav 7, kendetegnet ved, at den anden udvendige diameter (D8) er mindre end den første udvendige diameter (D7) og den første rørdel (42) er forbundet med den anden rørdel (44) ved hjælp af en overgangsdelen (46) af det indvendige rørelement (32).
9. Skal-og-rør-udstyr (10) ifølge krav 8, kendetegnet ved, at overgangsdelen (46) har en konisk eller pseudo-konisk form.
10. Skal-og-rør-udstyr (10) ifølge et hvilket som helst af kravene 1 til 9, kendetegnet ved, at en udvendig rørdiameter (D5) af hvert rør (16) i alt væsentligt er identisk eller mindre end en indvendig boringsdiameter (D4) af den tilsvarende rørpladeboring (20).
11. Skal-og-rør-udstyr (10) ifølge krav 7, kendetegnet ved, at den første udvendige diameter (D7) og den anden udvendige diameter (D8) i alt væsentligt er identiske og den første (42) og anden (44) rørdel er direkte forbundne, hvorved der dannes en enkelt lige rørdel.
12. Skal-og-rør-udstyr (10) ifølge et hvilket som helst af kravene 7 til 11, kendetegnet ved, at det indvendige rørelement (32) er samlet med røret (16) ved hjælp af mekanisk eller hydraulisk ekspansion af mindst en del af den anden rørdel (44) mod den indvendige overflade af røret (16).
13. Skal-og-rør-udstyr (10) ifølge krav 12, kendetegnet ved, at det udvendige rørelement (30) er forsynet med spalter eller huller (52), der er frembragt i en del af det udvendige rørelement (30), hvor det indvendige rørelement (32) ikke er ekspanderet mod det udvendige rørelement (30).
14. Skal-og-rør-udstyr (10) ifølge et hvilket som helst af kravene 1 til 13, kendetegnet ved, at det indvendige rørelement (32) er ekspanderet mod det udvendige rørelement (30) i en længde (L2), der er kortere end den aksiale længde (L5) af det udvendige rørelement (30).
15. Skal-og-rør-udstyr (10) ifølge et hvilket som helst af kravene 1 til 14, kendetegnet ved, at det udvendige rørelement (30), på den indvendige overflade deraf, er forsynet med én eller flere riller eller hulrum (48), der er designet til at frembringe en kraftig fastgørelse af det indvendige rørelement (32), hvor det indvendige rørelement (32) tvinges til at trænge ind i rillerne eller hulrummene (48), når det indvendige rørelement (32) ekspanderes mod det udvendige rørelement (30).

DRAWINGS

*Fig. 1*

**Fig. 2A****Fig. 2B**

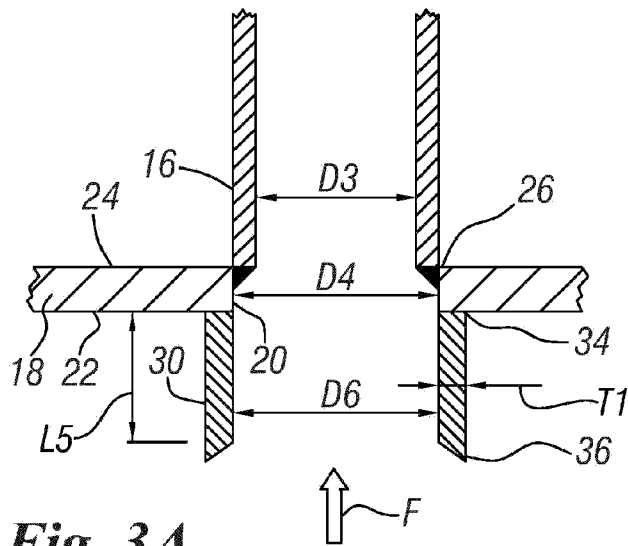


Fig. 3A

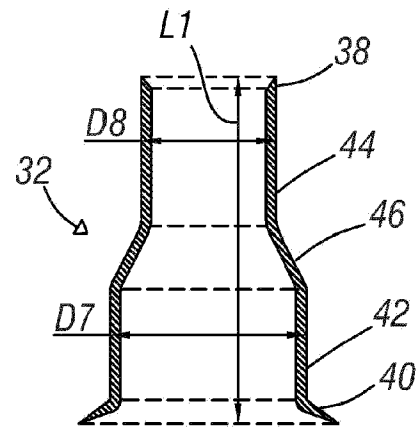


Fig. 3B

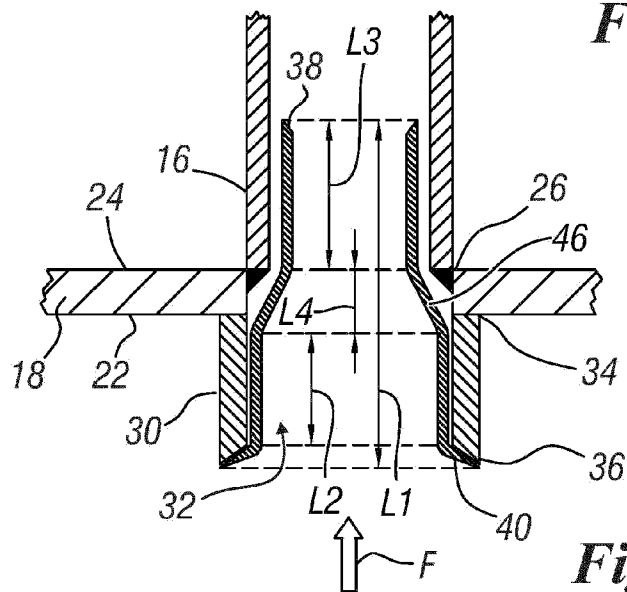
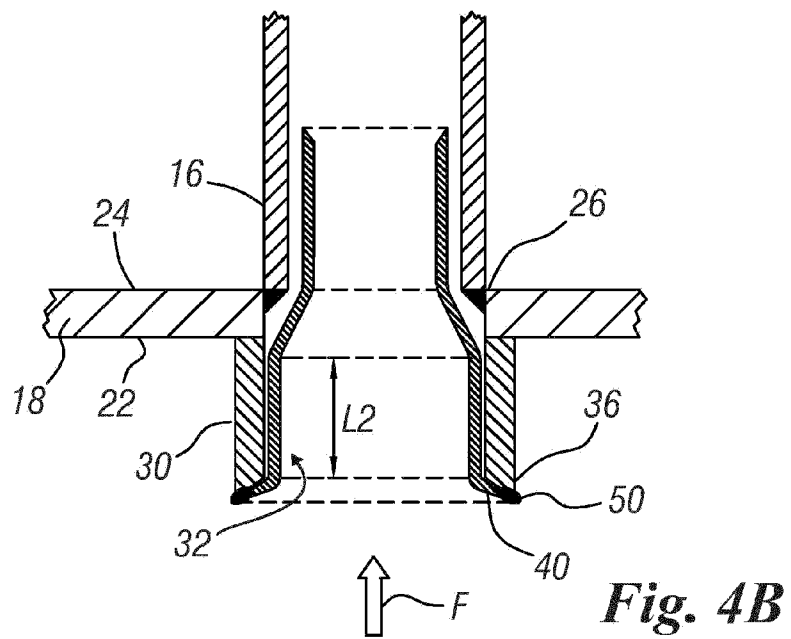
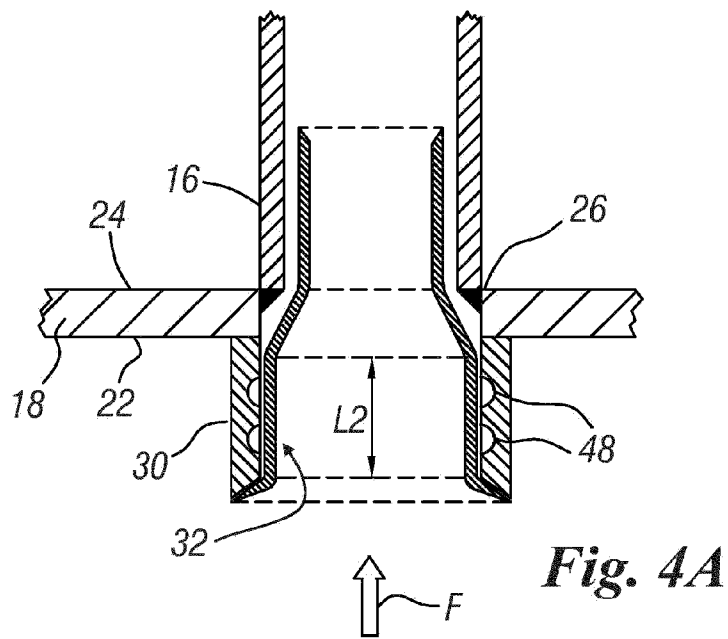
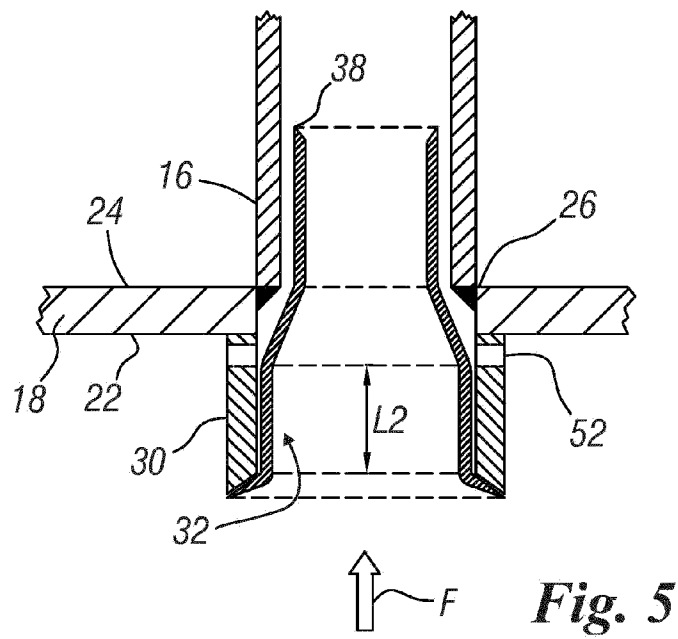
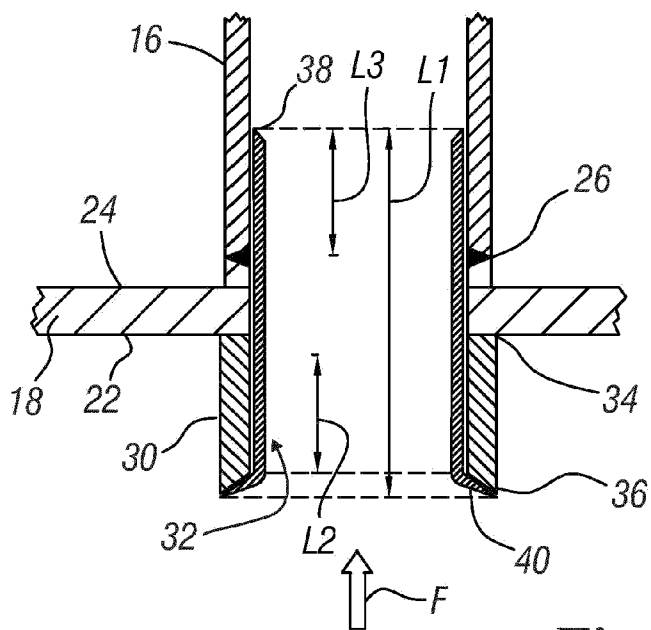


Fig. 3C



**Fig. 5****Fig. 6**