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(54) **TUBULAR SHELL HEAT EXCHANGER WITH CROSS FLOW**

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Description

Technical background

[0001] The invention relates to a tubular shell heat exchanger for use in the energy industry, in oil refining, in chemical engineering and in other industry branches where there is a need for heat exchange and/or waste heat treatment.

State of the art

[0002] Tubular shell heat exchangers are currently the most common type of heat exchangers and they are widely used especially in the oil industry, chemical industry and/or energy industry. At present, there is an increasing need to use low-potential heat, which has not been used yet, because it has low rentability or heat exchangers with the necessary parameters were not available. The difficult conditions of such industry branches increases demands on heat exchangers, especially for performance, wear resistance, clogging resistance and simplification of maintenance, increasing service life and efficiency.

[0003] Therefore, the designers constantly deal with the possibilities of improving and eliminating the shortcomings of existing heat exchangers and propose new ideas and constructions, especially arrangements and installations with the aim of intensifying performance, but also eliminating the shortcomings of existing solutions. In the heat exchanger, heat transfer takes place through the tube walls creating a closed tube system with different arrangements. On both sides of the tube wall surfaces there are media with different temperature and heat is transferred to the cooler medium through the wall surface of the tube bundle. Baffles are installed inside the shell to provide mechanical support to the tube bundle. Medium inside of the shell flows through a system of baffles, which help to create a turbulent flow so as to achieve the best possible parameters of heat energy transfer between the media.

[0004] The most common connection of a heat exchanger to a system is such, that the medium that transfers heat energy enters the heat exchanger on the opposite side than the medium that is to receive heat energy, so the temperature difference between the these two media along the heat exchanger shell is approximately constant and the heat exchanger shell temperature decreases from the inlet of the heating medium to its outlet. Such a flow arrangement is called counter-flow.

[0005] In less frequent cases, the connection of the heat exchanger to a system may be the opposite of the previous case, whereas the temperature difference between the two media at inlet is the largest and during passing through the heat exchanger is this difference significantly reduced. Such an arrangement is called parallel-flow.

[0006] Traditional heat exchangers with an installed

tube system with baffles are used in industrial applications, but there is a need to make them more efficient and eliminate a number of following disadvantages of common heat exchangers:

- 5 - medium inside the shell must constantly change the speed and direction of the flow, there is an enormous pressure loss during the passage of the heating medium through the heat exchanger and the demand for performance and thus the energy consumption of the pumps increases;
- 10 - especially on the rear sides of the baffles, zones of flow stagnation are created, which reduce the efficiency of the heat exchanger and can cause the fouling with all the negative effects;
- 15 - the heating medium inside the heat exchanger shell flows continuously around the tube bundle and also laterally, which causes vibrations and consequently fatigue damage to the tube bundle, thus shortening the service life of the whole system;
- 20 - unwanted flows and bypasses can be created between the tube plates and the shell, which reduces the efficiency of heat exchange inside the shell. Therefore, longitudinal flow heat exchangers have been designed, where the internal installation of these heat exchangers is designed so, that the medium inside the shell flows along the tube bundle, assuming a reduction of the pressure loss inside the shell, however there was never significant success.
- 25 Existing longitudinal flow heat exchangers still use baffles or grating plates, e.g. a heat exchanger generally composed of two or more flat fan-shaped plates, as it is for example in the document CN 206094996 U. Thus, although such a heat exchanger reduces pressure loss, it also significantly reduces heat exchange efficiency, while the longitudinal flow of high velocity fluid impinges on the tube plate at the end of its passage through the shell, which shortens the service life of the heat exchanger and the entire tube system.
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[0007] In document JPH0529668, a heat exchanger according to the preamble of claim is disclosed which consists of plurality of heat transfer tubes passing through multiple baffle plates having a circular shape which support the middle portions of the heat transfer tubes. The baffle plate consists of both a full upper portion with openings for the tubes and an empty lower portion. The orientation of the empty portion is always alternating with each baffle plate and this allows the flow of the heating medium to bend into waves. The full portions of the baffle plates for the heat exchanger are created by bent thin plates which are arranged to form a supporting grid.

[0008] This construction is intended to prevent vibration of the heat exchanger tubes. Thus, there are no sleeves to hold the tubes, the tubes are only held in place by the shape contact in the spaces formed between the thin plates. The disadvantage of the heat exchanger is

the complicated design and that the generated flow wave of the heating medium creates vibrations.

[0009] The aim of the present invention is to provide a tubular shell heat exchanger which overcomes the above mentioned shortcomings.

Summary of the invention

[0010] The above mentioned deficiencies are eliminated by tubular shell heat exchanger with cross flow according to the invention as defined by claim 1, which is characterised by the fact that deflectors on tubes in a lower adjacent row are inclined in the opposite direction to those above them, and they are offset by half of the distance, whereas deflectors are fixed to the tubes by means of fixing sleeves, wherein inlet is divided into branches which entry into the shell is in the position above deflectors arranged on the tube which is closest to the branches and deflectors in the place below each entry of the branch form either an assembly of two deflectors oriented to one side, or there is only one deflector oriented to the opposite side and the height of deflectors is less than the distance of the surfaces of two tubes arranged above each other.

[0011] In the preferred embodiment are the fixing sleeves formed as a U-shaped wire wrapped around tubes, wherein the threaded ends of the fixing sleeve being secured by nuts.

[0012] In another preferred embodiment is the deflector fixed on every second tube in a row perpendicular to the axis of the heat exchanger.

Brief description of the drawings

[0013] The invention will be further explained by means of drawings, in which Fig. 1 is a schematic view of a tubular shell heat exchanger according to the invention, Fig. 2 shows a detail of mounting deflectors on the tube bundle of the heat exchanger of Fig. 1 in a perspective view and Fig. 3 shows a detail of mounting deflectors on the tube bundle of the heat exchanger of Fig. 1 in axial view.

Detailed description of the invention

[0014] Fig. 1 is a schematic view of a tubular shell heat exchanger 1, which consists of a shell 12 and a set of connecting tubes 8 through which the heated medium flows, and which are fixed between two tube plates 2, 3, on one side to the inlet tube plate 2 and on the opposite side to the outlet tube plate 3. An inlet 4 of the heat transfer medium, i.e. a heating medium, is arranged on the top of the shell 12 of the heat exchanger 1 in the middle of the length of the heat exchanger 1 and an outlet 5 of the heating medium is arranged at the bottom. The supply of heated medium is ensured by an inlet tube 6 arranged in the axis of the shell 12 on the side of the inlet tube plate 2 and its discharge by an outlet tube 7, on the side

of the outlet tube plate 3. Heat transfer takes place through a bundle of tubes 8 which are arranged parallel to the axis from the inlet tube plate 2 to the outlet tube plate 3.

5 **[0015]** The inlet 4 of the heating medium in the upper part of the heat exchanger 1 is divided into several branches 11 connected to the shell 12 at several entries spaced apart along the upper length of the heat exchanger's shell 12. In the present embodiment there are four
10 branches 11, but the number of these branches 11 may vary according to the length of the internal space between the tube plates 2, 3 of the heat exchanger 1 and in particular according to the heat performance requirements.

15 **[0016]** It can be seen in Fig. 2 and 3 that deflectors 9 are fastened to the tubes 8 at regular mutual intervals perpendicular to these tubes 8 by means of fixing sleeves 10. Advantageously, the deflector 9 can be fixed on every
20 second tube 8 in a row, perpendicular to the axis. Deflectors 9 consist of a horizontal fastening strip 13 and an inclined wing 14. It is obvious that the fastening strip 13 serves to be fastened to the lower part of the tubes via fixing sleeves 10. The wing 14 is arranged obliquely at an angle $\alpha = 120$ to 140° to the fastening strip 13 in its horizontal position.

25 **[0017]** Deflectors 9 are arranged in rows next to each other, on one horizontal row of tubes 8 at a distance X, all of which are inclined in the same direction within such a formation. Deflectors 9 on tubes 8 in the lower adjacent row are again arranged at a distance X, but on the one
30 hand they are inclined in the opposite direction to those above them, and they are also offset by half of the distance X. Below this offset row the arrangement and inclination of deflectors are again the same as in a row above. Branches 11 are joined to the shell 12 in the position above deflectors 9 arranged on the tube 8 which
35 is closest to the entry of the branches 11. Deflectors 9 in the place below each entry form either an assembly of two deflectors 9 oriented to one side, or there is only one deflector 9 oriented to the opposite side. Due to this arrangement receives the flow from each individual entry the desired wavy trajectory, as indicated by the arrow in the example of the first branch 11.

40 **[0018]** The deflector 9 is made of sheet metal with a thickness of 4 to 5 mm. The fastening strip 13 has a width of 50 to 100 mm and there are openings for fixing sleeves 10, which are formed as a U-shaped wire wrapped around tubes 8, the threaded ends of the fixing sleeve 10 being secured with nuts. The height H of the deflector 9 as shown in Fig. 2, is less than the distance h of the
45 surfaces of two tubes 8 arranged above each other, as shown in Fig. 1, so that the lower edge of the deflector wing 14 does not touch the upper surface of the tube 8 arranged below it.

50 **[0019]** Deflectors 9 are arranged at distances from each other, and the inclination of wings 14 is alternately changed to one side or to the other side. For this purpose, the deflector 9 can be simply turned about 180° . This creates a system of chicanes in the space of the heat

exchanger 1, curving the trajectory of the cross-flowing medium, so that an intense turbulent flow is created in the heat exchanger, together with the influence of perpendicular inlet of heating medium into the inner space of heat exchanger 1. The medium moves not only forcibly downwards, but also mainly due to gravity it flows from the top to the bottom, thus the need to equip the interior space with baffles designed to disrupt laminar flow and initiate turbulent flow is eliminated, thereby significantly reducing pressure loss.

[0020] The use of gravity for the passage of the heating medium through the heat exchanger 1 reduces the demands on the performance of the pumps.

[0021] Deflectors 9, which are located in the inner space of the shell 12 of the heat exchanger 1, serve not only to create a turbulent flow, but also to fix the tubes 8 of the tube system in order to prevent vibrations, deflection and maintain its geometry.

[0022] The advantage of the invention consist in particular in the fact that the deflectors 9 have replaced fixed baffles known from the prior art. The heat exchanger 1 according to the invention does not have the disadvantages of the prior art solutions, such as clogging, creation of dead spots, wear, etc., and the deflectors do not form active obstacles to the flow of the medium. This allows intensive washing of the entire interior of the heat exchanger, so there is no accumulation of dirt and clogging of the heat exchanger on the sides, but especially on the lower inner surface of the shell, because any impurities are continuously washed away by the medium leaving the interior of the heat exchanger and leave freely without the opportunity and reason to accumulate.

[0023] Furthermore, the possible corrosion and wear of tubes 8 in the tube plate at the contact of the outer surface of the tube 8 and the baffle is eliminated. For the same reason, the vibration of tubes 8, mechanical-chemical corrosion and damage to their outer surface by micro-movements in the contact between the tube and the baffle are also eliminated, in a comparison with conventional heat exchangers.

[0024] Thus, the advantages of the present invention in a comparison with the prior art heat exchangers are as follows:

Unlike baffles known from the prior art, deflectors 9 do not increase the pressure loss and do not require increased pump performance. Changing the flow direction of the heating medium from horizontal to vertical and from the top to the bottom means significant energy savings, which in combination with the effect of creating a turbulent flow reduces the energy consumption for pumping approximately by 30 %. The homogeneous temperature field inside the heat exchanger shell results in an increase in the temperature difference between the heating and the heated medium from the inlet of the heated medium, which cannot be achieved with a conventional counter-flow arrangement. Although the temperature difference between the two media decreases through the heat exchanger, the integral of the temperature difference is still

significantly higher than in the common cases of existing counter-flow and parallel-flow arrangements and the heat transfer coefficient is therefore improved compared to conventional solutions.

[0025] Vibrations of the tube bundle are limited because the nature of the medium flow on the side of the shell passing through the tube bundle can significantly affect the fluid-induced vibrations of the tube bundle as well as the vibration resistance of the heat exchanger and thus ensure safe operation. It is significant to reduce the possibility of dirt accumulation, especially by removing the baffles and replacing them with deflectors 9.

[0026] By reducing the number of stagnant flow zones and by continuous flushing the interior of the heat exchanger, the possibility of dirt accumulation is significantly reduced and the resulting increased reliability and stable performance of the heat exchanger is achieved. The built-in and functioning heat exchanger can be quickly adjusted to optimum performance, which is enabled by the modular system of mounted deflectors 9 by a relatively simple changing of their number. This ensures the most efficient operation of the system without the need to dismantle the entire heat exchanger. The changing is relatively very simple and fast and can be realised during system temporary shutdown for other reasons.

[0027] Also important is the simplicity of operation, maintenance and repair of the heat exchanger 1 with deflectors 9 in a comparison with existing types of heat exchangers with fixed baffles, heat exchanger 1 according to the invention has significantly lower susceptibility to clogging and significant self-cleaning ability.

[0028] Furthermore, production, assembly and operational repairs are easier. By relatively simply changing the deflectors 9 without necessity of disassemble the entire heat exchanger 1, the exchanger can be fine-tuned to optimum performance by simply adjusting the tube bundle to a greater or lesser number of deflectors 9, in terms of their shape, angle and length.

Claims

1. Tubular shell heat exchanger (1), comprising a shell (12) with a set of connecting tubes (8) which are mounted parallel to the axis between two tube plates (2, 3), wherein the heating medium inlet (4) is located on the top of the shell (12) and the heating medium outlet (5) is arranged at the bottom and on the inlet tube plate side (2) is an inlet tube (6) for the heated medium and an outlet tube (7) is arranged on the side of the outlet tube plate (3), whereas the tubes (8) are provided with deflectors (9), which are fixed at regular mutual intervals and perpendicular to these tubes (8), whereas deflectors (9) consist of a horizontal fastening strip (13) and an inclined wing (14), which is arranged obliquely at an angle $\alpha = 120$ to 140° to the fastening strip (13) in its horizontal position, wherein deflectors (9) are in rows next to

each other, at a distance (X) within one horizontal row of tubes (8), all of which are inclined in the same direction within such a formation and deflectors (9) on tubes (8) in a lower adjacent row are again arranged at a distance (X), wherein below this offset row the arrangement and inclination of deflectors (9) are again the same as in the row above it, **characterized in that** deflectors (9) on tubes (8) in a lower adjacent row are inclined in the opposite direction to those above them, and they are offset by half of the distance (X), whereas deflectors (9) are fixed to the tubes (8) by means of fixing sleeves (10), wherein inlet (4) is divided into branches (11) which entry into the shell (12) is in the position above deflectors (9) arranged on the tube (8) which is closest to the branches (11) and deflectors (9) in the place below each entry of the branch (11) form either an assembly of two deflectors (9) oriented to one side, or there is only one deflector (9) oriented to the opposite side and the height (H) of deflectors (9) is less than the distance (h) of the surfaces of two tubes (8) arranged above each other.

2. Tubular shell heat exchanger according to claim 1, **characterized in that** the fixing sleeves (10) are formed as a U-shaped wire wrapped around tubes (8), wherein the threaded ends of the fixing sleeve (10) being secured by nuts.
3. Tubular shell heat exchanger according to claims 1 and 2, **characterized in that** the deflector (9) is fixed on every second tube (8) in a row perpendicular to the axis of the heat exchanger (1).

Patentansprüche

1. Querstrom-Rohrbündelwärmetauscher (1), der einen Mantel (12) mit einem System von Rohren (8) beinhaltet, welche parallel mit der Achse zwischen zwei seitlichen Rohrwandungen (2,3) befestigt sind, wobei auf dem Mantel (12) des Wärmetauschers (1) von oben ein Eintritt (4) des wärmetragenden Mediums angeordnet ist und unten ist ein Austritt (5) des wärmetragenden Mediums versehen und auf Seite der Eintrittsröhrwandung (2) ein Eintrittsrohr (6) für beheizte Medium ist, und auf Seite der Austrittsröhrwandung (3) ein Austrittsrohr (7) angeordnet ist, wobei zu den Rohren (8) senkrecht zu ihnen in regelmäßigen Abständen Deflektoren (9) befestigt sind, wobei die Deflektoren (9) aus einem horizontalen Befestigungsstreifen (13) auf ihrer Unterseite und aus einem schrägen Flügel (14) bestehen, der angesichts des Befestigungsstreifens (13) in seiner horizontalen Lage schräg unter einem Winkel α 120° bis 140° angeordnet ist, wobei die Deflektoren (9) nebeneinander in Reihen, im Rahmen einer horizontalen Reihe der Rohren (8) in einer Distanz (X) sind,

so dass alle im Rahmen von solcher Formation gekippt in demgleichen Sinne sind und die Deflektoren (9) auf den Rohren (8) in der niedrigeren benachbarten Reihe wieder in einer Distanz (X) angeordnet sind, wobei unter diesen versetzten Reihe die Anordnung und Kippen von Deflektoren (9) wie in der Reihe oben ist, **dadurch gekennzeichnet, dass** in der niedrigeren Reihe die Deflektoren (9) auf den Rohren (8) in dem umgekehrten Sinne als die oben ihnen gekippt sind, und auch um eine Hälfte der Distanz (X) versetzt sind, wobei die Deflektoren (9) zu den Rohren (8) durch Bügelschellen (10) befestigt sind, wobei der Eintritt (4) verzweigt ist und einzelne Zweigen (11) münden in den Mantel (12) oben von Deflektoren (9), die auf dem Rohr (8) angeordnet sind, die am nächsten zu diesen Einmündungen ist und die Deflektoren (9) an der Stelle unter jedem Einmündung entweder ein System von zwei Deflektoren (9) orientiert zu einer Seite bilden, oder dort nur ein Deflektor (9) orientiert zu die Gegenseite angeordnet ist und die Höhe (H) des Deflektors (9) kleiner als die Distanz (h) von Oberflächen zwei übereinander angeordneten benachbarten Rohren (8) ist.

2. Querstrom-Rohrbündelwärmetauscher nach dem Anspruch 1, **dadurch gekennzeichnet, dass** die Bügelschellen (10) als ein Draht in der Form von der umgekehrten Buchstabe U, der um die Rohren (8) obtoceny durchgeführt sind, und die Gewindeenden der Bügelschellen (10) mit Muttern versehen sind.
3. Querstrom-Rohrbündelwärmetauscher nach dem Ansprüchen 1 und 2, **dadurch gekennzeichnet, dass** der Deflektor (9) auf jedem zweiten Rohr (8) in einer zur Achse des Wärmetauschers (1) senkrechten Reihe befestigt ist.

Revendications

1. Échangeur de chaleur à faisceau tubulaire à écoulement transversal (1) comportant une coque (12) avec un ensemble de tubes de raccordement (8) qui sont fixées parallèlement à l'axe entre deux plaques tubulaires latérales extrêmes (2, 3), dans lequel, sur la gaine (12) de l'échangeur de chaleur (1), une entrée (4) pour le fluide caloporteur est disposée en haut et une sortie (5) pour le fluide caloporteur est situé en bas, et un tube d'entrée (6) pour le fluide chauffé est disposé sur le côté de la plaque tubulaire d'entrée (2) et un tube de sortie (7) est disposé sur le côté de la plaque tubulaire de sortie (3), dans lequel des déflecteurs (9) sont fixés perpendiculairement aux tubes (8) à intervalles réguliers, les déflecteurs (9) comprenant une bande de fixation horizontale (13) sur leur face inférieure et une aile inclinée (14) qui est disposée obliquement à un angle de 120° à 140° par rapport à la bande de fixation (13) dans

sa position horizontale, dans lequel les déflecteurs (9) sont disposés en rangées côte à côte, à l'intérieur d'une rangée horizontale de tubes (8) à une distance (X), tous les déflecteurs à l'intérieur d'une telle formation étant inclinés dans le même sens, et les déflecteurs (9) sur les tubes (8) dans la rangée adjacente inférieure sont de nouveau disposés à une distance (X), la disposition et l'inclinaison des déflecteurs (9) en dessous d'une telle rangée décalée étant de nouveau les mêmes que dans la rangée au-dessus, **caractérisé en ce que**, dans la rangée inférieure, les déflecteurs (9) sur les tubes (8) sont inclinés dans la direction opposée à ceux qui se trouvent au-dessus d'eux et sont également disposés à la moitié de la distance (X), les *défecteurs (9) étant fixés aux tubes (8) au moyen de colliers de fixation (10)*, l'entrée (4) étant ramifiée et les différentes branches (11) étant disposées dans une gaine (12) au-dessus des déflecteurs (9) disposés sur le tube (8), qui est le plus proche de ces entrées et les déflecteurs (9) en un point situé au-dessous de chaque entrée forment soit un ensemble de deux déflecteurs (9) orientés d'un côté, soit il n'y a qu'un seul déflecteur (9) orienté du côté opposé et la hauteur (H) du déflecteur (9) est inférieure à la distance (h) des surfaces de deux tubes adjacents (8) disposés l'un au-dessus de l'autre.

2. L'échangeur de chaleur à faisceau tubulaire selon la revendication 1, **caractérisé en ce que** les colliers de fixation (10) sont constitués d'un fil enroulé autour du tube (8) en forme de U inversé, les extrémités filetées des colliers de fixation (10) étant fixées par des écrous.
3. L'échangeur de chaleur à faisceau tubulaire selon les revendications 1 et 2, **caractérisé en ce que** le déflecteur (9) est fixé sur un tube (8) sur deux dans une rangée perpendiculaire à l'axe de l'échangeur de chaleur (1).

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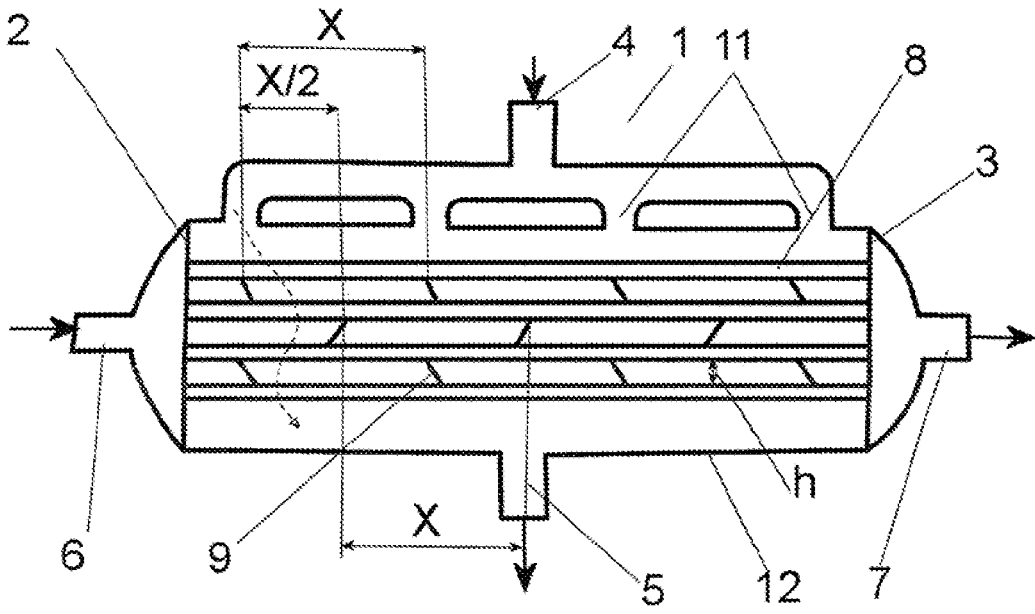


Fig. 1

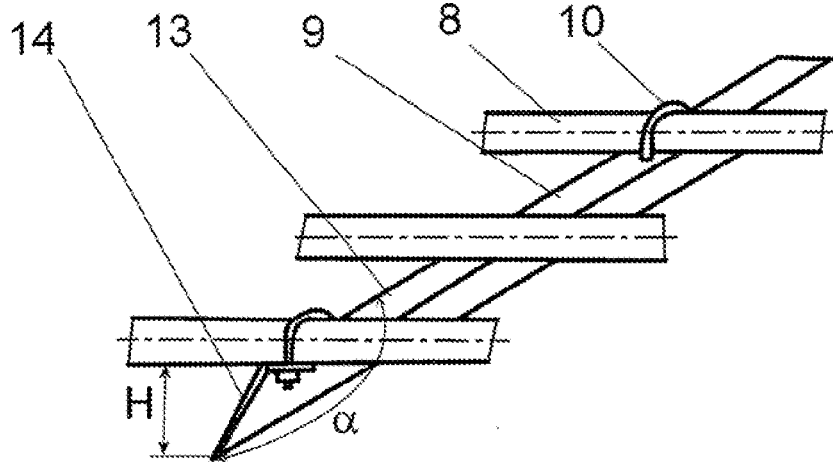


Fig. 2

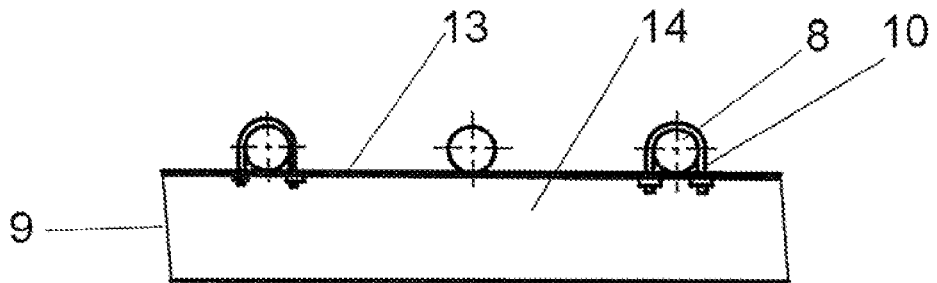


Fig. 3

REFERENCES CITED IN THE DESCRIPTION

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