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(54) Title: ELECTRIC GAS HEATER

(57) Abstract: The present invention refers to an electric gas heater (1) comprising a housing (2) possessing an inlet chamber (3) and an outlet chamber (4), a bundle (21) of electrically conducting tubes comprising at least a first electrically conducting tube (5) and a second electrically conducting tube (6), wherein the tubes of the bundle (21) are arranged parallel to each other and parallel to a longitudinal axis (7) and are arranged inside the housing (2) between the inlet chamber (3) and the outlet chamber (4), electrical conductors (8) for connecting tubes of the bundle (21) with an electric power supply, insulating elements (9) comprising a first insulating element configured to electrically insulate the first tube (5) from the second tube (6), a supporting element (10) arranged inside the housing (2) and configured to support the bundle (21) of tubes, wherein each tube (5, 6) of the bundle (21) of tubes has an inlet opening (11) connected to the inlet chamber (3) and an outlet opening (12) connected to the outlet chamber (4), wherein the first tube (5) carries the first insulating element.

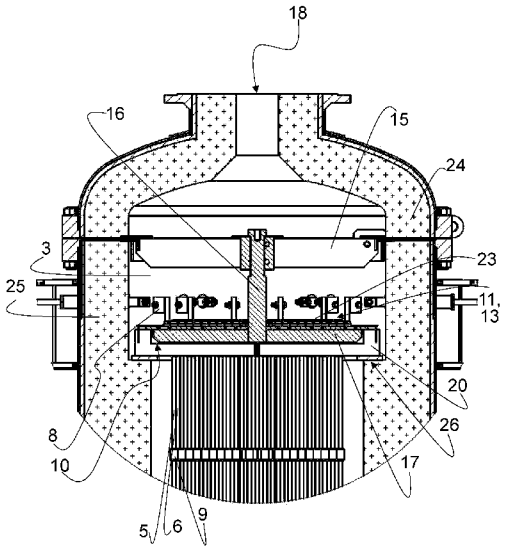


Fig. 2

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Electric gas heater

TECHNICAL FIELD

The present invention relates to an electric gas heater. The invention further elates to a method for heating a gas in an electric gas heater.

BACKGROUND

Electric gas heaters of a through flow type comprising electrically heated tubes, through which gas to be heated is conducted are known.

US 927173 discloses an electric heater having resistance members constructed of nickel tubes. In a housing a large number of thin walled nickel tubes are mounted through insulation in transverse sheet metal walls. The nickel tubes, through suitably disposed sheet metal strips, are interposed in series forming an uninterrupted conductor for electric current.

US 4233494 discloses a throughflow heater for fluids, in particular, an air heater for use in regenerating a carbon-dioxide adsorber in an air-rectification system.

A different kind of gas heater comprises one or more electrically heated wires extending through a number of tubes arranged in parallel e.g., as disclosed in US 2018/098385. A gas heater of this kind is distinctly different from the above discussed kind of fluid heaters comprising electrically heated tubes. Namely, the tubes through which the electrically heated wires extend have to be electrically insulating. This also means that the tubes can be positioned in abutment with each other in a bundle of tubes. Moreover, the gas is heated primarily by the electrically heated wires and secondarily by the tubes, which are heated indirectly by the electrically heated wires.

In order to ensure proper operation of the electric gas heater it is important that the tubes of an electric gas heater are separated from each other. Therefore, suspension of the tubes of an electric gas heater is complicated and may require intricate suspension arrangements to fulfil both its suspension and electrical insulation requirements. Particularly, if an electric gas heater shall comprise a large number of parallel tubes, the suspension needs to sufficiently strong in order to carry the weights of this large number of parallel tubes.

SUMMARY

It would be advantageous to achieve an improved electric gas heater overcoming, or at least alleviating, at least some of the above-mentioned drawbacks. In particular, it would be desirable to enable an efficient suspension of a large number of tubes of an electric gas heater. To better address one or more of these concerns, an electric gas heater having the features defined in the independent claims is provided.

According to an aspect of the present disclosure, there is provided an electric gas heater comprising a housing possessing an inlet chamber and an outlet chamber, a bundle of electrically conducting tubes comprising at least a first electrically conducting tube and a second electrically conducting tube, wherein the tubes of the bundle are arranged parallel to each other and parallel to a longitudinal axis and are arranged inside the housing between the inlet chamber and the outlet chamber, electrical conductors for connecting tubes of the bundle with an electric power supply, insulating elements comprising a first insulating element configured to electrically insulate the first tube from the second tube, a supporting element arranged inside the housing and configured to support the bundle of tubes, wherein each tube of the bundle of tubes has an inlet opening connected to the inlet chamber and an outlet opening connected to the outlet chamber, wherein the first tube carries the first insulating element.

Hence, the first tube supports the first insulating element. Particularly, it carries the weight of the insulating element partly or fully. In this sense, the first insulating element is mounted to the first tube according to the present disclosure.

This feature facilitates a separation of supporting and insulating, what again facilitates flexible design options for aligning the electric gas heater in dependency on the needed application.

According to embodiments, each tube of the bundle of tubes extends along the direction of the force of gravity from a skywards facing end towards an earthwards facing end, such that the longitudinal axis is vertically aligned.

Such a vertical alignment facilitates hanging down each tubes from a single suspension point such that no further supporting of the tubes is necessary. Further, using the force of gravity makes it simple to align the tubes parallel to each other, especially if the electric gas heater comprises a huge number of electrical conductive tubes like e.g. 400, since the gravity field is very homogenous in the near-Earth environment. A nearly perfect parallel alignment of the

tubes is always preferable since it causes a uniform flow distribution with a minimum of energy dissipation.

According to embodiments, each tube of the bundle of tubes extends horizontally from a first end towards a second end, such that the longitudinal axis is horizontally aligned. Such a horizontal alignment may be advantageous when adding a respective electrical gas heater to an existing industrial machine.

According to embodiments, the longitudinal axis may have any inclination angel of between 0 and 180 degrees.

The electric gas heater may herein alternatively be referred to simply as gas heater, or heater. The electric gas heater may be utilised for heating gas in an industrial process. The heated gas may for example be utilised in an industrial process, it may be an energy carrier in an industrial process, and/or it may be utilised as a heat source in an industrial process.

Herein, the electrically conducting tubes, especially the first electrically conducting tube and the second electrically conducting tube, may alternatively be referred to as tubes.

Multiple tubes are arranged in a bundle of tubes. In the bundle, the tubes are arranged in parallel at a distance from each other.

The gas heater provides directly electrically heated tubes and thereby direct energized tubes, which are void of any additional heating elements and thus, provide basis for an uncomplicated construction of the gas heater. The gas heater is of a simple construction requiring few different components. Although the heater may comprise hundreds of individual tubes, the tubes may be of a limited number of different kinds. This, inter alia, leads to the gas heater being operationally reliable.

According to embodiments, the tubes have a small diameter, particularly a diameter of 7 – 30 mm, and a thin wall thickness, particularly a wall thickness of 1 – 3 mm. A large number of tubes may thus be provided in a given volume of the gas heater. Accordingly, the tubes provide efficient use of the volume of the housing and thus, efficient heat transfer to the gas to be heated.

Moreover, since the number of tubes is configured to be connected to an external electric power supply, the tubes are directly electrically heated due to their intrinsic electrical resistance. The electric energy thus supplied is efficiently transformed into heat which is transferred to the gas to be heated in the electric gas heater.

Each tube provides a flow passage for the gas to be heated from the inlet to the outlet chamber. According to embodiments, the insides of the tubes lack any heat generating members extending there through. In other words, the tubes do not have any internal elements, such as wire heating elements, extending there through.

According to embodiments, a bundle of tubes is arranged inside the housing, the housing not only protects the bundle of tubes, but may additionally be devised as a pressure vessel. If the housing is devised as a pressure vessel, this means that individual tubes of the number of tubes do not have to be able to withstand any pressure difference between their insides and outsides more than the pressure drop which will be caused by the gas flow. Thus, additionally, no pressure rated tubes are needed.

The external electric power supply may comprise mains power or may be connected to mains power via a transformer for adapting a voltage of electric current supplied to the electric gas heater.

During use of the gas heater, the inlet chamber acts as a manifold for distributing a collective gas stream to the individual tubes. The outlet chamber acts as a manifold for converging gas that has been heated in the individual tubes into one collective gas stream.

The tubes comprise an electric resistance material, which is an electrical conductor. An electric current, when flowing through the electric resistance material, causes the electric resistance material to be heated.

According to embodiments, the electric resistance material is an aluminium oxide forming material. The aluminium oxide will form a protective layer and thereby, the tubes may withstand both high temperatures and other harsh environment conditions and thus, may enable heating of gas to high temperatures. Example of such material is the material sold by the company Kanthal under the tradename Kanthal® APMT and Kanthal® APM.

According to an alternative embodiment, the tubes are of a molybdenum based alloy. Such an alloy may be utilised when the gas to be heated is a non-oxidising gas such as hydrogen or nitrogen.

According to embodiments, the first insulating element is solely mounted to the first tube, such that the insulating element surrounds a part of the first tube's outer surface. Hence, an individual tube of the bundle carries an individual insulation element. This solution can be fabricated very simple and cost-efficiently.

According to embodiments, the first tube has an outer support flange, wherein the insulating element bears on the support flange. This is also a very simple and cost-efficiency solution for supporting an insulating element between tubes of the bundle. This solution makes use if the vertical alignment of the tubes.

According to embodiments, the first insulating element is an insulating sleeve surrounding at least a part of the first tube's outer surface. Such an insulating sleeve sufficiently insulates the first tube from the second tube. Furthermore, it can be easily mounted if the longitudinal axis is vertically aligned and an earthwards facing end portion of the insulating sleeve bears on an abutment surface of a support flange of a respective tube.

According to embodiments, the insulating sleeve possesses a radial wall thickness in a range from 10 mm to 20 mm. It has been shown that such a wall thickness is sufficient for insulating two adjacent tubes from each other with respect to many industrial applications.

According to embodiments, the first insulating element is made of a ceramic material.

According to embodiments, the first insulating element has a longitudinal extension of less than 50% of the longitudinal extension of the tubes of the bundle.

According to embodiments, the first insulating element has a longitudinal extension of less than 49% of the longitudinal extension of the tubes of the bundle.

According to embodiments, the first insulating element has a longitudinal extension of less than 45% of the longitudinal extension of the tubes of the bundle.

According to embodiments, the sum of all longitudinal extensions of all insulating elements of the first tube is less than 50 % of the longitudinal extension of the tubes of the bundle.

According to embodiments, the sum of all longitudinal extensions of all insulating elements of the first tube is less than 49 % but more than 1 % of the longitudinal extension of the tubes of the bundle.

According to embodiments, the sum of all longitudinal extensions of all insulating elements of the first tube is less than 45 % but more than 5 % of the longitudinal extension of the tubes of the bundle.

According to embodiments, the longitudinal extension of the first insulation element ranges from 10 mm to 300 mm.

According to embodiments, the longitudinal extension of the first insulation element ranges from 20 mm to 100 mm.

Hence, the insulation element is comparable short. Using short insulation elements is very material efficient and, therefore, cost efficient.

According to embodiments, the first insulating element and the supporting element are arranged along the longitudinal axis, such that a gap forms between the first insulating element and the supporting element. The axial length of the gap may depend on the temperatures reached inside the gas heater. The gap is configured to guarantee that there are no short circuit events between adjacent tubes during operation of the gas heater.

According to embodiments, the axial extension of the gap is larger than the axial extension of the first insulating element.

According to embodiments, the insulating elements comprise a set of multiple insulating elements, wherein each insulating element of the set of multiple insulating elements is mounted to an electrically conducting tube. Hence, the tubes carry the insulating elements. The insulating elements may be distributed in a most efficient way, in order to guarantee insulation of the tubes, on the one hand, and to minimize the material costs and weight of the gas heater on the other hand.

According to embodiments, each tube of the bundle of tubes carries at least one insulating element such as an insulating sleeve surrounding the outer surface of the respective tube. This decreases the risk of short circuits during operation of the gas heater.

According to embodiments, each tube of the bundle of tubes carries multiple insulating elements such as insulating sleeves. This further decreases the risk of short circuits during operation of the gas heater.

According to embodiments, the insulating elements comprise at least two insulating elements axially distanced from each other and defining an axial gap between each other. Also this gap is configured to guarantee that there are no short circuit events between adjacent tubes during operation of the gas heater.

According to embodiments, additionally to the first insulating element, a second insulating element and a third insulating element are carried by the first tube, wherein looking from the inlet opening of the first tube along the first tube, the first, second and third insulating element are arranged in a sequence starting with the first insulating element and ending with the third insulating element, wherein the second insulating element is arranged adjacent to the first insulating element and adjacent to the third insulating element, wherein the distance between the second insulating element and the third insulating element is smaller than the distance between the first insulating element and the second insulating element. This sequence arrangement with decreasing distances when going from the inlet opening to the outlet opening is motivated by the temperature distribution along the tubes. Since the tube is getting hotter from the inlet opening to the outlet opening, a higher frequency of insulation elements are needed in the hotter regions near the outlet opening than in the colder regions near the inlet opening.

According to embodiments, the distances between adjacent insulating elements of an individual tube of the bundle of tubes vary and/or range from 0 to 700 mm.

According to embodiments, the insulating elements comprise at least three insulating elements axially distanced from each other and defining an axial gap between each other. For long tubes, it is advantageous to provide a larger number (> 2) of axially spaced insulation elements.

According to embodiments, the first insulating elements is solely mounted to the first tube and extends along a first axial segment of the longitudinal axis and a further insulating element is mounted to a further tube and extends along a second axial segment of the longitudinal axis,

wherein the first axial segment and second axial segment overlap, wherein the first tube and the further tube are arranged in a way that the further insulating element and the first insulating element are in contact with each other or can come into contact with each other during operation of the electric gas heater.

According to embodiments, the bundle of electrically conducting tubes comprise more than two electrically conducting tubes, wherein the insulating elements are designed and arranged, such that each pair of adjacent tubes of the bundle of tubes is distanced and electrically insulated from each other within a first axial section at least by a single insulating element of the insulating elements.

According to embodiments, the supporting element comprises a main section, wherein the main section comprises a metallic material, wherein the main section is electrically insulted from the electrically conducting tubes. For gas heaters with a large number of tubes included in the bundle of tubes, the total weight of the tubes is very large such that the support element should be sufficiently strong. This strength can be achieved by the described main section comprising a metal material.

According to embodiments, the supporting element is configured to support the tubes of the bundle, such that each tube of the bundle is hanging down towards the ground, wherein the first tube is hanging down form a first suspension point and the second tube is hanging down from second suspension point.

According to embodiments, depending on the inclination of the longitudinal axis, the support element may also be configured to support the tubes of the bundle such to ensure that each tube is separated from each other and to ensure that the tubes are kept in the desired position.

According to embodiments, the first suspension point is the only suspension point of the first tube and the second suspension point is the only suspension point of the second tube. Such a single point suspension with respect to an individual tube simplifies a parallel alignment of the tubes of the bundle.

According to embodiments, the longitudinal axis is vertically aligned and the earthwards facing end of the first tube is hanging freely.

According to embodiments, the supporting element comprises an insulating section, wherein the insulating section is configured to electrically insulate each one of the first tube and the second tube from the metallic section of the supporting element.

According to embodiments, the insulating section comprises a ceramic material.

According to embodiments, the supporting element is mounted to the housing at least at a first axial mounting point and a second axial mounting point, wherein the first axial mounting point and the second axial mounting point have a non-zero axial distance to each other.

According to embodiments, the supporting element comprises a support plate, wherein the support plate is arranged in a plane being perpendicular to the longitudinal axis, such that the support plate possesses a first side surface and a second side surface, wherein at least the first tube and the second tube are mechanically connected to the support plate, wherein the first tube and the second tube are electrically isolated from the support plate.

According to embodiments, the supporting element further comprises suspension arms connected to a centre of the support plate's first side surface and configured to mount the support plate with respect to the housing.

According to embodiments, the support plate comprises at least a first channel and a second channel, both extending from the second side surface throughout the support plate to the first side surface, wherein a part of the first tube extends through the first channel, wherein a part of the second tube extends through the second channel, wherein the electric gas heater comprises an electrically conducting connector element, wherein the first tube is electrically and mechanically connected to the second tube via the connector element, such that an electric current is conductible through the first tube, the second tube and the connector element, wherein the connector element is arranged on or above the first side surface of the support plate, wherein the connector element and the supporting element are configured to electrically insulate the connector element from an electrically conductive section of the supporting element. Hence, the connector element, which is needed to connect the tubes anyway, is also used to support the tubes. Consequently, this solution is very material-efficient.

According to embodiments, an electrically insulating insert is arranged between the first tube and an inner surface of the first channel, such that the first tube is electrically insulated from

the support plate, wherein a further electrically insulating insert is arranged between the second tube and an inner surface of the second channel, such that the second tube is electrically insulated from the support plate. Hence, there is no risk of short circuits due to a contact of a tube of the bundle and the support plate during operation of the gas heater.

According to embodiments, both electrically insulating inserts are ceramic sleeves.

According to embodiments, the supporting element is also configured to electrically isolate the first tube from the second tube.

According to embodiments, the supporting element comprises a different material or material composition when compared with the insulating element.

According to embodiments, at least an individual insulating element of the insulation elements is also configured to support a tube of the electrically conducting tubes.

According to embodiments, a pair of adjacent tubes of the electrical conducting tubes of the bundle have a distance to each other ranging from 10 to 30 mm.

According to embodiments, a pair of adjacent tubes of the electrical conducting tubes of the bundle have a distance to each other ranging from 15 to 20 mm.

Insofar as in the foregoing as well as the following detailed description of the embodiments and claims reference is made to either the electric gas heater or the method for heating a gas heater, the features described are applicable for both the electric gas heater and the method for heating a gas.

According to an aspect of the disclosure, there is provided a method for heating a gas in an electric gas heater according to any one of the preceding claims comprising steps of: supplying a gas to the inlet chamber whereby the gas is conducted along gas flow paths parallel to the longitudinal axis of the electric has heater via the insides of the tubes to the outlet chamber; supplying an electric current to the in order to heat the tubes; continue with conducting the gas along the vertical gas flow paths via the insides of the tubes to the outlet chamber; and leading the gas from the outlet chamber.

According to embodiments, there is provided a method for heating a gas in an electric gas heater according to any one of the preceding claims comprising steps of: supplying a gas to

the inlet chamber whereby the gas is conducted along vertical gas flow paths parallel to the longitudinal axis of the electric has heater via the insides of the tubes to the outlet chamber; supplying an electric current to the in order to heat the tubes; continue with conducting the gas along the vertical gas flow paths via the insides of the tubes to the outlet chamber; and leading the gas from the outlet chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

Further advantages, features and applications of the present disclosure will become apparent from the following description of embodiments and the corresponding figures attached. The foregoing as well as the following detailed description of the embodiments will be better understood when read in conjunction with the appended drawings. It should be understood that the embodiments depicted are not limited to the precise arrangements and instrumentalities shown

Fig. 1 shows a cross sectional view of the centre of the electric gas heater, wherein the cross sectional plane includes the longitudinal axis.
Fig. 2 shows a close-up of the upper part of the electric gas heater shown in Fig. 1.

DETAILED DESCRIPTION

Aspects and/or embodiments of the invention will now be described more fully. Like numbers refer to like elements throughout. Well-known functions or constructions will not necessarily be described in detail for brevity and/or clarity. The Figs. and the detailed description relate to an electrical gas heater. However, the same principles as described below are also applicable to any heater as defined in claim 1 with or without some minor modifications.

Particularly, the following description refers to an electric gas heater with a vertically aligned longitudinal axis. However, the same features and advantageous – as described below – apply to an analogous electric gas heater with a horizontally aligned longitudinal axis equivalently or with a longitudinal axis having another inclination than 0, 90 or 180 degrees.

Fig. 1 illustrates a cross sectional view through the electric gas heater 1 along a cross sectional plane including the central longitudinal axis 7 of the electric gas heater 1.

The electric gas heater 1 comprises a housing 2. The gas to be heated flows through the housing 2, from an inlet 18 to an outlet 19. The heater 1 further comprises a bundle 21 of tubes

arranged inside the housing 2, particularly a first individual tube 5 and a second individual tube 6. Electrical conductors 8 are provided for connecting tubes of the bundle 21 of tubes with an external electric power supply.

According to the illustrated electric gas heater 1, the housing 2 has a tubular shape, the inlet 18 is located on the skywards facing side of the housing 2, and the outlet 19 is located at the earthwards facing side of the housing 2, such that the inlet 18 and the outlet 19 are aligned along the central longitudinal axis 7 of the electric gas heater 1.

However, the invention is not limited to the illustrated electric gas heater 1. The housing 2 of the gas heater 1 may have any suitable shape for accommodating a bundle of tubes, connecting electrical conductors to the tubes, and permitting a gas flow through the housing. For instance, the inlet and/ or the outlet may be arranged radially, i.e., along a horizontal axis being perpendicular to the longitudinal axis 7.

Fig. 2 illustrates the cross sectional view as shown in **Fig. 1** but focusing on the upper part of the electric gas heater, where the support element 10 is located.

In **Fig. 2**, the bundle 21 of tubes inside the housing 2 is clearly shown. The tubes of the bundle 21 may be of an electric resistance material or a molybdenum based alloy. The tubes of the bundle 21 are directly heated by electric current supplied to the tubes via the electrical conductors 8. When flowing through the electric resistance material or the molybdenum based alloy, the electric current causes the electric resistance material or the molybdenum based alloy to heat up.

Each tube of the bundle 21 has an inlet opening 11 connecting the inside of the tube with the inlet chamber 3 and an outlet opening 12 connecting the inside of the tube with the outlet chamber 4.

In the show example, the bundle 21 of tubes is divided into multiple subsets of tubes, wherein tubes of a certain subset are electrically connected to each other at their first, here skywards facing, end portions 13 or second, here earthwards facing, end portions 14 via electrically conductive connector elements 23. Hence, the connector elements 23 provide series connections between the tubes of a certain subset. Tubes of different subsets constitute a parallel connection.

In the shown example, the first tube 5 and the second tube 6 are both included in a single subset of tubes, namely a first subset. The first tube 5 is connected to an electric power supply by a conductor 8 on its skywards facing end portion 13. The second tube 6 is an adjacent tube with respect to the first tube 5. The first tube and the second tube are connected by an electrically conductive connector element 23 at their earthwards facing end portions 14. Again, the second tube is connected to a third tube of the first subset at their skywards facing end portions 13. Depending on the number of tubes included in a subset of tubes, the series of connecting two adjacent tubes at their earthwards facing end portions 14 and connecting two adjacent tubes at their skywards facing end portion 13 repeats several times, such that a single continuous electrical conductive path way is going back and forth from the skywards facing end to the earthwards facing end of the tubes of the respective subset along all tubes of the respective subset. This electrical conductive path way begins and ends at the skywards facing end of the tubes such that the series connection of tubes of a single subset can be connected to both poles of an electrical power supply by conductors 8 at the skywards facing end of the tubes.

In the here shown example, the bundle 21 of tubes comprises six subset of tubes in total, wherein all tubes of a single subsets constitute a series connection and tubes of different subset constitute a parallel connection.

Depending on the voltage connected to the electrical conductors 8 and the electrical resistivity of the individual tubes, an alternative suitable configuration of parallel and serial connection between the tubes of the bundle 21 may be provided.

Via the electrical conductors 8, the tubes of a subset are directly or indirectly connected to mains power. For instance, the tubes may be connected to each other in such a manner that mains power at 400 V may be supplied to the tubes via the electrical conductors 8.

The gas heater 2 shown in **Figs. 1 and 2** comprises a supporting element 10 configured for supporting the bundle 21 of tubes separated from each other. The here shown supporting element comprises a metallic support plate 17, an axially aligned metallic support arm 16 and multiple radially aligned metallic arms 15. Further, the here shown supporting element comprises an insulating plate 20.

The tubes of the bundle 21 are mounted to the support plate 17. Particularly, at least two adjacent tubes of a certain subset are connected by an electrically conductive connector element 23 on the first, here skywards facing side of the support plate 17, such that the respective

connector element 23 abuts on the support plate 17 due to the vertical alignment of the tubes and the weight of the tubes. Since the support plate 17 is at least partially made of metal in order to provide a sufficient strength for supporting, the support plate 17 comprises also an insulating section, wherein the above-mentioned connector element 23 abuts on an abutment surface of the insulating section. Consequently, the respective connector element 21 is insulated from an electrically conductive section of the support plate 17.

The support plate 17 itself is mounted with respect to the housing 2 in two ways. First, the support plate 17 directly or indirectly abuts on its radial end portions on a radially extending abutment surface 26 of the housing. This abutment defines a first axial mounting point. Second, at its centre, the support plate 17 is connected to an axial support arm 16 extending axially skywards. At the skywards facing end portion of this axial support arm 16, multiple radial support arms 15 are connected to the axial support arm 16, extending radially from the longitudinal axis. These radial support arms 15 are mounted to the housing 2 by a clamping connection. Particularly, the radial support arms 15 are clamped between an upper portion 24 of the housing 2 and a lower portion 25 of the housing 2. This clamping connection defines a second axial mounting point.

By using such a support element 10, a huge number of tubes can be securely supported and electrically heated up to high temperatures, at which the strength of the tubes is reduced.

In the shown example, the support element 10 further comprises an insulating plate 20, arranged on the second, here earthwards facing, side of the support plate 17 and arranged side-to-side with the support plate 17. The insulating plate 20 as well as the support plate 17 comprise multiple holes, wherein a hole of the support plate 17 is axially aligned with a hole of the insulating plate, such that each tube of the bundle extends through both, a hole of the support plate 17 and an adjacent hole of the insulating plate. Moreover, insulating sleeves (not shown) are inserted in the respective holes of the support plate 17 forming a part of the insulating section of the support plate 17 in order to insulate the electrically conductive tubes form the electrically conductive metallic section of the support plate 17.

Due to the hanging configuration of the tubes of the bundle 21, the insulation of the tubes from each other requires much less material than in cases of a horizontal alignment of the tubes. As shown in **Fig. 1** short insulating elements 9, namely insulating sleeves, are connected to tubes of the bundle 21. Particularly, a first insulating element 9 is mounted to the first tube 5.

For the purpose of carrying the insulation sleeve 9, the tubes of the bundle 21 possess small support flanges (not shown) on the earthwards facing side of each insulating sleeve 9, such that an insulating sleeve 9 bears on the support flange. The support flanges may be fabricated by point welding.

In the shown example, each tube of the bundle 21 carries multiple insulating sleeves 9 axially distanced from each other, wherein the axial positions of the insulating sleeves 9 of an individual tube of the bundle 21 are the identical axial positions of insulating sleeves 9 for all other tubes of the bundle 21, such that multiple subsets of insulating elements 9 are arranged in axial distanced horizontal planes. According to the shown example, the electric gas heater 1 comprises five subsets of insulating sleeves 9, wherein each subset is arranged in a different horizontal plane and wherein the distance between two adjacent planes is nearly constant.

Particularly, each tube of the bundle 21 carries an insulating sleeve 9 at the earthwards facing end portion 14 of the respective tube of the bundle 21.

The insulation element is composed of a hard ceramic material which will is electrically insulating. Examples of such materials are Al_2O_3, SiO_2 or a combination thereof.

As visible in **Figs. 1 and 2**, the inlet chamber 3 may be considered to form a manifold for distributing a collective gas stream to the individual tubes of the bundle 21. Similarly, the outlet chamber 4 may be considered to form a manifold for converging the distributed gas streams in the tubes of the bundle 21 back into one collective gas stream. Accordingly, in the common gas flow path extending from the inlet chamber 3 to the outlet chamber 4, distributed gas flow paths are provided via the insides of the tubes. In the distributed gas flow paths of the insides of the tubes of the bundle 21, the gas is heated.

The inlets of the respective individual tubes of the bundle 21 may be provided with flow restrictions. That is, an upstream portion of each tube of the bundle 21 may have a reduced inner diameter in comparison with downstream portions of the respective tube. Namely, at high gas flow, the gas flow is evenly distributed between the individual tubes of the bundle 21 irrespectively of whether the tubes are provided with flow restrictions or not. However, at low gas flow such flow restrictions may contribute to a uniform distribution of the gas flow between the individual tubes of the bundle 21 from the inlet chamber 3 into the tubes of the bundle 21. Thus, in a gas heater 1 wherein during use the gas flow varies over a larger flow range, such flow restrictions may be advantageous.

In the example shown in **Figs. 1 and 2**, the insulation plate 20 seals the inlet chamber 3 from the outlet chamber 4 to the extent that the gas flow paths inside the tubes of the bundle 21 constitute a main flow path for gas from the inlet chamber 3 to the outlet chamber 4. Accordingly, the insulation plate may not provide a gas tight seal between the inlet and outlet chambers 3, 4. However, the insulation plate 20 does provide a sufficiently high pressure drop, i.e. gas flow resistance, such that the gas flowing from the inlet chamber 3 to the outlet chamber 4 will mainly flow through the insides of the tubes of the bundle 21 instead of outside them. For instance, at least 90% of the gas may flow through the insides of the tubes of the bundle 21 from the inlet chamber 3 to the outlet chamber 4. A certain flow of gas along the outsides of the tubes of the bundle may be permitted since also along the outsides of the tubes, the gas may be heated. However, along an inner surface of the housing 2 any gas flow should be prevented by the insulation plate 20 since there the gas will not be heated. A bad seal along the inside of the housing 2 would permit a portion of the gas to escape unheated along the inside from the inlet chamber 3 to the outlet chamber 4. Furthermore, a gas flow of gas along the outside of the tubes often causes a non-uniform flow distribution.

Insides of the inlet and outlet chambers 3, 4 may be provided with protective elements 22 of the housing 2. The protective elements 22 may be arranged adjacent to an outer shell of the housing 2 in order to protect the outer shell of the housing from the warm gas in the inlet and outlet chambers 3, 4. According to an aspect of the present disclosure, the protective element 22 may comprise a fibrous material of the same kind as the insulation plate 20 or the insulation sleeve 9.

In this context, it may be mentioned that the gas heater 1 is suited to elevate the temperature of already hot gas. For instance, the gas flowing into the inlet chamber 3 may have a temperature within a range of 300 – 900 °C.

Mentioned purely as an example, the number of tubes of a bundle 21 may be e.g. 50 to 500 tubes, such as 200 – 300 tubes.

The tubes of the bundle 21 have a small diameter and a thin wall thickness. According to aspects of the present disclosure, individual tubes of the bundle 18 may have an inner diameter within a range of 7 – 30 mm, such as 9 – 20 mm and a wall thickness within a range of 1 – 3 mm, such as 1.5 – 2,.5 mm. In this manner, good heat transfer to the gas to be heated may be

achieved in the tubes of the bundle 21 without too large a pressure drop along each of the individual tubes.

Due the hanging support of the tubes of the bundle, the tubes may be of such weak dimensions as exemplified above, even when the lengths of the tubes are long. Mentioned purely as an example, the length of the individual tubes may be within a range of 0.5 – 2.5 m, or within a range of 1 – 2 m.

The tubes of the bundle 21 may be of an electric resistance material. An electric resistance material is a material that forms at least one heat resistant oxide. The electric resistance material may be an aluminium oxide (i.e. alumina) forming alloy.

According to one example, the alumina forming alloy is an iron chromium aluminium alloy comprising at least 3 wt% aluminium. Thus, the tubes of the bundle may be configured to be electrically heated up to a temperature of 1250 °C while maintaining a practical operational lifespan of the tubes.

It is believed that the bundle 21 of tubes may be configured for an energy transfer up to 5 MW/m^3 or even higher, according to one example, the energy transfer is within the range of 2 to 5 MW/m^3.

Namely, the herein discussed electric gas heater 1 provides a space efficient and material efficient transfer of energy/heat from the tubes of the bundle 21 to the gas to be heat.

Purely mentioned as examples, a gas heater 1 may be one designed for 5 -10 MW with a volume of the bundle 21 of approximately 1.5 - 2.0 m^3, wherein the bundle 21 may comprise several hundreds of tubes, which may be arranged within a range of 20 – 30 mm from each other. A comparatively smaller gas heater 1 may be designed for 0.5 – 1 MW with a volume of the bundle 21 of approximately 0.2 m^3, wherein the tubes within the bundle 21 may be arranged within a range of 10 – 20 mm from each other. The above-mentioned arrangements of the tubes from each other relates to ranges of distances between the outer diameters of adjacent tubes in the bundle 21.

Within the above discussed distance ranges of 20 – 30 mm and 10 – 20 mm, respectively, electric discharge and/or short circuit between the individual tubes of the bundle 21 is avoided. The voltage applied to the tubes is relevant in the context of the distance between the tubes.

Generally, the higher the power rating for a gas heater, the higher a voltage is applied to the tubes. Thus, the distance range between the tubes is larger for higher power rated gas heaters 1 than for lower power rated gas heaters 1.

According to embodiments, individual tubes of the bundle 21 may be arranged for an energy transfer of up to 70 W/cm^3, or up to 100 W/cm^3, or up to within a range of 40 – 70 W/cm^3, or up to within a range of 30 – 60 W/cm^3.

An efficient transfer of energy/heat from the individual tubes of the bundle to the gas to be heated is achieved in the gas heater 1. The tubes of the bundle 21 may suitable be of the dimension discussed above. Energy transfer in the upper range 100 W/cm^3 may come at the cost of a high pressure drop of the gas as it flows through the tubes and may be achieved for some gases, such as hydrogen, and/or under specific operating conditions, which may include one or more of operation under high pressure and/or with a lower outlet temperature e.g. 600 degrees Celsius. More reasonable pressure drop may be achieved at the energy transfer figures within the ranges 40 – 70 W/cm^3 and 30 – 60 W/cm^3. Also these energy transfer figures depend on the gas to be heated and the conditions under which the gas heater 1 is operated.

A different manner of specifying the energy transfer would be to define the energy transfer per area on an inside of the tubes of the bundle. For instance, the figure 60 W/cm^3 would correspond to approximately 15 W/cm^2 according to an example of the gas heater 1.

The following non-limiting examples relate to gas heaters 1 operated at atmospheric pressure provided with a bundle of tubes with tubes having outer and inner diameters of 17.15 and 12.53 mm and arranged with a centre-to-centre distance of 35 mm. A surface temperature of the tubes of 1250 degrees Celsius is provided and a maximum pressure drop of 100 mBar is allow. The gas heated is air with an inlet temperature of 20 degrees Celsius.

The respective gas heater 1 may be designed with an outlet temperature of 600 degrees Celsius, an energy transfer of approximately 18 W/cm^2 may be achieved. If instead an outlet temperature of 1100 degrees Celsius is provided by the gas heater 1, only a lower energy transfer of approximately 3 W/cm^2 may be achieved. Operating the gas heater 1 under pressure and/or permitting a higher pressure drop will improve these energy transfer figures.

It is thus, easily foreseeable that energy transfer figures within a range of 2 – 20 W/cm^2 may be achieved in the gas heater 1 when operated with air under atmospheric pressure.

The housing 2 may form a pressure vessel. Instead of the individual tubes of the bundle 21 being able to withstand a pressure difference between their insides and outsides, the housing 2 is devised to withstand a pressure difference between its inside and its outside. Depending on the relevant pressure levels, temperature levels, and type of gas being heated, the housing 2 may comprise low carbon unalloyed, low alloyed, alloyed, or stainless steel, which are suitable for forming a pressure vessel. Moreover, in gas heaters, wherein the housing forms a pressure vessel, the gas heater 1 may be directly connected to, and utilised in, industrial processes wherein the gas to be heated is pressurised.

Mentioned purely as an example, the pressure vessel may be designed to withstand a gas pressure inside the housing 2 within a range of 10 – 15 bar, or even up to 30 or 40 bar, depending on the industrial process wherein the heater 1 is used.

Some examples of industrial processes where the gas heater 1 with pressure vessel properties may be utilised are:
- Energy storage by means of the heated gas heating a bed of metal or ceramic pellets or beds comprising natural material such as rocks, volcanic rocks, the bed providing a counter pressure to the gas being heated in the gas heater.
- Direct reduction of iron pellets with hydrogen or natural gas to produce direct reduction iron, DRI. In this process the high gas temperature achieved in the gas heater 2 may be particularly useful. Gas heated to temperatures within a range of 1000 – 1100 °C or higher such as up to 1250 °C or up to 1300 °C is advantageous in the direct reduction process.
- Various chemical processes such e.g. Fischer-Tropsch synthesis.

Use of the heater 1 is not limited to these example processes. Moreover, the heater 2 may be utilised for heating non-pressurised or low pressure gas.

The gas heater 1 is particularly suited for heating large gas flows. Even the above exemplified gas heater being provided with a bundle 21 of tubes having a volume of 0.2 m^3 may heat a gas flow of 400 – 500 m^3/hour to temperatures within a range of 900 – 1250 °C. Further, the above exemplified gas heater being provided with a bundle 21 of tubes having a volume of 1.5 - 2.0 m^3 may heat a gas flow of up to 3000 m^3/hour to temperatures within a range of 900 – 1250 °C. Even larger flows, such as 15000 – 20000 m^3/hour are foreseen to be heated in larger versions of the gas heater.

For simple mounting, replacement, and servicing of the tubes of the bundle 21, the housing 2 may comprise a sealable opening sized such that the tubes arranged in a bundle may be extracted out of the housing 2 as one unit via the opening.

Fig. 3 illustrates a method 100 for heating a gas in an electric gas heater 2 according to any one of aspects and/or embodiments discussed herein, such as e.g. the gas heater 2 discussed above with reference to **Figs. 1 and 2**. Accordingly, in the following reference is also made to **Figs. 1 and 2**.

The method 100 for heating a gas in an electric gas heater 2 comprises the steps of:
- supplying 102 a gas to the inlet chamber 3 whereby the gas is conducted along vertical gas flow paths via the insides of the tubes of the bundle 21 to the outlet chamber 4,
- supplying 104 an electric current to the tubes of the bundle 21 in order to heat the tubes,
- continue 106 with conducting the gas along the vertical gas flow paths via the insides of the tubes to the outlet chamber 4, and
- leading 108 the gas from the outlet chamber 4.

The gas will start to flow as soon as it is supplied to the inlet chamber and thereby it will be conducted along the gas flow paths via the bundle of this tubes.

The method 100 may be utilised for heating gas in an industrial process.

Further, the gas may for example but not limited thereto to air, hydrogen, nitrogen, carbon dioxide, synthesis gas, or pyrolysis gases. In this manner, a suitable gas for a relevant industrial process may be heated in the gas heater 1.

The step 102 of supplying a gas to the inlet chamber 3 may comprise supplying the gas at a temperature within a range of 300 – 900 °C to the inlet chamber 3. In this manner, the property of the gas heater 1 to elevate already hot gas to even higher temperatures may be utilised in an industrial process.

It is to be understood that the foregoing is illustrative of various example embodiments and that the invention is defined only by the appended claims. A person skilled in the art will realize that the example embodiments may be modified, and that different features of the example embodiments may be combined to create embodiments other than those described herein, without departing from the scope of the invention, as defined by the appended claims.

CLAIMS

1. An electric gas heater (1) comprising:
a housing (2) possessing an inlet chamber (3) and an outlet chamber (4),
a bundle (21) of electrically conducting tubes comprising at least a first electrically conducting tube (5) and a second electrically conducting tube (6), wherein the tubes of the bundle (21) are arranged parallel to each other and parallel to a longitudinal axis (7) and are arranged inside the housing (2) between the inlet chamber (3) and the outlet chamber (4),
electrical conductors (8) for connecting tubes of the bundle (21) with an electric power supply,
insulating elements (9) comprising a first insulating element configured to electrically insulate the first tube (5) from the second tube (6),
a supporting element (10) arranged inside the housing (2) and configured to support the bundle (21) of tubes,
wherein each tube (5, 6) of the bundle (21) of tubes has an inlet opening (11) connected to the inlet chamber (3) and an outlet opening (12) connected to the outlet chamber (4), wherein the first tube (5) carries the first insulating element.

2. An electric gas heater (1) according to claim 1,
wherein each tube (5, 6) of the bundle of tubes extends along the direction of the force of gravity from a skywards facing first end (13) towards an earthwards facing second end (14), such that the longitudinal axis (7) is vertically aligned.

3 An electric gas heater (1) according to claim 1,
wherein each tube (5, 6) of the bundle of tubes extends horizontally from a first end (13) towards a second end (14), such that the longitudinal axis (7) is horizontally aligned.

4. An electric gas heater (1) according to one of the aforementioned claims,
wherein the first insulating element (9) is solely mounted to the first tube (5), such that the insulating element (9) surrounds a part of the first tube's outer surface,
wherein such as the first tube (5) has an outer support flange and the first insulating element (9) bears on the support flange.

5. An electric gas heater (1) according to one of the aforementioned claims,

wherein the first insulating element (9) is an insulating sleeve surrounding at least a part of the first tube's outer surface,
wherein such as the insulating sleeve possesses a radial wall thickness in a range from 5 mm to 30 mm, such as 5 mm to 20 mm.

6. An electric gas heater (1) according to one of the aforementioned claims,
wherein the first insulating element (9) is made of a hard ceramic material, such as Al_2O_3 or SiO_2.

7. An electric gas heater (1) according to one of the aforementioned claims,
wherein the first insulating element (9) has an longitudinal extension of less than 50% of the longitudinal extension of the tubes of the bundle (21),
wherein such as the longitudinal extension of the first insulation element (9) ranges from 10 mm to 300 mm,
wherein such as the longitudinal extension of the first insulation element (9) ranges from 20 mm to 100 mm.

8. An electric gas heater (1) according to one of the aforementioned claims,
wherein the first insulating element (9) and the supporting element (10) are arranged along the longitudinal axis (7), such that a gap forms between the first insulating element (9) and the supporting element (10),
wherein such as the axial extension of the gap is larger than the axial extension of the first insulating element (9).

9. An electric gas heater (1) according to one of the aforementioned claims,
wherein the insulating elements comprise a set of multiple insulating elements,
wherein each insulating element of the set of multiple insulating elements is carried by an electrically conducting tube of the bundle (21).

10. An electric gas heater (1) according to one of the aforementioned claims,
wherein each tube of the bundle of tubes carries at least one insulating element such as an insulating sleeve surrounding the outer surface of the respective tube.

11. An electric gas heater (1) according to the aforementioned claim,
wherein each tube of the bundle of tubes carries multiple insulating elements such as insulating sleeves.

12. An electric gas heater (1) according to one of the aforementioned claims,
wherein the insulating elements comprise at least two insulating elements axially distanced from each other and defining an axial gap between each other,
wherein such as the insulating elements comprise at least three insulating elements axially distanced from each other and defining respective axial gaps between each other.

13. An electric gas heater (1) according to one of the aforementioned claims,
wherein additionally to the first insulating element, a second insulating element and a third insulating element are carried by the first tube, wherein looking from the inlet opening of the first tube along the first tube, the first, second and third insulating element are arranged in a sequence starting with the first insulating element and ending with the third insulating element, wherein the second insulating element is arranged adjacent to the first insulating element and adjacent to the third insulating element, wherein the distance between the second insulating element and the third insulating element is smaller than the distance between the first insulating element and the second insulating element.

14. An electric gas heater (1) according to one of the aforementioned claims,
wherein the first insulating element (9) is solely mounted to the first tube (5) and extends along a first axial segment of the longitudinal axis (7) and a further insulating element is solely mounted to a further tube and extends along a second axial segment of the longitudinal axis,
wherein the first axial segment and second axial segment overlap,
wherein the first tube (5) and the further tube are arranged in a way that the further insulating element and the first insulating element (9) are in contact with each other or can come into contact with each other during operation of the electric gas heater.

15. An electric gas heater (1) according to one of the aforementioned claims,
wherein the bundle (21) of electrically conducting tubes comprises more than two electrically conducting tubes,
wherein the insulating elements are designed and arranged, such that each pair of adjacent tubes of the bundle (21) of tubes is distanced and electrically insulated from each other within a first axial section at least by a single insulating element of the insulating elements.

16. An electric gas heater (1) according to one of the aforementioned claims,
wherein the supporting element (10) comprises a main section,
wherein the main section comprises a metallic material,
wherein the main section is electrically insulated from the electrically conducting tubes of the bundle (21).

17. An electric gas heater (1) according to one of the aforementioned claims as far as it refers to claim 2,
wherein the supporting element (10) is configured to support the tubes of the bundle (21), such that each tube of the bundle (21) is hanging down towards the ground,
wherein the first tube (5) is hanging down form a first suspension point and the second tube (6) is hanging down from second suspension point,
wherein such as the first suspension point is the only suspension point of the first tube (5) and the second suspension point is the only suspension point of the second tube (6),
wherein such as the earthwards facing end of the first tube is hanging freely.

18. An electric gas heater (1) according to one of the aforementioned claims,
wherein the supporting element (10) comprises a support plate (17),
wherein the support plate (17) is arranged in a plane being perpendicular to the longitudinal axis, such that the support plate possesses a first side surface and second side surface,
wherein at least the first tube (5) and the second tube (6) are mechanically connected to the support plate, wherein the first tube (5) and the second tube (6) are electrically insulated from the support plate (17).

19. An electric gas heater (1) according to the aforementioned claim,
wherein the support plate (17) comprises at least a first channel and a second channel, both extending from the second side surface throughout the support plate (17) to the first side surface,
wherein a part of the first tube (5) extends through the first channel,
wherein a part of the second tube (6) extends through the second channel,
wherein the electric gas heater (1) comprises an electrically conducting connector element (23),

wherein the first tube (5) is electrically and mechanically connected to the second tube (6) via the connector element (23), such that an electric current is conductible through the first tube (5), the second tube (6) and the connector element (23),
wherein the connector element (23) is arranged on or above the first side surface of the support plate (17),
wherein the connector element (23) and the supporting element (10) are configured to electrically insulate the connector element (23) from an electrically conductive section of the supporting element (10),
wherein such as an electrically insulating insert is arranged between the first tube (5) and an inner surface of the first channel, such that the first tube (5) is electrically insulated from the support plate (17), wherein a further electrically insulating insert is arranged between the second tube (6) and an inner surface of the second channel, such that the second tube (6) is electrically insulated from the support plate,
wherein, most preferably, both electrically insulating inserts are ceramic sleeves.

A method (100) for heating a gas in an electric gas heater (1) according to any one of the aforementioned claims comprising steps of:
- supplying a gas to the inlet chamber (3) whereby the gas is conducted along gas flow paths being parallel to the longitudinal axis of the electric has heater via the insides of the tubes to the outlet chamber (4),
- supplying an electric current to the tubes in order to heat the tubes,
- continue with conducting the gas along the vertical gas flow paths via the insides of the tubes to the outlet chamber (4), and
- leading the gas from the outlet chamber (4).

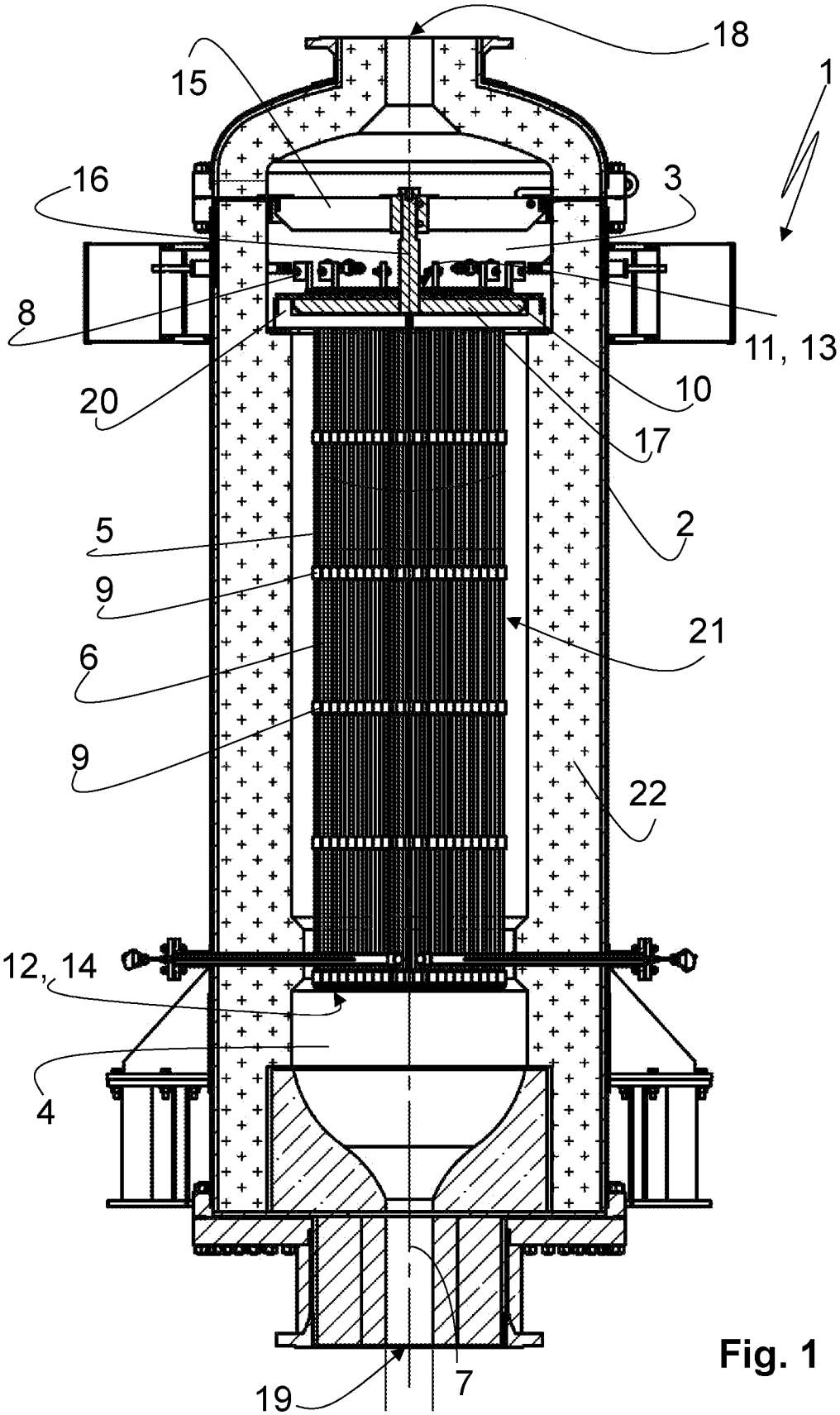


Fig. 1

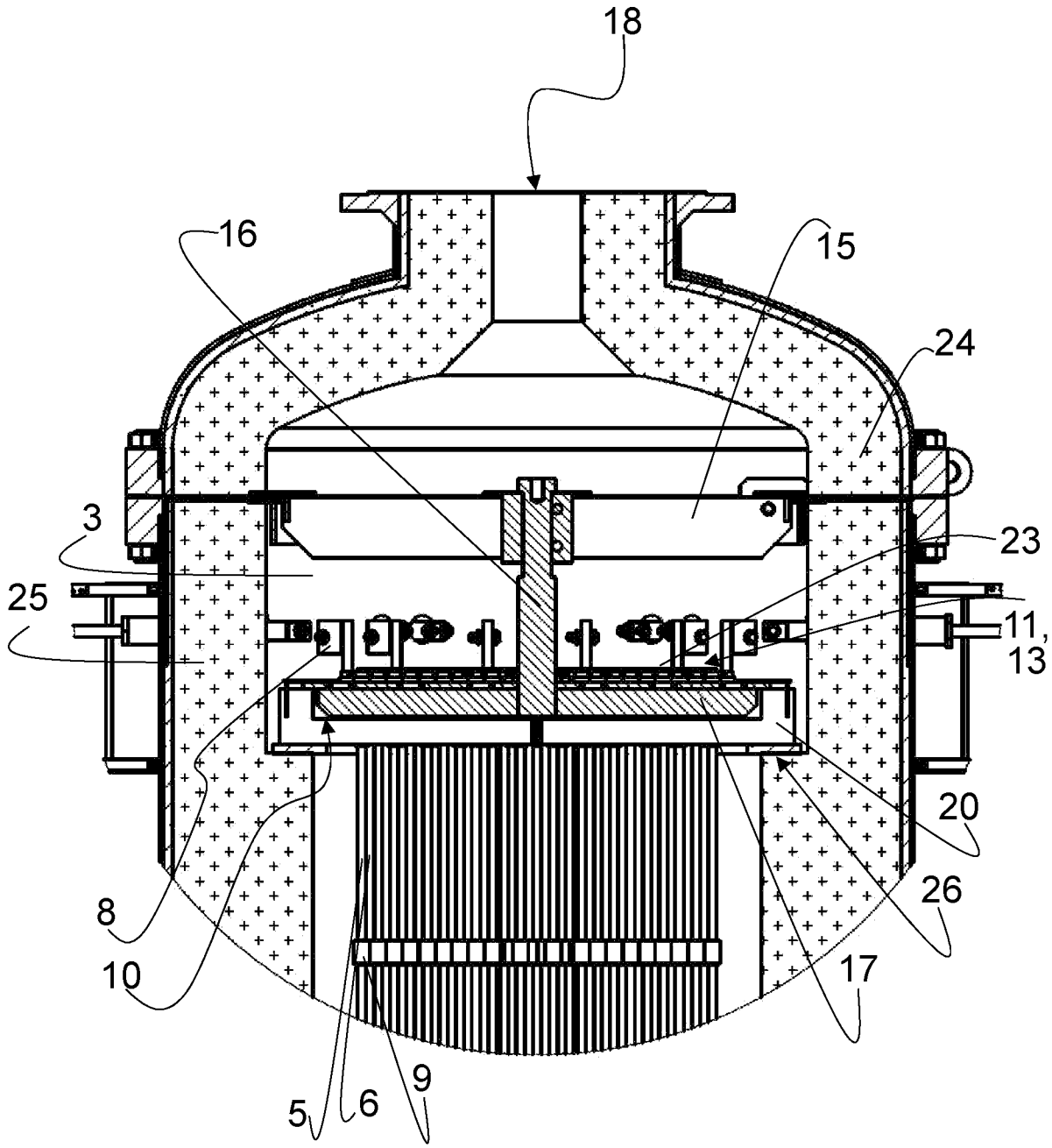


Fig. 2

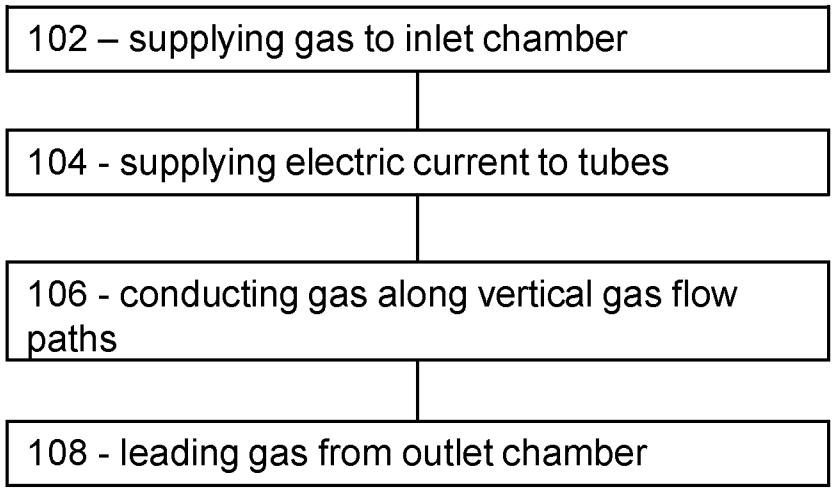

102 – supplying gas to inlet chamber
104 - supplying electric current to tubes
106 - conducting gas along vertical gas flow paths
108 - leading gas from outlet chamber

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2022/051155

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: F24H, F27B, H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3541304 A (COHN DITER), 17 November 1970 (1970-11-17); abstract; column 3, line 43 - line 44; column 4, line 9 - line 54; column 5, line 23 - line 70; all figures --	1-20
X	US 2868944 A (KOCH EUGENE C ET AL), 13 January 1959 (1959-01-13); column 5, line 19 - line 42; column 8, line 57 - line 64 --	1-3, 5-12, 15, 18, 20
X	RU 180162 U1 (UEC-AVIADVIGATEL STOCK CO), 5 June 2018 (2018-06-05); all figures --	1-7, 9-12, 15-16, 18, 20

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"D" document cited by the applicant in the international application

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26-01-2023	27-01-2023

Name and mailing address of the ISA/SE	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2022/051155

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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D, X	US 4233494 A (PAWLIK RUDOLF ET AL), 11 November 1980 (1980-11-11); column 4, line 35 - column 5, line 2; all figures -- --------	1-3, 5-12, 15-20

International application No.
PCT/SE2022/051155

Continuation of: second sheet

International Patent Classification (IPC)

F24H 3/04 (2022.01)
F24H 9/1863 (2022.01)
H05B 3/40 (2006.01)
F24H 3/02 (2022.01)
F24H 9/06 (2006.01)
H05B 3/06 (2006.01)

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