Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2872451 C 2018/02/06

(11)(21) **2 872 451**

(12) **BREVET CANADIEN**
**CANADIAN PATENT**

(13) **C**

(86) **Date de dépôt PCT/PCT Filing Date:** 2012/05/16
(87) **Date publication PCT/PCT Publication Date:** 2013/11/21
(45) **Date de délivrance/Issue Date:** 2018/02/06
(85) **Entrée phase nationale/National Entry:** 2014/11/03
(86) **N° demande PCT/PCT Application No.:** IB 2012/052479
(87) **N° publication PCT/PCT Publication No.:** 2013/171547

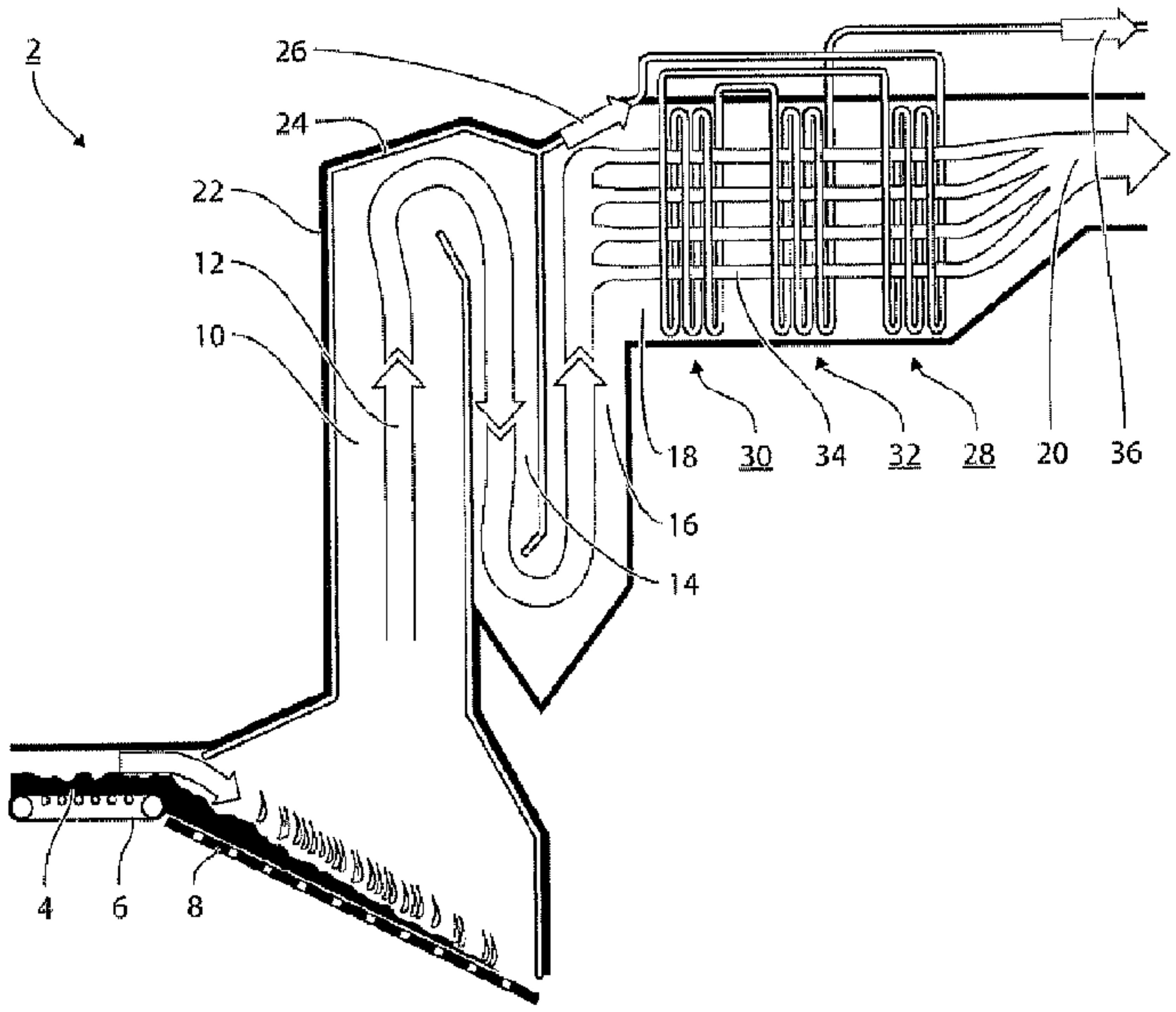
(51) **Cl.Int./Int.Cl.** *F28F 19/02* (2006.01), *F22B 31/04* (2006.01), *F28F 19/06* (2006.01)

(72) **Inventeur/Inventor:**
MIKKELSEN, LARS, DK

(73) **Propriétaire/Owner:**
BABCOCK & WILCOX VOLUND A/S, DK

(74) **Agent:** FETHERSTONHAUGH & CO.

(54) Titre : ECHANGEUR DE CHALEUR PRESENTANT UNE RESISTANCE ACCRUE A LA CORROSION
(54) Title: HEAT EXCHANGER HAVING ENHANCED CORROSION RESISTANCE




(57) Abrégé/Abstract:
The present invention provides a heat exchanger (32) for heating a fluid (26) in an incineration plant (2), the incineration plant (2) in operation producing a flue gas (34), the heat exchanger comprising at least one heat exchanger component (40) comprising a wall having a first side (46) in contact with the fluid (26), and a second side (48) in contact with the flue gas (34), the second side (48) being provided with a protective oxide (50) for protecting the heat exchanger component (40) against corrosion caused by corrosive compounds entrained or comprised by the flue gas (34), wherein the protective oxide (50) comprises a-Al2O3. A method of forming a scale (50) for protecting a heat exchanger component (40) against corrosion caused by corrosive compounds entrained or comprised by a flue gas (34) is also provided.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
21 November 2013 (21.11.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/171547 A1

(51) International Patent Classification:
*F28F 19/02* (2006.01) *F22B 31/04* (2006.01)
*F28F 19/06* (2006.01)

(21) International Application Number:
PCT/IB2012/052479

(22) International Filing Date:
16 May 2012 (16.05.2012)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: **BABCOCK & WILCOX VØLUND A/S** [DK/DK]; Falkevej 2, DK-6705 Esbjerg (DK).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **MIKKELSEN, Lars** [DK/DK]; Vestre Gade 14G, DK-2605 Brøndby (DK).

(74) Agent: **BUDDE SCHOU A/S**; Vester Søgade 10, DK-1601 Copenhagen V (DK).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Published**:
— *with international search report (Art. 21(3))*

(54) **Title**: HEAT EXCHANGER HAVING ENHANCED CORROSION RESISTANCE

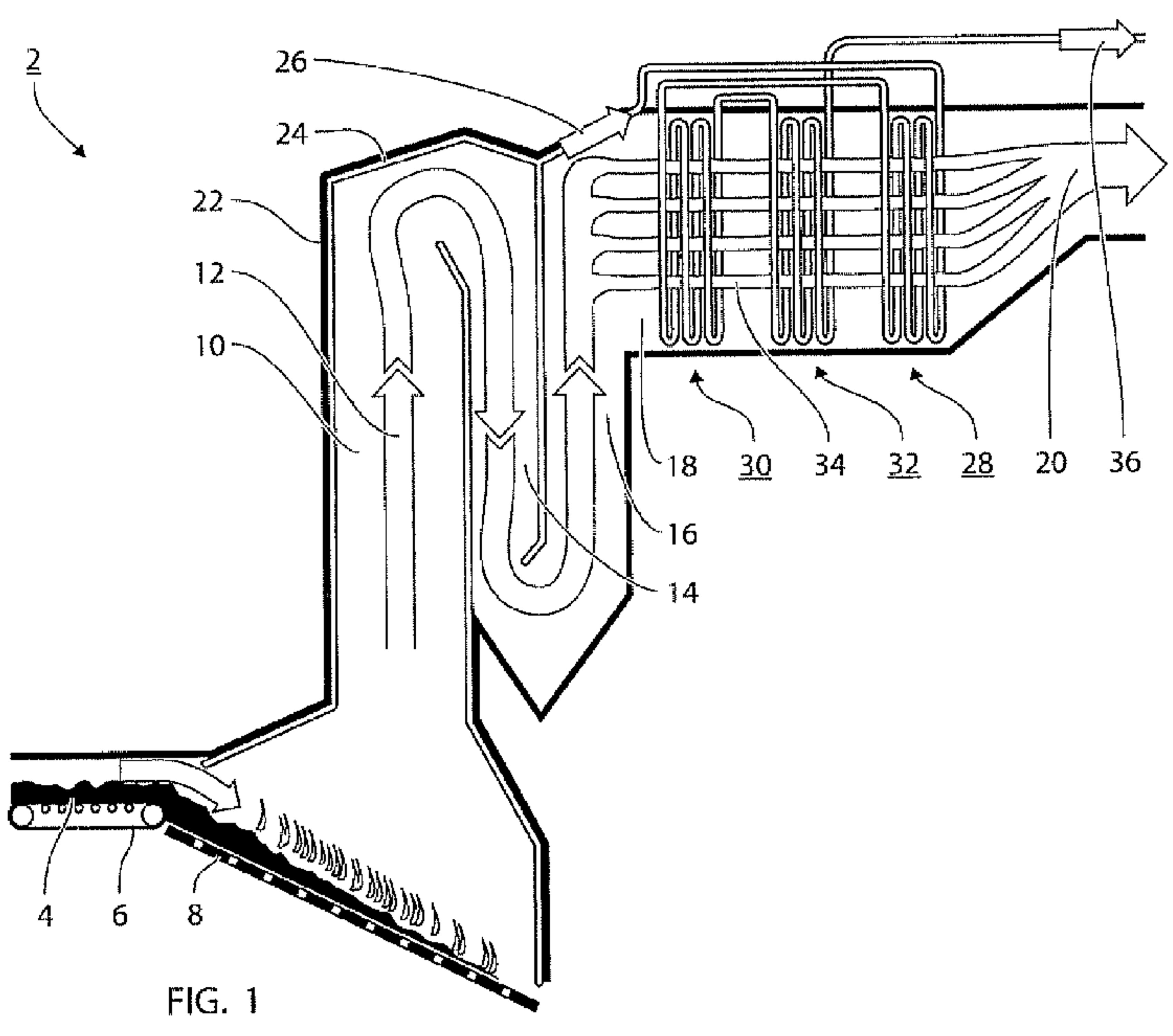


FIG. 1

(57) **Abstract**: The present invention provides a heat exchanger (32) for heating a fluid (26) in an incineration plant (2), the incineration plant (2) in operation producing a flue gas (34), the heat exchanger comprising at least one heat exchanger component (40) comprising a wall having a first side (46) in contact with the fluid (26), and a second side (48) in contact with the flue gas (34), the second side (48) being provided with a protective oxide (50) for protecting the heat exchanger component (40) against corrosion caused by corrosive compounds entrained or comprised by the flue gas (34), wherein the protective oxide (50) comprises $\alpha$-$Al_2O_3$. A method of forming a scale (50) for protecting a heat exchanger component (40) against corrosion caused by corrosive compounds entrained or comprised by a flue gas (34) is also provided.

WO 2013/171547 A1

# HEAT EXCHANGER HAVING ENHANCED CORROSION RESISTANCE

The present invention relates to a heat exchanger for heating a fluid in an incineration plant. The heat exchanger comprises at least one heat exchanger component having an enhanced corrosion resistance due to a scale provided on the heat exchanger component.

Heat exchangers are known in the field of incineration processes for transferring heat from flue gases to fluids for heating the fluids. One use of heat exchangers is for the heating of saturated steam from a boiler for converting the saturated steam into dry (also called superheated) steam more useable for example in power generation processes. Dry steam is for example used for driving steam turbines in power plants.

A heat exchanger typically includes a large number of heat exchanger components, each heat exchanger component having a wall with a first side in contact with a fluid to be heated and a second side in contact with a heating medium, which in an incineration process typically is flue gas generated by the incineration process. The heat exchanger components may be plates, as in a plate heat exchanger, but may alternatively be shaped as tubes, the inner and outer side of the tube wall defining the first and second side of the heat exchanger component. For producing superheated steam in an incineration plant for producing power the heat exchanger typically comprises a plurality of individual heat exchanger components in the shape of tubes, also called superheater tubes, through which the steam sequentially passes. The heat exchanger is placed in the path of the flue gasses so that the heat exchanger components are heated by the flue gas whereby heat is passed through the wall of the heat exchanger components to heat the steam within.

Different incineration processes burn different fuels. Common incineration plants for generating power burn waste. The waste may be household waste and/or other types of waste such as industrial waste etc. Such an incineration plant is also called a waste to energy incineration plant.

A problem related to the nature of the waste burnt in the incineration plant is that the flue gas, and/or the hot ashes entrained in the flue gas, to a lesser or larger extent depending on the exact nature of the waste being burnt, comprises corrosive compounds such as chlorine. The hot ashes entrained in the flue gasses condense onto the comparatively cooler surfaces of the heat exchanger, especially the heat exchanger components or super heater tubes, and form a sticky coating thereon. Chlorine present in this coating is highly corrosive and causes severe corrosion of the metal material of the heat exchanger components or superheater tubes.

The extent of corrosion is dependent on the temperature of the heat exchanger components. When superheating steam, the temperature of the heat exchanger components, through heat transfer between the steam and the heat exchanger component, is typically 30-50°C higher than that of the steam. Higher temperature of the steam speeds up the corrosion process, thus, in order to ensure a useful life of the heat exchanger components the temperature of the steam to be superheated has to be limited. This however severely limits the efficiency of the incineration plant, particular as regards power generation where the efficiency of a steam turbine is dependent on the temperature of the steam.

Where tubes of inexpensive steel, containing mostly Fe (iron), are used as heat exchanger components for superheating steam, the maximum steam temperature is approximately 400°C if excessive corrosion and an acceptable service life is to be achieved.

Approaches for allowing the steam temperature to be increase include providing tubes of inexpensive steel coated with more expensive alloys such as Inconel 625. Inconel 625 is a nickel based alloy forming a scale of chromium oxide on its surface when subjected to heat and corrosion. With this approach a steam temperature of approximately 440°C is possible with the same speed of corrosion and service life as that possible using the tubes of inexpensive steel at 400°C.

However, still higher steam temperatures are desired in order to maximize the efficiency of incineration plants.

It is known from other technical fields to form thermal barriers comprising $\alpha$-$Al_2O_3$, see for example EP1908857A2, however a thermal barrier prevents heat transfer and is thus not useable for protecting a heat exchanger component from corrosion. It is further known from JP4028914A to form a fire grate comprising $\alpha$-$Al_2O_3$. A fire grate is however watercooled and thus only subjected to low temperatures when compared to the steam temperature in heat exchanger for superheating steam.

Further documents related to coating or barrier layers include EP2143819A1, WO2011100019A1, EP1944551A1, EP659709A1 and US5118647A.

In EP 1 164 330 is disclosed a superheater tube comprising nickel in order to reduce corrosion. According to EP 1 164 330 a higher efficiency, and lower corrosion is achieved by reheating the steam leaving the first turbine by using steam A' from the steam drum. This gives a higher efficiency and a lower steam and pipe temperature.

An aspect of the present disclosure is directed to the provision of a heat exchanger having enhanced corrosion resistance.

Another aspect of the present disclosure is directed to the provision of a heat exchanger for increasing the efficiency of an incineration plant producing superheated steam.

Another aspect of the present disclosure is directed to the provision of a method for forming a scale for protecting a heat exchanger component against corrosion caused by corrosive compounds entrained in or comprised by a flue gas.

According to a first aspect of the present invention, there is provided a heat exchanger for heating a fluid in a waste to energy incineration plant, said incineration plant in operation producing a flue gas, said heat exchanger comprising at least one heat exchanger component comprising a wall having a first side in contact with said fluid, and a second side in contact with said flue gas, said second side being provided with a protective coating for protecting said heat exchanger component against corrosion caused by corrosive compounds entrained in or comprised by said flue gas, wherein said protective oxide comprises $\alpha$-$Al_2O_3$.

$\alpha$-$Al_2O_3$, also called alpha-alumina, is an aluminium oxide which is highly corrosion resistant. Thus the protective oxide has the effect of increasing the corrosion resistance of the heat exchanger. As the corrosion resistance is increased the fluid can be heated at higher temperatures, thus allowing the efficiency of heating the fluid to be increased while still maintaining an acceptable service life of the heat exchanger. The fluid may be any fluid suitable for being heated. Typically the fluid is water or steam. For a fluid such as steam the heat exchanger according to some embodiments of the first aspect of the present invention may be used with steam temperatures of above at least 480°C with a service life of at least 5 years. It is further contemplated that steam temperatures of up to 600°C can be used with at least 5 years of service life.

The incineration plant may incinerate fuels such as coal, other fossil fuels, biomass, demolition wood chips, refuse derived fuels, or waste. In the context of the present invention the term flue gas is to be understood as also comprising substances and particles generated by the incineration of a fuel. The flue gas may have a temperature of up to 1100°C to 1200°C where the flue gas is generated, i.e. where the incineration takes place.

In some embodiments, preferably the heat exchanger component is made of metal as metal has a high heat conductivity and is easily fabricated. The corrosion is typically heat corrosion.

In some embodiments, the fluid is steam and the heat exchanger is a superheater for super heating the steam. In some embodiments, the steam is saturated as the heating of saturated steam takes place at high temperatures at which the enhanced corrosion resistance of the heat exchanger according to the first aspect of the present invention is useful.

In embodiments of the heat exchanger wherein the fluid is steam and the heat exchanger is a superheater the at least one heat exchanger component may be a tube, also called a superheater tube.

In some embodiments, the protective oxide is a scale. A scale is generally understood to be an oxide layer. The scale is up to 10 μm thick and comprises predominantly α-$Al_2O_3$. More preferably, in some embodiments, the scale comprises substantially only α-$Al_2O_3$. This is advantageous as it increases the corrosion resistance of the scale. The scale is preferably dense.

In some embodiments, the heat exchanger component is made from a precursor material that forms the scale upon oxidation. In this arrangement a simple way of providing the heat exchanger component is provided. When the heat exchanger component is a superheater tube the superheater tube may typically have a diameter of 0.5 inches to 3 inches, corresponding to 12 to 77 mm. This heat exchanger component may for example be a tube or a plate.

In some embodiments, the heat exchanger component comprises a base material coated by a precursor material forming the scale upon oxidation. In this arrangement, the material costs of the heat exchanger component may be lessened since the base material can be a simple inexpensive corrosion liable steel whereas only the comparatively thinner coating need be of the precursor material. The coating need only have a thickness sufficient to allow forming of the scale and to avoid aluminium depletion in the alloy during operation.

This heat exchanger component may for example be a tube or a plate.

In some embodiments, the precursor material is coated upon the base material by welding. In this arrangement, a simple process is provided which may be used both for fabricating new heat exchange components and for retro-fitting existing heat exchanger components with the precursor material to increase the corrosion resistance of the existing heat exchanger component.

Welding is an example of applying the precursor material, but other methods known in the field may also be utilized for applying the precursor material. When welding, the coating may be from 1 mm to 20 mm thick.

In some embodiments, the heat exchanger component comprises an inner tube covered by an outer tube, the outer tube being made from a precursor material forming the scale upon oxidation. In this arrangement, the material costs can be lessened since the inner tube can be made of a simple inexpensive corrosion liable steel whereas only the outer tube need be of the precursor material. Further the assembly of the inner tube with the outer tube may be made rapidly or automatically.

In some embodiments, the inner tube and the outer tube are co-extruded. In this arrangement, a rational and effective way of providing a heat exchanger component is provided.

In an alternative embodiment of the heat exchanger component comprising a inner tube and an outer tube the outer tube is extruded onto the inner tube.

In some embodiments, the precursor material comprises an alloy comprising at least 4-5 wt.% aluminum. Possible precursor materials should be an alloy having a minimum of 4-5 wt.% aluminium content. One exemplary precursor material is Haynes 214 alloy. Further exemplary precursor materials include the alloys in table 1.

*Table 1: Constitution of exemplary alloys*

| Alloy | C | Al | Cr | Ni | Co | Fe | Mo | W | Others |
|---|---|---|---|---|---|---|---|---|---|
| IN 713C | 0.12 | 6 | 12.5 | Bal | - | - | 4.2 | - | 0.8Ti, 2Cb, 0.012B, 0.10Zr |
| IN 713LC | 0.05 | 6 | 12.0 | Bal | - | - | 4.5 | - | 0.6Ti, 2Cb, 0.1Zr, 0.01B |
| B-1900 | 0.1 | 6 | 8.0 | Bal | 10.0 | - | 6.0 | - | 1.0Ti, 4.0Ta, 0.1Zr, 0.015B |
| IN 100 | 0.18 | 6 | 10.0 | Bal | 15.0 | - | 3.0 | - | 1.0Ti, 4.0Ta, 0.1Zr, 0.015B |
| IN162 | 0.12 | 6.5 | 10.0 | Bal | - | - | 4.0 | 2.0 | 1.0Ti, 1.0Cb, 2.0Ta, 0.1Zr, 0.02B |
| IN 713 | 0.18 | 5.5 | 9.5 | Bal | 10.0 | - | 2.5 | - | 4.6Ti, 0.06Zr, 0.015B, 1.0V |
| M 21 | 0.13 | 6 | 5.7 | Bal | - | - | 2.0 | 11.0 | 0.12Zr, 1.5Cb, 0.02B |
| M 22 | 0.13 | 6.3 | 5.7 | Bal | - | - | 2.0 | 11.0 | 3Ta, 0.6Zr |
| MAR-M 200 | 0.15 | 5 | 9.0 | Bal | 10.0 | 1.0 | - | 12.5 | 2Ti, 0.05Zr, 0.015B, 1.0Cb |
| MAR-M 246 | 0.15 | 5.5 | 9.0 | Bal | 10.0 | - | 2.5 | 10.0 | 1.5Ti, 1.5Ta, 0.05Zr, 0.015B |
| RENE 100 | 0.16 | 5.5 | 9.5 | Bal | 15.0 | - | 3.0 | - | 4.2Ti, 0.006Zr, 0.015B |
| TAZ-8A | 0.12 | 6 | 6.0 | Bal | - | - | 4.0 | 4.0 | 8Ta, 1Zr, 2.5Cb, |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 0.004B |
| TAZ-8B (DS) | 0.12 | 6 | 6.0 | Bal | 5.0 | - | 4.0 | 4.0 | 8Ta, 1Zr, 1.5Cb, 0.004B |

In some embodiments, the incineration plant, in operation, incinerates waste, and the corrosive compounds comprise chlorine. The incineration plant may be a waste to energy incineration plant generating both heat for use in for example area heating and steam for electrical power generation. The waste may be household waste or industrial waste, preferably the waste is household waste or light industrial waste.

The α-$Al_2O_3$ is resistant to corrosive compounds such as S, $O_2$, $H_2O$, $Cl_2$, $N_2$, $CO/CO_2$ etc. Other corrosive compounds which may form in an incineration plant include Na, Ca, Cu, K, Cl, S, Cr, Pb, Zn, Fe, Sn and Al.

In some embodiments, the heat exchanger comprises a plurality of heat exchanger components. In this arrangement, the heat exchanging capacity of the heat exchanger is increased. In some embodiments, the heat exchanger is preferably a superheater comprising typically 150 to 300 superheater tubes.

In some embodiments, the heat exchanger component is a tube. In this arrangement, a heat exchanger component which is easy to form and which is suitable for heating a liquid in an incineration plant is provided. Further a tube is suitable where the liquid is pressurized, such as for example superheated steam. Where the heat exchanger is a superheater and the heat exchanger component is a superheater tube, the superheater tube typically up to 6 m long.

According to a second aspect of the present invention, there is provided a method of forming a scale for protecting a heat exchanger component in a waste to energy incineration plant against corrosion caused by corrosive compounds entrained in or comprised by a flue gas, comprising the steps of: providing a heat exchanger component comprising a precursor material arranged for protecting the heat exchanger component after oxidation against said corrosion, said precursor material comprising aluminium, oxidizing said heat exchanger component at a temperature, atmosphere and for a time adapted to form said scale on said precursor material, a major part of said scale consisting of α-$Al_2O_3$.

By oxidizing the heat exchanger component at a temperature, atmosphere and for a time adapted to form a scale on the precursor material, the scale comprising predominantly α-$Al_2O_3$, an even and complete scale is provided on the heat exchanger component providing a effective protection of the heat exchanger component.

The temperature, atmosphere and time should be adapted such that a dense scale is formed. The scale formed during the oxidation step should have a thickness of 0.1 µm to 2 µm. The time needed will depend on the exact precursor material used.

The atmosphere should have a low partial pressure of oxygen, $pO_2$. The $pO_2$ should be below $10^{-8}$ atm, more preferably below $10^{-11}$ atm.

In a preferred embodiment of the method according to the second aspect of the present invention, the method further comprises an additional step of assembling the oxidized heat exchanger component into a heat exchanger.

In an alternative embodiment of the method according to the second aspect of the present invention, the method further comprises an additional step of assembling the heat exchanger component into a heat exchanger prior to the heat exchanger component being oxidized.

In some embodiments, the temperature is at least 950°C, and in some embodiments, the temperature is 1100°C to 1200°C. The temperature has to be adapted so that α-$Al_2O_3$, as opposed to other types of aluminium oxides, is formed. If the temperature is too low, α-$Al_2O_3$ will not form.

In some embodiments, the atmosphere comprises an argon-hydrogen mixture containing 2% water vapour. In this implementation, a suitable atmosphere for the oxidation step for most precursor materials is provided.

In some embodiments, the oxidizing step is performed for a time of at least 2 hours. In this implementation, a suitable time for the oxidation step for most precursor materials is provided.

According to another aspect of the present invention, there is provided a heat exchanger for heating a fluid in a waste to energy incineration plant, said incineration plant in operation producing a flue gas, said heat exchanger comprising at least one heat exchanger component comprising a wall having a first side in contact with said fluid, and a second side in contact with said flue gas, said heat exchanger component comprising a base material coated by a precursor material, the precursor material, upon oxidation thereof, forming on the second side of said heat exchanger component a protective oxide coating comprising $\alpha$-$Al_2O_3$, for protecting said heat exchanger component against corrosion caused by corrosion compounds entrained in or comprised by said flue gas.

Examples of embodiments of the invention and their many advantages will be described in more detail below with reference to the accompanying schematic drawings, which for the purpose of illustration show some non-limiting embodiments, and in which

Fig. 1 shows a partial overview of a waste to energy incineration plant provided with a heat exchanger according to an embodiment of the present invention,

Fig. 2 shows, in side view, heat exchanger components, in the form of superheater tubes, of the heat exchanger according to an embodiment of the present invention, and

Fig. 3 shows, in partial cutaway side view, first second and third embodiments of heat exchanger components, in the form of superheater tubes, of the first second and third embodiments of the heat exchanger according to the first aspect of the present invention.

In the below description, one or more subscript roman numerals added to a reference number indicates that the element referred to is a further one of the element designated the un-subscripted reference number.

Further, A superscript roman numeral added to a reference number indicates that the element referred to has the same or similar function as the element designated the un-superscripted reference number, however, differing in structure.

When further embodiments of the invention are shown in the figures, the elements which are new, in relation to earlier shown embodiments, have new reference numbers, while elements previously shown are referenced as stated above. Elements which are identical in the different embodiments have been given the same reference numerals and no further explanations of these elements will be given.

Fig. 1 shows a partial overview of a waste to energy incineration plant 2. Waste 4 to be incinerated is fed into the incineration plant by a conveyor 6 onto a grate 8 on which the waste 4 is burnt. Flue gas resulting from the incineration of the waste 4 on the grate 8 rises upwards as illustrated by arrow 12. The flue gas 12 may have a temperature of up to 1100°C to 1200°C and is then led through the first second and third radiation passes 10 14 and 16 to a horizontal convection pass 18 after which the flue gases are eventually led to a chimney and released to the atmosphere as indicated by arrow 20.

The walls 22 of the first second and third radiation passes 10 14 and 16 are provided with tubes 24 to which water is fed for generating steam. The steam is then, as indicated by arrow 26, in turn led through superheaters 28 30 and 32, each of which represents a heat exchanger, positioned in the horizontal convection pass 18. The superheaters 28 30 and 32 are heated by the flue gas 12 passing through the convection pass 18 as illustrated by arrow 34. The heat from the flue gas 34 is transferred to steam 26 so that the steam 26 is converted into superheated steam 36 which is led to a steam turbine (not shown) or similar consumer of superheated steam.

Additionally (not shown) the superheater 28 may be preceded by an evaporator for producing further saturated steam, the evaporator being placed upstream of the superheater 30 in the path of the flue gases 12, and being similar in construction to the superheater 28.

The flue gas 34 heating the superheater 28 30 and 32 comprises inter alia corrosive compounds and particles of hot ash 38, not shown in fig. 1, which particles of hot ash 38 may themselves comprise corrosive compounds.

The temperature of the steam 26 increases as it is led through the superheaters 28 30 and 32. The lowest steam temperature of 250°C to 300°C is found in superheater 28 and the highest steam temperature is found in superheater 32. Thus the risk of corrosion is highest for superheater 32. In the incineration plant 2 all superheaters may be identical to the superheater 32, which superheater 32 is a heat exchanger according to the present invention. Alternatively, to save costs, only superheater 32 is a heat exchanger according to the present invention whereas superheaters 28 and 30 are superheaters consisting of conventional materials.

Each superheater 28 30 32 comprises a number of superheater tubes representing heat exchanger components.

Fig. 2 shows superheater tubes, one of which is designated the reference numeral 40, of the superheater 32 in Fig. 1. As seen in Fig. 2, steam 26 runs through the superheater tubes 40 while flue gas 34 passes between the superheater tubes 40 to heat the superheater tubes 40 and the steam 26 running within the superheater tubes 40. The superheater tubes 40 may be joined to each other by bends, one of which is designated the reference numeral 42, which may be formed separate from the superheater tubes 40 and joined thereto, or which alternatively may be formed integrally with the superheater tubes 40.

Fig. 3A shows a first embodiment of a superheater tube 40, representing a heat exchanger component, of the super heater 32, representing a first embodiment of the heat exchanger according to the first aspect of the present invention.

Superheater tube 40 comprises a main tube 44 including a wall having a first side 46 in contact with the steam 26 and a second side 48 facing the flue gas 34. The main tube 44 is made from a precursor material which upon oxidation forms a scale 50 comprising $\alpha$-$Al_2O_3$ at least on the second side.

Flue gas 34 passes the superheater tube 40 and deposits particles of hot ash 38 on the main tube 44, thus forming a sticky deposit 52 upon the second side 48 of the single material tube 44. Corrosive compounds comprised by the flue gas 34 and/or the particles of hot ash 38 are thus present in the sticky coating 52. Corrosion of the main tube 44 is however prevented, or at least diminished, by the scale 50 covering the second side 48 of the main tube 44.

Fig. 3B shows a second embodiment of a superheater tube $40^I$, representing a heat exchanger component, of a super heater $32^I$, representing a second embodiment of the heat exchanger according to the first aspect of the present invention.

Superheater tube $40^I$ comprises a main tube $44^I$, made from a material which does not form a scale comprising $\alpha$-$Al_2O_3$ upon oxidation. Instead superheater tube $40^I$ comprises, on the second side 48 of the main tube $44^I$, a welded cladding 54 of a precursor material which upon oxidation forms the scale 50 comprising $\alpha$-$Al_2O_3$. The scale 50 on the welded cladding 54 prevents, or at least diminishes, corrosion of the main tube $44^I$ due to corrosive compounds comprised by the flue gas 34 and/or the particles of hot ash 38.

Fig. 3C shows a third embodiment of a superheater tube 40'', representing a heat exchanger component, of a super heater 32'', representing a third embodiment of the heat exchanger according to the first aspect of the present invention.

Superheater tube 40'' comprises an inner tube 44'', representing a main tube, made from a material which does not form a scale comprising α-$Al_2O_3$ upon oxidation. Instead superheater tube 40'' comprises, on the second side 48 of the main tube 44'', an outer tube 56 made of a precursor material which upon oxidation forms the scale 50 comprising α-$Al_2O_3$. The scale 50 on the outer tube 56 prevents, or at least diminishes, corrosion of the inner tube 44'' due to corrosive compounds comprised by the flue gas 34 and/or the particles of hot ash 38.

The superheater tube 40'' may be manufactured by co-extruding the main tube 44'' and the outer tube 56.

List of parts with reference to the figures:

| |
|---|
| 2. Incineration plant |
| 4. Waste |
| 6. Conveyor |
| 8. Grate |
| 10. First radiation pass |
| 12. Flue gas |
| 14. Second radiation pass |
| 16. Third radiation pass |
| 18. Horizontal convection pass |
| 20. Arrow indicating flue gases being led eventually to a chimney |
| 22. Walls of radiation passes |
| 24. Tubes |
| 26. Saturated steam |
| 28. Superheater |
| 30. Superheater |
| 32. Superheater |
| 34. Arrow indicating flue gas passing through convection pass |
| 36. Superheated steam |
| 38. Particles of hot ashes |
| 40. Superheater tube |
| 42. Bend |
| 44. Main tube |
| 46. First side |
| 48. Second side |
| 50. Scale |
| 52. Sticky deposit |
| 54. Welded cladding |
| 56. Outer tube |

CLAIMS:

1. A heat exchanger for heating a fluid in a waste to energy incineration plant, said incineration plant in operation producing a flue gas, said heat exchanger comprising at least one heat exchanger component comprising a wall having a first side in contact with said fluid, and a second side in contact with said flue gas, said second side being provided with a protective coating for protecting said heat exchanger component against corrosion caused by corrosive compounds entrained in or comprised by said flue gas, wherein said protective oxide comprises $\alpha$-$Al_2O_3$.

2. The heat exchanger according to claim 1, wherein said fluid is steam and said heat exchanger is a superheater for superheating said steam.

3. The heat exchanger according to claim 1 or 2, wherein, said protective oxide is a scale.

4. The heat exchanger according to claim 3, wherein said heat exchanger component is made from a precursor material forming said scale upon oxidation.

5. The heat exchanger according to claim 3, wherein said heat exchanger component comprises a base material coated by a precursor material forming said scale upon oxidation.

6. The heat exchanger according to claim 5, wherein said precursor material is coated upon said base material by welding.

7. The heat exchanger component according to claim 5 or 6, wherein said precursor material forms a coating on said base material, with a coating thickness of from 1mm to 20mm.

8. The heat exchanger according to claim 3, wherein said heat exchanger component comprises an inner tube covered by an outer tube, said outer tube being made from a precursor material forming said scale upon oxidation.

9. The heat exchanger according to claim 8, wherein said inner tube and said outer tube are co-extruded.

10. The heat exchanger according to any one of claims 4 to 8, wherein said precursor material comprises an alloy comprising at least 4-5 wt.% aluminium.

11. The heat exchanger according to any one of claims 3 to 10, wherein a major part of said scale consists of $\alpha$-$Al_2O_3$.

12. The heat exchanger according to claim 11, wherein said scale comprises substantially only $\alpha$-$Al_2O_3$.

13. The heat exchanger according to any one of claims 1 to 12, wherein said incineration plant in operation incinerates waste and said corrosive compounds comprise chlorine.

14. The heat exchanger according to any one of claims 1 to 13, wherein said heat exchanger comprises a plurality of said heat exchanger components.

15. The heat exchanger according to any one of claims 1 to 14, wherein said heat exchanger component is a tube.

16. A method of forming a scale for protecting a heat exchanger component in a waste to energy incineration plant against corrosion caused by corrosive compounds entrained in or comprised by a flue gas, comprising the steps of:

providing a heat exchanger component comprising a precursor material arranged for protecting the heat exchanger component after oxidation against said corrosion, said precursor material comprising aluminium,

oxidizing said heat exchanger component at a temperature, atmosphere and for a time adapted to form said scale on said precursor material, a major part of said scale consisting of $\alpha$-$Al_2O_3$.

17. The method of claim 16, wherein said temperature is at least 950°C.

18. The method of claim 17, wherein said temperature is 1100°C to 1200°C.

19. The method of any one of claims 16 to 18, wherein said atmosphere comprises an Argon-Hydrogen mixture containing 2% water vapour.

20. The method of any one of claims 16 to 19, wherein said time is at least 2 hours.

21. The method of any one of claims 16 to 20, wherein said heat exchanger component comprises a base material coated by said precursor material.

22. The method of claim 21, wherein the precursor material is coated upon said base material by welding.

23. The method of any one of claims 16 to 22, wherein said precursor material has a thickness of from 1mm to 20mm.

24. The method of any one of claims 16 to 23, wherein said scale comprises substantially only $\alpha$-$Al_2O_3$.

25. A heat exchanger for heating a fluid in a waste to energy incineration plant, said incineration plant in operation producing a flue gas, said heat exchanger comprising at least one heat exchanger component comprising a wall having a first side in contact with said fluid, and a second side in contact with said flue gas, said heat exchanger component comprising a base material coated by a precursor material, the precursor material, upon oxidation thereof, forming on the second side of said heat exchanger component a protective oxide coating comprising $\alpha$-$Al_2O_3$, for protecting said heat exchanger component against corrosion caused by corrosion compounds entrained in or comprised by said flue gas.

26. The heat exchanger according to claim 25, wherein said precursor material forms a coating on said base material with a coating thickness of from 1 mm to 20 mm.

27. The heat exchanger according to claim 25 or 26, wherein said precursor material is coated upon said base material by welding.

28. The heat exchanger according to any one of claims 25 to 27, wherein said precursor material comprises an alloy comprising at least 4-5 wt.% aluminum.

29. The heat exchanger according to any one of claims 25 to 28, wherein a major part of said scale consists of $\alpha$-$Al_2O_3$.

30. The heat exchanger according to claim 29, wherein said scale comprises substantially only $\alpha$-$Al_2O_3$.

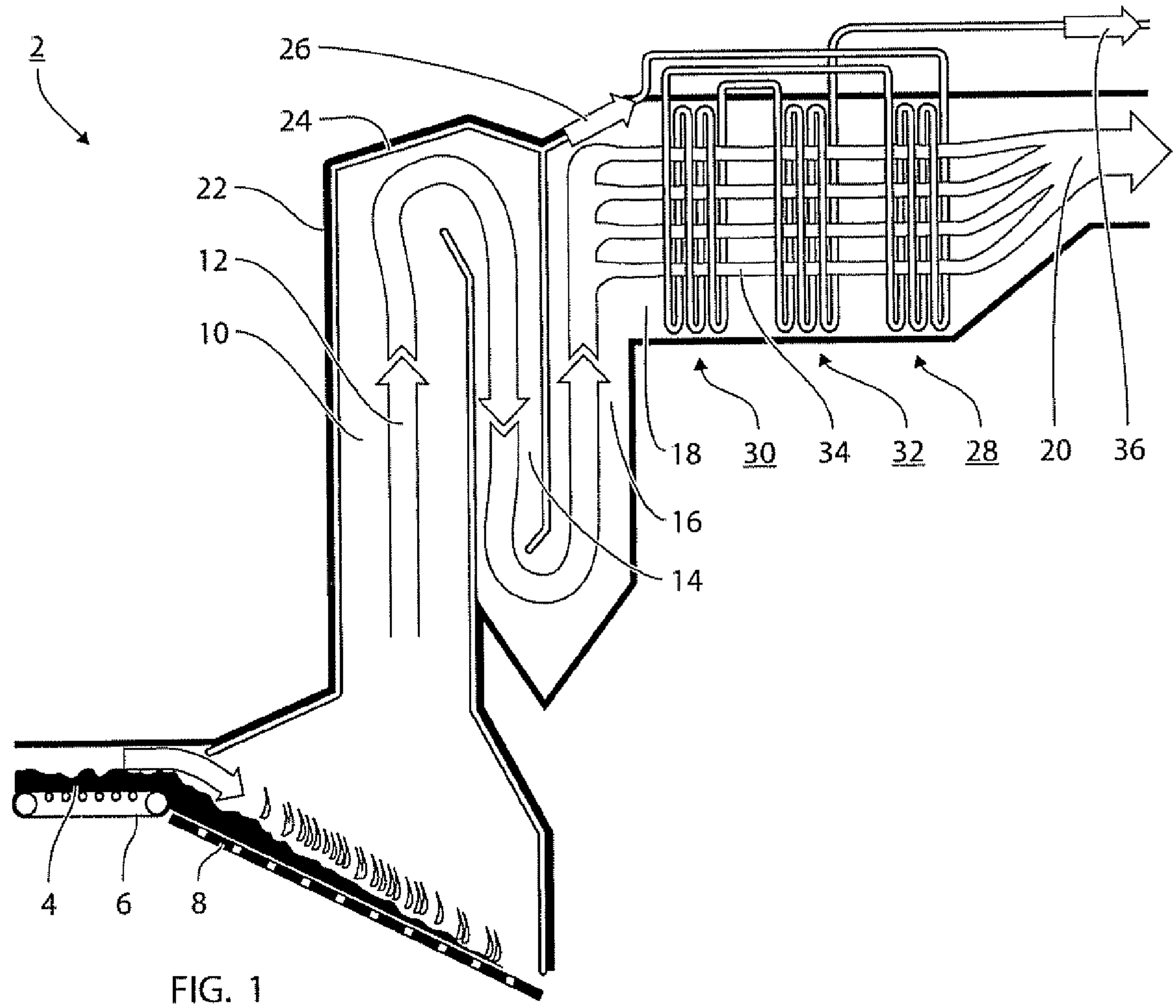

2
26
24
22
12
10
18
30
34
32
28
20
36
16
14
4
6
8

FIG. 1

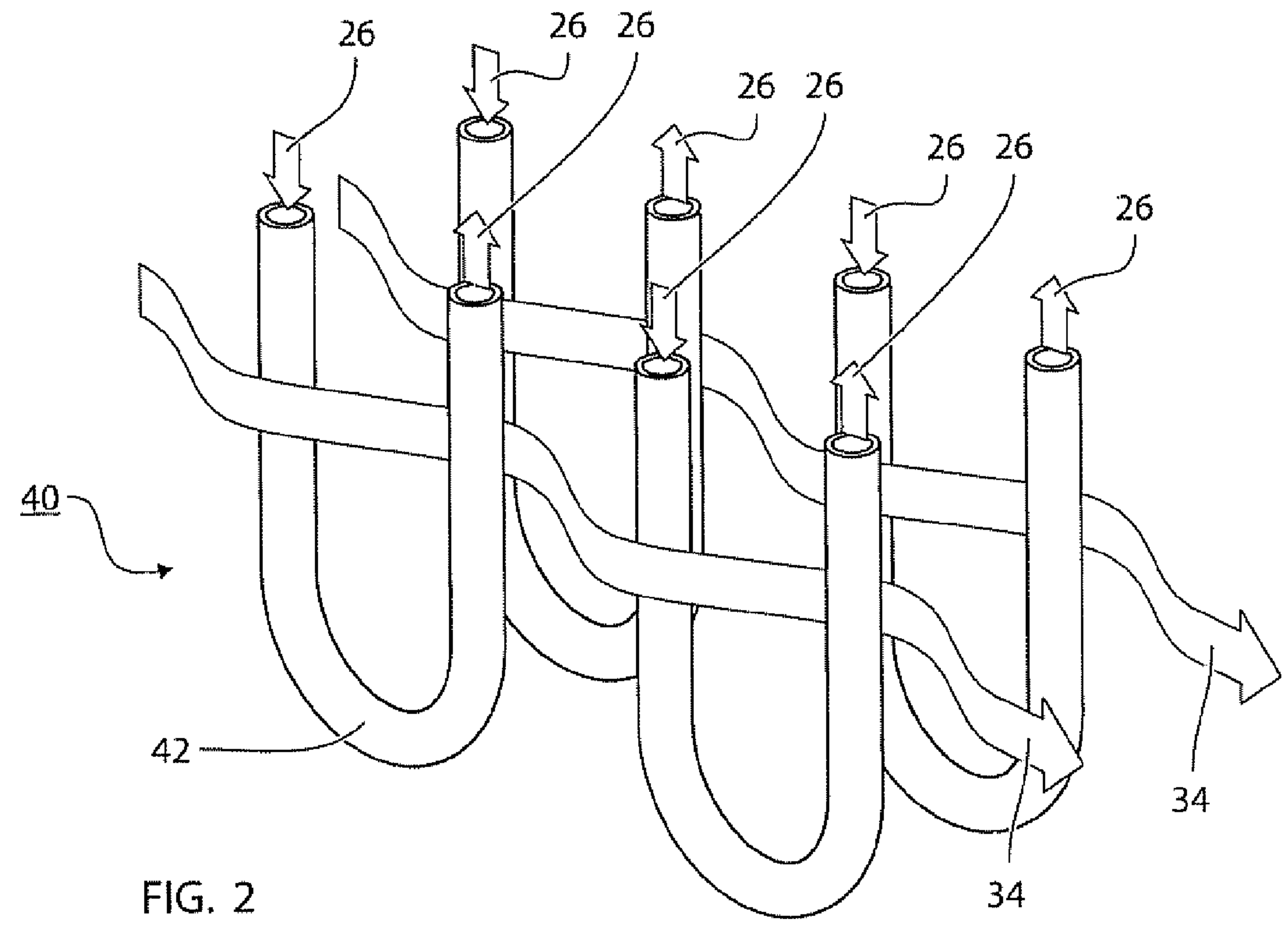

26
26
26
26
26
26
26
26
40
42
34
34

FIG. 2

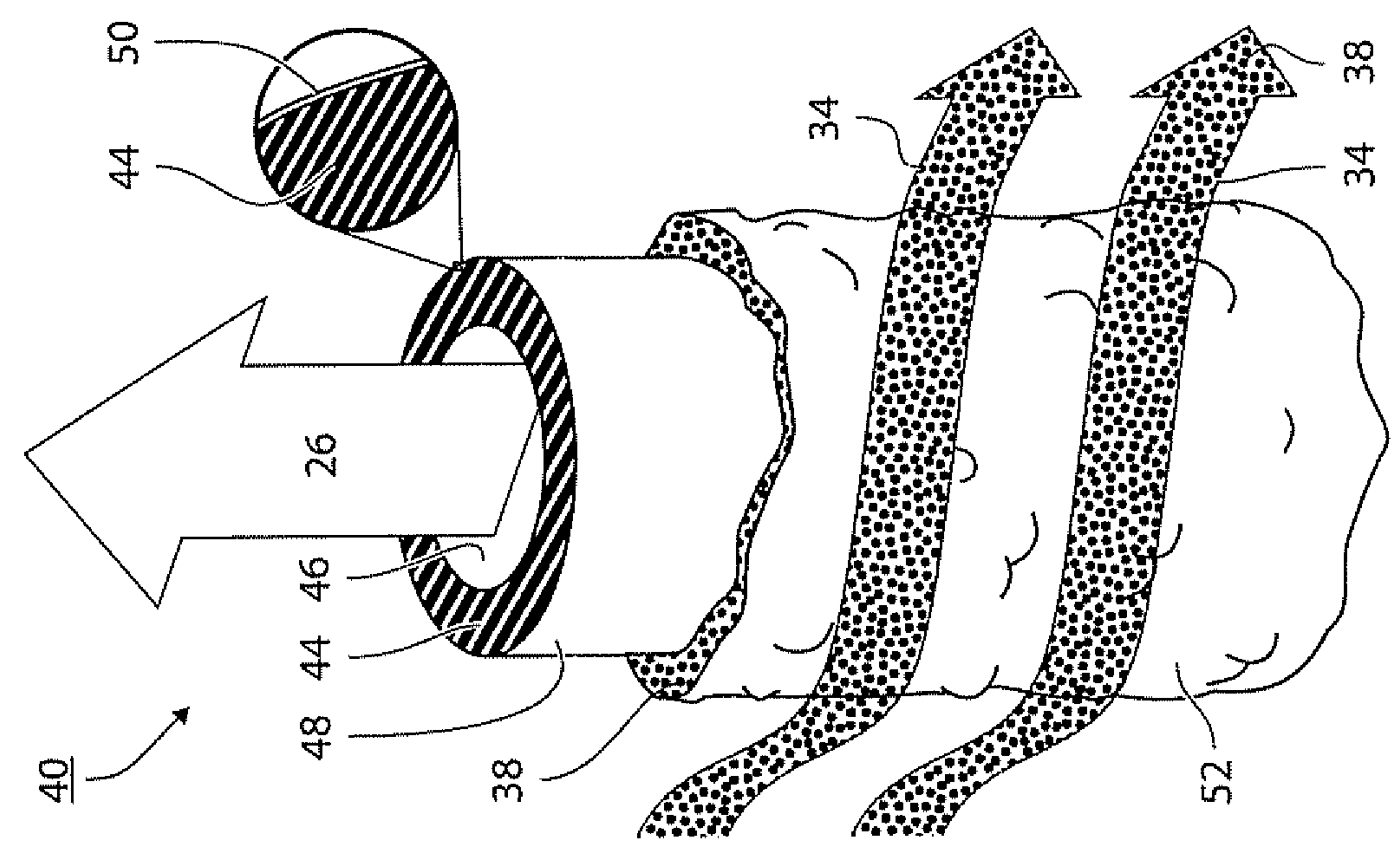



FIG. 3A

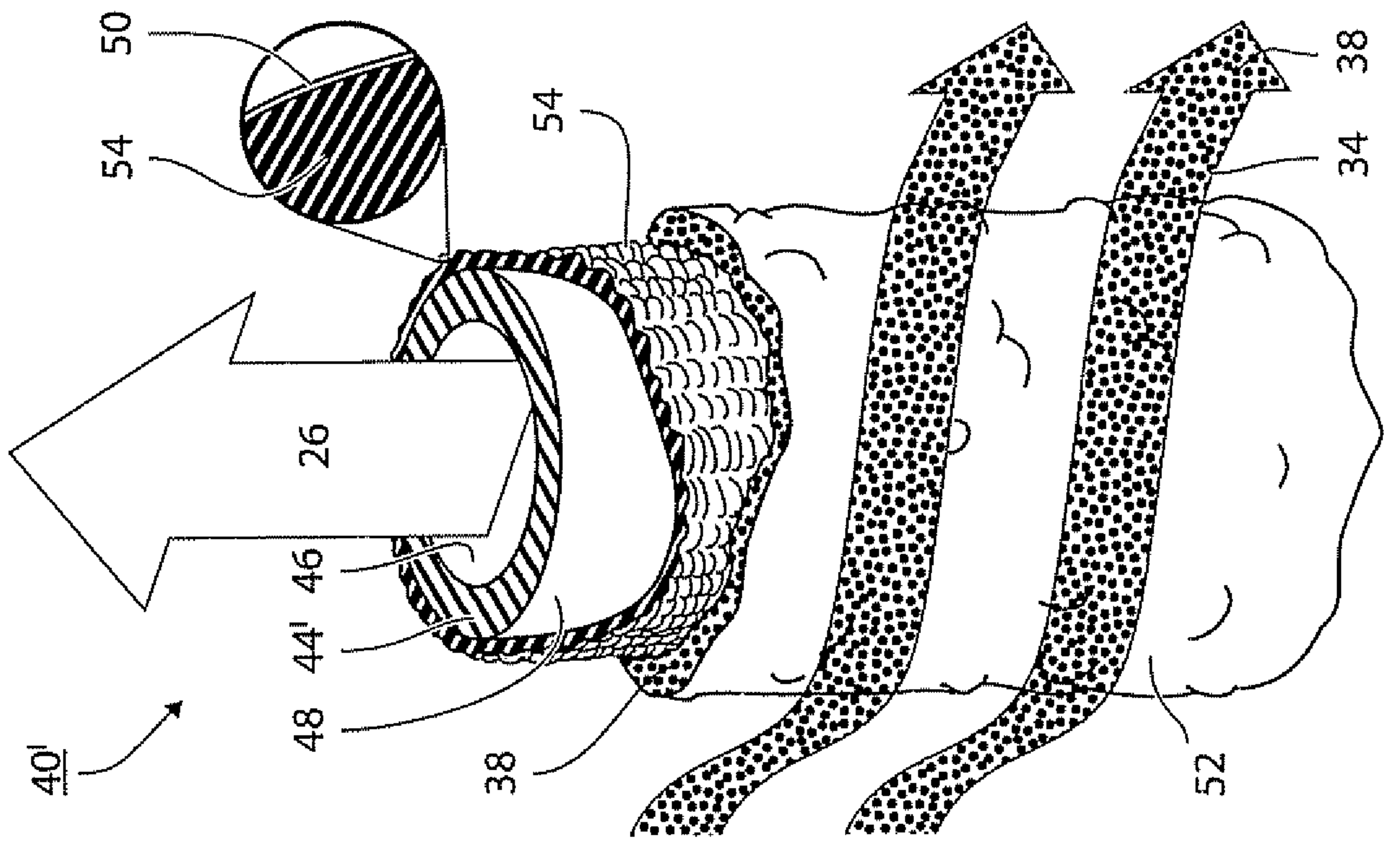



FIG. 3B

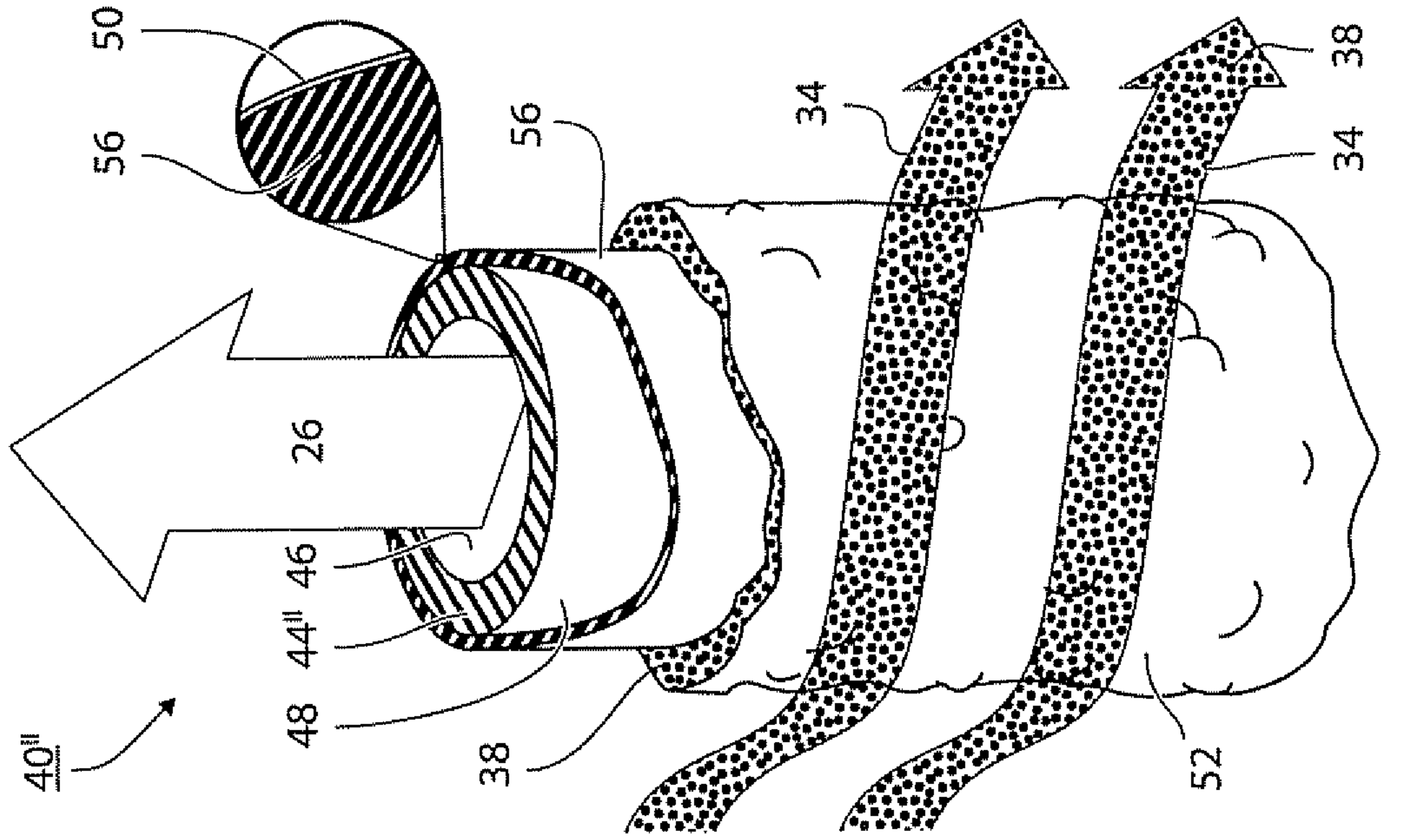
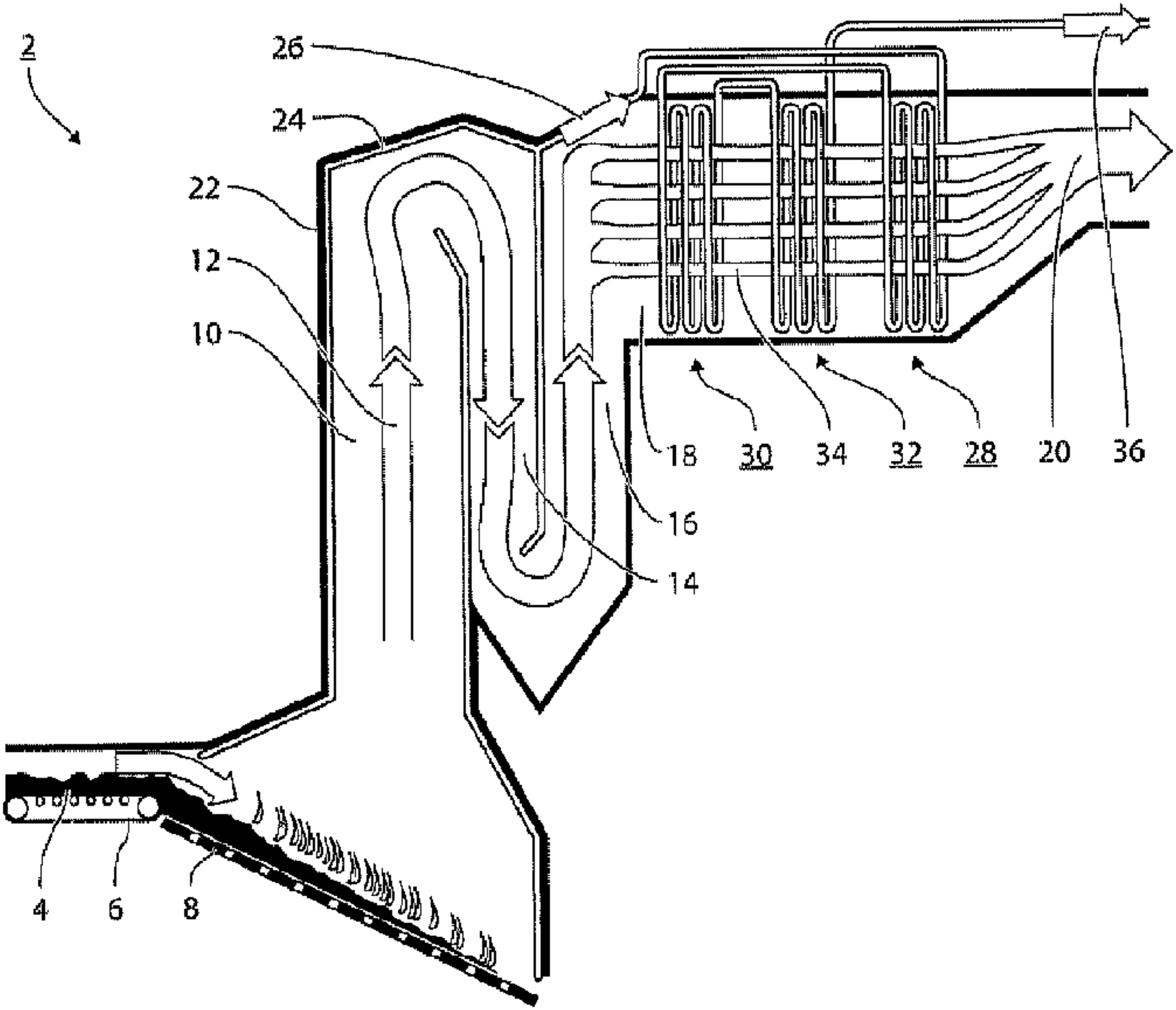



FIG. 3C


2
26
24
22
12
10
18
30
34
32
28
20
36
16
14
4
6
8