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(54) **Equipment for treating gases and use of said equipment for treating a synthesis gas contaminated with tars**

(57) The present invention relates to a system provided with two chambers, one treatment chamber (1) and another heating chamber (14), for treating gases by means of thermal plasma technology. Separating both chambers is an intermediate wall (4) such that the gas under treatment does not come into direct contact with the plasma, thus preventing a dilution of the combustible gases, which would cause a loss of their calorific value and a contamination of their composition.

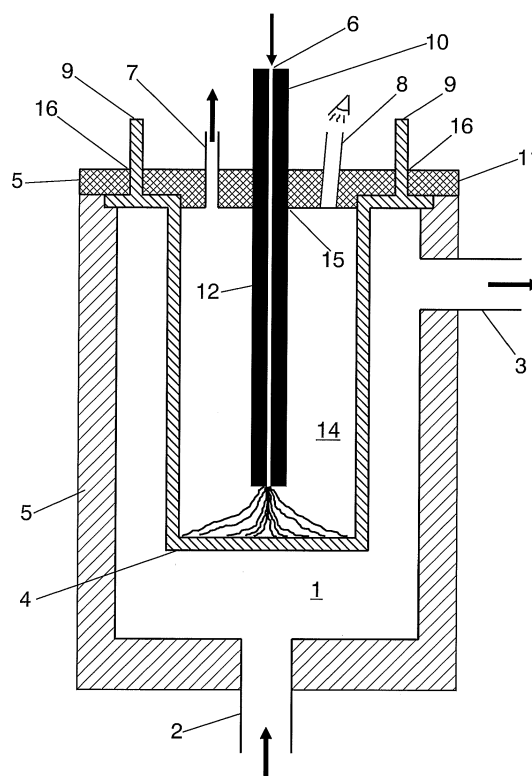


FIG. 1

Description

Field of the Invention

[0001] The present invention is encompassed within the techniques for treating and purifying gas flows for removing, for example, tars or other impurities contained in the synthesis gas generated in a prior gasification process to be subsequently used in an energy harnessing system.

Background of the Invention

[0002] Gasification is a thermo-chemical process in which a carbonaceous product or residue is transformed into a combustible gas called synthesis gas -having moderate calorific value- by means of treatment with a gaseous reagent (water, air and/or oxygen) at high temperature.

[0003] Gasification process has been historically used for various industrial applications. More recently it has undergone new growth by being used for energy recovery from waste flows of various origins: agricultural, forestry, industrial and MSW. Waste must have high carbon content in order to be gasified. Biomass gasification processes are acquiring special relevance today in an attempt to make them a competitive alternative for energy harnessing. The gas generated can be used for direct energy recovery or, less often, as base for the synthesis of new chemical products. In this last case, it is important to mention the synthesis of combustible liquids for use in automotive industry.

[0004] Gasification process requires a very strict control on both the composition and the feeding flow. If the ratio between the carbonaceous matter and the gasifying agent become imbalanced, the result obtained varies substantially. Upon increasing the gasifying agent with respect to carbon, the products obtained tend to be typical incineration products characterized by a lower heating value than those from gasification. If the ratio is the opposite, the products tend to be those typical of pyrolysis process. In spite of this difficulty, gasification is especially attractive due to the fact that it potentially offers the possibility of obtaining energy with a yield greater than that obtained with conventional incineration technology followed by steam generation as energy vector. This is due to the fact that the synthesis gas resulting from a gasification process can be used for feeding an internal combustion engine or a turbine, the energy yield obtained being increased.

[0005] One of the main obstacles slowing down the development of the technology and its industrial implementation is that the gas obtained tends to contain contaminants: particles, tars, nitrogen (if air has been used as a gasifying agent), chlorides, sulphurs, alkaline compounds and heavy metal. According to the gasified material, the residence time, the temperature of the reactor and the design thereof, the concentration of the contam-

inants can vary, but treating the gas prior to use is always necessary. Furthermore, it is necessary that the gasifiers are fed as homogenous as possible in terms of quantity and quality, given that changes in feeding cause very significant temperature and concentration changes at the outlet of the reactor. Although most of the mentioned contaminants are generated depending on the nature of the treated waste, the appearance of the so-called tars is a specific phenomenon of gasification processes. These compounds condense when the gas cools below 500°C, causing complications for its subsequent use as well as a loss of process yield.

[0006] Tars are a complex mixture of organic products with an undefined composition. The reduction of tars up to acceptable levels for making their use possible can be performed by several methods:

- Physical removal- It is based on the use of electrostatic precipitators, rotatory particle separators, filters or scrubbers or in combination with catalytic removal technologies:

- Electrostatic precipitators: They are used for removing liquid drops and particles in gas flows but they are not effective when the tars are in the gaseous phase.

- Rotatory separators: They consist of a rotatory cylinder with a central cyclone. These systems have been very useful for removing particles in gas flows without tars such that two removal methods for removing them have been investigated: condensing the tars and then removing them, and injecting a solvent and then removing the saturated solvent.

- Cyclones: They use centrifugal force for removing solids in the form of aerosols and tars. They work well for particle sizes of 5 µm or larger, not being effective for tarry aerosols including particles with a size even smaller than 1 µm.

- Filters: Conventional filters with filtering fabrics are not used because, by being collected therein due to its high viscosity, the tars block the filters. Filters coated with catalytic crackers are used.

- Absorption in aqueous medium: It is one of the most widely used systems. It consists of a gas washing system in which the tars are held in aqueous medium.

- Absorption by means of organic products: Organic liquids can be used as absorbing means instead of water. This is the case, for example, in the use of various oils as methyl ether derived from rapeseed oil. This absorption process can be performed in successive steps in separate columns.

- Cracking- It consists of causing tar decomposition at high temperature. There are several types:

○ Thermal cracking: The gas is treated at a temperature in the range of 1400-1600°C. Therefore, all the long chain hydrocarbons are broken down, only small amounts of light hydrocarbons remaining. The drawback of this technique is that, the higher heating value and the efficiency of the cold gas drop considerably when part of the fuel is burned for reaching high temperatures.

○ Catalytic cracking: The gas is treated at 800-900°C using dolomite or nickel as catalysts. The efficiency ranges between 90-95% by using dolomite. It is used at the temperature and pressure of the gasifier in the fluidized bed reactors, but the catalyst degrades progressively. The catalyst is protected if it is carried out in a special reactor (different from that of the gasification and downstream reactor), but it is necessary to add oxygen for oxidising the gas and increasing the temperature.

○ Plasma-assisted cracking: cold plasma and thermal plasma. Processes based on plasma technology can be considered as the most recently developed processes among the mentioned processes for treating tars:

■ Cold plasma: It is generated by discharge between two electrodes. Cold plasma which is made up of a set of excited electrodes giving rise to the appearance of ions, secondary electrons, UV radiations, free radicals, excited molecules, etc., is generated in this discharge. These species are responsible for removing tars. To that end, the energy of the electrons must be high enough for breaking the molecular bonds and giving rise to free radicals. Not all the tars are removed with this system, reaching yields of around 40%.

■ Thermal plasma: It removes tars at high temperature. This process has significant advantages compared with conventional thermal cracking due to the possibility of obtaining high temperatures with a fast and effective control without needing to dilute the gas with N₂ or CO₂. Given the relevance of this process in the present invention, it is analyzed in detail below.

[0007] Plasma is known as an ionized gas formed by an equivalent number of positively charged ions and negatively charged electrons containing or not containing a specific amount of neutral gas and being overall electrically neutral, collectively responding to magnetic and electric fields. Plasma technology has been used for different industrial uses: welding, surface treatment, cutting metal materials, chemical synthesis, etc. One of the most recent applications, encompassed in the environmental

industry, is the thermal treatment of waste. Its features make it especially ideal for use in this field. First, high temperatures of around 10,000-20,000 °C are generated, substantially increasing the heat decomposition kinetics of organic products. Furthermore, plasma can be generated by means of supplying electrical energy and a small flow of a gas, called plasmagene gas, which can be chosen according to the application, preventing the entrance of air and, subsequently, the dilution with nitrogen. The new obtained products are hydrogen and carbon monoxide, increasing the energy value of the gas flow. If a complete gasification does not occur, the obtained product will be carbon in the form of carbon black which is easier to handle than tar and can be reused in several industrial applications. It is also important to highlight that with plasma technology, high energy densities are obtained allowing significant productivity with small reactors. These properties have been utilized in waste thermal treatment reactors as a power supply system. Specifically, it is one of the systems used in the aforementioned gasifiers due to the fact that the metallization and/or the vitrification of the inorganic fraction can occur simultaneously with the gasification of the organic matter.

[0008] However, a new use has recently been developed but not as a gasification system per se, but as a system for treating and purifying the gases generated in a prior gasification reactor. In other words, it is an alternative system to those described above for treating synthesis gas and especially for removing tars. The developed systems are characterized by introducing a plasma torch inside a reactor through which the gas from the gasifier flows. The plasma is thus in direct contact with the gas to be treated and mixes its plasmagene gas flow with the synthesis gas flow. (Patent US 2009/0077887; Patent US 2003/0209174; Patent US 5785923; Patent WO 2011/084301; Patent WO 2007/131234). These systems have different configurations, but they have in common that the plasma torch is applied directly to the gas flow to be treated. This approach causes the plasmagene gas to be mixed with the synthesis gas generating a dilution of the combustible gases causing a loss of their calorific value and a contamination of their composition, which may complicate certain applications. Furthermore, the operation and stability of the plasma torch are influenced by its surrounding atmosphere, being able to hinder its correct use. This last point is important for plasma of all types, but it is especially critical in the so-called transferred plasmas, where it can cause serious alterations in their operation even extinguishing the plasma.

Object of the Invention

[0009] The object of the invention is to overcome the technical problems mentioned in the above section. To that end, the invention proposes equipment for treating gases comprising a treatment chamber provided with an inlet for the entrance of gas to be treated, its corresponding outlet and a heating chamber provided with thermal

plasma generating means. According to the invention, both chambers are independent and are separated by an intermediate wall such that the thermal plasma acts on the intermediate wall for indirectly heating the treatment chamber. In other words, the thermal plasma heats the intermediate wall (the face of the intermediate wall which is in the heating chamber) which in turn heats the face of the intermediate wall which is in the treatment chamber, without there being neither a direct contact nor a mixture between the thermal plasma and the gases to be treated.

[0010] The heating chamber can be partially surrounded by the treatment chamber, the intermediate wall being inside the treatment chamber.

[0011] In another embodiment, the heating chamber can be adjacent to the treatment chamber and is separated from the latter by the intermediate wall.

[0012] The generating means for generating the thermal plasma can be a transferred arc plasma torch or a non-transferred arc plasma torch, non-transferred arc plasma torch being understood as a torch comprising two electrodes such that an arc generated by the thermal plasma is formed between both electrodes. Transferred plasma torch is understood when the torch incorporates only one electrode (for example, a graphite electrode) but the arc is formed between the torch (electrode) and an element outside the torch.

[0013] In an embodiment of the invention, the thermal plasma generating means can comprise a transferred arc plasma torch located in the heating chamber, electrical connections associated with the intermediate wall for the operation of said wall as a counter electrode and a plasmagene gas supply source which is introduced through a conduit traversing the transferred arc plasma torch. The electrode can be a graphite electrode.

[0014] In another embodiment, the thermal plasma generating means comprise a transferred arc plasma torch comprising a solid graphite electrode located in the heating chamber and electrical connections associated with the intermediate wall for the operation of said wall as a counter electrode. There is no plasmagene gas supply in this embodiment.

[0015] In another embodiment, the thermal plasma generating means comprise a non-transferred arc plasma torch associated with the heating chamber, electrical connections connected to the torch itself and a plasmagene gas supply source which is introduced through a conduit traversing the non-transferred arc plasma torch.

[0016] Another object of the invention is the use of the described equipment for the heat treatment of a synthesis gas mainly contaminated with tars generated in a prior gasification process.

Brief Description of the Drawings

[0017] For the purpose of aiding to better understand the features of the invention according to a preferred

practical embodiment thereof, a set of drawings is attached to the following description in which the following has been depicted with an illustrative character:

Figure 1 is a schematic depiction of equipment with a transferred plasma torch comprising a graphite electrode and a plasmagene gas source according to the invention and a heating chamber partially surrounded by the treatment chamber

Figure 2 is a depiction of equipment with a non-transferred plasma torch and plasmagene gas source according to the invention and a heating chamber partially surrounded by the treatment chamber.

Figure 3 is a schematic depiction of a plasmagene gas-free equipment with a transferred plasma torch comprising a solid graphite electrode according to the invention and heating chamber partially surrounded by the treatment chamber.

Figure 4 is a schematic depiction of equipment with a transferred plasma torch comprising a graphite electrode and a plasmagene gas source according to the invention and a heating chamber adjacent to the treatment chamber.

Figure 5 is a schematic depiction of equipment with a non-transferred plasma torch and a plasmagene gas source according to the invention and a heating chamber adjacent to the treatment chamber.

Figure 6 is a schematic depiction of plasmagene gas-free equipment with a transferred plasma torch comprising a solid graphite electrode and a heating chamber adjacent to the treatment chamber.

Figure 7 shows a diagram of the process for treating a synthesis gas generated in a prior gasification process according to the invention.

Detailed Description of the Invention

[0018] As can be seen in the drawings, the equipment is provided with two independent chambers. On one hand, the treatment chamber 1, where the reactions for removing contaminant load from the treated gas flow (mainly tars) take place and, on the other hand, the heating chamber 14 housing the thermal plasma technology-assisted heating system. Both chambers 1 and 14 are separated from one another by an intermediate wall or membrane 4.

[0019] The chamber 1 is provided with an inlet opening 2, through which the gas flow to be treated is introduced, and an outlet opening 3, through which the gas flow is evacuated once it has been treated. This chamber 1 is insulated from the exterior by means of a refractory material 5.

[0020] The chamber 14 is provided with an opening 15 through which a non-transferred plasma torch 13 (Figures 2 and 5) or a transferred plasma torch 12 comprising an electrode, generally a graphite electrode (Figures 1, 3, 4, and 6), is introduced. Alternatively, the graphite electrode can be a solid electrode (Figures 3 and 6). Like the

case of chamber 1, the chamber 14 is insulated from the exterior by a refractory material 5.

[0021] In the embodiments shown, transferred plasma is understood as that plasma in which the electric arc is generated between the electrode 12 (acting as a cathode or an anode) and the intermediate wall 4 which is to be heated and which acts of a counter electrode. Therefore, this intermediate wall 4 separating the chambers 1 and 14 forms part of the electric circuit and is connected to a power supply source (not shown) through an electric contact 9. A second electric contact 10 is connected to the electrode 12, closing the electric circuit with the supply source. In contrast, in the case of non-transferred plasma, the electric arc is generated between two electrodes located in the same torch 13 independently from the intermediate wall 4. In the latter case, the two electric contacts 9 and 10, along with the power supply source, are in the torch 13 itself. It must be highlighted that the torch 13 can also be configured as a transferred torch.

[0022] The plasma torch 12 or 13 can be provided with a plasmagene gas source which is introduced through a conduit 6 (Figures 1, 2, 4 and 5). The plasmagene gas is extracted by means of an opening 7. In the case of using a solid graphite electrode and therefore without supplying plasmagene gas (Figures 3 and 6), this opening 7 is not necessary.

[0023] In the embodiments shown in Figures 1, 2 and 3, the heating chamber 14 is partially surrounded by the treatment chamber 1 such that the intermediate wall 4 is housed inside the treatment chamber 1.

[0024] In the alternative embodiments shown in Figures 4, 5 and 6, the treatment chamber 1 and heating chamber 14 are adjacent and are separated by the intermediate wall or membrane 4.

[0025] The equipment has a top cover 11 through which the chambers 1 and 14 are accessed. Like the rest of the equipment, this cover has a refractory material 5 for insulating the inner chambers. The opening 7 for extracting the plasmagene gas and the opening 15, through which the plasma torch is introduced, are provided in the top cover 11 which further has a peephole 8 through which the inside of the chamber 14 can be seen.

[0026] Figures 1, 3, 4 and 6 show the electrical connection points 9 for the transferred plasma torch. Depending on how the electrical connection is made, the intermediate wall 4 can behave as an anode and the electrode 12 as a cathode or vice versa. The top cover 11 comprises an opening 16 for the passage of the electrical connection points 9.

[0027] The gas flow carrying the contaminants to be treated is introduced through the opening 2 directly accessing the treatment chamber 1. The gas flow reaches high temperatures in the treatment chamber 1 as it comes into contact with the intermediate wall 4, which in turn is heated on the opposite surface by the plasma torch 12 or 13. The gas flow is evacuated through opening 3.

[0028] The intermediate wall 4 can be made up of various materials: ceramic materials, carbonaceous mate-

rials, metallic materials; either made entirely from one of them or a combination thereof depending on the requirements of the process to be implemented. In some cases it is of interest that the construction materials of this surface are inert against the gas flow to be treated, but, in other cases, it may be of interest that they interact with same either acting as reagents or acting as a reaction catalyst.

[0029] The configurations shown in Figures 1-3 allow obtaining three areas with different temperatures: an area inside the treatment chamber 1 which is not in contact with the gas to be treated and two areas inside the heating chamber 14 both in direct contact with the gas. The first area is the area produced inside the heating chamber 14 which is affected by the direct presence of the plasma generated by the electrode 12 or the torch 13. The temperature around the plasma can be up to 20,000°C, dropping to 1,000-3,000°C in the intermediate wall 4. The temperature will be the highest possible at the part directly struck by the plasma and the temperature will be in the range 1,000-1,500°C at the farthest part close to the contact with the cover 11. The second area corresponds to the face of the intermediate wall 4 belonging to the reaction chamber 1. The temperature in this face can be in a range of 850-3,000°C, very close to the other face, and with a temperature distribution similar to that mentioned above. This high temperature is achieved, without the direct presence of plasma, by means of conducting heat through the material of the intermediate wall 4. A very hot surface, so much hotter than that achieved in conventional systems is thus obtained, causing a significant increase of the rates of reaction -in this case organic molecule destruction- and allowing a significant decrease in the volumes of reaction necessary for a similar level of progress of the reaction. The gases enter through the opening 2 located right in front of the hottest area of the chamber 1 and strike that area of highest temperature of the intermediate wall 4. Finally, the third area of temperature corresponds to the room temperature of the reaction chamber 1, which is an area of lower temperature, normally in the range 700-2,200°C where the gas to be treated will remain during the residency time necessary for each case. The highest temperature in this area will be limited by the materials used especially in the outer wall 5 of the reactor.

[0030] Figure 7 shows the diagram of a heat treatment process for treating gas flows generated in a gasifier containing combustible gases, typically CO and H₂, along with tars, which must be removed before using the synthesis gas in various applications. The materials to be gasified 17 including waste materials are fed to a gasifier 19 along with a gasifying agent 18 (oxygen, water, etc.) where they are treated at temperatures normally in the order of 600-900°C. After the gasification step, the gas product is treated by means of thermal treatment equipment by means of the indirect application of plasma 20 (described previously in Figures 1 to 6). The objective of the process shown is to obtain a synthesis gas from or-

ganic products and waste which, after removing the impurities and contaminants which it may contain, is used in step 21 by means of an energy harnessing system (steam generation, internal combustion engine, turbine, etc.) or a chemical synthesis process. To that end, the gas generated in the gasifier is treated at a higher temperature, typically in the range 1,100-1,700°C. The temperature limit will be determined by the materials used in the construction of the reactor provided with a plasma torch. Potentially, the treatment temperature could be higher than that indicated since the plasma torch can reach temperatures ranging between 10,000 and 20,000°C. When the gas exits the reactor 20 through the opening 3, it must be treated appropriately before being used. To that end, it will be subjected to successive cooling, filtration and washing processes. Cooling can be a moderate cooling down to the range of 400-600°C followed by a filtration by means of ceramic filter, or a more intense cooling down to 100-250°C, followed by a filtration by means of a conventional bag filter. Furthermore, the gas may require a chemical cleaning step depending on the original chemical composition of the material fed to the gasifier. Cleaning will normally be performed in a tower provided with packing by means of an alkaline solution with counter-current flow for removing the acid gases generated by chlorine and sulphur derivative. The gas finally obtained can be used in an energy generation system by means of feeding it to an internal combustion engine, a turbine, a boiler or the like. Generally, there will be a storage step prior to feeding it to mentioned equipment.

Claims

1. Equipment for treating gases comprising a treatment chamber (1) provided with an inlet (2) for the entrance of the gas to be treated, its corresponding outlet (3) and a heating chamber (14) provided with thermal plasma generating means, **characterized in that** both chambers (1, 14) are independent and are separated by an intermediate wall (4) and **in that** the thermal plasma acts on the intermediate wall (4) for the indirect heating of the treatment chamber (1).
2. Equipment according to claim 1, wherein the heating chamber (14) is partially surrounded by the treatment chamber, the intermediate wall (4) being inside the treatment chamber (1).
3. Equipment according to claim 1, wherein the heating chamber (14) is adjacent to the treatment chamber (1) and is separated from the latter by the intermediate wall (4).
4. Equipment according to any of the preceding claims, wherein the thermal plasma generating means comprise a transferred arc plasma torch (12) located in

the heating chamber (14), electrical connections (9) associated with the intermediate wall (4) for the operation of said wall (4) as a counter electrode and a plasmagene gas supply source which is introduced through a conduit (6) traversing the transferred arc plasma torch (12).

5. Equipment according to any of claims 1-3, wherein the thermal plasma generating means comprise a transferred arc plasma torch (12) comprising a graphite electrode located in the heating chamber (14), electrical connections (9) associated with the intermediate wall (4) for the operation of said wall (4) as a counter electrode and a plasmagene gas supply source which is introduced through a conduit (6) traversing the transferred arc plasma torch (12).
6. Equipment according to any of claims 1-3, wherein the thermal plasma generating means comprise a transferred arc plasma torch (12) comprising a solid graphite electrode located in the heating chamber (14) and electrical connections (9) associated with the intermediate wall (4) for the operation of said wall (4) as a counter electrode.
7. Equipment according to any of claims 1-3, wherein the thermal plasma generating means comprise a non-transferred arc plasma torch (13) associated with the heating chamber (14), electrical connections (9,10) connected to the torch itself and a plasmagene gas supply source which is introduced through a conduit (6) traversing the non-transferred arc plasma torch (13).
8. Use of the equipment according to any of the preceding claims for the thermal treatment of a synthesis gas generated in a prior gasification process.

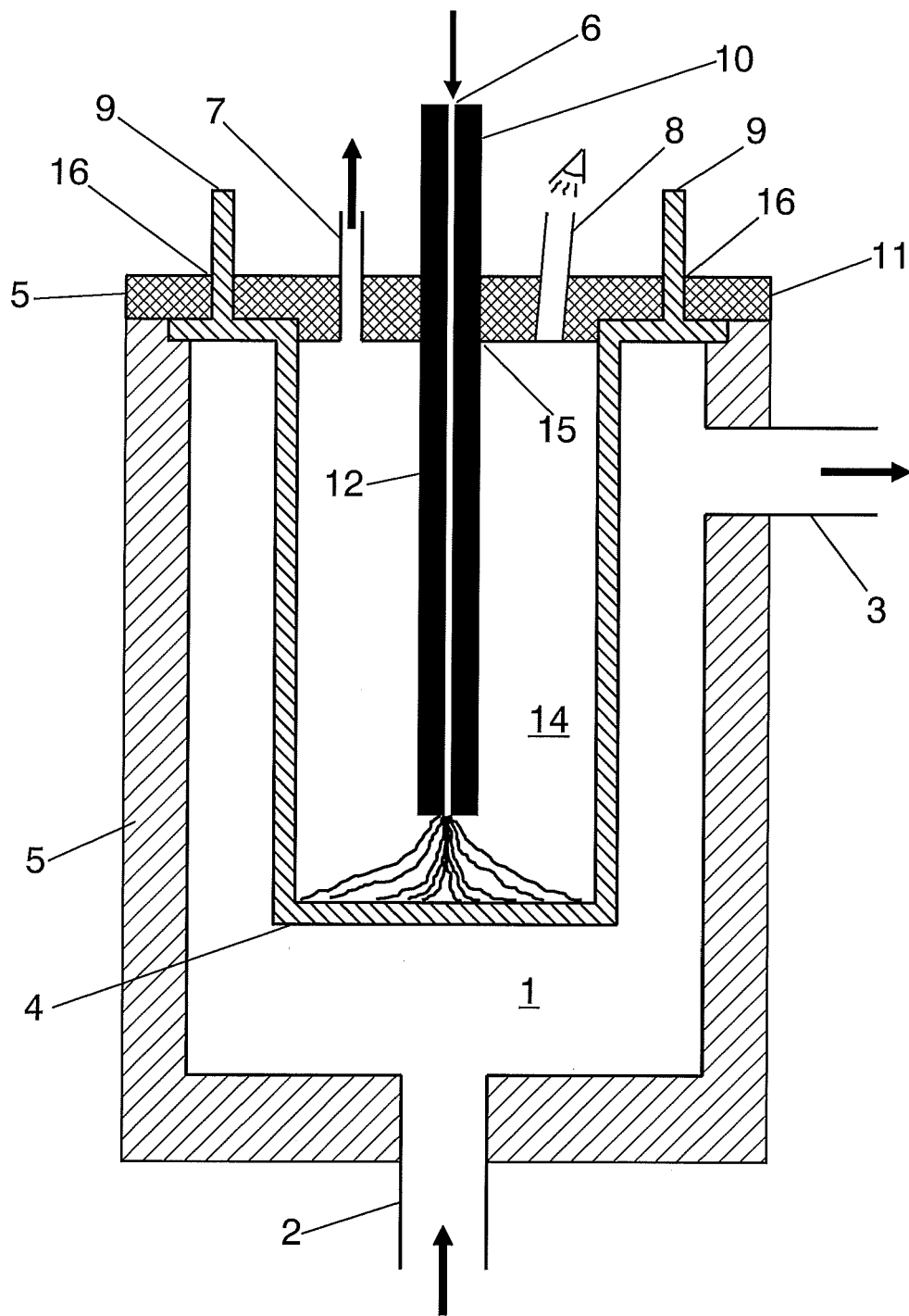


FIG. 1

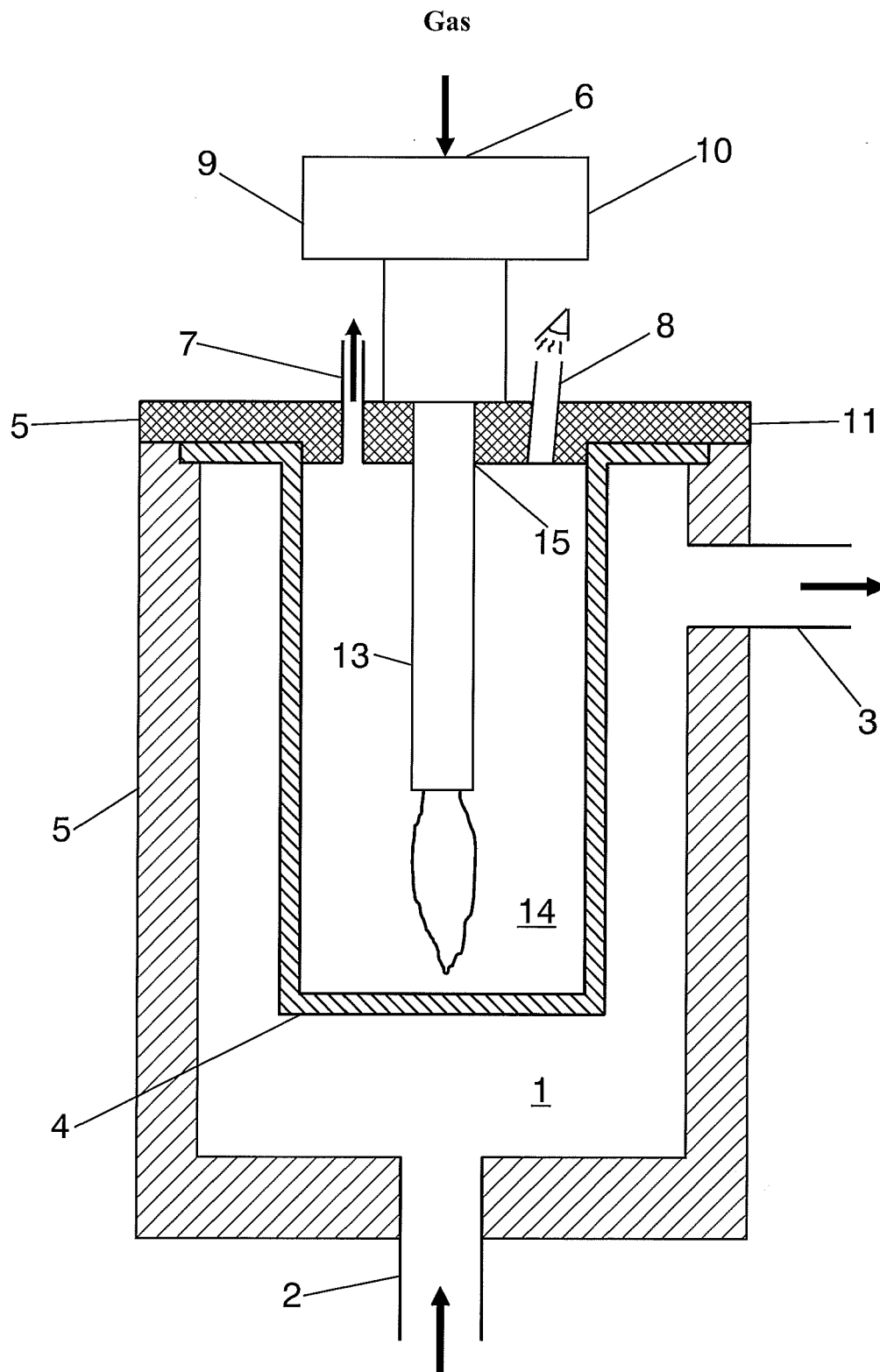


FIG. 2

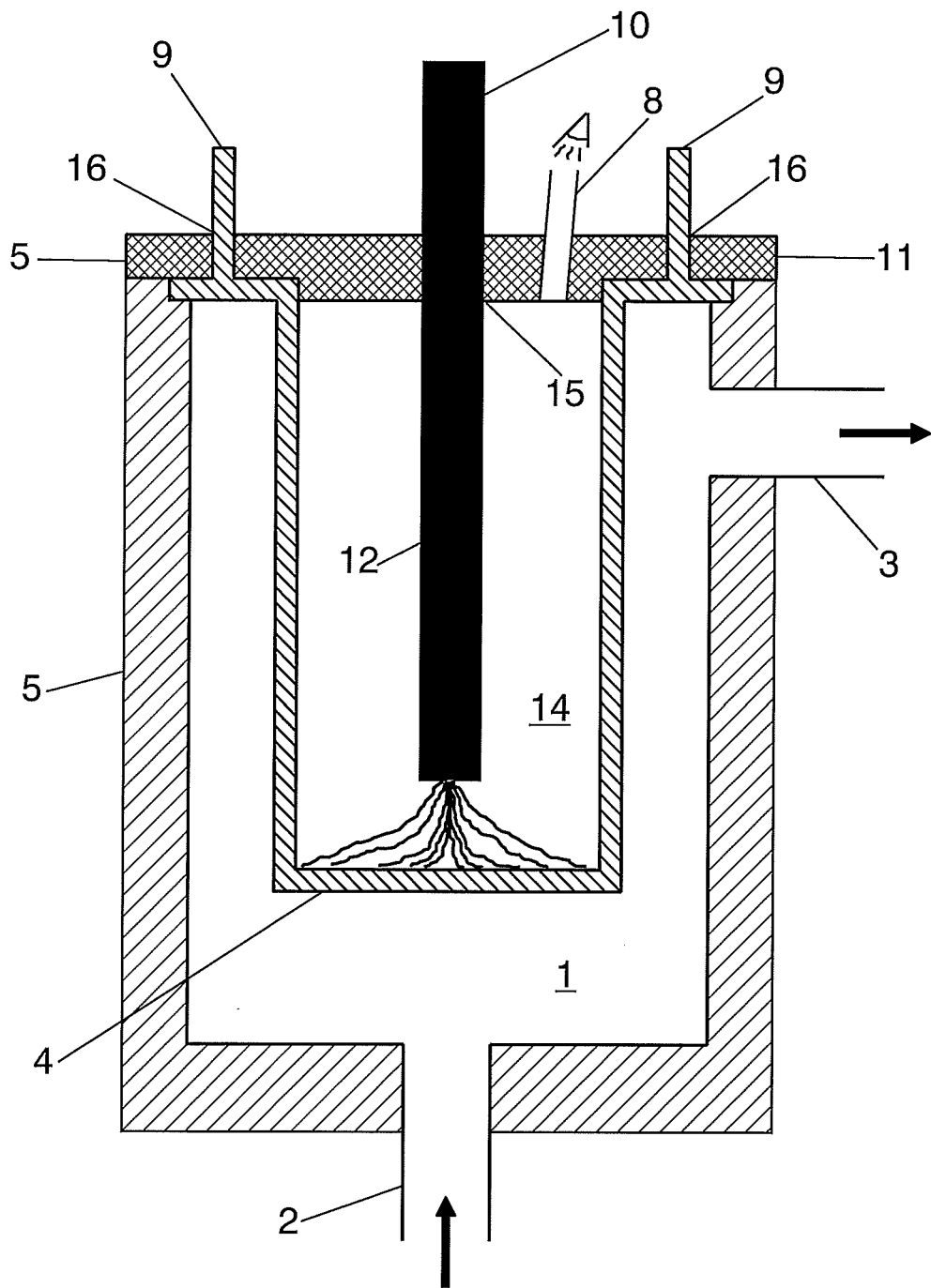


FIG. 3

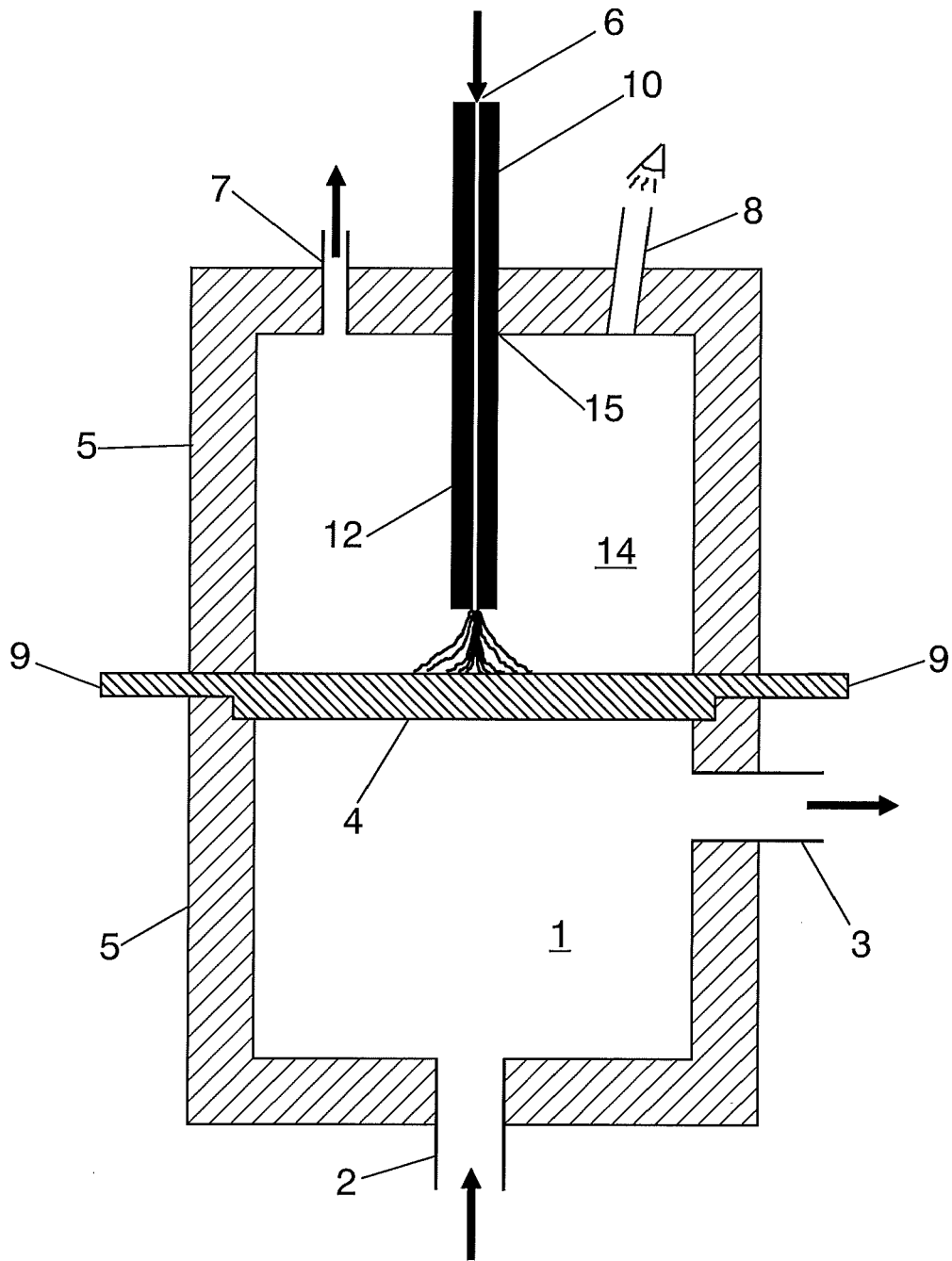


FIG. 4

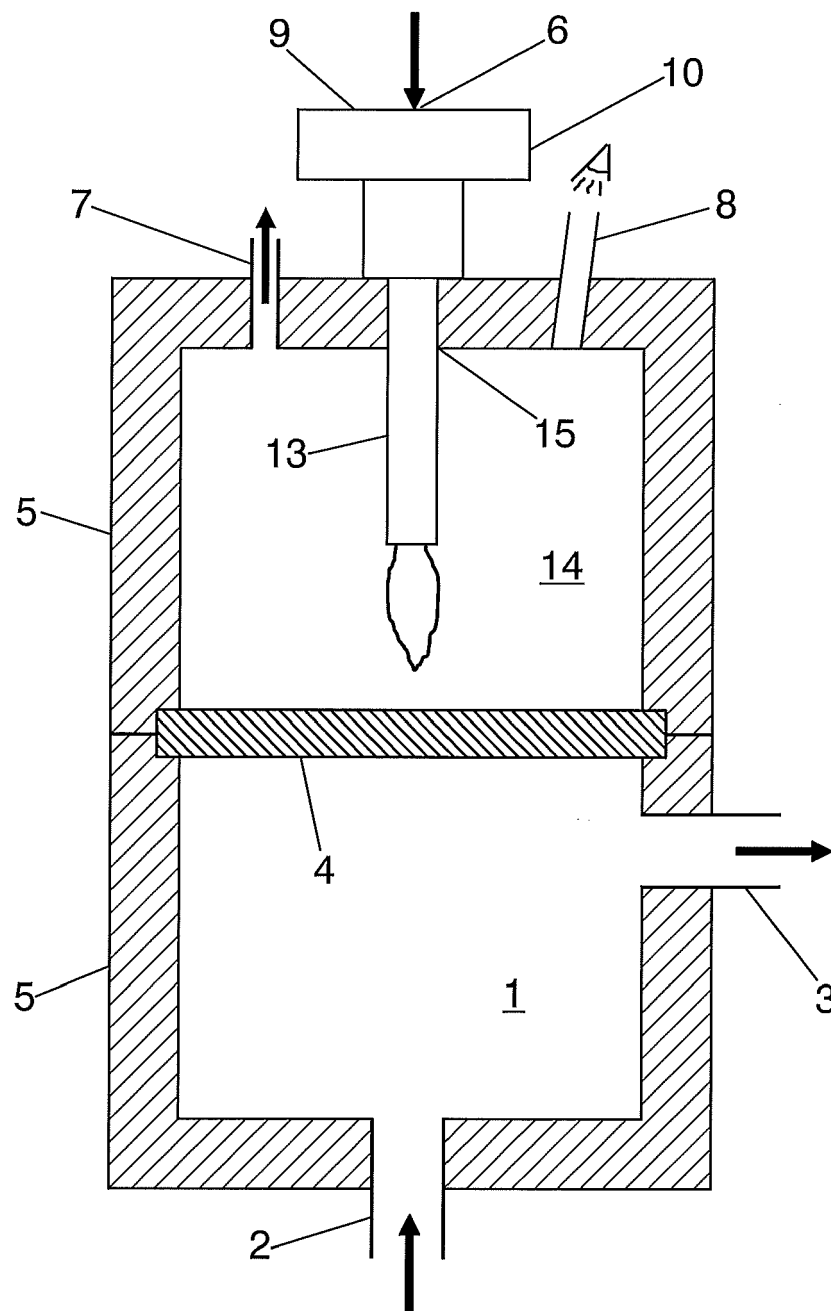


FIG. 5

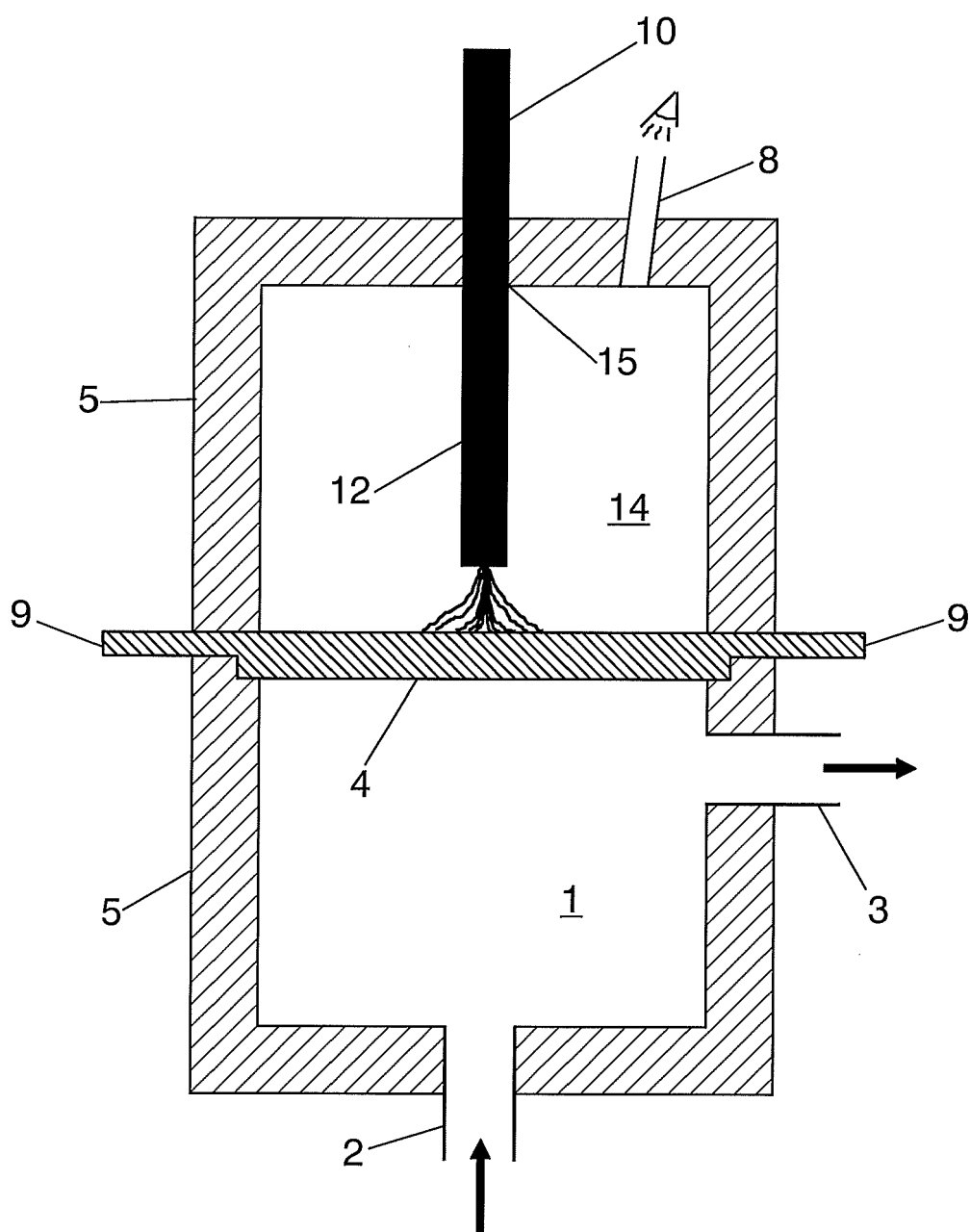


FIG. 6

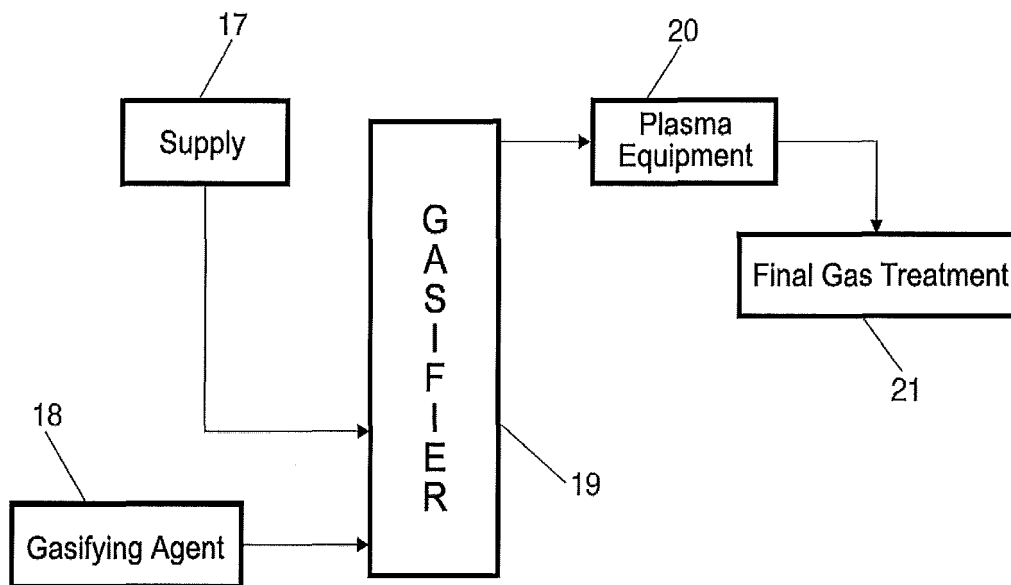


FIG. 7



EUROPEAN SEARCH REPORT

 Application Number
 EP 12 38 2295

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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