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CROSS REFERENCE
SEARCH ROOM

March 22, 1966 P. RICATEAU ETAL 3,241,490

METHOD AND DEVICE FOR PUMPING A GAS

Filed June 26, 1962 3 Sheets-Sheet 1

FIG. 1

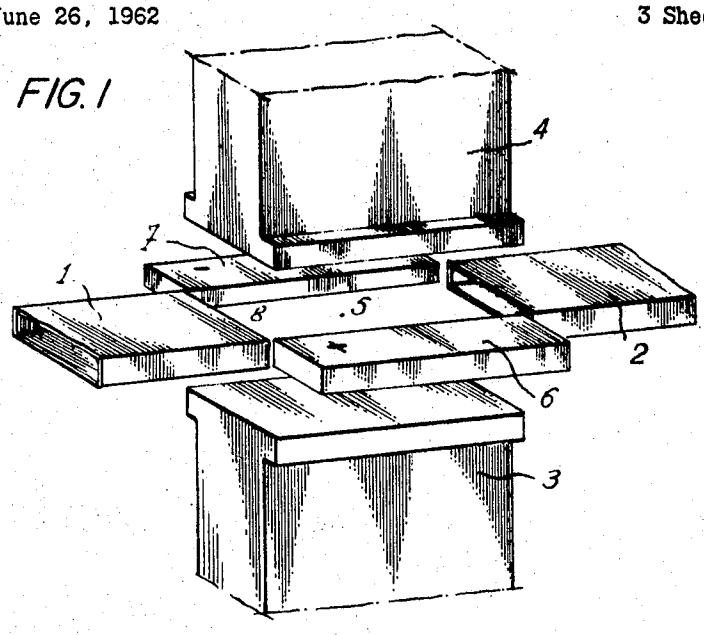

FIG. 2

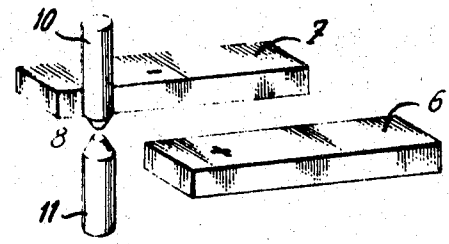

FIG. 3

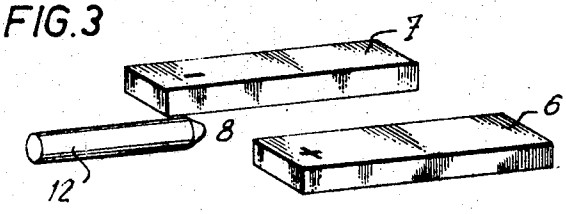

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FIG. 4

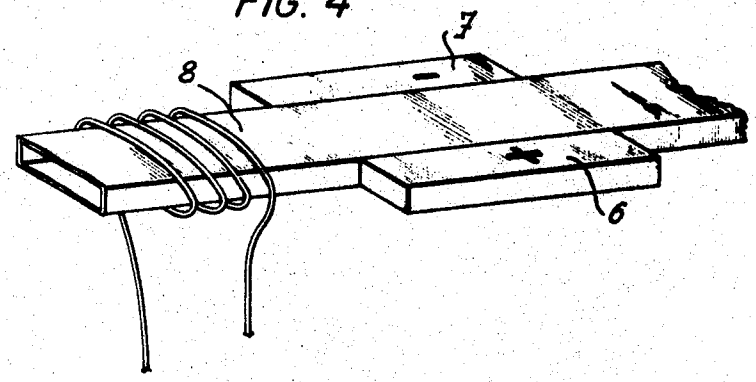


FIG.5

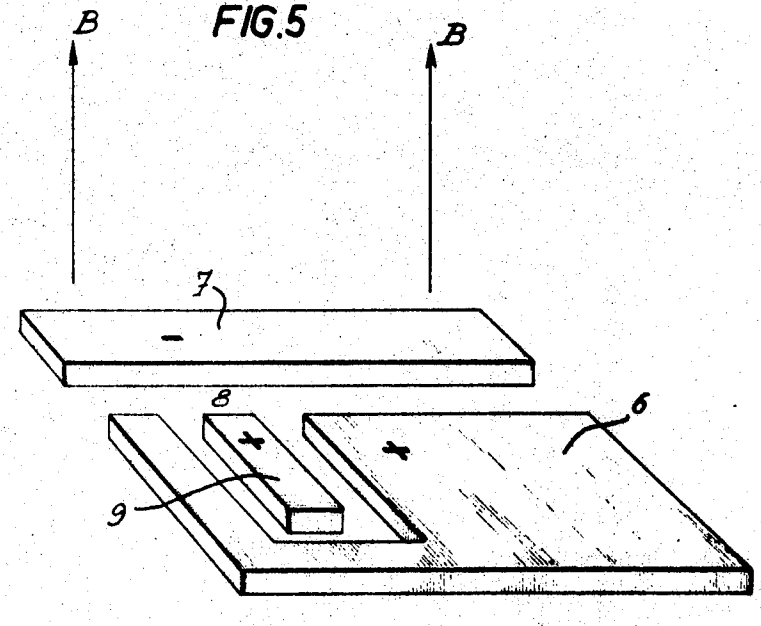
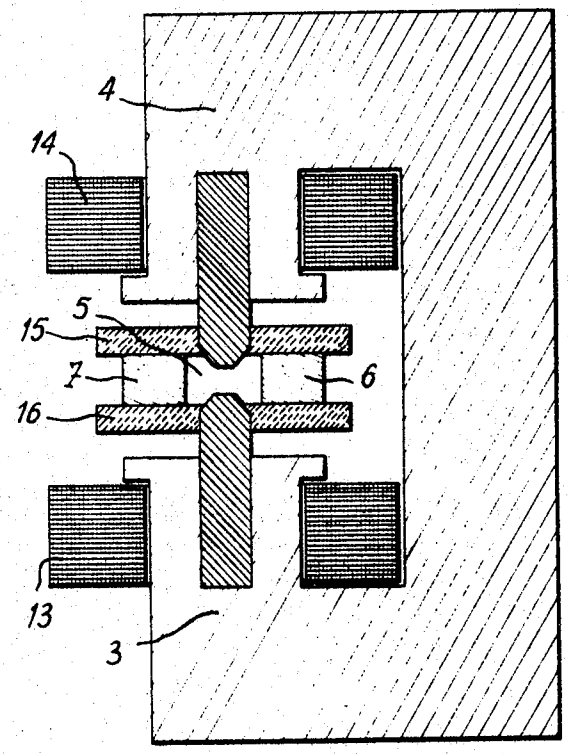


FIG.6



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3,241,490

METHOD AND DEVICE FOR PUMPING A GAS

Pierre Ricateau, Garches, and Camille Vavasseur, Clamart, France, assignors to Commissariat a l'Energie Atomique, Paris, France

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7 Claims. (Cl. 103—1)

The present invention relates to a method which is intended to permit the propulsion of a gas in a pipe and also relates to a device for the practical application of the said method.

It is known that, except at very high temperatures, the circulation of a gas in a pipe is usually carried into effect by means of a pump or compressor having as its essential element a mechanical component which is movable either in rotation or in reciprocating motion and which is in direct contact with the gas to be driven. The mounting or fitting of this component which is adapted to move inside the pump body or compressor body usually entails accurate tolerances while the movement thereof calls for appropriate mechanical qualities of the material employed.

Moreover, it is known that in the case of corrosive gases or gases having very high temperatures, it is extremely difficult or even impossible to find a material which can be machined to the requisite precision while having sufficient mechanical strength and length of life which are compatible with effective utilization.

The present invention has for its object both a method and device for driving a gas which eliminates all moving parts and dispenses with the need for strictly accurate tolerances when machining other parts of the apparatus.

This method of pumping a gas through a propulsion zone in a given direction makes use of the combined action of a permanent magnetic field and a permanent electric field, the directions of which are at right angles to each other and at right angles to the direction of propulsion, and mainly consists in effecting the ionization of the gas at the input end of the propulsion zone at a repetition rate such that there exists at each moment an electric arc which is orientated in the direction of the electric field and which is movable in the direction of propulsion.

The device which serves for the practical application of the above method is characterized in that it comprises in combination means for confining the zone of propulsion of the gas to be pumped and for producing in the said zone a magnetic field at right angles to the direction of propulsion, means for maintaining between two main electrodes or sets of electrodes extending in the direction of propulsion a continuous potential difference producing an electric field at right angles to the magnetic field direction and to the direction of propulsion, and means for striking an arc through the gas to be driven at the input end of the said propulsion zone and at a pre-determined repetition rate,

Further characteristic features of the invention will be more clearly and precisely explained in the following description of various examples of embodiment which are given by way of indication without any limitation being implied.

In the accompanying drawings:

FIG. 1 illustrates the method of propulsion employed.

FIGS. 2, 3, 4 and 5 illustrate various means for ionizing the gases to be driven.

FIG. 6 shows in cross-section at right angles to the direction of propulsion, the complete pump assembly in accordance with the present invention and making use of the ionization means of FIG. 2.

Only those elements have been made to appear in the figures which are essential to the understanding of the invention, while corresponding elements shown in these figures have been given identical reference numbers.

The principle of propulsion is illustrated in the exploded view of FIG. 1. The gas arrives through the inlet pipe **1** and passes out through the outlet pipe **2**. One or the other of these pipes can be simple openings when suction or delivery takes place in free air. Between these two pipes is located the pumping passage **5** which is closed both at the top and bottom by electrically insulating walls which are preferably constituted by plates of refractory material, the said pumping passage being closed on its two other faces by electrodes **6** and **7** between which an arc is to be established. The said electrodes can be either cooled or not by internal circulation of a cooling liquid such as water, and can be constructed of a material which is customarily employed in the technique of electric-arc formation and which is suitable for use at very high temperatures, such as graphite. Such electrodes can also be made of metal, on condition that the surface of this metal is maintained by appropriate cooling means at a temperature which is compatible with its length of life.

In the pumping passage is located an upwardly directed magnetic field which is produced by a permanent magnet or an electromagnet, the north and south poles of which are designated by the references **3** and **4** respectively.

The electrodes **6** and **7** are supplied with direct current from a source which is designed to provide sufficiently high voltage and current intensity to maintain an arc previously struck between the electrodes in the presence of the magnetic field and in spite of the dynamic effect of the flowing gas. Although it is not essential to do so, it is possible to improve the stability of the arc by means of an inductance coil connected in series in the supply circuit or by means of a high-frequency source which delivers current between the same electrodes **6** and **7** or by means of these two arrangements at the same time.

It is known that unless there is a very high voltage between the electrodes **6** and **7**, the arc does not strike spontaneously. Even if a special arrangement such as a spark initiates the arc in region **8**, experience has shown that the arc, which is blown as a result of the action of the magnetic field, is displaced towards the outlet **2** of the passage and is then broken.

If it is desired to prevent the interruption of the current between **6** and **7**, the arc must be restablished in region **8** at the very moment when the breaking of the previous arc takes place at the outlet of the passage.

To this end, a permanent plasma is formed in accordance with the present invention, in region **8** of FIG. **1**. The function of the said plasma is to initiate the arc in region **8** and to compel the arc to re-form in this region each time it is interrupted.

The permanent plasma can be produced by a second direct-current arc which is initiated in region **8** parallel to the lines of force between the auxiliary electrodes **10** and **11**, this arrangement being shown diagrammatically in FIG. 2. As in the case of the main arc, these electrodes can be cooled by the internal circulation of a cooling fluid. The permanent plasma can also originate from a high-frequency discharge which can be initiated either between the electrodes similar to **10** and **11** or between an electrode **12** and the electrodes **6** and **7** of the main arc as indicated in FIG. 3. In the case of a high-frequency discharge, the said discharge can follow a direction which is different from that of the lines of force. The said permanent plasma can also be produced by means of a high-frequency dis-

charge which is induced inside a coil-winding without being brought into direct contact with the plasma (as shown in FIG. 4). In this latter case, the discharge thus induced does not usually take place spontaneously and must be established by another means at the time of setting the apparatus to work.

The above-mentioned devices for re-forming the arc have the disadvantage of creating a very hot zone which is localized at the inlet of the passage and which is consequently subject to increased erosion.

One improvement consists in striking the arc by producing a moving arc having a frequency of movement which is either very high or equal to a whole multiple of the repetition frequency of the main arc.

The principle of this new arc-striking device is illustrated in FIG. 5. A new electrode **9** which can be of the same material as the electrodes **6** and **7** has been housed inside a recess cut in the electrode **6**. The said electrode is entirely located in the zone which corresponds to the field of force of the magnet. It has been stated that the main supply source brought the electrode **6** to a positive potential with respect to the electrode **7**. Similarly, a new direct current supply source connected to the electrodes **6** and **9** brings the electrode **9** to a positive potential with respect to the electrode **6**. This auxiliary source can have a lower power output than that which produces the main arc.

In view of the polarities adopted, when an auxiliary arc is struck between the electrodes **9** and **6**, the said arc, being subjected to the field of magnetic force, is caused to move around the electrode **9**. Each time that the arc travels into the region **8**, it introduces a burst of plasma into the pumping passage, thus having the effect of striking the main arc. It is possible, for instance, by means of magnetic devices such as auxiliary magnetic cores modifying the magnetic circuit of the electromagnetic field to regulate the field of force in the zone of the auxiliary electrode in such manner that the auxiliary arc is re-established at the point **8** at the precise moment when the main arc is suppressed at the outlet **2** of the pumping passage. By providing a sufficient frequency of the auxiliary arc, it can also be made possible for this latter to appear in region **8** at least once during the period of breaking of the main arc at the outlet of the driving passage. In this latter case, the said frequency does not need to be regulated with precision.

The apparatus operates as follows: when the plasma appears in region **8**, an arc is formed between the main electrodes **6** and **7**. If I designates the arc current, B the magnetic induction, L the distance between main electrodes, a force $F=IBL$ appears, is applied to the gas and initiates the propulsion thereof. When the current I is sufficient, the arc travels from the passage inlet towards the outlet and is broken at the outlet; another arc is then formed again in region **8** by virtue of the presence in this region of a strong continuous ionization, this new arc travels in turn in the same manner and so forth. In view of the rapid displacement of the arc, there is distinctly less heating and wear of the electrodes **6** and **7** than in the case of a stationary arc, the current intensity being equal.

It will be observed that in one case as in the other, although the conductive zone represents only a part of the zone which is subjected to the field of magnetic force, the so-called "Rayleigh-Taylor" instability which could have a detrimental effect on the operation does not in fact hinder the propulsion of gas.

It has been stated above that, as a result of the absence of moving parts, of accurately machined components and parts requiring special mechanical strength, this method of propulsion was particularly well suited to the propulsion of corrosive or very hot gases. A particularly important application is that of high-temperature wind tunnels. Accordingly, by virtue of this method, the hot gas can be retained in the return circuit instead of being discharged into the outer air. The result thereby achieved is a considerable saving of power.

An application of a different nature is that of the propulsion of gases at pressures which are lower than atmospheric pressure. In this new application, the method offers the advantages of absence of sealing joints as employed in mechanical transmission systems and absence of vapours of foreign gases such as vapours from lubricating oils of mechanical pumps or mercury vapours of molecular pumps.

The complete gas pump assembly in accordance with the present invention is illustrated in FIG. 6 (seen from the input end of the passage). The apparatus is designed to entrain air at atmospheric pressure.

The device is placed between the poles **3** and **4** of a direct curent electromagnet, the magnetizing coils of which are designated by the references **13** and **14**, and which is capable of producing a magnetic field of 2,000 G's in the pumping zone. The passage **5** of square section, with sides which each measure 6 mm., is closed both at the top and bottom by isolating refractory plates **15** and **16** and laterally by main electrodes **6** and **7** of graphite. The said main electrodes are connected through an inductance coil which has not been shown in the drawings to a direct current drooping-characteristic generator, the excitation of which is regulated in such manner as to obtain, for example, an arc of 150 amp. at 45 v. between the said electrodes. The auxiliary arc jumps between the electrodes **11** and **10** which are placed at the entrance of the passage inside an enlarged portion of the main electrodes; the said auxiliary arc is fed from an independent current source which can be adjusted to 40 amp. at 40 v.

As soon as the auxiliary arc is struck, the main arc is struck in turn and then displaced. At the same time, the air is set in motion inside the passage.

What is claimed is:

1. In a method of pumping gases through a propulsion zone in a given direction by means of the combined action of a permanent magnetic field and a permanent electric field the directions of which are at right angles to each other and at right angles to the direction of propulsion of the gas, the step of ionizing a portion of the gas adjacent the input end of the propulsion zone at a repetition rate such that electric arcs are created approximately at the time the preceding arc leaves the propulsion zone and which are oriented in the direction of the electric field and then moving the electric arcs in the direction of propulsion of the gas by the action of said fields.

2. A device for pumping gas comprising means for confining a zone of propulsion for the gas to be pumped, means for producing in said zone a magnetic field at right angles to the direction of propulsion of the gas, main electrodes extending in the direction of propulsion of the gas, means for maintaining between said main electrodes a continuous potential difference producing an electric field at right angles to the direction of the magnetic field and to the direction of propulsion of the gas and means for striking arcs through the gas to be pumped at the input end of the propulsion zone and at a predetermined repetition rate such that arcs are created approximately at the time the preceding arc leaves the propulsion zone, said fields moving said arcs in the direction of propulsion of the gas.

3. A device as described in claim **2** in which said arc-striking means comprise two auxiliary electrodes connected across the terminals of a suitable electric current source, the common axis of said auxiliary electrodes being parallel to the magnetic field.

4. A device as described in claim **2** in which said arc-striking means comprise at least one auxiliary electrode which is connected to a high-frequency electric current source with its circuit completed through one of said main electrodes.

5. A device as described in claim **2** in which said arc-striking means comprise a coil-winding which is connected to a high frequency electric current source.

6. A device as described in claim 2 in which said arc-striking means comprise at least two auxiliary electrodes, an electric non-alternating current source connected to said auxiliary electrodes which is capable of maintaining a moving discharge between said auxiliary electrodes and an annular discharge zone between said auxiliary electrodes subjected to the field of magnetic force and communicating with the propulsion zone, the long axis of said annular zone and said auxiliary electrodes being disposed in a plane at right angles to the magnetic field.

7. A device as described in claim 6 in which said main electrodes comprise certain of but not all of said auxiliary electrodes.

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LAURENCE V. EFNER, *Primary Examiner.*