

[54] **PLASMA CURTAIN OF TWO OR MORE PLASMAS**

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315/166

[51] Int. Cl. **H05h 1/00**

[58] Field of Search 313/231, 36;
219/121 P, 76; 315/111, 161, 166, 176

[56] **References Cited**

UNITED STATES PATENTS

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Primary Examiner—Palmer C. Demeo
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[57] **ABSTRACT**

A process or apparatus for producing two or more plasmas which comprises projecting opposed plasmas into a closed space to meet in the space and form a common arc, and expelling the combined plasmas from the closed space sideways with respect to their original direction under the pressure of plasmagenic gas through at least one nozzle elongated in the sideways direction and thus producing a flame projecting outward through the elongated nozzle as at least one blade of a continuous plasma jet. In one of the forms two or more blades are projected through elongated nozzles which may be parallel to one another, divergent from one another, or convergent to one another. The curtain of plasma may deposit material on the inside or the outside or both of a tube. The chamber from which the plasma curtain issues may be supported on a roller carriage. The single chamber may also be rotated around an axis. In one embodiment the chambers are held by links on the outside of a roller or the like.

13 Claims, 9 Drawing Figures

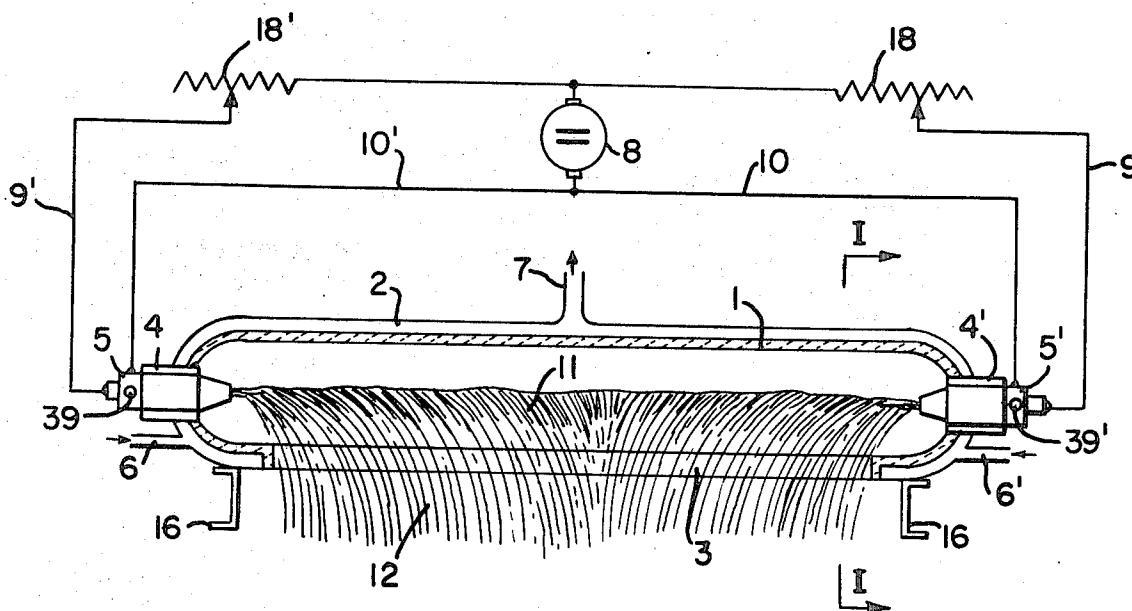


FIG. 1

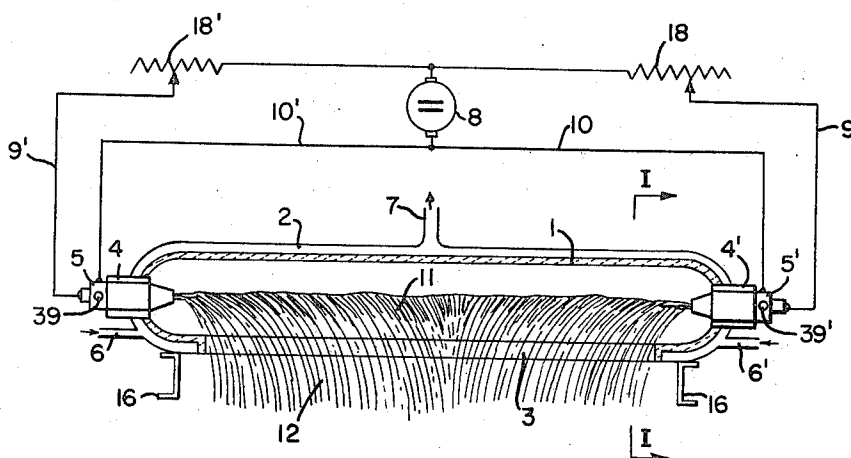


FIG. 2

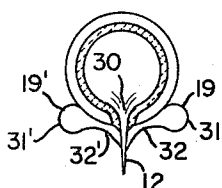


FIG. 3

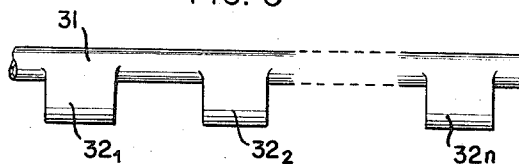


FIG. 4

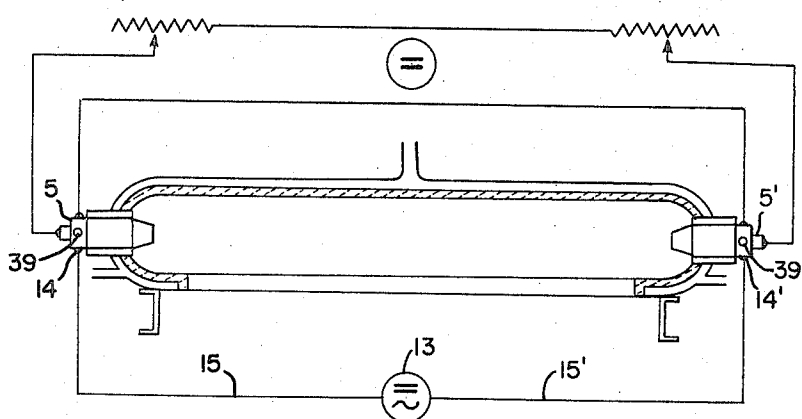


FIG. 7

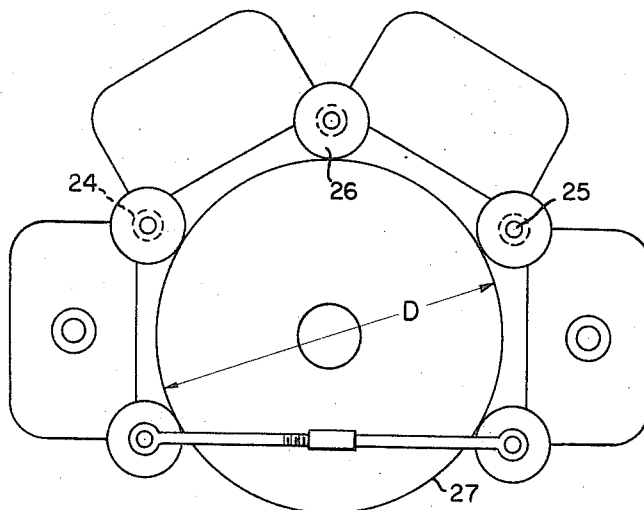


FIG. 9

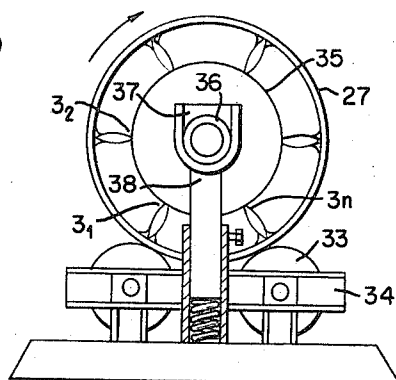
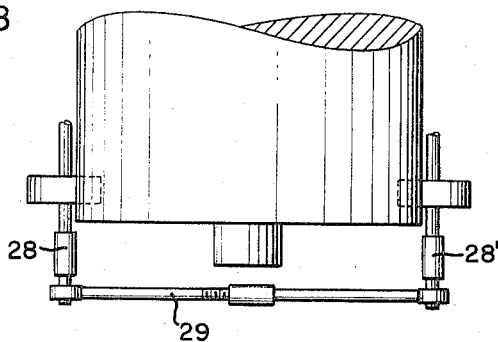


FIG. 8



PLASMA CURTAIN OF TWO OR MORE PLASMAS

DISCLOSURE OF INVENTION

The present invention relates to a process and apparatus for producing a plasma curtain. A divisional application is being filed on a process for producing a thick wall tube from a thin wall tube.

Industries active in treating and coating large surfaces, in metallizing strips continuously, in overlaying metal layers on large mechanical parts and the like by techniques using high temperatures have been led by the necessities of production and the requirements for obtaining high production to consider plasma processes and equipments where the flame or arc takes the shape of a curtain.

This refers to processes, as for example described in Belgian patent No. 730,815, which solve at one stroke the task accomplished by one plasma torch in time-consuming steps. This latter process involves the striking of a plurality of arcs from a corresponding number of standard torches held side by side, to trace one or more continuous straight lines or curved lines, in V-shape or parallel or in some other way. Despite the slight linear pulsation of the curtain of plasma jets produced, this process remains the prototype in the field of producing plasma curtains.

Later on, it was observed that the process could be improved by equipment in which the cathode is shaped like a broad knife while the anode is matching in linear shape of the knife. In this device, the plasma flame is supposed to have the same width as the anode. In fact, however, the arc struck between these two electrodes is concentrated at only two points of preferred impingement, one on the cathode and the other on the anode, so that the expected result cannot be achieved. One means has been discovered to solve this problem. It consists in moving the anodic and cathodic impingement spots along the width of the electrodes at suitable frequencies by mechanical, electrical or magnetic means. Despite encouraging results obtained by this solution, the latter does not appear to have a great future because the attempt is costly and cumbersome.

In the present invention, two plasma jets facing one another at opposite ends of a chamber produce two plasmas which join. These combined plasmas are pushed along sideways through at least one elongated nozzle by the pressure of the plasmagenic gas producing a flame projected outwardly which nozzle is shaped as one or more blades, which may be parallel, divergent or convergent. The space in which the plasma is formed is surrounded by a cooling jacket. The torches themselves may be actuated by a single source of direct current or may have superimposed on the plasma direct or alternating current to further heat the plasma (Sunnen, U.S. Pat. No. 3,205,338, granted Sep. 7, 1965 for EQUIPMENT FOR FORMING HIGH TEMPERATURE PLASMAS and Sunnen, U.S. Pat. No. 3,248,513, granted Apr. 26, 1966 for EQUIPMENT FOR FORMING HIGH TEMPERATURE PLASMAS).

There may be several containers surrounding several spaces in which plasma curtains are produced and the containers may be contained within a common cooling jacket for all of the containers. On the other hand all of the containers may be mounted on a cooling carriage. The containers may also be separated and articu-

lated by hinges connected as for chain links. Also a single container may provide plasma curtains which issue through several slots, the container being rotated to distribute the curtains outwardly. In one embodiment the plasma curtains may be applied on the inside and outside of a thin walled tube or tubular container to overlay it internally and/or externally.

The process of the invention overcomes the difficulties encountered in these prior methods, and it also has the advantage of being simpler. It consists in producing one or more plasma flames by the use of at least one pair of jets which meet along one alignment or several parallel alignments so that the twin arcs obtained are pushed laterally by the pressure of the plasmagenic gases across at least one elongated nozzle, from which one or more blades of plasma flame emerge.

The description of the invention covers only a few of the forms, and has been selected to present a clear view and precise idea of the invention and its advantages which may not be clear from the preceding description. In the examples identical or similar concepts are referred to by the same reference characters.

FIG. 1 is a partial longitudinal schematic axial cross-section of the device of the invention showing the simplest form.

FIG. 2 is a transverse section on the line I—I of the equipment of FIG. 1.

FIG. 3 is a partial schematic longitudinal elevation of the equipment for implementing the process of FIGS. 1 and 2, showing particularly the means of applying the overlaying materials.

FIG. 4 is a partial schematic axial section similar to FIG. 1, showing one of the units of a group with modifications.

FIG. 5 is a partial schematic axial section, oriented in horizontal top plan of a further embodiment of the invention in which the containers are mounted on a carriage.

FIG. 6 is a schematic top plan view of the embodiment shown in FIG. 5.

FIG. 7 is a vertical end elevation of a further embodiment of the invention.

FIG. 8 is a partial top plan view of FIG. 7, showing the end construction.

FIG. 9 is a vertical end elevation partially in cross-section of another embodiment of the invention.

In the embodiment of FIG. 1, a container has a refractory liner 1 surrounded by a cooling jacket 2. The container is suitably cylindrical and has a longitudinal slot 3 which is quite narrow and parallel to the long axis of the container with two apertures 4 and 4' respectively at opposite ends to receive two plasma torches 5 and 5'. The torches are supplied with direct current from a power source 8, and they are fed by inlets 39 and 39' with plasmagenic gas reaching the inner passages of the torches. The container may be of larger or smaller diameter and where desired to reduce the loss of heat, it may approach in diameter the width of the slot.

Electric conductors 9 and 9' and 10 and 10' connect the torches to the power source, and variable resistors 18 and 18' are inserted in conductors 9 and 9'. It goes without saying that several individual sources may be used instead of a common source to energize the pilot arcs of the torches.

The access of the cooling fluid into the jacket 2 is obtained by inlets 6 and 6' and an outlet 7. A frame 16

underneath acts as a support. As soon as the electrical current is fed through the torches, the arcs are struck and since the plasma torches face one another, the arcs meet in the chamber, forming a common arc 11. Under the pressure created in the container by the plasma-
 5 genic gas entering inlets 39 and 39', the common arc 11 is expelled sideways with respect to the major axis of the container through slot 3, shaping itself as a continuous blade 12.

When an overlay of materials is desired on a surface
 10 to be treated so that the deposit distribution is even, the slot is provided with injecting manifolds 19 and 19' on either side of the orifice 30 as shown in FIG. 2. These manifolds project either a running powder of suitable grain size such as a metallic oxide powder, or a liquid
 15 or gas reacting with the plasmagenic gas to form a solid compound adhering to the surface being treated. The manifolds 19 and 19' illustrated schematically in FIG. 2 consist as shown in FIG. 3 of tubes 31 and 31' provided with a number of flat outlets 32 and 32' . . . 32_n
 20 and 32_n' aligned in the same plane and having suitable shape to direct the flame of ingredients into the plasma. These manifolds are described as mere examples and do not represent the only manner of bringing powder into the plasma. Regarding the distribution of plasma-
 25 genic gas and/or secondary gas, it should be noted that these gases will tend to change the temperature distribution in the plasma curtain.

The device illustrated in FIG. 4 differs from that described in FIGS. 1 and 2 in that a source 13 is connected to terminals 14 and 14' by conductors 15 and 15'. This superimposes an arc heating current supplied
 30 by an AC or DC power source on the plasma curtain.

FIG. 5 is a schematic view suitably in plan section of
 35 equipment in which several plasma curtains are produced in several containers simultaneously. It consists of a single housing 17 containing several identical containers side by side with their major axis parallel and each container being constructed according to FIGS. 1 and 2 or FIG. 4. The cooling jacket 2 and the electrical
 40 circuits 9, 10 and 15 are common to all of the units and are connected by multiple conductors 9₁, 10₁, 15₁ . . . 9_n, 10_n, 15_n in parallel. Switches 20₁, 20₂ . . . 20_n allow some units to be disconnected at will. Adjustable resistors 18₁, 18₂ . . . 18_n are inserted in the conductors 9₁, 9₂ . . . 9_n. It will be seen that each of these containers has its slot directed in the same direction, and each slot is parallel to each other slot in this embodiment.

As shown in FIG. 6, the carriage which can be like
 50 FIG. 5 is supported on four caster wheels or rollers 21 which roll on tracks 22 and 23 to guide the carriage along the plate or other substrate. The maximum area S which can be treated in one operation is expressed by the length *l* of one slot multiplied by the total span of the slots plus one spacing *d* between two consecutive slots. The distance of a leading slot to the lagging slot is D:

$$S = l (D + d)$$

The time required to treat the entire surface of a plate
 60 equals as many times the time required for one operation as the entire surface bears to S, the length of the plate being instrumental for each application in designing the length D as a non-fractional divider of the entire plate length. This can be done by cutting off one or
 65 more units electrically by means of the switch. It is obvious that the units of the multiple group can be built

to embody any of the forms shown in FIGS. 1 to 4. They are then bolted by attachment lugs which are provided to a single rolling carriage, to fit the proper number of units best adjusted to the given length of the
 5 plates to be treated or conversely to elect the plate length as a multiple of $D + d$.

In another form of execution of the invention as shown in FIGS. 7 and 8 and intended to overlay rolling mill rolls, the units are articulated to each other by
 10 hinges 24 to form a chain having large links. The hinges have extended shafts 25 carrying freely wheels 26 bearing upon the surface of the mill roll 27 and rotating around it. The number of units is such that the development of the chain is greater than $\pi D/2$ while the end links are connected by turn-buckles 29 to the shaft
 15 extensions 28 and 28' to tighten all of the wheels 26 so that they engage the outside of the work as shown in FIG. 8.

The equipment shown in FIG. 9 is designed to treat
 20 the inside surface of a tube or conduit 27. It consists in a flame container as shown in FIGS. 1 to 4 except that several slots are provided radially around the circumference, preferably distributed uniformly instead of a single slot. These slots are identified by 3, and 3₂ . . .
 25 3_n. The tube which is the work is supported on rollers 33 of a rotary positioner 34 while the plasma container 35 is mounted coaxially of the tube upon pivot cups 37 suspending it by axial trunnions 36 on posts 38 at the
 30 opposite ends of the positioner, the posts being adjustable by jacks as shown. One of the rolls 33 which rotates the work 27 is driven by a motor and speed reducer not shown at a suitable speed.

The treatment operation begins by starting the motor
 35 and speed reducer and starting simultaneously the plasma torches engaging the clutch on the speed reducer. After $1/n$ turn has been rotated, the entire surface of the tube has been treated and the motor and speed reducer are stopped unless it is proposed to apply
 40 more than one overlay layer. When simultaneous surface treatment is required on both the inside and the outside of the tube, it is required, for economy, to use simultaneously the equipment shown in FIGS. 7 and 8 on the one hand and FIG. 9 on the other hand, provided the number of units of the type of FIGS. 7 and 8
 45 is adequate for the area treated. One or the other of these equipments can be used to produce heavy wall tubes starting by overlaying thin wall tubes.

The shape of the flame or curtain of plasma can be
 50 modified at will by acting on the flame by a magnetic field reacting upon the ionized gas according to the Lorentz laws.

The process per the invention may still be used advantageously as a process of de-pollution, disinfection
 55 or de-bacterization of moving air or water, for example.

In this case the secondary gas propelled through the plasma is oxygen which is transformed in the plasma to ozone. The de-bacterizing effect results from the combined action of this ozone with ultraviolet radiation
 60 also produced by the plasma.

In view of my invention and disclosure, variations and modifications to meet individual whim or particular need will doubtless become evident to others
 65 skilled in the art, to obtain all or part of the benefits of my invention without copying the process and apparatus shown, and I therefore claim all such insofar as they fall within the reasonable spirit and scope of my claims.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. A process of producing at least two plasmas, which comprises projecting opposed plasmas into a closed space to meet in the space and from a common arc, and expelling the combined plasmas from the closed space sideways with respect to their original direction under the pressure of a plasmagenic gas through at least one nozzle elongated in the sideways direction and thus producing a flame projecting outward through the elongated nozzle as at least one blade of a continuous plasma jet.

2. The process of claim 1, which comprises projecting at least two blades of continuous plasma jet through at least two such elongated nozzles.

3. The process of claim 2, in which the elongated nozzles are parallel to one another.

4. The process of claim 2, in which the elongated nozzles are divergent from one another.

5. The process of claim 2, in which the elongated nozzles are convergent to one another.

6. A device for producing at least two plasmas which comprises a closed container, a cooling jacket around the container, the closed container having an elongated nozzle therein and having opposite apertures therein and in which the nozzle is located in sideways position, opposed plasma torches inserted in the opposite apertures facing each other, said torches having anodes and cathodes, means for connecting the anodes and cathodes to a source of direct current, and means for projecting plasmagenic gas through the plasma torches.

7. The device of claim 6, in combination with means for connecting said plasma torches to an additional source of electric current.

8. The device of claim 7, in which the additional source of electric current is a source of alternating current.

9. The device of claim 7, in which the additional source of electric current is a source of direct current.

10. A device for producing at least two plasmas, which comprises a plurality of closed containers each provided with an elongated nozzle and with two opposite apertures therein and in which the nozzle is located in sideways position, plasma torches inserted in the op-

posite apertures facing each other and having anodes and cathodes, a common source of direct current for energizing each plasma torch, means for projecting plasmagenic gas through each plasma torch, the containers being arranged parallel to each other, a common cooling jacket surrounding the containers and a rolling carriage mounting the containers.

11. A device for producing at least two plasmas, consisting of a plurality of containers each provided with an elongated nozzle and with two opposite apertures therein and in which the nozzle is located in sideways position, a cooling jacket for each container, opposed plasma torches inserted in the apertures of each container facing one another, said torches having anodes and cathodes, means for connecting the anodes and cathodes to a common source of electric power, means for projecting plasmagenic gas through the plasma torches, and a rolling carriage mounting each of the containers with the elongated nozzles parallel to one another.

12. A device for producing at least two plasmas, comprising a plurality of containers each provided with an elongated nozzle and with two opposite orifices therein and in which the nozzle is disposed in a sideways direction, a cooling jacket for each container, plasma torches inserted in each orifice facing one another, the plasma torches having anodes and cathodes, means for connecting the anodes and cathodes to a source of direct current, means for passing plasmagenic gas through the plasma torches, links connecting the containers forming a chain and hinges integrating the links together.

13. A device for producing at least two plasmas, comprising a chamber provided with a plurality of elongated nozzles from the chamber oriented in a sideways direction and with opposite apertures therein at the ends thereof, a cooling jacket for the chamber, plasma jets inserted into the apertures facing one another and having anodes and cathodes, means for connecting the anodes and the cathodes to a source of direct current, means for projecting plasmagenic gas through the plasma torches, and means for rotating the chamber about an axis disposed between the opposite apertures.

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