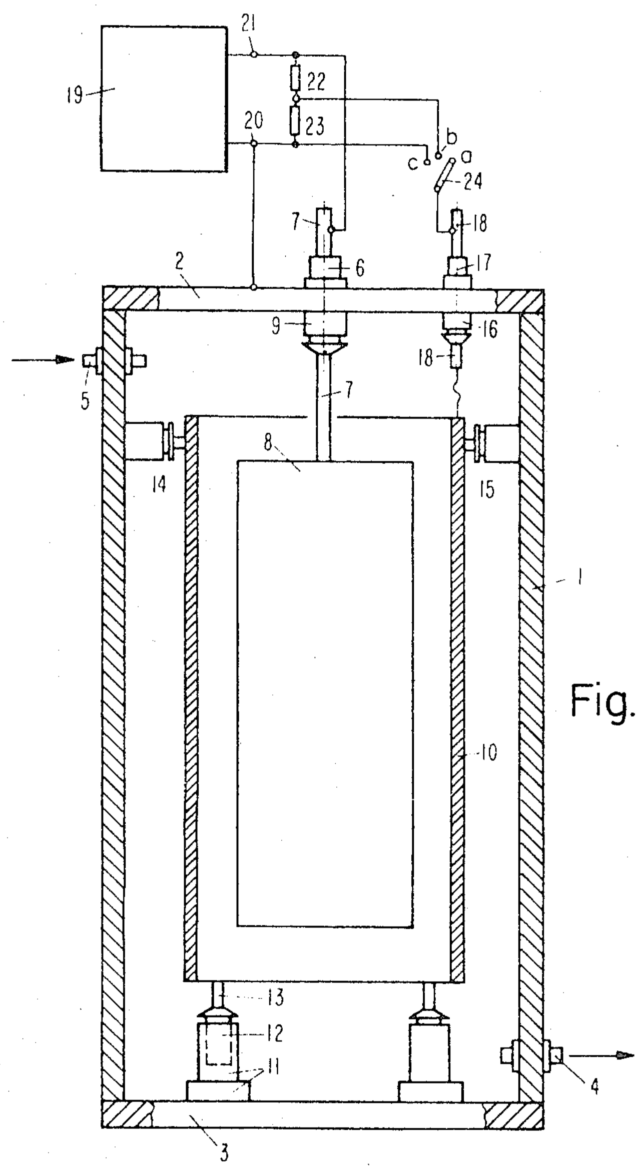

Fig. 1

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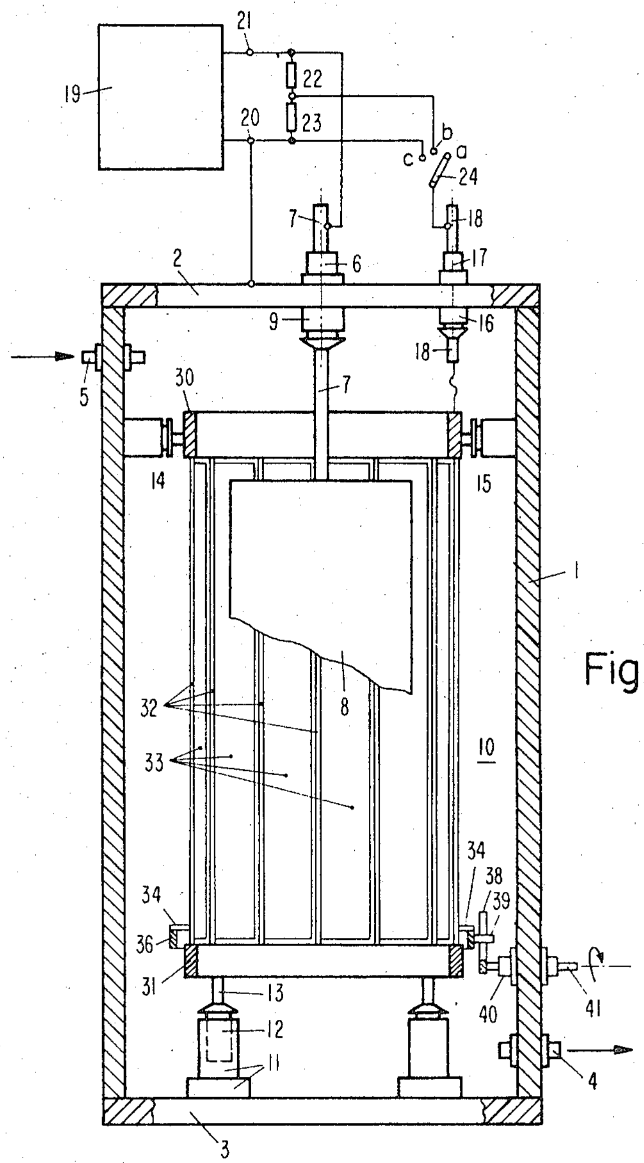

Fig.2

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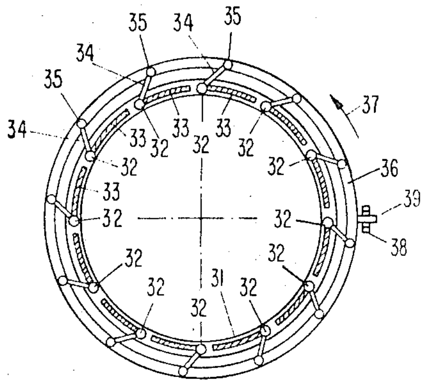

Fig. 3

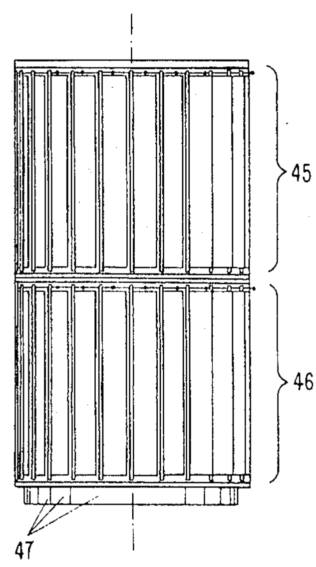

Fig. 4

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3,730,863

METHOD OF TREATING WORKPIECES IN A GLOW DISCHARGE

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Int. Cl. C23c *11/16*
U.S. Cl. 204—164 5 Claims

ABSTRACT OF THE DISCLOSURE

In nitriding ferrous workpieces in a glow discharge the workpiece and the container constitute the glow discharge electrodes during normal operation. A third electrode is positioned between the workpiece and container and is provided with a heat reflecting surface facing the workpiece. During starting, the third electrode is held at a potential lower than that of the container to provide a low energy glow discharge to the workpiece and is later connected to the container to be at the same potential.

The present invention relates to a method of treating workpieces, particularly of iron and steel, in a metal container in a gas atmosphere by means of a glow discharge. The workpieces at least temporarily form the cathode and the metal container the anode. In addition, a supplementary metallic electrode which shields the workpieces against the container is provided.

This invention further relates to a device for the performance of the said method.

A number of processes for the treatment of workpieces in a glow discharge in a gas atmosphere are know, by way of example for nitriding workpieces made or iron and steel in a nitrogenous gas atmosphere. The workpieces there constitute the cathode and are connected to the negative pole of a source of current which may be adjusted, by way of example, within the range from 400 to 1,500 volts and which has its positive pole connected to the metallic container which thus forms the anode. If an alternating or a three-phase current source is employed, the workpieces at least temporarily constitute the cathode of the glow discharge. In such a treatment, the workpieces normally assume a temperature, by way of example within the range from 450 to 550° C. or more, so that it has proved to be of advantage to reduce the temperature radiation absorbed by the commonly rough interior of the container wall by arranging a supplementary metallic electrode within the container and connected thereto in order to ensure improved reflection of the impinging thermal radiation. The electrode shielding the workpieces from the container wall naturally has the same potential as the container itself.

For the treatment of workpieces at an elevated temperature in a glow discharge it has proven to be necessary initially to perform a so-called starting process in a first space of time as described in greater detail in U.S. Pat. No. 2,884,511, assigned to the assignee of the present case.

To begin with, a glow discharge was ignited with a relatively low voltage while strongly reducing discharge energy and taking appropriate measures to prevent the glow discharge from changing into an arc so that the traces of burning and melting caused by the area of impact of such an arc could be avoided. The starting process must be continued with rising energy until all imperfections present on the surface of the workpieces, such as traces of grease and dirt, gas inclusions, shrink holes and the like, are eliminated and the workpiece has reached the temperature required for the performance of the desired treatment. It is only after this first period that the treatment with the full energy of discharge commonly

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begins through a second period, the treatment process proper.

The performance of such processes, particularly for the metallurgic treatment of workpieces, is effected in accordance with the said considerations on a broad industrial level and with satisfactory results. The cost of a fully automatic control of the starting and treatment processes is, however, considerable since particularly the gradual increase of voltage and energy during the starting period, the protective measures in the supply circuit for the stabilization of the discharge and the prevention of arc flashover and the brief disconnection of the current source in the event of major disturbances in the discharge by the automatic control must be adjusted to one another.

The present invention has for its object the simplification of the performance of such processes and relates to a method of treating workpieces, particularly made of iron and steel, in a metal container in a gas atmosphere by means of a glow discharge, in which the workpieces form the cathode and the metal container the anode at least temporarily and in which an additional metallic electrode is arranged which shields the workpieces from the container. The method is characterized in that this additional electrode is operated, during a first space of time, with a lower potential than the container and that a glow discharge is maintained between it and the workpiece until the imperfections of the surfaces of the workpieces have been removed whereupon, during a second space of time, the electrode is electrically connected to the container and the glow discharge maintained between it and the workpieces is run with the greater energy required.

This invention further relates to a device for the performance of this method using a container made of metal in which the workpieces to be treated are insulatedly arranged and connected to a pole of a voltage source which is at least temporarily negative, via an insulated current lead-in, the other pole of the said voltage source being connected to the container. The device is characterized by an additional metallic electrode located between the workpieces and the container wall which shields the workpieces, the said electrode being insulated in respect of the container and connected, via an insulated current lead-in, with a switching device located outside the container.

A number of embodiments of the invention will now be described in greater detail with reference to the attached drawings Nos. 1 through 4 in which:

FIG. 1 is a longitudinal section of an embodiment of a device according to this invention;

FIG. 2 is a further embodiment of a device;

FIG. 3 is a diagrammatic plan view of the electrode **10** in FIG. 2, and

FIG. 4 is a diagrammatic elevation of a further embodiment of the electrode **10** in FIG. 2.

The device according to FIG. 7 comprises a metallic container **1** preferably made of iron, shown in a diagrammatic longitudinal section, and closed by a metallic cover **2** and a base plate **3**. Connected to a suction connection **4** communicating with the interior of the container is a pump unit which maintains a predetermined underpressure, by way of example inferior to 10 mm. Hg, while a gas supply connection **5** delivers the gas mixture desired for the contemplated treatment to the container. Arranged in the cover **2** as a lead-in is a metal rod **7** enclosed by the insulating sheath **6** and insulated relative to the cover **2**, the said rod **7** carrying the workpiece **8** which is here a cylinder made of iron or steel. The portion of the insulating sheath **6** extending into the container is provided, in the known manner, with a metallic shield **9** which is connected to the cover **2** on the one hand and, on the other, forms a protective gap together with the rod **7** in the known manner, the said gap preventing the penetration of the glow discharge towards the insulation **6**. This current lead-in **6**, **7** and **9** is naturally fitted to the cover **2** so as to be gas-tight.

Arranged within the container **1** is an additional electrode **10** which shields the workpiece **8** from the wall of the container and which here possesses, by way of example, cylindrical shape and is arranged coaxially with the cylinder **8**. This additional electrode **10** is insulated relative to the container wall on all sides. By way of example, the electrode **10** rests, on several insulating components, on the base plate **3** of the container **1** of which only two are indicated in the drawing. Such insulating supporting members are known (Swiss Patent 354,871) and may consist of a metallic sleeve **11** attached to the base plate **3** and carry an insulating tube **12** projecting over the lower rim of the metal sleeve **11** and holding a metal rod **13** attached to the electrode **10**. This rod **13** forms, together with the upper rim of the metal sleeve **11**, a gap in the known manner so as to prevent the entry of the glow discharge as far as the insulating tube **12**. Since such insulating supports are known, a more detailed description may be dispensed with. The electrode **10**, which is here cylindrical and open at its upper and lower ends so as to facilitate the access of gas to the workpiece **8**, has its upper end advantageously propped against the inside wall of the container by means of supporting members **14**, **15**. Such insulating supporting members are known as well (Swiss Patent 373,114) so that a more detailed description may be dispensed with. At all events the electrode **10** must on all sides be electrically insulated relative to both the container **10** and the workpiece **8**.

This additional metallic electrode **10** is connected to a current lead-in consisting of the metal sleeve **16**, the insulating tube **17** and the metal rod **18**, the said lead-in being arranged in gas-tight relationship with the cover **2** of the container **1**.

For the purpose of producing and maintaining a glow discharge in the container **1**, a current source **19** is provided which may, by way of example, supply a direct voltage gradually or continuously adjustable between 400 and 1500 volts which should supply a power of about 50 kw. for the treatment of workpieces with a surface of up to 5000 cm.^{2}. The positive pole **20** of this curent source **19** is commonly connected to the container, here to the cover **2**, while the negative pole **21** is connected, via the metal rod **7**, to the workpiece **8** which in the present case thus permanently forms the cathode of the glow discharge obtained. In the present embodiment, the connections **20** and **21** of the current source **19** are additionally provided with a voltage divider and the metal rod **18** connected to the additional electrode **10** is equipped with the switch **24** having the three positions (a), (b) and (c). In the position (a) of the switch **24**, the additional electrode **10** is without exterior connection and is thus fully insulated in the container **1**. On the other hand, in position (b) of the switch **24**, the electrode **10** is connected to the central tap of the voltage divider **22**, **23** and thus has a lower potential than the container **1** connected to the positive pole **20** of the current source **19**. In position (c) of the switch **24** the electrode **10** is also connected to the positive pole **20** of the current source **19** and is thus under the same potential as the container **1**.

The device according to the embodiment disclosed enables workpieces to be treated in any atmosphere desired within the container **1** according to a simplified process. During the first space of time required for the commencement of the treatment, the so-called starting process, the switch **24** may e.g. be placed in its position (a). The electrode **10** is then without any electrical connection with the container **1**; nonetheless a glow discharge, though weak, occurs between the container wall and the workpiece **8**, the said glow discharge producing a plasma within the container. This plasma results in that the electrode **10** assumes a certain positive potential and that a glow discharge of comparatively low energy is obtained between the electrode **10** and the workpiece **8**. The intensity of the current of discharge for this weak glow discharge in the said first space of time, however, is limited by the fact that the electrode **10** in its turn obtains the current of discharge, via the plasma, from the walls of the container **1**. So if imperfections of the surfaces of the workpiece **8** cause a tendency of the glow discharge towards arcing, such arcing cannot form because the current necessary therefor is not supplied by the electrode **10** and the potential of the electrode **10** drops accordingly, possibly causing a brief interruption of the glow discharge. This behaviour of the electrode **10**, which is supplied only by the plasma in the container **1**, has for a result, during the first space of time, that no arcs or flashovers to the workpiece **8** occur owing to the weak energy of the glow discharge and that all imperfections of the workpiece surfaces are removed in the course of time without the hazard of the appearance of traces of burning or melting. Naturally the presence of the electrode **10**, which has its inside preferably provided with a polished surface results in that heat radiated from the workpiece **8** is largely reflected back to the said workpiece so that the comparatively low energy of discharge will already suffice to heat it to an elevated temperature. If the energy of discharge, however, does not suffice to achieve the treatment temperature of the workpiece **8**, the switch **24** may be turned, by way of example, to its position (b) in which the electrode **10** obtains a potential dependent on the ratio of the resistances **22**, **23** and lower than that of the container **1**, appropriate selection of the resistances **22**, **23** making it possible for the energy of discharge to suffice to raise the workpiece **8** to the necessary temperature.

Upon termination of the first space of time and removal of the imperfections of the workpiece surface, the switch **24** may then be thrown into its position (c) in which the electrode **10** receives the same potential as the container **1** and is directly connected to the positive pole **20** of the current source **19**. The treatment of the workpiece **8** can then be performed in the glow discharge at full energy.

Experience has shown that care must be taken, also during the second period of the treatment of the workpiece **8** at full energy, that, in the event of a sudden appearance of a disturbance in the glow discharge, a sudden change into an arc is avoided, i.e. that the current source **19** has its voltage briefly reduced or is completely disconnected. To this end, various types of so-called fast-action switches are known, by way of example a fast-action switch (Swiss Patent 499,825) monitoring the working point on the current-voltage characteristic of the discharge process.

In the present method, such a fast-action switch may advantageously be employed to actuate the switch **24** from its position (c) into the position (b) or (a) so that the energy of the discharge caused between the workpiece **8** and the electrode **10** is substantially reduced and a rise of the current of discharge to the value necessary for the formation of an arc or flashover is prevented. This measure, which necessitates merely a switch-over of the connection of the electrode **10** must more readily be taken than the disconnection of the current source and can naturally be effected inertialessly if the mechanical switch **24** shown diagrammatically is replaced by an electronic switch of known design.

The present method, in conjunction with the additional electrode **10**, however enables the power delivery to the workpiece **8** to be particularly simply adjusted during the treatment process proper. It is usual for the temperature of the surface of the workpiece **8** treated to be monitored by incorporated thermocouple elements or other measuring instruments and the operating voltage of the current source **19** to be so influenced that the prescribed temperature is maintained within the tolerances given. This monitoring and influencing of the workpiece temperature can be substantially simplified in the present method in that the switch **24**, which is in its position (c) during the actual treatment process is thrown to position (b) or (a) when the workpiece temperature rises inadmissibly until the said temperature has again reached the predetermined level, whereupon the switch **24** is again thrown to position (c). Such switching may as well be effected by known electronic means, virtually inertialess and at very little expense.

In the embodiment of the present method above described with reference to FIG. 1 and the device therefor, a direct current source **19** is indicated. The method is naturally not limited thereto but may be performed in the same manner using an alternating current source. For certain purpose three workpieces are treated simultaneously in a common container, the said workpieces being supplied by the three phases of a three-phase current source of which the neutral point is connected to the container; in that case, too, the present method may be performed. If indicated, only a single additional electrode need be arranged in the container which effects shielding of the three workpieces from the container and is used to control the discharge energy analogously with the method above described.

In the embodiment of the device according to FIG. 1 a voltage divider formed by the resistance **22, 23** is provided between the poles **20, 21** of the current source **19**; if so desired, voltage division may be dispensed with and the resistance **22** omitted so that only the series resistance **23** is located in the circuit of the electrode **10**. Mention should also be made of the fact that, in the operation with direct current as shown in FIG. 1, glow discharge does not occur at either the additional electrode **10** or the container wall; for this reason the insulating supports **11, 12, 13** and **14, 15** may also be simplified and designed without a protective gap system.

FIG. 2 shows a different embodiment of the device disclosed with reference to FIG. 1, similar components being designated by the same reference numerals. In contradistinction to FIG. 1 the additional electrode **10** is here designed as a cage and, in the present embodiment, consists of the upper and lower metal rings **30** and **31** both shown in section and twelve metallic connecting bars **32** rotatably attached to the said metal rings **30, 31**. Each connecting bar **32** carries a metallic wing **33** which, in the position of the connecting bars **32** shown in FIG. 2, form a metallic cylinder which is as closed as possible. Rotation of the connecting bars **32** enables the individual wings **33** to be swung outwards. As shown in FIG. 3, each of the twelve connecting bars **32** can therefore be turned by means of its own rigid lever **34** and a pivot bearing **35** with the adjusting ring **36** of which movement in the direction of the arrow **37** causes all wings **33** to be swung out.

In the device shown in FIG. 2, actuation of the adjustment ring **36** in operation is contemplated to which end a pin **39** is provided on the adjustment ring **36** which projects into the gap between the two prongs of a fork **38** which can be rotated by means of the shaft **41** through a lead-in **40** which is electrically insulated relative to the container **1**. This is how the wings **33** can be swung more or less in operation, from the one extreme position shown, to the other extreme position in which all wings **33** are almost radially disposed.

In the first space of time of treatment above described, the wings **33** of the additional electrode **10** are advantageously positioned tangentially so as to form, together with the connecting bars **32**, an almost closed cylindrical surface. Since the wings **33** advantageously have a polished surface inside, the heat radiated from the workpiece **8** is largely reflected back to the same so that the relatively small energy of discharge suffices to bring the workpiece **8** to the desired temperature. If it proves to be of advantage to reduce the reflecting surface of the electrode **10**, the wings **33** may be swung out more or less from their tangential position. However, it should at all times be ensured that the glow discharge occurs largely between the workpiece **8** and the electrode **10** and not on the inside of the container **1**.

Thanks to the wings **33**, which are highly heat-reflecting in their tangential position, the workpiece **8** is treated with the least possible consumption of energy since only such energy need be supplied as ensures the maintenance of the prescribed elevated temperature of the surface of the workpiece **8**. However, it may sometimes be desirable to increase the energy without raising the temperature of the surface beyond the desired level in order to obtain particular metallurgical effects by an increased ion bombardment of the surface of the workpiece, by way of example to achieve a greater nitrogen supply in ionitriding. This is rendered possible by the electrode **10** with its adjustable surface in that the wings **33** are swung more or less into a radial position from the tangential position by rotation of the shaft **41**. Depending on the position of the wings **33** heat reflection by the electrode **10** is reduced so that the necessary increase in the energy of discharge must be effected for the maintenance of the prescribed temperature of the workpiece surface.

In the operation of a device indicated in FIG. 2 it has been found that, by way of example, in ionitriding large workpieces made of iron in a nitrogenous gas atmosphere, the energy of discharge necessary to maintain a surface temperature of 510° C. varies in the range of 1:3 to 1:5, depending on the position of the wings **33** of the electrode **10**. More particularly, with large containers of 3 to 5 $m.^3$ volume and in the treatment of correspondingly large individual workpieces or a corresponding number of smaller workpieces in such containers, it has been found to be of advantage to adjust the energy supplied by the workpieces by heat radiation to a constant value by means of an adjustable additional electrode of the design described. Otherwise, the said heat losses may be quite variable since they depend on the radiating capacity of the workpiece surface and, respectively, the inside of the container so that treatment must be effected with correspondingly different energies of discharge, which may result in quality differences in the workpiece surfaces. While treatment has previously been effected at a prescribed surface temperature of the workpieces and the energy of discharge accordingly adjusted, the present device enables both the temperature and the energy of discharge to be prescribed and the maintenance of temperature to be ensured by modification of the heat reflection of the additional electrode.

The additional electrode, which may have its surface adjusted, may naturally be employed also if the device is run, as previously described, on alternating or three-phase current.

A further embodiment of an additional electrode **10** with a plurality of adjustable surface sections is shown diagrammatically in FIG. 4. The additional electrode here consists of two superposed groups **45** and **46** formed of adjustable wings which are designed in a manner similar to that shown in FIGS. 2 and 3, i.e. of wings attached to rotatable bars. With this design the wings of the groups **45** and **46** may be provided with adjusting means which can be separately actuated. Further wings **47** may be provided which can be adjusted independently of the two groups **45** or **46**, such wings enabling more or less intense reflection of the bottom of the container to be obtained.

In the embodiments disclosed the adjustment of the wings of the additional electrode is effected via a fork **38** insulatedly passed through the container wall located on the shaft **41**. Other suitable actuating means are naturally possible. By way of example, the shaft **41** need not be electrically insulated relative to the container **1** if the pin **39** is formed of an insulating material or if the fork **38** is replaced by an eccentrically designed disc formed of a nonconductive material. It is also possible to employ adjustment means which are magnetically operated.

The wings of the additional electrode shown in Figs. 2 through 4 are represented as curved shells which, in their tangential final position, form a largely closed cylinder electrode together. In the presence of a sufficiently large number of wings or of a sufficiently large diameter of the additional electrode, flat wings may naturally be employed as well.

What is claimed is:

1. A method of treating workpieces, particularly workpieces made of iron and steel, by nitriding in a metal container in a nitrogenous gas atmosphere by means of a glow discharge in which the workpieces at least temporarily form the cathode and are heated to the treatment temperature by the ion bombardment of the glow discharge and the metal container forms the anode while an additional metallic electrode is arranged between and insulated from the container and the workpieces so as to shield the workpieces from the container, characterized in that this additional electrode is provided with a heat reflecting inner surface and is operated at a potential lower than that of, the container and that a low energy glow discharge is maintained, in a first space of time, between the said additional electrode and the workpieces until the surface imperfections of the workpieces have been removed and that, during a second space of time, the electrode is electrically connected to the container and the glow discharge between the said electrode and the workpieces is run at the necessary greater energy.

2. A method according to claim **1** characterized in that

the additional electrode is electrically separated from the container during the first space of time.

3. A method according to claim **1** characterized in that, during the second space of time, the electrical connection between the electrode and the container is broken during an adjustable interval of time whenever the energy of the glow discharge must be reduced.

4. A method according to claim **1** characterized in that the heat-reflecting surface of the additional electrode is altered between a maximum and minimum value by a swinging motion of surface members of the electrode from a tangential position toward a radial position.

5. A method according to claim **4** characterized in that a plurality of surface components of the additional electrode are simultaneously displaced in the same direction to alter said heat-reflecting surface.

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U.S. Cl. X.R.

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