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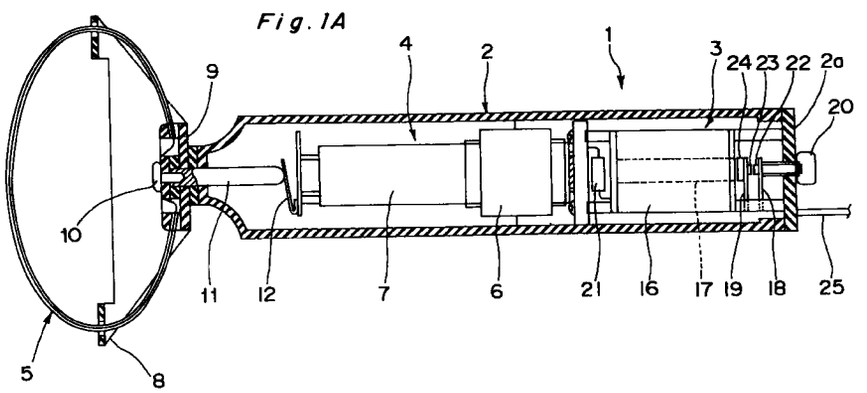
(54) Small-sized atmospheric plasma generating apparatus and surface processing method using the apparatus

(57) The plasma generating apparatus (1) is provided with a simple switching circuit (3) for generating AC power of high frequency by a magnet (16) for switch driving use for repeating the excitation and the demagnetization by AC power and a contact switch (S) to be opened or closed by the magnet (16), a simple voltage transforming circuit (4) for converting AC power of high frequency outputted from the switching circuit (3) into AC power of high voltage, a discharge electrode (5) for receiving AC power of high frequency and high voltage outputted from the voltage transforming circuit (4) to cause corona discharging, when the opposite electrode has been approached, to cause the plasma. The plasma producing apparatus (1) is easier to be carried, because the switching circuit (3), the voltage transforming circuit (4), and the discharge electrode (5) are respectively simple, compact in construction. The apparatus (1) becomes smaller in power capacity and is reduced in cost.

Fig. 1A



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Description

BACKGROUND OF THE INVENTION

1. Field of the invention

The present invention relates to a small-sized portable atmospheric plasma generating apparatus of a handy type, and to a surface processing method including the step of performing plasma processing onto a surface of various types of objective things to be processed with the use of the plasma generating apparatus so as to improve the quality of the surface, and to improve various surface characteristics such as adhesive property, adherence property and so on of the surface.

2. Description of the prior art

In general, when a certain member is adhered to a surface of an objective thing formed of resin, paper, aluminum, cloth, iron or the like by using an adhesive, when paint is applied to the surface or when printing is performed to the surface, surface processing is performed to the objective thing to be processed in order to improve the adhesive property of the adhesive or the paint onto the surface of the objective thing, the printing characteristics of printing ink, the clouding preventing property of the surface, the washing property of the surface or the friction characteristics of the surface or the like. Conventionally, as such a surface processing operation, there has been widely used plasma processing, in which the surface is improved in quality by applying plasma caused in air by corona discharging onto the surface of the objective thing to be processed. The plasma processing is disclosed in, for example, the article "Corona surface processing" described on pages 24 through 30 of No. 4, Volume 35 of magazine "Technology of Adhesion & Sealing" issued by Kobunshi kanko-kai, 1991.

In the plasma processing, a plasma generating apparatus is used for generating plasma in air near the objective thing by the corona discharging. The conventional plasma generating apparatus is generally adapted to apply AC power or pulse power of high voltage and high frequency onto a discharging electrode, to bring the discharging electrode to come into contact with (or close to) the objective thing which is placed on the opposite electrode retained at an approximately ground voltage so that plasma may be generated in air near the objective thing by causing the corona discharging between the discharging electrode and the opposite electrode or the objective thing. The conventional plasma generating apparatus used for plasma processing of the objective thing is generally of a fixed type. Accordingly, the objective thing is carried to the plasma generating apparatus with the use of a carrying apparatus or the like so that the plasma processing is adapted to be performed within the plasma generating apparatus.

However, the conventional plasma generating apparatus to be used for plasma-processing such objective things has problems in unsuitability in individual processing or repairing processing such as processing of the objective things of relatively complicated shape, local plasma-processing with respect to one portion of a given objective thing, plasma-processing stronger than in the other portions, or the like, although the conventional one is suitable for mass and standard processing of the objective things of relative simple shape, because the conventional plasma generating apparatus is of a large scale, a fixed type, and large in electric capacity (for example, several tens of Kw or so). Also, such a plasma generating apparatus which is larger in size and capacity has problems in that it is impossible to be carried and becomes expensive in cost. Further, the conventional plasma generating apparatus has problems in that sparking is caused from the discharging electrode to damage the objective things by sparks although discharging is concentrated in metal portions so that processing becomes considerably unequal in processing when the metal portions exposed near the metal surfaces or the processed faces exist. Also, it has a possibility of causing problems due to the discharging concentration into the metal portion when a paint film defect such as extremely small pin hole exists even where the surfaces of the steel plate are covered with paint film or the like.

SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to provide a plasma generating apparatus for satisfying the following conditions (at least one) or a method of processing the surfaces of the objective things for by the plasma generating apparatus used.

〈Conditions〉

(1) It is lighter in weight and easier to carry.
(2) It is smaller in power capacity
(3) It con endure longer hours' processing.
(4) Processed things are not damaged, because sparks are not caused from the discharging electrode.

(5) It is lower in cost (for example, approximately several tens of thousands yen).

(6) Safety is higher in the handy handling of higher tensions.

(7) Expected intensity of plasma processing can be effected in desired position of the processed thing.

(8) Plasma processing can be effected on the processed things whose surface has metallic portions disposed.

Thus, according to a first aspect of the present invention performed to solve the above problems, there is provided a small-sized atmospheric plasma generating apparatus which is capable of being carried. The apparatus includes (A) a switching circuit for converting power fed from a power source into AC power of high frequency by rapidly repeated switching of a contact switch therein, (B) a voltage transforming circuit (so-called Tesla coil) including a primary coil fewer in the number of turns for receiving the AC power of high frequency outputted from the switching circuit and a secondary coil more in the number of turns disposed in a concentric shape to the primary coil, the voltage transforming circuit being capable of generating AC power of high voltage and high frequency in the secondary coil in accordance with the power received into the primary coil, (C) a discharging electrode for causing corona discharging with respect to an opposite electrode retained at approximately ground voltage to cause plasma in air when the opposite electrode has been approached while receiving the AC power caused in the secondary coil of the voltage transforming circuit, and (D) a small size of casing formed of an electrically insulating material for containing the switching circuit, the voltage transforming circuit and the discharging electrode therein.

The small-sized atmospheric plasma generating apparatus of the first aspect is made in simple, light and compact construction and easy to be carried, with a switching circuit provided with switching contacts to be switched rapidly, a voltage transforming circuit provided with the primary coil and the secondary coil placed in concentric shape, and a discharge electrode on which high voltage and high frequency of AC power to be caused in the secondary coil is applied being engaged with a small-sized casing. Therefore, the small-sized atmospheric plasma generating apparatus can be carried manually or with a robot to cause the discharging electrode to contact with (or be close to) a desired objective thing mounted on the opposed electrode so that the plasma processing can be effected on the portion. Thus, the surface characteristics such as adhesive property, paint film adherence property or the like of the surfaces of the processed things become better. Also, the strength of the plasma processing to be effected upon the portion can be controlled by the adjusting time when the discharging electrode is caused to come into contact with the portion. For example, make the contact time longer, and the stronger plasma processing can be effected on the portion. Also, such simple construction of plasma generating apparatus becomes lower in manufacturing cost and the power capacity becomes smaller. Further, safety can be improved in handling of high voltage by placement of the switching circuit and the voltage transforming circuit within the insulating casing.

In the small type of atmospheric plasma generating apparatus, it is preferable that the contact switch may be opened or closed, accompanied through alternation between exciting condition and demagnetising condition with the provision of an electromagnet, the switching circuit has, where the excited condition and the demagnetized condition are repeated by the AC power supplied from the power supply, and power supply is an AC power supply. In such extremely simple and compact construction, the AC power of the high frequency can be caused effectively within the switching circuit, which causes the corona discharging with discharge electrode, thus causing stronger plasma.

According to a second aspect of the present invention, there is provided a small-sized atmospheric plasma generating apparatus which is capable of being carried. The apparatus includes (A') a switching circuit for causing spark discharge in a pair of electrodes disposed across a slight gap to each other with power fed from a power source to cause oscillating current, so as to generate AC power of high frequency by the oscillating current. Further, the apparatus includes (B) a voltage transforming circuit, (C) a discharging electrode and (D) a small size of casing, each of which has the construction as same as that of the above-mentioned apparatus of the first aspect of the present invention. In this case, an assembly composed of a switching circuit having a sparking gap and a voltage transforming circuit (Tesla coil) forms a Tesla voltage transformer.

The small-sized atmospheric plasma generating apparatus of the second aspect is made in simple, light and compact construction so that it can be easily carried, with a simple switching circuit provided with an electrode pair for causing the oscillation current with spark discharging, a voltage transforming circuit provided with the primary coil and the secondary coil placed in concentric shape, a discharge electrode on which high voltage and high frequency of AC power to be caused on the secondary coil is applied being engaged into the small sized casing. Therefore, the small-sized atmospheric plasma generating apparatus can be carried manually or with a robot to cause the discharging electrode to contact with (or be close to) the desired portion of the processed thing mounted on the opposed electrode so that the plasma processing can be effected on the portion. Thus, the surface characteristics such as adhesive property, the paint film adherence property or the like of the surfaces of the processed thing become better. Also, the strength of the plasma processing to be effected upon the portion can be controlled by the adjusting time when the discharging electrode is caused to come into contact with the electrode. For example, make the contact time longer, and the stronger plasma processing can be effected on the portion. Also, such simple construction of plasma generating apparatus becomes lower in manufacturing cost and the power capacity becomes smaller. Also, safety can be improved in handing of the high voltage by placement of the switching circuit and the voltage transforming circuit within the insulat-

ing casing.

In each of the above-described small-sized atmospheric plasma generating apparatus, it is preferable that the discharging electrode is provided with a discharge wire of a good conductor material, connected to an output terminal of the secondary coil of the voltage transforming circuit, and with a coating member of a dielectric material, for covering the discharge wire. Particularly, the discharge wire is desired to be a flexible wire of stainless-steel, and the coat member is desired to be a tube of vinyl-chloride or Teflon.

In this manner, the sparking can be prevented from being caused in the discharge electrode, and further the objective thing in which metal portion exists on the surface thereof can be plasma-processed, because the discharge wire made of stainless-steel or the like is coated with a coating member composed of dielectric material such as vinyl-chloride, Teflon or the like. Also, safety is much improved in handing of the high voltage, because the discharge wire on which the high voltage is applied is coated with dielectric material, namely, insulating material. Further, the discharge electrode can be brought into soft or elastic contact with the objective thing to be processed, because the discharge electrode is flexible.

According to a third aspect of the present invention, there is provided a surface processing method using any one of the above-mentioned small-sized atmospheric plasma generating apparatuses. The method includes the steps of (a) carrying the small-sized atmospheric plasma generating apparatus manually or with a robot so that the discharging electrode of the small-sized atmospheric plasma generating apparatus may be brought closer to or into contact with a surface of a given thing to be processed, the thing being placed on an opposite electrode retained at an approximately ground voltage, and (b) performing plasma processing onto the surface of the thing to be processed with plasma generated by the discharging electrode so as to improve the surface in quality. The surface processing method is applicable with respect to the objective thing made of non-conductive materials such as resin (plastics), paper, cloth or the like, and/or conductive materials (metal materials) such as aluminum, steel or the like. Concretely, plastic film, resin mold product, PCM steel plate, paper for printing use or the like can be used.

In the surface processing method, the plasma generating apparatus can be carried into a position where the objective thing exists to effect the plasma processing with desired strength upon the desired portion of the objective thing. Accordingly, it can be easily processed for repairing or individual processing such as processing of the objective things of relatively complicated shape such as deep grooves, holes or the like, local plasma processing with respect to only one portion of the given objective thing or plasma processing stronger than in other portions.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description given below and the accompanying drawings, wherein:

Fig. 1A is a longitudinal section view for illustrating a plasma generating apparatus of the present invention;
Fig. 1B is a cross sectional view for illustrating the discharging electrode of the plasma generating apparatus shown in Fig. 1A;
Fig. 2 is an electric circuit diagram of the plasma generating apparatus shown in Fig. 1A;
Fig. 3 is a view showing a plasma processing method of the invention; and
Fig. 4 is a graph showing the results of the measured peeling off strength of a coated steel plate plasma- processed of the invention and the coated steel plate not plasma processed.

DESCRIPTION OF PREFERRED EMBODIMENTS

Hereinafter, embodiments of the present invention will be concretely described. As shown in Figs. 1A, 1B and 2, in a portable plasma generating apparatus 1 of atmospheric specification which is small and light, a switching circuit 3 for converting AC power fed from the AC power source (not shown) into AC power of high frequency, and a voltage transforming circuit 4 for causing AC power of high voltage and high frequency through the voltage transformation of the AC power of high frequency outputted from the switching circuit 3 are disposed within an approximately cylindrical, hollow casing 2 made of insulating material. Further, in the plasma generating apparatus 1, there is provided a discharge electrode 5 which generates plasma in air around it by causing corona discharge between an opposite electrode and itself when the opposite electrode retained at approximately ground voltage (approximately earth voltage) has been approached thereto while receiving the AC power generated in the voltage transforming circuit 4. In the present specification, the "approximately ground voltage" includes "ground voltage" where the conductor is earthen.

The voltage transforming circuit 4 is so-called Tesla coil where the primary coil 6 (winding) which is fewer in the number of turns, and the secondary coil 7 (winding) which is more in the number of turns are disposed in concentric cylindrical shape for distraining of high-frequency loss. In the voltage transforming circuit 4, an iron core (not shown) of a ferrite core is used for increasing the output. The voltage transforming circuit 4 of such construction can cause sufficient high voltage in spite of extremely simple construction which is small in size and light in weight.

One example of size, shape or the like of the voltage transforming circuit 4 which is compact and light in weight and high in voltage transformation performance is shown as follows.

(1) size of the voltage transforming circuit (200 through 300 mm in length, 30 through 60 ∅mm in diameter)
(2) voltage between the output peaks of the voltage transforming circuit (15 through 35 kV)
(3) power capacity of the voltage transforming circuit (0.3 through 1.0 kV)
(4) turns number of the primary coil (3 through 8 units)
(5) turns number of the secondary coil (300 through 800 units)

A discharge electrode supporting plate 8 composed of an insulating material is mounted on the front end portion of the casing 2 with the use of a mounting member 9 composed of an insulating material, and a discharge electrode 5 is supported by the discharge supporting plate 8. And a discharging wire 13 composed of stainless wire flexible connected with the output terminal of the secondary coil 7 of the voltage transforming circuit 4, and a Teflon tube 14 (coating member made of dielectric material) for coating the discharge wire 13 are provided on the discharge electrode 5 through a connecting screw 10, a connecting rod 11, and a connecting pin 12 each made of a good conductor material. The diameter of the discharge wire 3 is made, for example, 1 mm, and the outer diameter of the Teflon tube 14 is made, for example, 2 mm.

A conductor 15 is provided in the switching circuit 3, supplying the AC power (for example, 60 Hz) of 100 V through a plug 26 from the AC power supply (not shown). The switching circuit 3 has a magnet 16 (electromagnet) for switch driving use with one portion of the conductor 15 being wound on a rod 17 formed with a ferromagnetic material. Further, the switching circuit 3 has a contact switch S composed of a first contact 18 whose one end is connected with a P2 point of the conductor 15, and a second contact 19 connected with a P1 point of the conductor 15. A switching knob 21 for adjusting the operation characteristics of the contact switch S is provided with respect to the contact switch S. The switch adjusting knob 21 is sewed into the rear end wall 2a of the casing 2 and is adapted to move in the directions Y1 • Y2 by pivoting around the axial line thereof. The conductor 15 is earthen at a P3 point with a capacitor 21 for noise removing use being interposed, to prevent the noises from being caused within the conductor 15, in the conductor 15 between the P1 point and the P3 point.

The switching circuit 3 may be formed with the use of a switch having an electrode pair and a simple on and off function, or semiconductor switch (for example, transistor), instead of such construction. Also, the switching circuit 3 may be made a switch circuit which produces the AC power of high frequency with oscillating current by causing the oscillation current through causing sparking discharges in the electrode pair disposed across the slight gap with power fed from the power supply. In this case, the assembly composed of the switching circuit 3 and the voltage transforming circuit 4 becomes a Tesla transformer.

When a given AC power is fed to the conductor 15, a magnet 16 for the switching driving use repeats the exciting condition and the demagnetic condition in accordance with the frequency of the AC power to make open and close the contact switch S. Namely, when the magnet 16 for switch driving use is in an exciting condition, a ferromagnetic material piece 24 mounted in the second contact 19 is attracted to the magnet 16 for switch driving use to separate the contact portion 22 of a first contact 18 and the contact portion 23 of a second contact 19 to open the contact switch S. On the other hand, when the magnetic 16 for switch driving use is in a demagnetic condition, the second contact point 19 is restored to its original position by the elasticity thereof to cause the contact portion 22 of the first contact 18 to contact with the contact portion 23 of the second contact 19 to close the contact switch S. In this manner, the contact switch S is continuously made open, closed at high speed to cause the AC power of high frequency in the switching circuit 3 for inputting the alternate current into the primary coil 6 of the voltage transforming circuit 4. The making, breaking characteristics of the contact switch S and the oscillating characteristics of the AC power of high frequency to be caused by the switching circuit 3 can be adjusted if desired by the adjusting operation of the switching adjusting knob 20.

In this manner, the AC power of high frequency caused by the switching circuit 3 is inputted into the primary coil 6 of the voltage transforming circuit 4 to cause the AC power of high frequency and high voltage in the secondary coil 7 of the voltage transforming circuit 4 for inputting the AC power into the discharge wire 13 of the discharge electrode 5. The other terminal (terminal not connected with the discharge wire 13) of the secondary coil 7 of the voltage transforming circuit 4 is earthen so that the plasma producing apparatus 1 becomes equal in potential as that of the opposite electrode in the using of the plasma generating apparatus 1.

Corona discharging is caused between the discharge electrode 5 and the opposite electrode, when the discharge electrode 5 is caused close to or brought to come into contact with the opposite electrode retained at the approximately ground voltage in feeding the AC power of high frequency and high voltage to the discharge electrode 5, to cause the plasma in air between the discharge electrode 5 and the opposite electrode by the corona discharging. In this case, sparking is not caused between the discharge electrode 5 and the opposite electrode, because the discharge wire 13 is coated with a Teflon tube 14 (dielectric).

The plasma generating apparatus 1 of the invention can be easily carried, because the switching circuit 3 and the voltage transforming circuit 4 both being simple, small and light, are accommodated within the casing 2, and a dis-

charge electrode 5 simple, small and light is supported by the discharging electrode supporting plate 8 provided in the tip end portion of the casing 2, thus resulting in simple, compact construction. Therefore, the plasma producing apparatus 1 can be carried with manual hands or a robot to bring the discharge electrode into contact with (or closer to) the desired portion of the desired processed things placed on the opposite electrode so that the plasma processing can be effected on the portion.

Also, in the plasma generating apparatus 1, safety is increased considerably in handling high voltage, because the switching circuit 3 and the voltage transforming circuit 4 are accommodated within the casing 2 composed of insulating material and the discharge wire 13 is coated with Teflon tube 14 of the insulting body.

One example of the size, shape or the like of the plasma producing apparatus 1 simple, compact is shown, which satisfies all the demanding conditions.

(1) size (400 through 600 mm in length, 50 through 80 ∅mm in diameter)
(2) weight (1 through 3 kg)
(3) manufacturing cost (30,000 through 80,000 yen)

A method (surface processing method) of effecting plasma processing with respect to the objective thing with the use of such plasma generating apparatus 1 will be described hereinafter. In such processing, at first, non-conductive materials such as resin (plastic), paper, cloth or the like and/or objective thing 31 (concretely, for example, plastic film, resin mold products, PCM steel plate, paper for printing use or the like) composed of conductive materials (metal materials) such as aluminum, iron or the like are placed on the opposite electrode 30 (earth electrode) where the voltage is retained at the ground voltage (earth voltage) as shown in, for example, in Fig. 3. The metal plate of stratified member can be earthen without provision of opposite electrode when the objective thing 31 includes the stratified metal, for example, stratified member with resin, paint and so on being coated on such metal plate as PCM steel plate. Even in this case, strong corona discharging is caused and strong plasma is produced.

Then, the plasma generating apparatus 1 is carried manually or with a robot so that the discharging electrode 5 of the pressure plasma generating apparatus 1 is caused to come into contact with a proper position within a range to be plasma-processed on the surface of the objective thing. And the discharge electrode 5 which remains in contact with the surface of the objective thing is caused to move onto the range to be plasma-processed. The discharge electrode 5 is desired to move evenly at the moving speed of, for example, 1 cm/sec. through 2 cm/sec. Also, it is desired to move the discharge electrode 5 repeatedly about 1 through 5 times on the surface of the objective thing when the normal plasma processing is effected on the surface of the objective thing.

The time for causing the discharge electrode 5 to come into contact with the surface of the objective thing is set preferably in accordance with the strength of the plasma processing to be required. At this time, the corona discharge is caused between the discharge electrode 5 and the opposite electrode 30 to generate the plasma in air near the surface of the objective thing by the corona discharging so that the surface of the objective thing is plasma-processed by the plasma. Thus, the various types of surface characteristics such as adhesive property, adherence property of the adhesive agent or the paint onto the surface of the objective thing, printing characteristics of the printing ink, the cloudiness preventing property of the surface, washing property or friction characteristics or the like are improved or changed in quality when other member is bonded, paint is coated or prints are effected with the use of adhesive with respect to the surface of the objective thing 31.

The strength of the plasma processing to be effected upon the position can be controlled by the adjustment of time when the discharging electrode 5 is caused to come into contact with the position, to be plasma-processed, of the surface of the objective thing. For example, the stronger plasma processing can be effected on the portion when contact time is made longer. Accordingly, the plasma processing of the desired strength can be effected upon the desired position of the objective things 31.

Also, according to such plasma processing, the surface of the objective thing is plasma-processed without causing the spark discharging with plasma to be generated between the Teflon tube 14 and the surface of the objective thing by contacting or sliding contact and moving of the Teflon tube 24 with respect to the surface of the objective thing in effecting of the plasma processing upon the objective thing 31, because the flexible discharging wire 13 is coated with Teflon tube 14 (dielectric) as described above. Also, the plasma processing can be completed for a short time (for example, few seconds) without causing damages on the surfaces of the objective thing, because the discharging wire 13 (steel wire) or Teflon tube 14 comes into soft contact with the surface of the objective thing with proper pressing force through the elastic force. The plasma processing can be effected by selection of the shape or the material quality corresponding to the portion with respect to portions of deep grooves, holes or the like which were insufficient in processing by the conventional fixed type large on scale. Also, the processing efficiency can be improved with the joint use of the fixed type when the objective things relatively complicated in shape, material quality and larger in processing area are processed.

The Teflon tube 14 is to be consumed, whose life service depends upon the using limit or other factors to be consumed. But the above problems can be coped by making the Teflon tube 14 detachable or exchangeable, namely, as consumption product.

Make the discharging wire 13 wound by plural to coat it with Teflon tube 14, and the contact area between the discharge electrode 5 and the surface of the objective thing becomes larger so that the time required for the plasma processing is further shortened.

(Example 1)

Fig. 4 shows results where the surface processing is effected with respect to the coating steel plate by the plasma processing with the use of the plasma generating apparatus of the invention to have the improved results of the surface measured. Steel plate with primer and white paint (Fureki-coat made by Nippon Paint Co., Ltd.) being coated on it is used as coated steel plate. Plasma processing different in number is effected on the coating surfaces of a plurality of coating steel plate. Thereafter, a plurality of coating steel plate plasma-processed in this manner are pasted with the use of adhesive (Power-tight 110, made by Nippon Paint Co., Ltd.) (the same type of coating steel plates are pasted with each other) respectively on the coated steel plates not plasma-processed. Thereafter, one portion of the coated steel plate pasted is peeled off to measure the peeling strength with the use of a Tensilon peeling strength testing apparatus.

As apparent from Fig. 4, the peeling off strength is considerably increased by the plasma processing operation of the invention. Namely, the peeling strength becomes higher in approximate proportion to the number of plasma processing operation when the plasma processing is five times or lower in number although the peeling strength is about 3 kgw/inch in the coated steel plate not plasma-processed. In the coated steel plate where plasma processing has been processed five times, the peeling strength is increased as high as about 28 kgw/inch. As apparent from Fig. 4, the peeling strength is not extended so much as expected if the plasma processing is effected five times or more. Accordingly, it is desirable for the plasma processing to be effected by 1 time through 5 times in accordance with the processing strength to be required.

(Example 2)

The result where the adhesive property between the electrodeposited coating surface being plasma-processed of the invention and the coating surface not plasma-processed and the sealer is measured is shown as follows. A sample where the plasma processing has been effected five times with carrying speed of 0.5 m/min. on the steel plate surface electrodisposedly coated, and a sample not plasma-processed are respectively baked with the sealer being coated. The adhesive property is measured through the measurement of the break strength through pulling of the sealer by the Tensilon apparatus.

〈Measured results〉

(1) Break strength of the sample plasma-processed 7.0 through 8.0 kgw/cm^2
(2) Break strength of the sample not plasma-processed 4.5 kgw/cm^2

As apparent from the measured results, in the coated steel plate plasma-processed of the invention, the adhesive property is also considerably increased with respect to the sealer as compared with the sample not plasma-processed.

(Example 3)

Then, the results are shown through the measurement of the results of the improved surface where the surface processing is effected with respect to resin mold product having three dimensional shape by the plasma-processing with the use of the plasma generating apparatus of the invention. The bowl-like shape made of polypropylene is used for a resin mold product. Plasma processing is effected on the outer peripheral portion of 10 mm in width from the top portion of the side face of the resin mold product. Two types of plasma processing has been effected, of a) rotating the resin mold product with the discharge electrode being secured, and b) rotating the discharging electrode with resin mold product being fixed. The peeling test has been effected with cellophane tape by effecting a checkerboard squares cutting operation in accordance with JIS K5400 with respect to the outer peripheral portion plasma-processed and not plasma-processed in this manner, with R-215 (two component type urethane paint) made by Nippon Bee Chemical Co. being applied and dried.

〈Test results〉

Residual factor of the checkerboard squares

a) discharging electrode fixed/resin mold production rotation 100/100

b) resin mold product fixed/discharge electrode rotation 100/100

c) unprocessed 0/100

The adhesive property of a particular portion only can be improved by the use of the plasma generating apparatus of the invention.

(Example 4)

Then, the results are shown where the improved results of the surface have been measured by the surface processing effected with respect to the resin mold product whose surface includes the metal portion by plasma processing with the use of the plasma generating apparatus of the invention. The discharging wire of the plasma generating apparatus is coated with Teflon tube. A bumper for automobile made of polypropylene, with the metal portion being exposed onto the surface due to the metal nut closed, processed by a large size of fixed type plasma generating apparatus is used as the resin mold product with the metal portion being masked. A portion of 5 cm in radius around the metal portion including the masked portion of the resin mold product has been plasma-processed. The peeling test has been effected with cellophane tape by effecting a checkerboard squares cutting operation on the surface of the resin mold product after the processing in accordance with JIS K5400, with R-215 (two component type urethane paint) made by Nippon Bee Chemical Co. being applied and dried, thus obtaining the results of 100/100.

It was impossible to process, because the discharging operation onto the metal portion was effected in a case where the metal portion was not masked by the large-size fixed type of plasma generating apparatus and where the discharging wire of the plasma generating apparatus was not coated with Teflon tube. It can be possible to improve the quality of the surface including the metal portion on the surface by the use of the plasma generating apparatus of the invention.

(Example 5)

Then, the results are shown where the improved results of the surface have been measured by the surface processing effected with respect to the resin mold product having complicated shape by the plasma processing with the use of the plasma generating apparatus of the invention. The door trim, for automobile use, made of polypropylene having a groove of about 5 mm in depth and about 5 mm in width is used as the resin mold product. And the plasma processing operation has been effected on the bottom portion of the groove of the resin mold product. The evaluation was effected by flowing of the two component type of adhesive agent on the market into the bottom of the grooves, bonding into the insertion the polypropylene plate suitable for the size of the grooves to measure the peel strength of the polypropylene plate with respect to the basic material with the use of the Tensilon, because such direct evaluation as surface tension measurement was difficult in the result of the surface improvement of the bottom of the grooves.

〈Measurement results〉

Processing by the plasma producing apparatus of the invention	1050 g/cm
Processing* by the atmospheric plasma producing apparatus of large fixed type	250 g/cm
Unprocessed	120 g/cm

* 5 file passing in 0.8 m/min with field strength 6 kV/cm

The surface having complicated shape such as grooves insufficient in processing effects can be improved in quality in the conventional large, fixed type of plasma generating apparatus by the use of the plasma generating apparatus of the invention.

Although the present invention has been described in relation to particular embodiments thereof, many other variations and modifications will become apparent to those skilled in the art. It is preferred, therefore, that the present invention be limited not by the specific disclosure herein, but only by the appended claims.

Claims

1. A small-sized atmospheric plasma generating apparatus which is capable of being carried, said apparatus com-

prising:

a switching circuit (3) for converting power fed from a power source into AC power of high frequency by rapidly repeated switching of a contact switch (S) therein;
a voltage transforming circuit (4) including a primary coil (6) fewer in the number of turns for receiving the AC power of high frequency outputted from said switching circuit (3) and a secondary coil (7) more in the number of turns disposed in a concentric shape to said primary coil (6), said voltage transforming circuit (4) being capable of generating AC power of high voltage and high frequency in said secondary coil (7) in accordance with the power received into said primary coil (6);
a discharging electrode (5) for causing corona discharging with respect to an opposite electrode (30) retained at approximately ground voltage to cause plasma in air when said opposite electrode (30) has been approached while receiving the AC power caused in said secondary coil (7) of said voltage transforming circuit (4); and
a small size of casing (2) formed of an electrically insulating material for containing said switching circuit (3), said voltage transforming circuit (4) and said discharging electrode (5) therein.

2. The small-sized atmospheric plasma generating apparatus recited in claim 1, wherein said power source supplies AC power and said switching circuit (3) includes an electromagnet (16) in which excited condition and demagnetized condition are alternately repeated by the AC power fed from said power source, said contact switch (S) being adapted to be switched, accompanied through alternation between the excited condition and the demagnetized condition of said electromagnet (16).

3. A small-sized atmospheric plasma generating apparatus which is capable of being carried, said apparatus comprising:

a switching circuit (3) for causing spark discharge in a pair of electrodes (18,19) disposed across a slight gap to each other with power fed from a power source to cause oscillating current, so as to generate AC power of high frequency by the oscillating current;
a voltage transforming circuit (4) including a primary coil (6) fewer in the number of turns for receiving the AC power of high frequency outputted from said switching circuit (3) and a secondary coil (7) more in the number of turns disposed in a concentric shape to said primary coil (6), said voltage transforming circuit (4) being capable of generating AC power of high voltage and high frequency in said secondary coil (7) in accordance with the power received into said primary coil (6);
a discharging electrode (5) for causing corona discharging with respect to an opposite electrode (30) retained at approximately ground voltage to cause plasma in air when said opposite electrode (30) has been approached while receiving the AC power caused in said secondary coil (7) of said voltage transforming circuit (4); and
a small size of casing (2) formed of an electrically insulating material for containing said switching circuit (3), said voltage transforming circuit (4) and said discharging electrode (5) therein.

4. The small-sized atmospheric plasma generating apparatus recited in any one of claims 1 to 3, wherein said discharging electrode (5) is provided with a discharge wire (13) of a good conductor material, connected to an output terminal of said secondary coil (7) of said voltage transforming circuit (4), and with a coat member (14) of a dielectric material, for covering said discharge wire (13).

5. The small-sized atmospheric plasma generating apparatus recited in claim 4, wherein said discharge wire (13) is a flexible wire of stainless-steel, and said coat member (14) is a tube of vinyl-chloride or Teflon.

6. A surface processing method using the small-sized atmospheric plasma generating apparatus of any one of claims 1 to 5, said method comprising the steps of:

carrying said small-sized atmospheric plasma generating apparatus (1) so that the discharging electrode (5) of said small-sized atmospheric plasma generating apparatus (1) may be brought closer to or into contact with a surface of a given thing (31) to be processed, said thing (31) being placed on an opposite electrode (30) retained at an approximately ground voltage; and
performing plasma processing onto the surface of said thing (31) to be processed with plasma generated by said discharging electrode (5) so as to improve the surface in quality.

7. The surface processing method using the small-sized atmospheric plasma generating apparatus, recited in claim

6, wherein the surface of said thing (31) to be processed has a complicated shape.

8. The surface processing method using the small-sized atmospheric plasma generating apparatus, recited in claim 6 or 7, wherein the surface processing is performed to only one portion of the surface of said thing (31) to be processed.

9. A surface processing method using the small-sized atmospheric plasma generating apparatus of claim 4 or 5, said method comprising the steps of:

carrying said small-sized atmospheric plasma generating apparatus (1) so that the discharging electrode (5) of said small-sized atmospheric plasma generating apparatus (1) may be brought closer to or into contact with a surface of a given thing (31) to be processed, said thing (31) being placed on an opposite electrode (30) retained at an approximately ground voltage, and the surface of said thing (31) to be processed containing a metal portion; and

performing plasma processing onto the surface of said thing (31) to be processed with plasma generated by said discharging electrode (5) so as to improve the surface in quality.

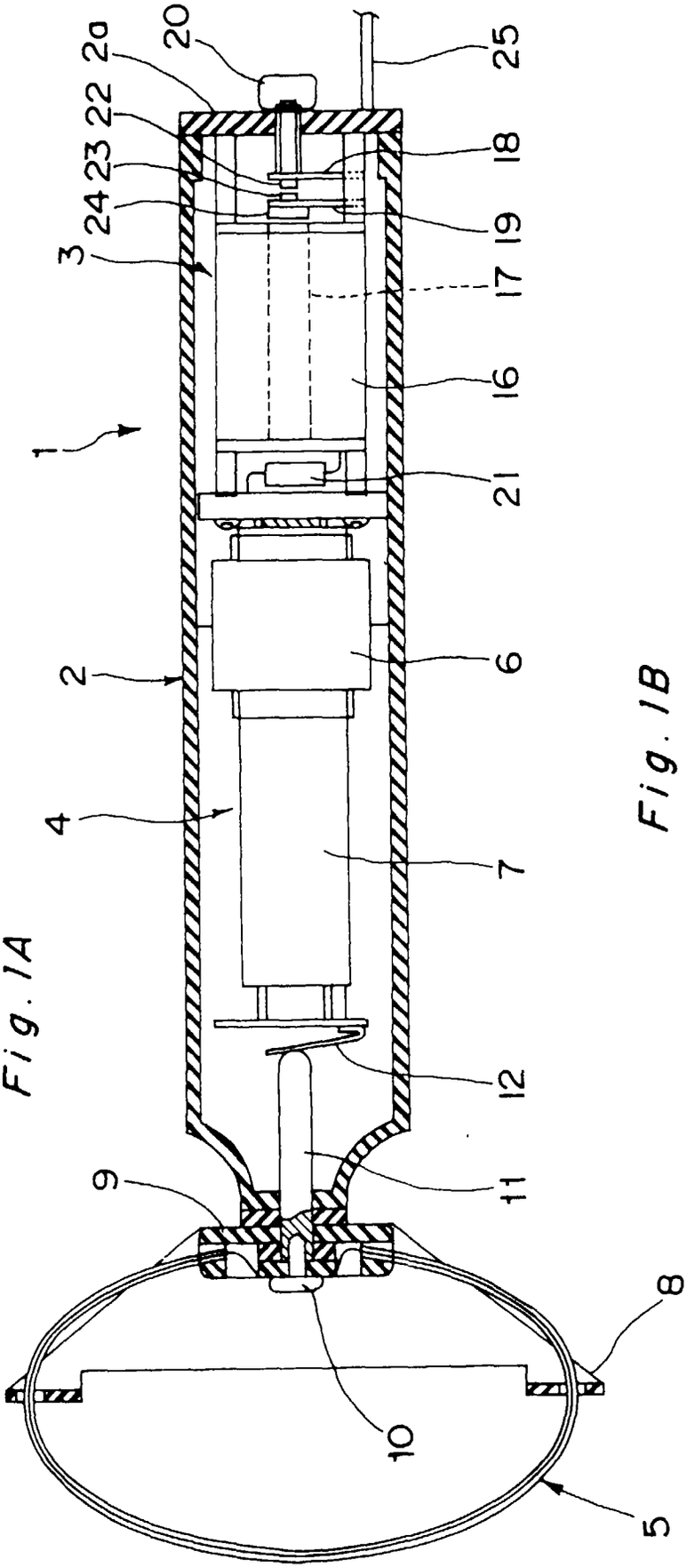


Fig. 1A

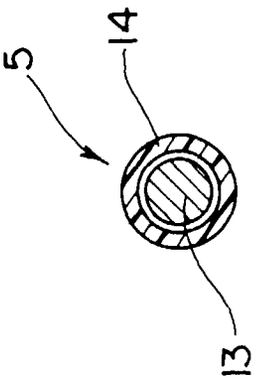


Fig. 1B

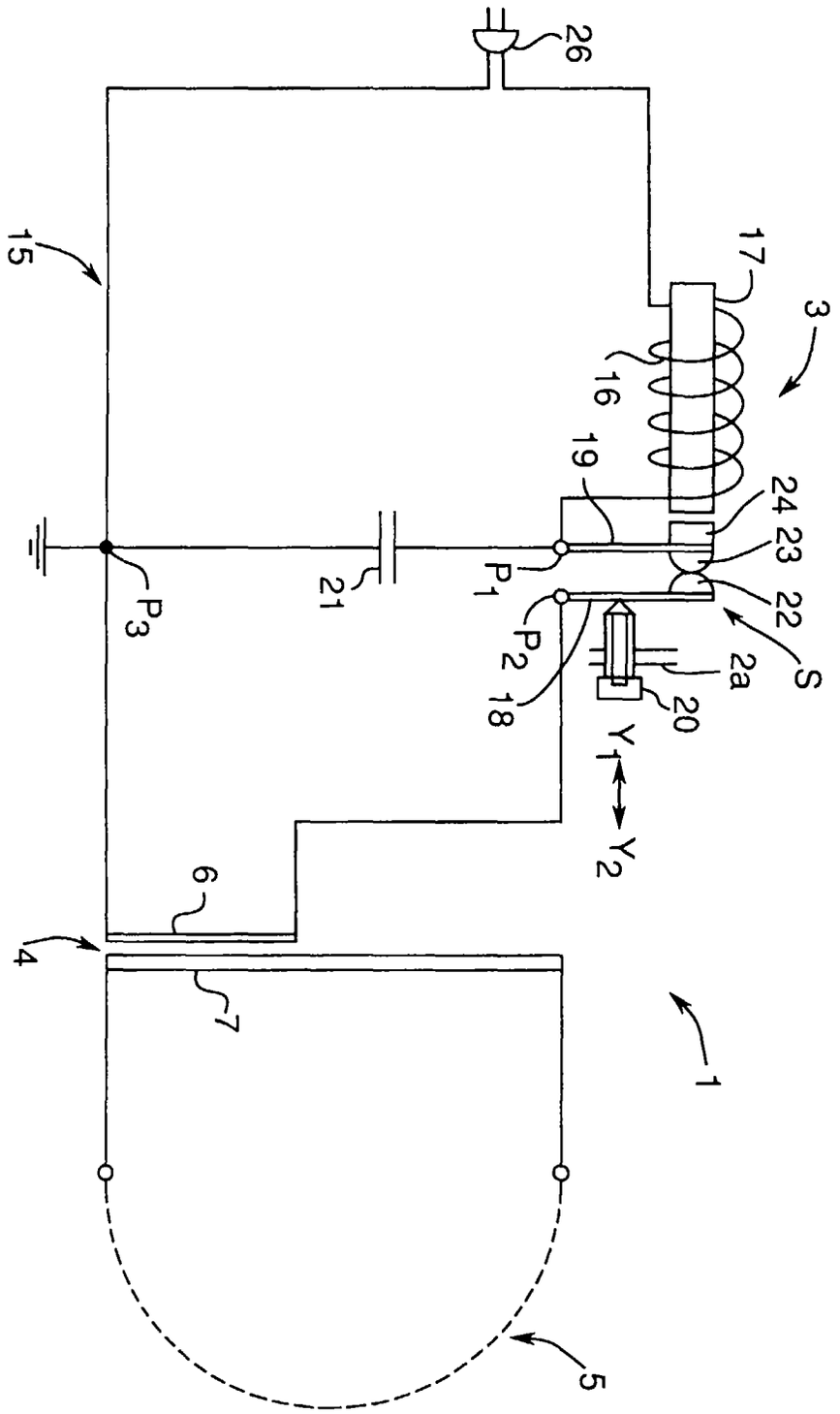


Fig.2

Fig. 3

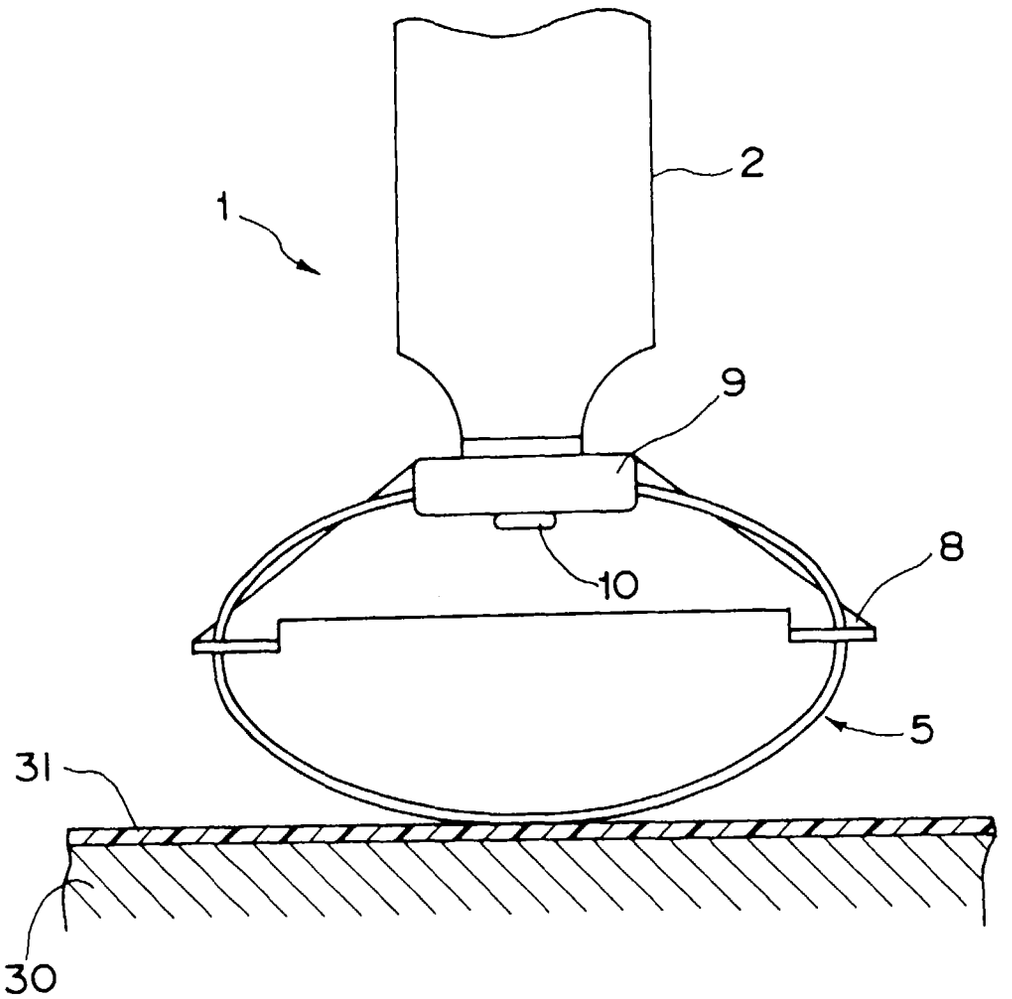
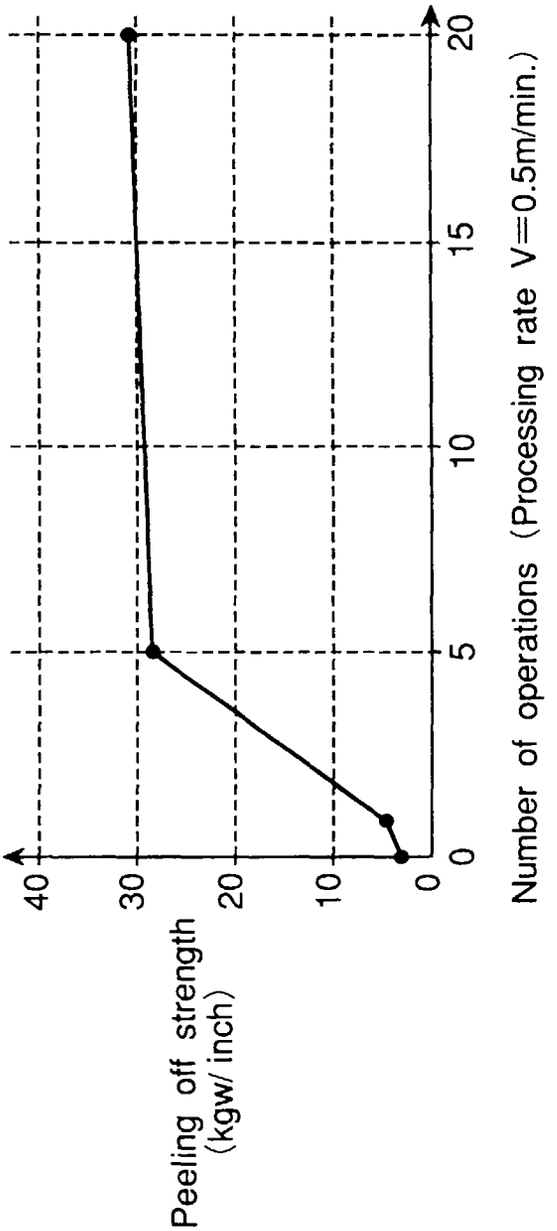


Fig. 4


40
30
20
10
0
Peeling off strength
(kgw/ inch)
0
5
10
15
20
Number of operations (Processing rate V=0.5m/min.)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 10 1968

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	DATABASE WPI Section Ch, Week 8414 Derwent Publications Ltd., London, GB; Class M13, AN 84-084296 XP002031061 & JP 59 032 937 A (SANKYO DENGYO KK) , 22 February 1984 * abstract * ---	1,6	H05H1/24
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	16 May 1997	Capostagno, E

CATEGORY OF CITED DOCUMENTS

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EUROPEAN SEARCH REPORT

Application Number
EP 97 10 1968

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
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A	US 5 249 575 A (DI MINO ALFONSO ET AL) 5 October 1993 * the whole document * ---	1	
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
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