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[11] **3,857,772**

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[54] **ELECTROPLATING APPARATUS FOR SIMULTANEOUSLY AND UNIFORMLY ELECTROPLATING INSIDE SURFACES OF ANNULAR BODIES**

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[52] **U.S. Cl.** ..... **204/224 R,** 204/228, 204/272, 204/275

[51] **Int. Cl.** **C23b 5/74,** B01k 3/00

[58] **Field of Search** ..... 204/228, 272, 275, DIG. 7, 204/26, 224 R

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Assistant Examiner—D. M. Valentine

[57] **ABSTRACT**

Herein disclosed is an improved electroplating apparatus for simultaneously and uniformly electroplating the inside surfaces of a plurality of annular bodies. The electroplating apparatus includes an upright anode disposed within registered bores of the annular bodies with its outer contour equi-distantly spaced from the inside surfaces forming inbetween an electrolyte passage, and adjusting means for adjusting at an equal elvel the effective electric currents flowing between the anode and each of the annular bodies, even when the electric conductivity of the flowing electrolyte differs along the axis of the registered bores due to generation of gases in the electrolyte.

2 Claims, 2 Drawing Figures

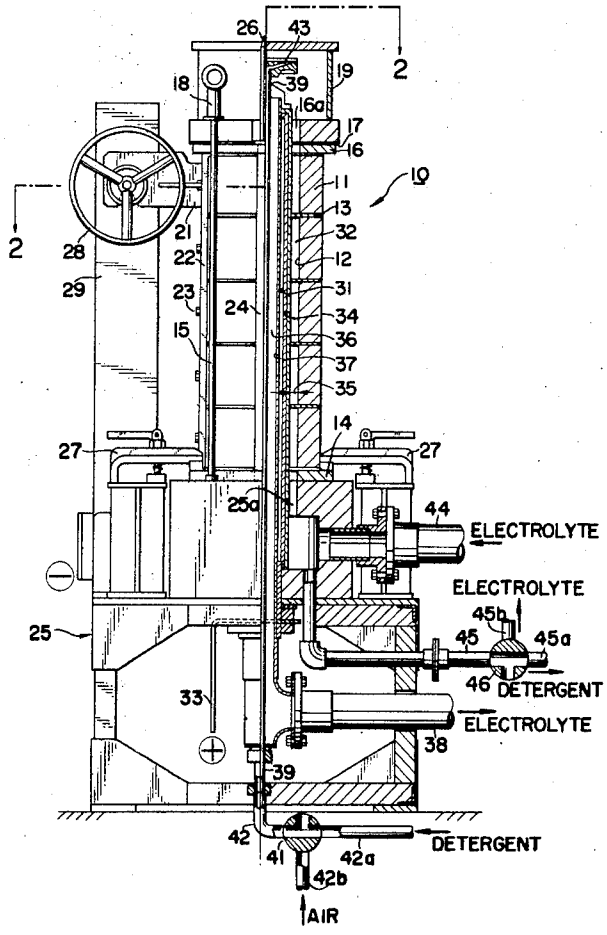

FIG. 1

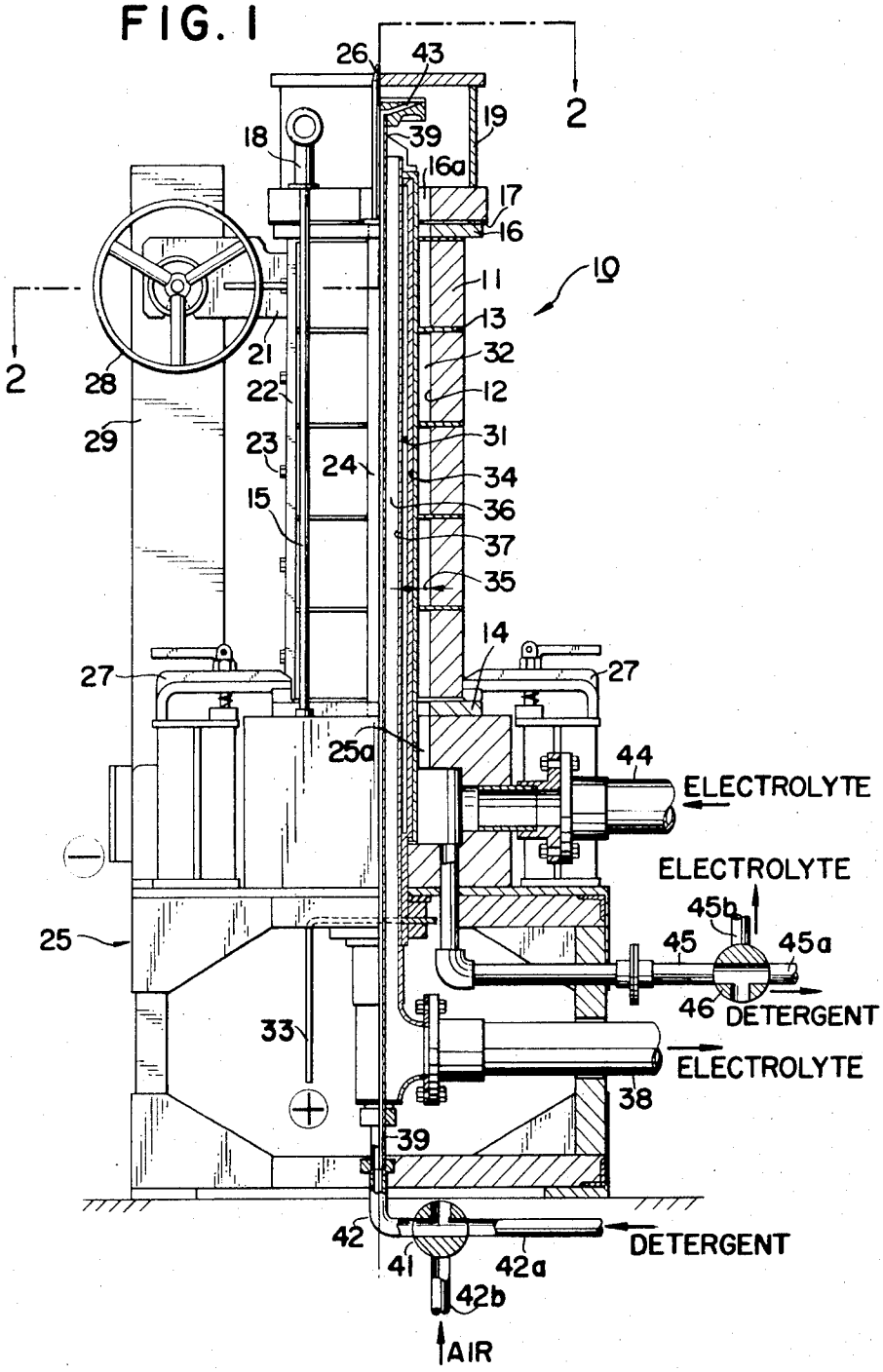
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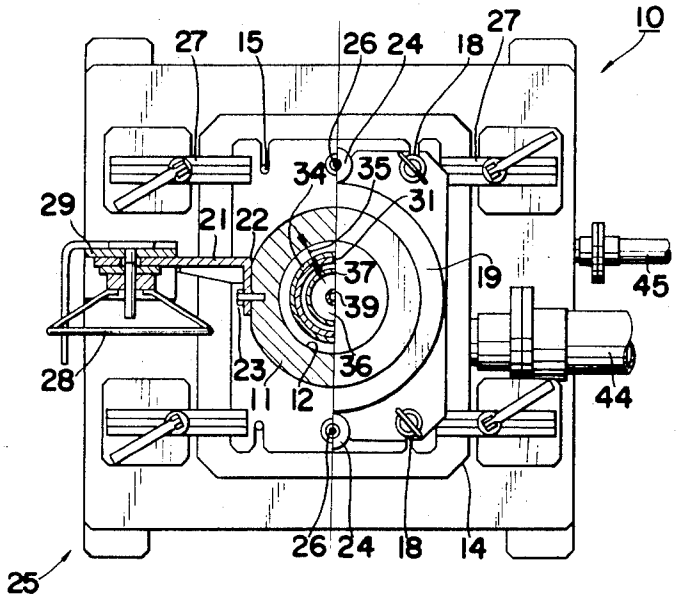
FIG. 2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ELECTROPLATING APPARATUS FOR SIMULTANEOUSLY AND UNIFORMLY ELECTROPLATING INSIDE SURFACES OF ANNULAR BODIES

BACKGROUND OF THE INVENTION

The present invention relates to the art of electroplating, and more particularly to an improvement in an electroplating apparatus for simultaneously and uniformly electroplating the inside surfaces of a plurality of annular bodies, such as, cylinders of internal combustion engines.

In a conventional electroplating apparatus for simultaneously electroplating the inside surfaces of a plurality of annular bodies, it is an established practice to pile the annular bodies one over another through a sealing seat. An anode is disposed within the bores of the annular bodies and has its outer contour equi-distantly spaced from the inside surfaces of the bodies to form inbetween an electrolyte passage. Each of the bodies is electrically connected with the negative terminal of an energy source through a lead wire. An electrolyte is forced to flow vertically upwardly in the electrolyte passage so as to effect electroplating on the inside surfaces. The electrolyte, then, overflows the upper surface of the piled annular bodies for recovery.

One of the drawbacks concomitant with the conventional apparatus is that since the bodies to be electroplated are maintained at an equal potential the effective currents flowing between anode and each of the bodies are not an equal level. This is because the electric conductivity of the flowing electrolyte is not an equal level along the vertical line of the piled bodies due to generation of gases resulting from the electroplating operation. This fact invites inconsistency in the thickness of the electroplated layer on the inside surfaces of the annular bodies. That is, the layer thickness of the lower body has a larger value than that of the upper body. Since, therefore, the thickness of the electroplated layer should have a minimum value, the lower body has an electroplated layer of unnecessary thickness. This thickened layer must be gound later to have a proper thickness level. This fact is naturally accompanied by an elongated time period required for the electroplating operation, with the resultantly degraded production efficiency, in addition to the bothering grinding operation. Moreover, the increased thickness of the electroplated layer invites spare consumption of the electroplating material such as chromium and accordingly an increased production cost.

As has been described, on the other hand, the electrolyte is guided to overflow the top surface of the piled annular bodies so as to be discharged into an electrolyte reservoir. A hat member, which covers the top surface of the bodies, must be provided with joints for connecting a discharge tube or the like. In addition to this complicated structure, the sealing between the hat member and the discharge tube will become a cause of trouble, because the hat member must be detachably mounted on the particular top surface for installation of the assembled annular body structure. The degraded sealing will permit leakage of the electrolyte and/or the generated gases, and accordingly will produce a problem of firing or pollution.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide an improved electroplating apparatus free from the above disadvantages.

Another object of the invention is to provide an improved electroplating apparatus for simultaneously and uniformly electroplating the inside surfaces of a plurality of annular bodies.

Still another object is to provide an improved electroplating apparatus, in which an upright anode is disposed within registered bores of the annular bodies with its outer contour equi-distantly spaced from the inside surfaces of the annular bodies for forming inbetween an electrolyte passage, and in which adjusting means adjust at an equal level the effective electric currents flowing between the anode and each of the annular bodies, even when the electric conductivity of the flowing electrolyte differs along the axis of the registered bores due to generation of gases in the electrolyte.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the present invention will be apparent from the description made in conjunction with the accompanying drawings, in which:

FIG. **1** is a partially sectional view of an electroplating apparatus according to the present invention, taken in the vertical line; and

FIG. **2** is a partially sectional view taken along the line **2 — 2** of FIG. **1.**

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIGS. **1** and **2,** an electroplating apparatus according to the present invention is generally designated at numeral **10,** which is used to simultaneously and uniformly electroplating a plurality of annular bodies **11** such as cylinders of internal combustion engines. The annular bodies **11,** which are formed with inside surfaces **12** to be electroplated, are piled one over another through an electrically insulating seat **13** in a manner to have their bores registered with each other. That is, each of the seats **13** is interposed between any adjacent pair of the annular bodies **11** so as to electrically insulating the bodies **11** from each other and at the same time to keep hermetically sealed joint between the adjacent pair of the bodies **11,** thereby forming an upright tubular body (not numbered). This tubular body rests on a base plate **14** and is assembled into a block by means of elongated bolts **15** which are held at the corners of the base plate **14.** On the top surface of the tubular body, more specifically, are mounted an annular head disc **16** and a packing **17** both formed with registered bores, through which the bolts **15** upwardly extend. The uppermost ends of the bolts **15** are threaded so that they are nutted up by corresponding hanging members **18** after a hat **19** has been placed on the packing **17** with its brim portion being fastened to the bolts **15.** Thus, the hat **19** is hermetically mounted on the upper surface of the tubular body through the head disc **16** and the packing **17,** thereby providing a unitary structure assembled with the tubular body and the base plate **14.**

In the outer vicinity of the tubular body is a vertically disposed cathodic conductor **22,** hereinafter called "cathode" formed with an upper projection **21.** It

shoulld be noted here that the cathode **22** has a predetermined intrinsic resistance, as will be discussed later. This cathode **22** is electrically connected with each of the annular bodies **11** through a fastening bolt **23.** The location of the fastening bolts **23** may be anywhere with respect to the annular bodies **11,** but they should be equi-distantly spaced from any adjacent coleagues.

As better shown in FIG. **2,** two guide pipes **24** are inserted into corresponding bores formed in both the base plate **14** and the head disc **16.** On the upper surface of an apparatus main body **25,** are anchored two guide rods **26** which are inserted into the guide pipes **24** when it is intended to install the assembled block in position on the main body **25.** This installment is finished by fastening four arms **27** which are mounted on the main body **25,** as shown.

Indicated at numeral **28** is an operating handle acting to mount the projection **21** of the cathode **22** on a cathode plate **29** for rendering electrically conductive the connection between the cathode **22** and the cathode plate **29.** This operating handle **28** is electrically connected with the negative terminal of an energy source (not shown) so as to apply a negative potential to the annular bodies **11.**

Disposed within the registered bores **12** of the tubular body is an upright anode **31** which is mounted on the apparatus main body **25** in a manner to upwardly extend into the chamber of the hat **19** through the bore **16***a* of the head disc **16.** This anode **31** is made of highly conductive material and is electrically connected with a positive terminal of the energy source by way of an anode plate **33.** It should also be noted that the anode **31** has its outer contour equi-distantly spaced from the inside surfaces **12** of the tubular body, thereby forming inbetween an electrolyte passage **35** in which an electrolyte is forced to flow. The outer surface of the anode **31** may preferably be coated with some suitable material **34** having a high conductivity and a sufficient resistance to the attacking of the flowing electrolyte. One of the materials suitable for this purpose is lead.

The anode **31** is not solid but has another electrolyte passage **36** formed therein and defined by an electrolyte pipe **37** which has a sufficient resistance to the attacking of the electrolyte. This electrolyte pipe **37** has its upper end extending into the chamber of the hat **19,** thus offering to the electrolyte passage **36** a fluid communication with the electrolyte passage **35** in the particular chamber. The lower end of the electrolyte pipe **37** is, on the other hand, communicated with an electrolyte reservoir (not shown) by way of a discharge pipe **38.**

In the anode **31,** there is also formed a detergent-air passage **39** for supplying therethrough a detergent or air to the chamber of the hat **19** and to the two electrolyte passages **35** and **36.** After the electroplating operation has been completed, the detergent thus introduced acts to clean the chamber and the passages **35** and **36,** while the introduced air acts partly to dilute gases remaining in the chamber and partly to scavenge the chamber and the passages. The detergent-air passage **39** has an outlet port **43** of nozzle shape extending into the chamber. At the lower extension of the passage **39** is provided a change-over or two-way valve **41** which changes the connection thereof with a detergent supply and with an air supply, respectively, through pipe branches **42***a* and **42***b.* In another modification, the detergent-air passage **39** under discussion may be divided into two pipelets (not shown) each for detergent and air introductions. Then, the change-over valve **41** may be dispensed with.

Indicated at numeral **44** is an electrolyte supply pipe through which an electrolyte is supplied to the electrolyte passage **35** by way of an electrolyte inlet port **25***a* formed in the apparatus main body **25,** as shown. The electrolyte supply pipe **44** is as customary provided with a valve (not shown) for allowing and inhibitting the electrolyte supply to the passage **35.** The inlet port **25***a* is bypassed to an electrolyte-detergent discharge pipe **45** which is provided with a change-over or two-way valve **46.** By controlling this change-over valve **46,** an electrolyte and/or detergent remaining in the passage **35** and the inlet port **25***a* are selectively discharged through pipe branches **45***a* and **45***b.*

With these construction arrangements, since the anode **31** has already been electrically connected with the positive terminal of the energy source, the assembled block with piled annular bodies **11** to be electroplated is fastened to the apparatus main body **25.** Then, by manual handling of the operating handle **28,** the projection **21** of the cathode **22** is electrically connected with the cathode plate **29.** In the meanwhile, the valve mounted in the electrolyte supply pipe **44** is opened, and the two change-over valves **46** and **41** are closed. At this stage, an electrolyte is pumped into the electrolyte passage **35** by way of the supply pipe **44** and the inlet port **25***a.* As a result, the electrolyte passage **35** is filled with the incoming electrolyte. At this stage, electric conduction starts to take place between the annular bodies **11** and the lead layer **34** applied on the anode **31,** so that the inside surfaces **12** of the bodies **11** are electroplated with the accompanying gas formation in the passage **35.** The generated gases, which are in the form of tiny bubbles, are conveyed in the passage **35** by the flowing electrolyte. Since, in this instance, the flow of the electrolyte is directed upward, the conductivity of the electrolyte decreases as it goes up, due to the increasing gas content. This requires a higher bath voltage for the higher annular body **11.** It should be appreciated that the above difficulty is obviated in the electroplating apparatus **10** of the present invention by increasing the negative potential of the annular body **11** positioned at a higher level. That is, the effective electric currents flowing between the anode **31** and each of the annular bodies **11** are adjusted at an equal level by compensating the electric conductivity of the electrolyte in the passage **35** differs along the axis of the tubular body. As has been touched shortly, the cathode **22** has a predetermined intrinsic resistance of considerable value, and the negative potential to be applied to any of the annular bodies **11** is smaller than that to the overlying body **11** by a value determined the distance between the two adjoining fastening bolts **23.** Therefore, if the intrinsic resistance of the cathode **22** is preset at a suitable value, then the resultant negative potential drop between any adjacent annular bodies **11** will compensate the increase in conductivity of the electrolyte wetting each of the inside surfaces **12** thereof due to the decrease in existance of the generated gases. With this condition being satisfied, the thickness of the obtained electroplated layer on the inside surfaces **12** of the annular bodies **11** is equal along the axis of the tubular body.

After the electroplating operation has been completed, the valve in the electrolyte supply pipe **44** is closed, and the change-over valve **46** in the discharge pipe **45** is turned to have communication with the pipe branch **45***b*. Then, the change-over valve **41** in the pipe **39** is changed to have comunication with the pipe branch **42***b* so as to introduce pressurized fresh air therethrough. The air thus introduced scavenge the passage **36**, the chamber in the hat **19** and the passage **35**, in other words, the air discharges an electrolyte remaining in the latter passage **35** in to the electrolyte reservoir (not shown) through the pipes **45** and **45***b*.

After the electrolyte has been expelled out of the passage **35**, the valve **41** is changed to have communication with the detergent reservoir (not shown) through the pipe **42***a*, and at the same time the valve **46** is changed to have communication with the detergent reservoir through the pipe **45***a*, as shown in FIG. **1**. Then, a detergent is pumped into the pipe **39** and injected into the chamber in the hat **39** through the nozzle **43**. The detergent thus injected falls down in the passage **35** while cleaning the electroplated inside surfaces **12** of the annular bodies **11**, and finally is returned to the detergent reservoir.

As has been described in the above, since the conductivity of the flowing electrolyte is uniform everywhere in the passage **35** irrespective of the gradual increase of the generated gases, the resultant electroplated layers formed on the annular bodies have the same thickness. The electroplated inside surfaces **12** of the annular bodies **11** need not be ground or finished to have an equal thickness, as contrary to the conventional electroplating apparatus. The time period required for the electroplating operation is considerably shortened. Moreover, spare consumption of an electroplating material is remarkably reduced.

The electroplating apparatus of the present invention should also be appreciated in the point that it has its discharge pipe formed in the anode and its outlet port formed in the apparatus main body, keeping its hat hermetically mounted on the assembled annular body structure to be electroplated. Thus, the present electroplating apparatus is free from any joint or hose provided at the hat for discharging the remaining electrolyte remaining in the passages of the apparatus. As a result, free emission of noxious gases generated in the apparatus is prevented, which might otherwise invite firing. The apparatus itself can be made highly compact, providing for a simplified handling when in operation.

We claim:

1. An electroplating apparatus for simultaneously and uniformly electroplating the inside surfaces of a plurality of annular bodies placed upon one another so that their central bores are registered comprising: an upright anode about which said annular bodies are to be placed with the inner surfaces equi-distantly spaced from the outer surface of said anode to thereby define therebetween an annular passage; a plurality of seats respectively separating adjacent ones of said annular bodies to electrically insulate the same from each other; means for forcing an electrolyte through said passage; an elongated cathode conductor for applying a negative potential to said annular bodies; said cathode conductor being substantially vertical and constituting a single member having a considerable intrinsic resistance, said cathode conductor having individual means along its length to apply a different negative potential to each of said annular bodies with the negative potential increasing in the direction of flow of the electrolyte, so that the effective electric current flowing between said anode and the respective annular body is substantially equal even though the electric conductivity of the electrolyte differs along said passage due to the generation of gases in the electrolyte.

2. An electroplating apparatus according to claim **1**, wherein said individual negative potential applying means includes a plurality of fastening bolts connecting said single member to said annular bodies and equidistantly spaced from each other for building up a potential drop therebetween determined by the intrinsic resistance of said single member.

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