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B. BERGHAUS ET AL
METHOD OF COATING PISTONS
Filed Oct. 5, 1938

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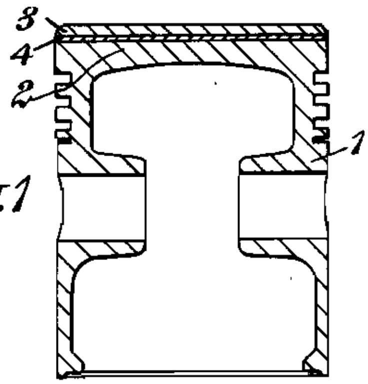

Fig.1

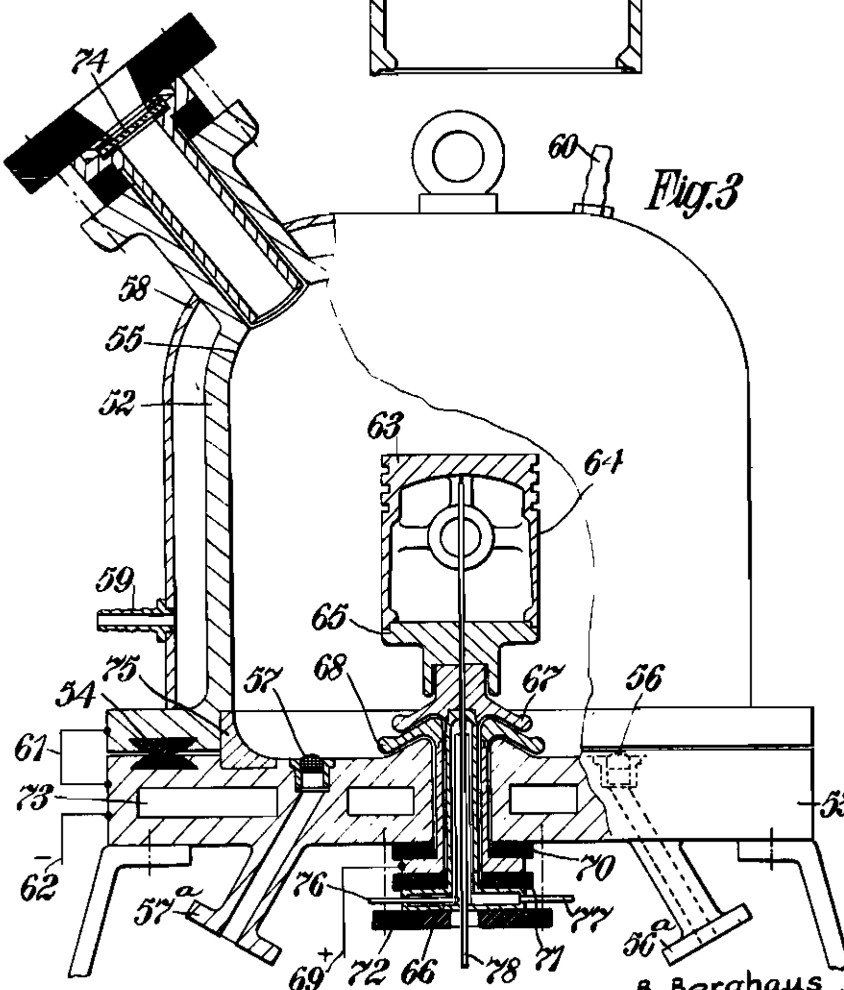

Fig.3

B Berghaus
W. Burkhardt
Inventors

By: Glascock Downing & Seebold
Att'ys

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3 Sheets-Sheet 2

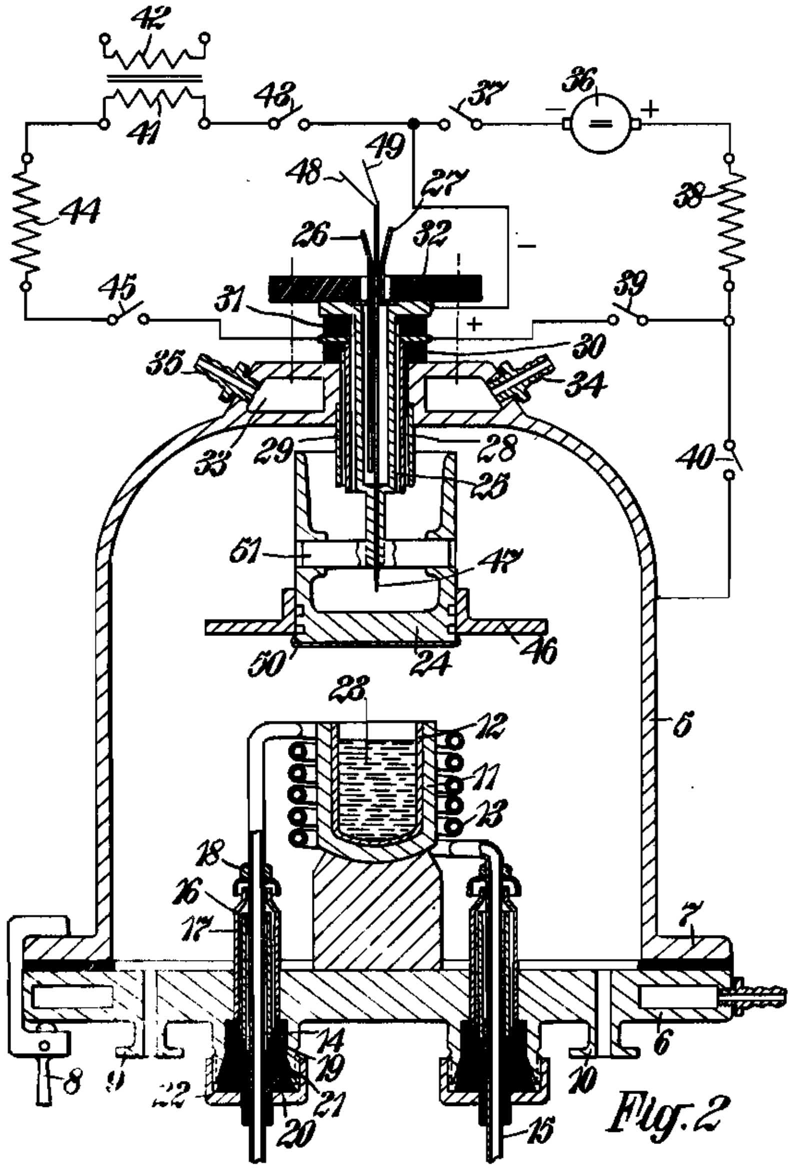

Fig. 2

B. Berghaus
W. Burkhardt
Inventors

By: Glascock Downing & Seebold
Attys.

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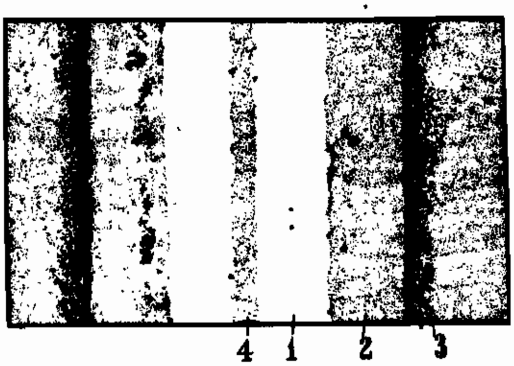
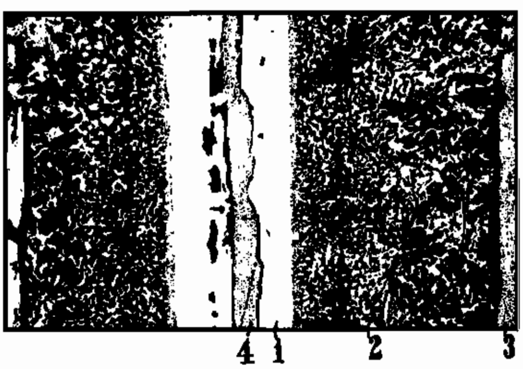
Fig. 4.



1. PURE SILVER LAYER
2. DIFFUSION ZONE
3. FOUNDATION MATERIAL:-LIGHT METAL (PISTON ALLOY)
4. INTERMEDIATE COPPER FOIL.



1. PURE SILVER LAYER
2. ALLOYING ZONE
3. FOUNDATION MATERIAL:-LIGHT METAL (PISTON ALLOY)
4. INTERMEDIATE COPPER FOIL

Fig. 4a.

B. Berghaus
W. Burkhardt
Inventors,

By: Glascock Downing & Seebold
Attys.

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ALIEN PROPERTY CUSTODIAN

LIGHT METAL PISTONS

Bernhard Berghaus, Berlin-Lankwitz, and Wilhelm Burkhardt, Berlin-Grunewald, Germany; vested in the Alien Property Custodian

Application filed October 5, 1938

In order to increase the life of pistons or to increase the output of the engine attempts have already been made to provide light metal pistons, that is pistons made of aluminum or magnesium alloys with metallic protecting layers. Attempts have been made to apply the protective metal by means of metal spraying pistols and by galvanic means. The metal coatings obtained in this way, however, do not meet the great demands put upon the piston during running since they have only slight adhering power and easily become detached from the base material during running whereby serious stoppages may be caused if the parts which have scaled off get between the sliding surfaces. With pistons consisting mainly of magnesium for example, it is impossible to apply protective layers galvanically. These drawbacks are avoided by the invention.

The invention relates to a light metal piston which is characterised by the feature that it is partly or wholly, and especially at the head of the piston, covered with a metallic protective layer, the basis of which is secured to the base material by diffusion or formation of alloy. The metallic protective layer may preferably have a thickness of from 0.005 up to a few millimetres. The application of the metallic layer is effected preferably by cathode disintegration with a filling gas pressure of 3-0.01 mm. mercury. The application of the metallic layer can also be effected by thermal evaporation at a filling gas pressure of $3–10^{-6}$ mm. The metal layer may consist of various metals according to requirements. Thus, for example, it is advantageous to apply to the piston head a protective layer of silver or copper to obtain better conduction and reflection of heat while, on the skirt of the piston, in order to improve the running properties, layers are applied which experience little wear during running or even have a lubricating effect. The metal layers applied according to the invention are far better than the hitherto known protective layers as regards adhering power and are able to stand up to the thermal and mechanical stresses during running.

The invention further relates to a light metal piston of aluminium, magnesium or aluminium or magnesium alloys for engines which is characterized by the feature that it is partly or wholly covered with one or more metal or metal alloy layers applied by cathode disintegration or thermal evaporation in vacuo. The metal or metal alloy layer applied by cathode disintegration or thermal evaporation in vacuo is preferably alloyed with the base material of the piston or partly or wholly diffused into the base metal. The metal piston is further characterized by the feature that the metal or metal alloy layer applied by cathode disintegration or thermal evaporation in vacuo is of a thickness of over $1/1000$ mm. preferably $5/1000$ to $5/100$ mm. up to 1 or more mm., is finely crystalline, of compact structure and strongly adherent.

The invention further relates to a method for making an engine piston of aluminium, magnesium or aluminium or magnesium alloys which is partly or wholly metallised on its surface and which is characterised by the feature that the covering material or the alloy is applied by means of cathode disintegration or thermal evaporation at reduced pressure or in vacuo. Also several metal layers may be applied successively by cathode disintegration or evaporation. The metallising of the light metal piston by cathode disintegration or evaporation is preferably carried out in a neutral or reducing atmosphere at pressures below 50 mm. mercury, preferably between 5 and 10^{-6} mm. mercury. It is particularly advantageous if the metal or metal alloy layer applied by cathode disintegration or evaporation is alloyed with, or diffused into, the piston, by the piston being heated to the alloying or diffusing temperature, preferably in the cathode disintegration or evaporation chamber itself, before, during or after the cathodic metallising or evaporation. The heating of the piston is preferably effected by means of a gas discharge before, or after, the cathode disintegration or evaporation, the temperature of the piston being adjusted by varying the discharge output or by altering the filling gas pressure. The piston is subjected to the gas discharge as a cathode, neutral or as anode. In the cathode disintegration only a fraction of the electrical energy supplied is utilised for disintegrating the cathode. The greater part is converted into heat at the cathode and in the gas space. The quantity disintegrated increases with the discharge power supplied, but at the same time also the heating of the cathode increases. It is thus preferable to cool the cathode in order that the greatest possible disintegrating power may be applied. The energy released in the gas space serves for heating the piston. In order to obtain uniform heating of the piston the cathode preferably surrounds the piston on all sides. The cathode thus preferably itself forms the disintegrating chamber or parts and is provided with a cooling jacket through which water flows. The output at the discharge path is restricted by the temperature to be imparted to the piston. It has been found experimentally that the temperature of the piston can also be regulated by varying the pressure and the temperature is reduced by increasing the filling gas pressure and vice versa. By correctly choosing the pressure it is thus possible to obtain an optimum disintegration output in the discharge path, and to reduce the deposition time to a minimum. A suitable constructional form is therefore one in which the cathode forms the wall of the vessel which feeds power from the discharge to the article uniformly from all sides in order to obtain uniform heating, and is uniformly disintegrated.

According to the method of the invention any metals or alloys can be applied to the piston by the cathode disintegration or thermal evaporation in vacuo and parts which are not to be metallised are covered by a protective layer or a protecting member. The metal layer applied to the metal piston of aluminium, magnesium or aluminium or magnesium alloys by cathode disintegration or evaporation consists preferably of metals such as chrominum, molybdenum, tungsten, iron, cobalt, nickel, copper, silver, platinum, palladium, tin, lead, aluminium, rhodium, cadmium, zinc, vanadium, tantalum, zirconium or the like, separately or in any desired combination. If, for example, only the head of the piston is to be metallised, the side wall of the piston is covered by a protective sleeve or a suitably shaped disintegrating electrode is used. The layers applied by cathode disintegration or evaporation are found to adhere extremely strongly especially when in the alloyed-on state, so that a piston thus covered not only has a very high wear value, but also is protected against the attack of acid condensates from the combustion chamber. According to the melting point of the metal which it is desired to apply it is of advantage to interpose intermediate layers of other metals so that alloys of ternary or higher systems are formed which can be more easily alloyed-on than the pure metal and on to which, finally, the pure metal can be disintegrated or evaporated. The piston skirt is preferably coated with copper, nickel, iron or chromium by cathode disintegration or evaporation. It has been found that silver and nickel as well as chromium applied on the piston head by cathode disintegration or evaporation are good heat reflecting materials while, in the interior of the piston, in order to radiate heat, preferably copper is applied by cathode disintegration or evaporation, which after the conclusion of the disintegration or evaporation, may be oxidised by introducing oxygen into the cathode disintegration or evaporation chamber. If it is desired to have metals of high melting point at the surface it is particularly advantageous for anchoring the layer if intermediate layers are introduced which form alloys of lower melting point with the piston material and the metal of high melting point. The metals and the temperatures to be used depend upon the desired properties of the surface.

According to the method of the invention light metal pistons of any desired composition and construction of aluminium, magnesium or aluminium or magnesium alloys can easily be metallised as is shown by the following examples.

A light metal piston of the Nelson-Bohnalite type of 77.5 mm. diameter, for example, was coated on its surface by cathode disintegration with a layer of copper, the piston being coated at a temperature of about 450 to 550° C. Preferably at the beginning and at the end of the deposition the piston is brought for a short time to the diffusion temperature and in the intermediate time the metal is deposited upon the hot piston at a somewhat lower temperature. The deposition was carried out in hydrogen at a pressure of 3 mm. mercury. The disintegrating voltage was rectified alternating voltage the effective value of which was 700 volts with a disintegrating current of 7 amps.

Further a light metal piston made of alloy containing magnesium and of 77.5 mm. diameter was coated on its surface by cathode disintegration with a layer of silver, the metal piston being coated at a temperature of 450–500° C. Preferably at the beginning and at the end of the deposition the piston was for a short time brought to the diffusion temperature and in the intermediate time the metal is deposited on the hot piston at a somewhat lower temperature. The deposition is carried out in argon at a pressure of 1 mm. mercury. The disintegrating voltage was a rectified alternating voltage the effective value of which was 700 volts at a disintegrating current of 7 amps. The heating of the piston to the alloying or diffusing temperature was effected in both cases by gas discharge in the cathode disintegrating chamber. The copper or silver layer obtained in this manner was extremely firmly secured to the piston material.

Further, e. g., a light metal piston of the Nelson-Bohnalite type of 77.5 mm. diameter was coated on its surface with a layer of copper by thermal evaporation in vacuo the piston being kept by a temperature of about 450–550° C. Preferably at the beginning and at the end of the evaporation the piston was for a short time brought to the diffusion temperature and in the intermediate time the metal was evaporated on to the hot piston at a somewhat lower temperature. The evaporation was carried out in hydrogen at a pressure of 0.3 mm. mercury.

Finally a light metal piston of 77.5 mm. diameter made of an alloy containing magnesium was coated on its surface with a layer of silver by thermal evaporation in vacuo the piston being kept at a temperature of 450–550° C. Preferably at the beginning and at the end of the evaporation the piston was brought for a short time to the diffusion temperature and in the intermediate time the metal was evaporated on to the hot piston at a somewhat lower temperature. The evaporation was carried out in argon at a pressure of 0.01 mm. mercury. The heating of the piston to the alloying or diffusing temperature was effected in both cases by gas discharge in the evaporation chamber. The heating voltage was a rectified alternating voltage the effective value of which was 700 volts at a disintegrating current of 3 amps. The copper or silver layer obtained in this manner was extremely firmly secured to the piston material.

The invention further relates to an apparatus for carrying out the described method which is characterized by a cathode disintegrating chamber with a metallic lower part which can be cooled and a removable metallic upper part which can be cooled, of which the metallic wall forming the cathode consists of the metal to be deposited on the piston or is coated therewith. The metallising chamber has an anode which is led through the metallic wall of the chamber being insulated and screened. The metallising chamber is further characterised by a metallic lead-in which can be cooled and is insulated and screened, preferably in the lower part of the cathode disintegrating chamber on which the piston to be metallised is mounted by means of a conducting or insulating supporting plate.

The invention further relates to an apparatus for carrying out the described method which is characterised by a vacuum evaporating chamber with a metallic lower part which can be cooled and a removable metallic upper part which can be cooled the wall of which carries a metallic current lead-in which can be cooled and is insulated and screened and on which the piston to be metallised is arranged by means of a supporting device which conducts the electric current, and by an electrically heated crucible containing the metal to be evaporated underneath the piston, and also by a source of continuous or alternating voltage of which one, preferably the negative, pole is connected to the current lead-in with the piston while the other, preferably the positive, pole can be connected with the screening or the wall of the chamber.

In the accompanying drawing the invention is illustrated diagrammatically with reference to the constructional example, and Figure 1 shows a section through a light metal piston **1** the head part **2** of which is covered with a metal layer **3**, e. g. copper or silver, which is firmly anchored in the base material by the formation of an alloy layer **4** of the base material of the piston and the applied metal. In a similar manner the remaining part of the piston wall can be metallised as required. Moreover, the accompanying specimen shows a cross-section through a piston head provided e. g., with a silver layer the lower part of which is secured to the base material by diffusion. The two photographs which are further attached show in one case an alloy zone and in the other case a diffusion zone between the coating material and the base material.

The metal protective layer applied according to the invention was applied over the gas phase of the metal to be deposited in vacuo. It is also possible to begin with a solid or liquid phase of the metal to be applied. Thus, e. g., the material can be so highly heated in a crucible that it evaporates and condenses on the suitably arranged piston. For this purpose preferably a filling gas pressure of 3 to 10^{-6} mm. is used in the evaporation apparatus.

When using electrical disintegration filling gas pressures of e. g., 3 mm. to 10^{-3} mm. are used. The material to be disintegrated may be used in the liquid or solid state. According to the invention, when using thermal evaporation or cathode disintegration as the method of applying the metal the piston is brought to the temperature at which the material to be applied can be connected with the base material by diffusing or formation of alloy. This temperature is maintained until the desired depth of penetration of the applied material into the base material is reached. Then the temperature is slowly reduced in order to obtain the pure metal on the surface as a protective layer. According to the requirements it may be sufficient to produce only a diffusion or alloy zone. The desired formation of the layer is obtained by regulating the temperature of the piston to be coated.

Figure 2 shows a section through an apparatus for thermal evaporation of metal on to light metal pistons in vacuo.

The apparatus for thermal evaporation consists of a vessel **5** which can be evacuated and which can be hermetically closed by means of a cover **6** with a packing **7** interposed which can be cooled by means of the air passage provided in the cover, by means of the eccentric catch **8**. A vacuum pump which is not illustrated is connected to the branch **9** and through the branch **10**, if necessary, a preferably reducing filling gas, such as hydrogen, can be introduced in small quantities. By means of the vacuum pump any desired reduced pressure, for example under 50 mm. mercury, up to the highest attainable vacuum, can be obtained in the vessel.

The material to be evaporated, for example a metal or an alloy, is placed in the evaporating crucible **11** which is provided with a lining or insertion **12** which is not attacked by the metal to be evaporated. The heating of the crucible up to the evaporation of the metal is effected for example by means of a hollow high frequency coil **13** which can be cooled, the ends of which are led through the cover **6** into the vacuum vessel by means of the two current leads **14** and **15**, being insulated, vacuum tight and screened. The lead **14** is screened by means of the metal screening sleeves **16** and **17** arranged at a small distance from the lead and is covered by a protective cap **18**. **19** and **20** are two insulating bodies between which is a packing body **21**. The screw ring **22** is used for pressing the whole together. The current lead **15** is constructed in the same manner. The molten metal **23** evaporates in the crucible **12** and the vapour is deposited upon the metal piston **24** which is arranged on a current lead-in **25** which is hollow and can be cooled, it being possible to introduce through the pipe **26** and to withdraw through the branch **27** a cooling medium such as water. The parts **28** and **29** form two metallic screens which are arranged at such a small distance from the current lead-in and from one another that no glow discharge takes place in the intermediate spaces. The parts **30** and **31** are two insulating and sealing rings, while the part **32** is a pressure ring. By means of the cooling device **33** in the vacuum vessel the current lead-in is cooled and the cooling medium can be introduced through the branch **34** and withdrawn through the branch **35**. One end of the secondary winding **41** of the alternating current transformer **42** can be connected through the switch **43** with the lead-in **25**, and the other end of the secondary winding can be connected through the regulable resistance **44** and the switch **45** with the screening sleeve **28**.

The negative pole of a continuous current source **36** is connected through a switch **37** with the lead-in **25**, while the positive pole of the voltage source can be connected through a regulable resistance **38** either through the switch **39** with the screen **28** or through the switch **40** with the wall of the vacuum chamber **5**. The part **46** is a screening ring which can be used as required if the side walls of the piston are not to be metallised. The part **47** is a thermo element with the ends **48** and **49**. The part **50** is the vaporised metal layer and the part **51** is the supporting device for the piston.

In Figure 3, which shows a section through a cathode disintegration metallising chamber for light metal pistons made, for example, of aluminium, magnesium or aluminium or magnesium alloys, in which the wall is formed as the cathode to be disintegrated which surrounds the piston to be metallised on all sides, the part **52** is the removable metallic disintegration vessel hood which can be hermetically connected with the metallic bottom **53** with an interposed packing **54**, consisting for example of two rubber rings. The whole inner surface **55** of the cathode disintegrating chamber, that is, both the bottom and the hood, may consist of the metal or metal alloy to be deposited or may be coated therewith. Such metals may be principally chromium, molybdenum, tungsten, iron, cobalt, nickel, copper, silver, platinum, palladium, rhodium, cadmium, zinc, vanadium, tantalum, zirconium, aluminium, magnesium or the like, separately or in any desired combination. The vacuum pump, which is not illustrated, is connected to the branch **56**, while the branch **57** serves for introducing a neutral or reducing gas, such as nitrogen, hydrogen, a rare gas such as argon or the like. In the gas inlet **57** there is placed a sieve **57**a and in the gas outlet **56** according to the invention a sieve **56**a is placed which prevents a gas discharge, more particularly a glow discharge, striking into the gas inlet or outlet. The size of mesh of the sieve is, for example, smaller than 1 mm. The hood **52** is surrounded by a cooling jacket **58** to which the cooling medium, for example water, oil or air, can be supplied through the branch **59**. The cooling medium is led away through the branch **60**. The bottom can be conductively connected through the removable conductor **61** with the furnace vessel. The negative voltage is supplied through the current cable **62** which can be secured to the bottom.

The piston **64** to be metallised with the metal layer **63** rests, for example, on an insulating or conducting plate **65** which is carried by the lead-in **66** which can be cooled, through the intermediary of a body **67** of metal or insulating material. The part **66** is the anode which is insulated and is screened from the bottom plate **53** and the lead-in **52** by a narrow gap in each case and which is connected through the cable **69** with the positive pole of a continuous voltage source. The parts **70**, **71**, **72** are rings of insulating and sealing material. The ring **72** is pressed against the bottom by means of screens which, for the sake of simplicity, are not illustrated. Between the anode **68** and the wall of the disintegrating vessel which is connected up as cathode, the gas discharge required for disintegrating the metal and for heating the piston up to the desired alloying or diffusion temperature is formed at a pressure between 40 and 0.001, preferably about 5–0.1 mm. mercury. The cathode distintegrating chamber is further provided with a screened inserted observation glass **74**. The part **75** is a ring for covering the gap between the vessel and the bottom. The branch **76** serves for supplying the cooling medium for the lead-in **66** and the branch **77** serves for withdrawing the cooling medium. The bottom is provided with cooling passages **73**. The part **79** is a thermo element for measuring the temperature of the piston during the deposition.

BERNHARD BERGHAUS.
WILHELM BURKHARDT.