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Small Dynamos and How to Make Them (including Electric Motors). Describes the construction of a number of small and model dynamos and electric motors, including a 60-watt "students'" dynamo, a hand-driven dynamo for experimental purposes, electric motors for model tramcars and locomotives, etc. etc. A feature of the book is a detailed description of, with instructions on making, a cycle-lighting dynamo driven by contact with the road wheel.

ELECTRO-PLATING

Electro-Plating

WITH NUMEROUS ENGRAVINGS AND DIAGRAMS

EDITED BY
PAUL N. HASLUCK

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PUBLISHERS' NOTE

This treatise on Electro-plating is largely from the experienced pen of the late G. E. Bonney, and it is issued in the confident belief that it is not only thoroughly practical and reliable, but is so simply worded that even inexperienced readers can understand it.

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ELECTRO-PLATING

CHAPTER I.

INTRODUCTION: TANKS, VATS, AND OTHER APPARATUS.

ELECTRO-PLATING is the process by which a metal or alloy held in solution by a liquid is deposited electrically on a prepared surface. From the solution, the metal (nickel, silver, brass, copper, etc.) is thrown on to the object receiving the deposit, and simultaneously an equal quantity of a similar metal to that held in solution is fretted off from metal plates (anodes) suspended in the electro-plating bath. Thus, although the solution is being constantly robbed of metal, it is yet being fed, and so its strength is maintained. Of course, the anodes must be plates of similar metal to that contained in solution; thus, nickel anodes in a nickel solution, silver anodes in a silver solution, and so on.

Anode is the name given by Dr. Faraday to the positive plate or wire in a solution undergoing electrolysis. It is derived from two Greek words: *ana*, meaning "upwards"; and *odos*, "a way"—the way in which the sun rises—and is an indication that the current rises from the battery to enter the electro-plating solution, this way being from the negative element of the battery to the positive element in the solution to be electrolysed (see the arrows in Fig. 1). The negative element of a battery receives the electric current immediately it is generated, and transmits it to the anode

placed in the electro-plating bath; the negative element is, therefore, the positive pole, and its connection to the anode by a wire makes the anode the positive pole or element in the solution. By way of illustration: the carbon element in a Bunsen battery (see pp. 28 to 30) is the negative element, because it receives the electric current generated by the positive, or zinc, element of the battery; but it is also the positive pole, because, through it and its metal connections, the current is transmitted to work outside the battery. Fig. 1 shows at a glance what is meant.

Another scientific term has now to be referred to. Anion is a term invented by Dr. Faraday to indicate the radical of an acid, or the portion of a salt set free at the anode during electrolysis. It has been defined as "the electro-negative, or chlorous radical of the acid or salt decomposed" Assume that a solution of the double cyanide of silver and potassium is being used in the work of electro-plating. The salt of silver in this solution is combined with a salt of potassium, and three distinct substances are present, apart from the water which holds them all in solution; these are —silver, potassium, and cyanogen. When the electric current is passing through the solution in the process of plating, silver and potassium are set free at the goods being plated, and cyanogen is set free at the silver anode. The salt is thus broken up or decomposed, and cyanogen is the anion of this salt.

Anodes may be soluble or insoluble in an electrolyte, as may be required to suit the nature of the work in hand. Insoluble anodes are used when it is wished to decompose an electrolyte, and break it up into its several component parts without adding another element to it, as when acidulated water is decomposed by the electric current to form oxygen and hydrogen—in which case a platinum anode is used, because platinum

is not soluble in the acidulated solution. Insoluble anodes are also used when it is wished to extract all the metal from its solution, and deposit it in a pure condition on the cathode (the article plated). Anodes are said to be insoluble when they are made of elements which are neither soluble in the solution to be electrolysed, nor can be made soluble therein under the influence of the electric current. Some solutions of the acids and alkalis will act very feebly, or not at all, on an element, even when heated to boiling point, but

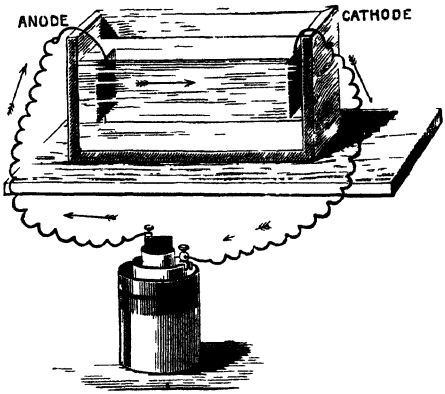

Fig. 1.—Diagram showing Positions of Anode and Cathode in Electro-plating.

will dissolve it freely when a current of electricity is passed from it through the intractable solutions. For instance, gold is only feebly soluble in a strong solution of potassium cyanide when exposed to air, even when the solution is heated; but it is freely soluble in the same solution when only a feeble current of electricity is passed from it through the solution. Insoluble anodes are generally made of platinum or carbon.

Soluble anodes are used when it is wished to maintain an electrolyte (the plating solution) at its

to note changes of colour in the metals; but the light over the vats should be a northern light if possible, because sunlight decomposes all plating solutions. The plating shop should be roomy and clean, for the most perfect cleanliness in the process is necessary to success. The plating vats should be covered with canvas when not in use, to exclude dust. Ventilation is necessary, because all the exhalations of gas from the solutions are extremely poisonous and soon debilitate the strongest workmen when fresh air is absent. Not only is an even temperature conducive to regular working of the solutions, but the *employés* do better and more work when the shop is well ventilated and comfortably warmed.

If the solution vats are placed in a corner of an ordinary workshop, they will soon get contaminated with dust and dirt. If the dynamo is near the polishing lathe, or where metal dust is lying about, it will soon be ruined.

Metal castings, forgings, etc., are surfaced for plating on emery bobs, etc., as will be described in later chapters; they are then immersed in a hot solution of caustic potash, to loosen and remove grease and oil contracted at the polishing lathe. The solution for this purpose is contained in a wrought-iron tank, the usual dimensions for which are 4 ft. by 2 ft. by 1 ft. 9 in., to hold 50 gallons of liquid; or one for larger work, measuring 5 ft. by 2 ft., to hold 100 gallons. The size of the tank will be determined by that of the work, and the vessel must be large enough to receive the longest articles likely to be plated. It is made of wrought iron, which is not attacked by caustic potash. Tanks of galvanised iron, lead-lined tanks, zinc tanks, and tanks with soldered joints are unsuitable, because all these metals and solder are soluble in caustic potash, which will hold the dissolved metal in solution and deposit it on any articles cleaned in the tank.

As the potash solution will have to be worked hot, the tank must be placed in a position where it can be conveniently heated, either by steam passing through a coil of iron pipe in the solution, by an ordinary furnace in which coal or coke is burnt, or by gas jets. Steam and gas are preferable to coal, because the heat can be regulated to a nicety, and there is no danger from fire after the day's work is done. Even when heated by steam, it is advisable to support the tank above the floor on brickwork to a height suitable for easy working. The solution is composed of American potash dissolved in water, at the strength of 1 lb. to each gallon of water.

The articles are rinsed in hot water after they are taken from the potash tank, so a second tank, of equal dimensions and of the same material, must be fitted up in a similar manner next to the potash tank. This is kept supplied with clean hot water.

In the preparation of articles to be plated, the polisher aims at getting the finest polish obtainable on the surface of the article; whilst the plater tries to free the surface from every trace of grease, oil, sweat, and other foreign matter. The polished work may be beautifully clean from a polisher's point of view, and yet be very dirty when viewed from the plater's point of view. The surface must be chemically clean before the article is placed in the plating vat, to ensure the deposited coat of metal adhering firmly to the surface of the metal on which it is deposited. The vessel in which the articles are thus further cleansed is named the scouring trough or tray, and is shown by Fig. 2. It consists, as shown, of a shallow trough of thick wood divided into two parts, lined with lead, and furnished at one end with a plug and overflow pipe. In some scouring trays a narrow shelf is fixed a little below the upper edge, and the work rests on this whilst being cleaned. Some work-

men hold the work on a piece of board placed across the tray. The tray must be placed on strong wooden trestles, at a height to suit the workman, and kept half full of clean water, to rinse the articles after scouring.

The plating vat is the name given to the vessel intended to hold the plating solutions. This vessel must be roomy enough to take the largest article likely to be plated in it, and then leave an abundance of space all round. It is usual to plan plating vats to hold several such articles at

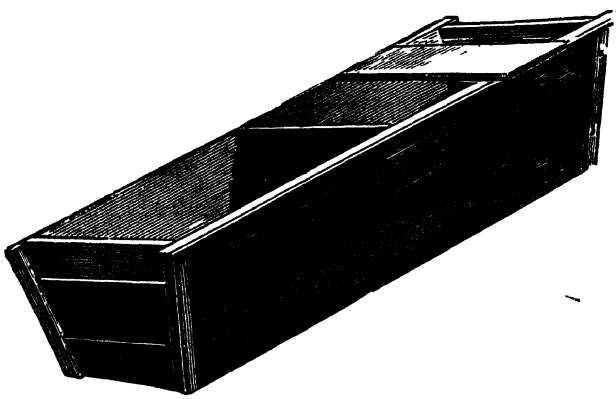

Fig. 2.—Scouring Trough.

once, so that time may be saved. Those in general use for nickel, copper, brass, and silver-plating, are made of thick pine-wood, well jointed, and strengthened with iron bolts across the ends, lined with sheet-lead put together with burnt joints, then match-lined to prevent metallic contact with the lead lining. The appearance of these vessels when finished is shown by Fig. 3. They are made in a great number of sizes, the capacities ranging from 19 gal. to several hundred gallons.

A vat to hold the solution may be of vitreous stoneware; but this material is liable to fracture,

and is not easily made into large rectangular vessels. The next best is enamelled iron, which, being smooth, retards the creeping action of the cyanide salts, so that the sides of the vat are kept clean, and enamelled iron vats are suitable for small work; their use is almost compulsory when the solution must be used hot. In large plating establishments the vats are wood, lined with lead, as already mentioned.

Plating vats constructed of thick slate slabs, grooved and well bolted together, are also sold for the purpose, but apparently they cost 50 per

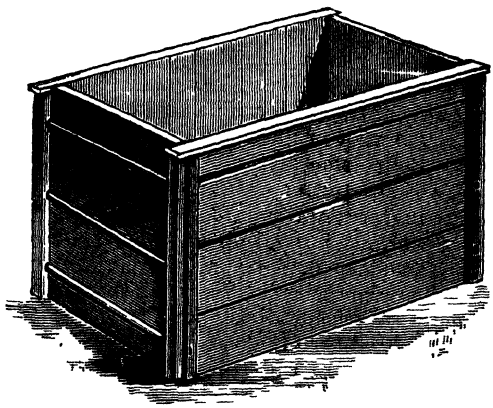

Fig. 3.—Plating Vat.

cent. more than the lead-lined wood vats. Vats made of iron only, unless they are lined with thick enamel, are altogether unsuitable as plating vats; copper, brass, iron, and zinc are readily corroded by the action of the acid or the alkali present in the plating solution.

A light vat should be supported on short stout trestles, at a height suitable to the workmen—that is, with the upper rim about the same height as an ordinary table. Two, three, or four such

supports will be required, according to the length of the vat. If, however, the vat is large and heavy, it should be supported by a strong foundation of masonry, and this should be so built as to ensure free access of air to the under side, thus preventing rot in the wood. If the floor round the vat can be coated with cement or asphalt it can be easily kept clean, and it is also advisable to have wooden grids on the floor by the sides of the vat, on which the workmen may stand.

Special iron stands for vats can be obtained (see Fig. 4); these are provided with means of heating the vat by gas.

It is possible to make a small electro-plating bath with glass plates cemented together and enclosed in a wooden box. The cement may be either marine glue, which can be bought, or 2 parts of pitch and 1 part of gutta percha can be melted together. Pour some of the melted material into the wooden box and spread in a thin layer over the bottom with a warm iron; while the cement is warm (not hot) press the bottom plate firmly into it. The sides may be treated in the same way, but before putting in the glass plates warm them gently and coat all the edges with a thin layer of the cement, so that when they are pressed together the surfaces will adhere thoroughly; the joints will then be waterproof. Make the wood box a trifle large, allowing room for the layer of cement, or if the glass plates be forced in and nothing allowed for contraction and expansion the glass box will probably crack at the weakest part. Another suitable cement is prepared as follows: Make some good flour paste, and allow to get cold. Prepare a quantity of thin glue, add 10 gr. of powdered bichromate of potash to each gill of glue, bring it to a boiling temperature, and then pour it into the cold paste whilst stirring. Use this cement warm, and expose to strong sunlight afterwards. It will resist acids, but not hot

cyanide of potassium solutions. Still another cement is made by dissolving best isinglass in acetic acid by the aid of heat; it is used hot.

The electrical fittings of the plating vat are described in the next chapter.

The articles to be plated are suspended in the plating solution from copper rods (see p 51) by means of short lengths of wire, named slinging wires. These are made of bare copper wires, ranging in gauge from No 8 to No 18, the larger

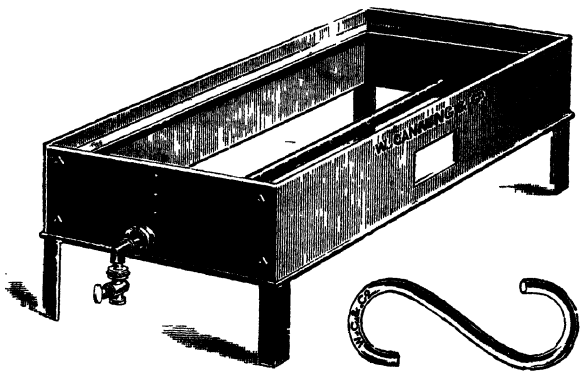

Fig 4.—Iron Stand for Vat

Fig. 5.—Copper Hook.

size being employed for heavy, and the smaller sizes for light, articles Two wires of No. 18 will hold up a cycle handle-bar; but it is always advisable to have more wires or larger wires than required merely to support the articles, since these wires convey the electric current from the goods being plated; and an insufficient wire conductor here will prevent the nickel from going on as fast or as well as may be required Small wires offer a greater resistance to the current, and should be avoided for this reason.

The connection between the slinging wires and the articles to be plated is by means of copper

hooks, the usual pattern of which is shown by Fig. 5.

The plated articles are rinsed in hot water after leaving the plating vat, and are then transferred at once to hot boxwood sawdust, in which they are dried quickly. This treatment is needed to prevent the coat of deposited metal from being marked by stains. The sawdust is held in a shallow pan or tank of iron placed next the hot water tank. This pan is heated by hot water or steam. If hot water is used, it occupies the double bottom, this being heated by steam jets: by the other method, the steam passes through a coiled pipe in the double bottom (see Fig. 6). Direct heat from a fire or from gas jets is inadmissible, because this would char the sawdust, and thus stain the work If live high-pressure steam is employed, this should be used in a coil of pipes not directly in contact with the sawdust (see Fig. 6), as such very hot steam is liable to char the sawdust. Boxwood sawdust is employed, because this does not contain resinous matter, likely to be extracted by heat, and stain the metal; but the sawdust of sycamore could be used as a substitute if more readily obtainable. The sawdust tank and the hot-water tank may be of galvanised iron, if this is of any advantage.

The Bunsen burner will frequently be useful It is composed of a short burner inside a piece of gas barrel some five or six inches in length, to which air is admitted at the lower end The air mixes with the incoming gas in the barrel, and the mixture burns together at the top with an intensely hot, smokeless, and non-luminous flame. When the tube of the burner is surmounted with a cap, the flame spurts out of the holes, and forms a "rose burner," the flame from which can be used for general heating purposes.

The balances or scales required by an electro-

plater will vary with the class of work on which he is engaged. For the ordinary work of weighing the goods before and after plating, to determine how much metal has been deposited, a pair of scales with a stout steel or brass beam will be required. For weighing gold and gilded articles a lighter pair, indicating a turn on one grain at least, should be provided; these will also serve for weighing out the ingredients used in making up solutions. For rough assays and estimations a small cheap balance indicating a turn

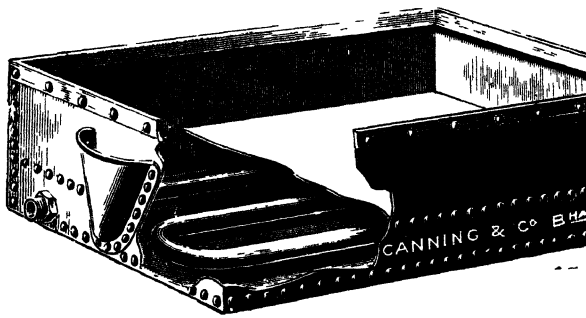

Fig. 6.—Steam-heated Sawdust Pan.

of $\frac{1}{10}$ grain will serve the purpose; the cost of this, together with weights from 500 grs. down to $\frac{1}{10}$ grain, will be about £1 10s. For assays, analysis, and calibrations, a still more elaborate and delicate balance will be required, such as an Oertling assay balance fitted with agate bearings and indicating a turn with at least $\frac{1}{100}$th of a grain. Such a balance, with a full set of weights, will cost from £5 to £10.

In some plating establishments the weight of deposited metal is determined during the operation of plating by means of a plating balance. This is merely a pair of large scales furnished with a scale pan at one end of the beam and a

metal frame suspended over the bath at the other end The goods to be plated are slung to the metal frame, and the whole is balanced by weights placed in the scale pan. The pillar of the beam is connected to the negative pole of the machine or battery. As the metal goes on the goods to

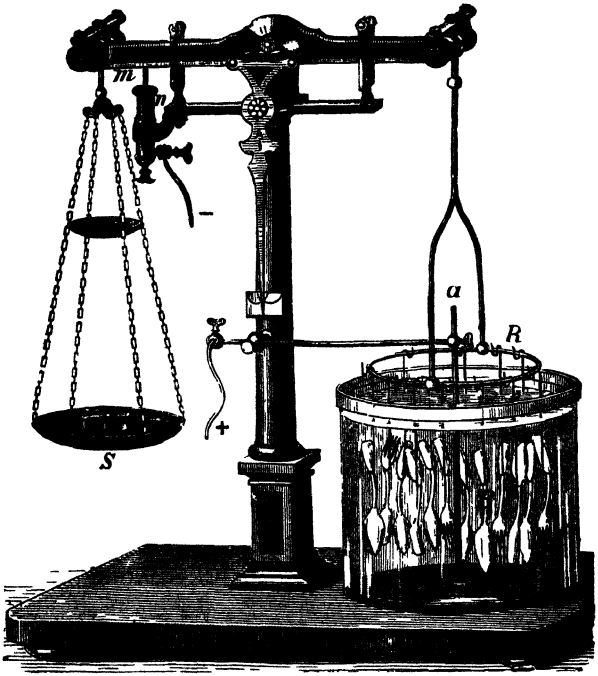

Fig. 7.—Roseleur's Plating Balance.

be plated, the beam is thrown out of balance, and the exact weight deposited can be ascertained at any time by additional weights placed in the scale pan.

Roseleur's plating balance is shown by Fig. 7. The beam carries at one end a metal ring R, from which the objects to be plated are suspended in

the bath B. The anode *a* is shown as a rod connected through terminals, etc., to the positive pole of the battery. From the opposite end of the balance the pan S is hung. A metal pin *m* dips into the mercury cup *n*, and this cup is connected to the negative pole of the battery. The path of the current is therefore from the battery by way of the anode *a* through the bath, and thence, by way of the articles to be plated, through the beam and mercury contact back to the battery. In the horizontal position of the beam, *m* does not make contact with *n*. But the weight of the articles is balanced by adding weights to the pan S, and further weights are then added equal to the weight of silver to be deposited. This brings *m* down and completes the circuit. When the required weight of metal has been deposited, the left arm of the beam (as seen in Fig. 15) rises and breaks the circuit. It will be seen that the balance is automatic, cutting off the current when the articles are plated to the extent intended.

The work of the plating balance is done in a different way by a special ammeter (p. 54) which records the amount of silver deposited per hour.

Beakers are tumblers made of very thin Bohemian glass for special use in chemical manipulations where small quantities of acids and other liquids are employed at high temperatures. Tumblers made of ordinary glass would soon break in pieces, but these thin glass beakers will bear boiling water being poured into them, or will hold acid whilst it is being boiled in them over a gas stove. They are also useful in analysis of solutions, as the clear glass enables the operation of precipitation to be observed whilst the operator holds the beaker away from his face, and thus avoids breathing the deleterious fumes.

CHAPTER II.

BATTERIES, DYNAMOS, AND ELECTRICAL ACCESSORIES.

The electric current used to deposit metal from plating solutions must be obtained from a convenient source; this may be a battery for occasional jobs, and for the general use of the amateur or small professional; and it may be a dynamo when large quantities of work have to be treated. The advantages of the dynamo are many. The current is more constant, labour is lessened, and the cost of maintenance is much reduced. The current can also be regulated, and thus any class of work can be done from one machine. A plating dynamo gives a large current at a low pressure; the armature may be of the drum or ring pattern, and the machine is shunt wound. With a large machine, capable of giving, say, 200 ampères, large surfaces of work may be acted on in several vats simultaneously, and nickel-plating may proceed at the same time as silver-plating.

The electro-motive force required to be supplied by the battery or dynamo varies according to the bath. Thus, for gold and silver, it may be from $\frac{1}{2}$ to 4 volts; for copper, with an acid bath, it may be from $\frac{1}{4}$ to $1\frac{1}{2}$ volts, or, with a cyanide bath, from 3 to 6 volts. The ampèrage will vary with the area of the anode and cathode surfaces.

The word battery, as applied to electrical apparatus, belongs strictly to a collection of Leyden jars charged with static electricity. These discharge their store of force in a violent manner, totally unlike the equable flow of current obtained from collections of voltaic or galvanic cells.

TABLE OF BATTERIES USED BY ELECTRO-PLATERS.

Name of Battery.	*Negative Element and Solution.*	*Positive Element and Solution.*	*E.M.F. of Cell.*	*Approximate Resistance of each Cell.*	*Work for which it is most suited.*
Daniell.	Copper in saturated solution of sulphate of copper.	Zinc in sulphuric acid solution, 1 to 12 or 15.	1·079 volts.	2 to 5 ohms.	Gold-, silver-, and copper-plating and electrotyping.
Smee.	Platinised silver in dilute sulphuric acid, 1 to 10, 15, or 20.	Zinc in dilute sulphuric acid, 1 to 10, 15, or 20.	0·47 volts.	0·5 ohms.	Electro-gilding, silver-plating, and electrotyping.
Walker.	Platinised carbon in dilute sulphuric acid, 1 to 10, 15, or 20.	Zinc in dilute sulphuric acid, 1 to 10, 15, or 20.	0·66 volts.	0·4 ohms.	Electro-gilding, silver-plating, and electrotyping.
Bunsen.	Carbon in nitric acid.	Zinc in sulphuric acid solution, 1 to 15 or 20.	1·7 volts.	0·8 to 0·11 ohms.	Nickel-plating and copper-plating in alkaline solutions.
French Bunsen.	Carbon in strong sulphuric acid.	Zinc in sulphuric acid solution, 1 to 15 or 20.	1·6 volts.	0·11 ohms.	Electro-gilding, silver-plating, copper-plating in alkaline solutions, and nickel-plating.

French electricians speak and write of such generators under the name of "Piles," doubtless in deference to the form of the first voltaic generator of electricity made—the pile of metal discs invented by Volta. English electricians apply the word battery to all apparatus in which electricity is generated by chemical decomposition, and also to two forms of storage cells known respectively as accumulators and Leyden jars.

A tabulated list of the batteries in use by electro-platers is given on p. 25, and the table will show at a glance the battery most suitable for any particular work.

Other batteries, such as the Fuller, Wollaston, Gassner, and very occasionally the Leclanché, are also used by some platers; these will be referred to later

The Daniell is best for depositing copper from its sulphate solution and silver from the usual plating solution, but the Bunsen may be used for this purpose if the exciting liquid is sufficiently weakened One or two large cells in series will be enough for all ordinary purposes. The Bunsen is best for depositing copper and brass from their alkaline solutions, and also for the deposition of nickel, because its electro-motive force is high, enabling the current to push through high resistances. It is not suitable for the work of silver-plating, gilding, and electrotyping, because its high E M.F. causes the metal to go on too fast and in a granular condition. In all these operations the Daniell will be found to be the best because its E M.F. is lower than that of the Bunsen, and its current equally constant in volume. The Smee, and also Walker, are eminently useful cells for giving a current suitable to the work of electro-gilding small articles of jewellery. Batteries with a high E.M.F. cause gold to go on too fast, and give the deposit a brown colour.

Some information as to the form and construction of the various batteries used by electroplaters may now be given.

The Daniell cell is known in several modifications, Fig. 8 showing the internal arrangement of the porous pot form The glass or glazed vitrified stoneware jar J contains the cylindrical plate C (made of sheet copper), the porous pot P (made of unglazed earthenware), and the zinc

Fig. 8.—Daniell Cell.

Fig. 9.—Bunsen Battery.

rod Z Inside the porous pot dilute sulphuric acid is poured, while the copper plate C stands in a saturated solution of copper sulphate. The connections are made to the two wires shown in the illustration The maximum electromotive force of the cell is about 1·14 volts, with an internal resistance of 3 ohms in the 3-pint size, and 1·6 ohms in the 3-quart size

A Daniell battery is re-charged in the following way: Thoroughly clean all the parts and reamal-

gamate the zincs; charge the porous pot, containing the zinc, with a solution of 1 part of sulphuric acid in 12 or 13 parts of water, and the outer jar, containing the copper plate, with a saturated solution of sulphate of copper. The small sieve or tray near the top of the containing jar, but below the level of the copper solution, should contain crystals of sulphate of copper to keep the solution saturated. If copper is allowed to deposit on the porous pot, the current will fail, not only on account of a higher internal resistance, but also because this short-circuits the cells. To prevent this, the zinc and also the zinc sediment must be kept from touching the porous partitions.

The Daniell battery is very constant. Whilst the sulphate of copper solution is kept saturated, and the zinc kept in working order (well amalgamated—coated with mercury), the current will not flag at all during the day; it is therefore most suitable for silver-plating and gilding, but it is very troublesome to keep in working order, unless kept well at work and employed every day.

The Bunsen battery as used in England is made up of an outer containing cell of stoneware, containing a cylinder of amalgamated zinc, inside which is a cell of porous earthenware containing a square bar of carbon (see Fig. 9). The outer cell is charged with sulphuric acid diluted with water, and the inner cell is charged with strong commercial nitric acid. The electro-motive force given by this cell is variously stated by authorities as 1·85 to 1·95 volts. The internal resistance of the cells varies with their size, the condition of the porous cell, and the condition of the acid charges; the resistance being variously given as 0·30, 0·08, and 0·06 ohms These probably represent respectively the pint, quart, and half-gallon sizes of cells used by the persons testing them. The E.M.F. of the quart Bunsen when charged with sulphuric acid diluted with twelve parts of

water in the outer cell, and strong nitric acid in the inner cell, may be put down at 1·86 volts, and its internal resistance at 0·08 ohm. This will give a current of about 23 ampères on a short circuit, or 1·78 ampères through an external resistance of 1 ohm. As gold is deposited from its solutions at the rate of 37·31 grains per ampère hour, this current will deposit 64·17 grains per hour. It will also deposit 105·50 grains of silver in the same time. As, however, silver is best deposited with a low E.M.F. of from 1·5 to 1·6 volts, and gold with an E.M.F. of 1·2 volts, the Bunsen has a tendency to deposit both of these metals in a rough condition, unsuited to work that must be burnished.

The Bunsen cell is well suited to gilding and silvering small articles, such as chains and trinkets slung to fine wires offering a high resistance; but, for plating spoons and forks, and for plating on large surfaces, the current from a large Daniell, Smee, or Wollaston is preferable, because it deposits a coat more adapted to the action of the burnisher. The Bunsen cell, however, has become a favourite with trinket platers, because it is easy to set up and cleanly in working, thus causing very little labour in setting up and putting away.

A Bunsen battery may be made as follows: Obtain a stoneware jar of quart size or larger, and in it place a cylinder of zinc about $\frac{1}{8}$ in. thick; inside this zinc cylinder place a porous pot about $\frac{1}{2}$ in. smaller in diameter but 2 in. higher than the stone cell, and inside the porous pot put a rectangular stick of carbon, say 2 in. by $1\frac{1}{4}$ in. by 10 in. to 12 in. long. The zinc cylinder must be well amalgamated with mercury, being dipped in a dilute solution of oil of vitriol to clean, and then placed in a shallow porcelain tray (such as photographers use) in which is a quantity of hydrochloric acid and mercury. On rubbing the

mercury over it the zinc will be coated inside and out. Allow the zincs to stand on end for a time to drain the excess mercury off. Fix the zincs and carbons with brass connections, and join the batteries in series—that is, connect the zinc of one cell to the carbon of the next, leaving a free end of the zinc and of the carbon. The batteries must be charged with acid as follows. Run the nitric acid inside the porous cell till about three-quarters full, and fill the space between the porous cell and the stoneware with a mixture of 1 part of sulphuric acid to 9 parts of water.

The French Bunsen is made up with sulphuric acid in the porous cell with the carbon, thus producing a constant generator with a lower E.M.F. The current from the French Bunsen has an E.M.F. of 1·8 volts at starting, but it soon falls to 1·6 or 1·5 volts when the circuit is closed, because the sulphuric acid is inferior to nitric acid as a depolariser. This form is also less troublesome to keep in working order than the ordinary Bunsen, and it is free from noxious fumes, which render the presence of the ordinary Bunsen well-nigh intolerable in close workshops.

Nearly all the batteries given in the list on p. 25 may be modified. A modification of the Bunsen has just been noticed. In the table, mention is made of the various strengths of acid solutions to be used in the zinc compartments of the batteries. These suggest other important modifications, the E.M.F. of the battery varying with the quantity of acid used. For instance, the E.M.F. of the Bunsen charged with a solution of one part sulphuric acid and eight parts of water may give an E M.F. of 1·95 volts, but when charged with a solution of 1 part sulphuric acid to 10 or 12 parts of water the E.M.F. may fall to even less than 1·80 volts. The Daniell, Smee, and Walker may be modified in like manner.

The Wollaston battery takes the form shown

by Fig. 10. All the couples of copper and zinc plates are contained in separate cells *a d* of glass or porcelain, which hold the sulphuric acid or other exciting fluid The zinc plates are each kept adjusted centrally by wooden slips between the halves of a doubled copper plate bent round under them. The whole set of plates is connected by copper strips *m*, and is secured to the wooden frame K; so it can at pleasure be lifted out of the fluid and the action of the battery stopped

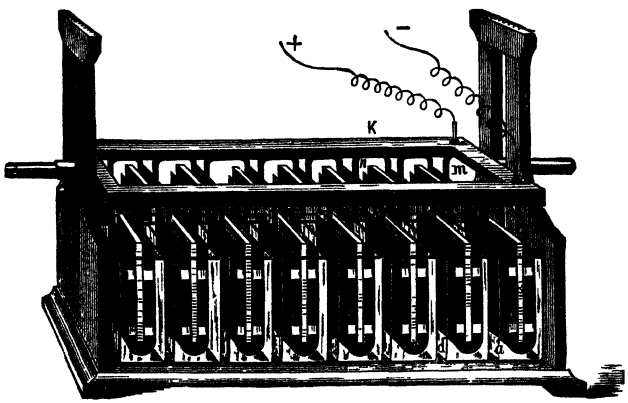

Fig. 10.—Wollaston Battery.

This is one of the earliest galvanic batteries introduced after Volta's original invention

The Wollaston battery is the least costly and least troublesome of all the plater's galvanic batteries, but it is also most inconstant, as its current is apt to fall off rapidly after being set to work; but it recovers its strength after a few minutes' rest, and it is a handy battery for such short jobs as generally fall to the lot of the country jeweller. One form of it may be made at home as follows· Get three or four open-mouthed jars of glass, stoneware, or porcelain, of any size

from one quart to one gallon, the larger size being preferable; these are to serve as battery cells. Next get some three or four plates of rolled zinc, just large enough and long enough to go in the jars; clean the plates well in hot water containing washing soda, and rinse them in clean water. Pour some water in an earthenware baking-dish, about enough to cover a zinc plate; then pour in carefully some sulphuric acid, 1 part for every 10 parts of water in the dish. In this mixture immerse the zinc plates, one at a time, and pour on each a small quantity of mercury; spread this over both sides of each plate with a mop made of tow containing a few brass wires, and then coat them perfectly. This is termed "amalgamating" the zincs. The acid mixture may be used with some more to work the battery, and the excess mercury can be used over again. These zinc plates have to be suspended to a cross-head of wood (each plate between two plates of copper in each cell). The wood supports should be cut out of hard wood to the shape shown in Fig. 11, so as to enclose each zinc plate between two pieces of wood, the plates fitting in the recesses cut for them. The wood should now be well varnished, or, better still, well soaked in melted paraffin wax. Each zinc plate can then be enclosed between two wooden supports, these secured to each other by long brass screws passing through both, and the plate held up by a binding screw on the top, as shown in Fig. 12. A pair of copper plates must now be obtained for each zinc plate, the copper being slightly larger than the zinc, and of any thickness. They work all the better if they are cross-scored with a file, or if they have a rough coat of electrotype copper deposited on them; they work better still if they are coated with platinum, but this necessitates the use of a battery and a costly platinum solution. The copper plates may be secured to the

cross-heads on each side of the zincs by very short brass screws, care being taken not to let any of them touch the zinc plates; or they may be clamped with brass clamps (Fig. 12) sold for

Fig. 11.—Part of Battery Plate Support.

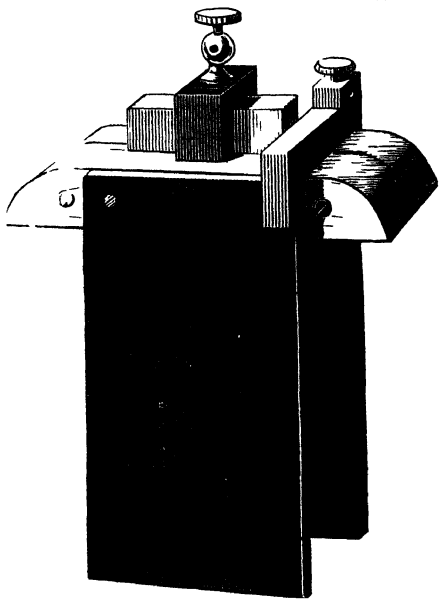

Fig. 12.—Battery Plates Mounted for Use.

the purpose. When clamps are used, it is always quite easy to remove the plates for cleaning, and to reverse the zinc plates so as to wear both ends equally. The battery jars are charged with an acid mixture, made by pouring one part by volume

of sulphuric acid into twelve parts of water, and allowing it to cool before using The plates are suspended by the wooden cross heads in this mixture When it is wished to increase the pushing force (the E M F) of the current, the copper plates of one cell are connected by a length of No 16 copper wire to the zinc plate of the next cell, and so on through the whole series of cells, taking in as many as may be wanted When a low tension current of large volume is desired, all the copper plates of the cells are connected together by one set of wires, and all the zinc plates by another set of wires The cells may be placed in a wooden tray or in a shallow box, and all the cross heads may be secured to a long bar of wood, which may be suspended to a support above, or to an arrangement for lifting all the plates out of the cells when the battery is not wanted This arrangement will also be found to be most convenient for controlling the current, as its volume can be lessened at any time by exposing a less surface of the plates to the action of the battery acid When the battery is not required for use, the plates should be lifted out of the cells, and if they are not likely to be wanted for a few days, they should be well rinsed in an abundance of water, to free them from acid It will be necessary to take out the zinc plates occasionally, clean them, and freshly amalgamate their surfaces This must be done at any time if the

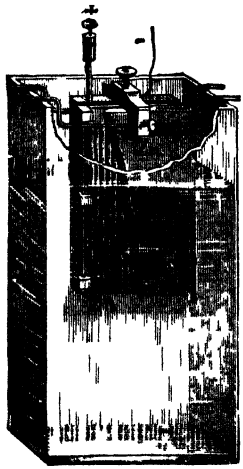

Fig 13.—Smee Cell.

plates give off a hissing noise, and appear to be blackened by the acid

The Smee cell is constructed on the principle shown in Fig 13. In a rectangular glass vessel are two zinc plates Zn, held together by a screw, and between them, well insulated, is a platinum plate or a silver plate covered with platinum (see Ag). The vessel is filled with diluted H_2SO_4, and is made larger than the plates so that the

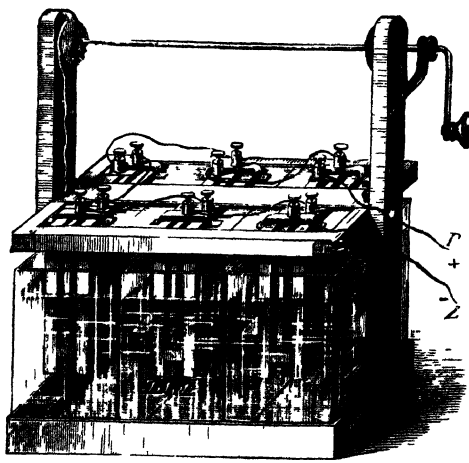

Fig. 14.—Battery of Smee Cells.

zinc sulphate which is forming may not come into contact with the plates, and may fall to the bottom of the vessel. A battery of Smee cells is shown by Fig 14. In this figure, Z and P respectively indicate the zinc and platinum and their connections It is possible to make up the Smee in a similar manner to that described for the Wollaston, except that platinised silver foil, soldered to copper frames, is used instead of copper plates for the negative elements, but in all other respects the battery may be made like the Wollaston, and

will give similar results, but its action is longer sustained after being connected to the work, because it does not polarise so soon The proper exciting liquid is a mixture of one part by measure of sulphuric acid and seven of water, which will be found strong enough for all purposes Frequently it is advisable to use only one part of acid to ten or sixteen parts of water, and to add acid as required, taking care, however, that the quantity of acid never exceeds one-fourth of the original water, for any excess above that quantity will be useless, as the liquid will then become saturated with the sulphate of zinc Still further modifications may be made in the battery by enlarging or diminishing the size of the negative or the positive element, or both of these, and in altering the size of cell containing them As a rule, the enlargement of elements and cells tends to an increased output of current, because the internal resistance of the battery is lowered, and there is, consequently, more available force for the outer circuit Enlarging the negative element will frequently bring about the desired result of lowering the internal resistance of the battery and increasing its volume of current This is specially noticed in the Daniell, Smee, and Walker batteries.

The Fuller cell (Fig 15) has an outside stoneware jar with an inner porous pot, the outer jar having a plate of carbon in chromic acid or bichromate of potash solution, with one-quarter of its bulk of sulphuric acid. In the illustration a part of the porous pot is cut away the better to show the zinc. The inner porous pot contains a rod of zinc ending in a plug z, the bottom of the pot is covered with mercury, the remainder of the cell being filled with sulphuric acid and water The electromotive force is 1·50 volts.

One of two charges can be used for a Fuller cell. In one the porous pot with the zinc plug is

charged with a solution of 1 oz. of common salt to 1 pint of water. In the other a solution of 12 parts of water to 1 part of sulphuric acid is used. In using either of these solutions, about 1 oz of mercury should be placed at the bottom of the porous pot, to ensure constant amalgamation of the zinc, thereby preventing waste. The outer jar, containing the carbon plate, is charged with a solution made by dissolving bichromate of potash 3 oz. to every pint of warm water, and then adding 3 oz. of sulphuric acid gradually, stirring with a stick. The addition of the acid causes the solution to become scalding hot, so care should be taken to make the mixture in a vessel that will not crack. All the solutions should be quite cold when the cell is put up for use. The size of the porous pot depends on the shape and size of the outer one. It should stand up about 1 in. above the outer pot, and should comfortably hold the zinc plug without occupying too much room in the outer jar.

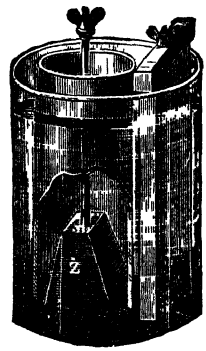

Fig 15.—Fuller Cell

When a battery is wanted for use for only a few minutes at a time, or merely to flash on a thin coat of silver to hide defects or discoloured patches, the Gassner dry battery may be used. This battery needs no attention in the way of setting up or cleaning, as it is always ready for work, and will furnish current sufficient to gild a brooch, scarf pin, or even a bracelet, or to plate such an article with a thin coat of silver. The large double-carbon square cells should be selected for this purpose, and the battery should be made up of two of these cells in series. They will last about two years, without renewal, on such

intermittent work as has just been mentioned. If used for jobs which will necessitate a constant supply of current for more than ten minutes, the battery will soon be exhausted.

The Gassner cell (Fig. 16), one of the earliest of dry batteries, is complete in itself, instead of being a composite cell made up of inner and outer vessels. There is no porous cell of any kind, or any outer cell of glass, porcelain, or other breakable material. The battery case is of thin sheet zinc, which may be made in any form and of any size required. The sheet zinc case, which forms the positive element, is nearly filled with a paste composed of zinc oxide and gypsum, moistened with a solution of zinc chloride. A capped cube of carbon, bearing a binding screw on its head, forms the negative element in the centre of the case, where it is surrounded by the conducting and exciting paste. The whole is sealed over with a composition resembling marine glue It will thus be seen that there is no liquid to spill, nor is any required, as the paste is moist enough to excite the zinc, and it will retain its moist condition for any length of time. The cells may therefore be laid on their sides, or turned upside down, without impairing their working qualities. They may be placed in any convenient position, regardless of the temperature of the room in which they are located. When a Gassner cell is exhausted, a strong current of electricity (such as that from a battery of Bunsen cells) is sent through the cell from carbon to zinc for about an hour to regenerate its contents, but the effect is only temporary. Other dry cells have equal value.

The square form of the Gassner cell here recommended is divided by a zinc partition into two equal parts, each containing a block of carbon This increases the exposed surfaces of the two elements, and ensures a corresponding low internal resistance to the cell. There is also a

small cell made, and this is furnished with a hollow cube of carbon The tall oblong form is enclosed in a case of vitrified iron, which gives additional strength and adds to its appearance Each carbon is furnished with a terminal binding screw, as in the Leclanché battery, but a piece of stout copper wire is soldered to the zinc case for

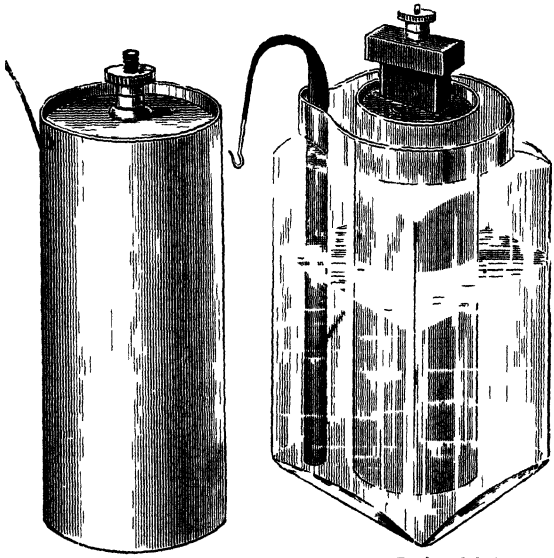

Fig. 16.—Gassner Dry Cell. Fig. 17.—Leclanché Cell

connecting purposes The top of each cell is sealed with a resinous composition

The Leclanché cell is not suitable for regular plating; but if an occasional plater happens to possess one he can use it for small jobs requiring current for a few minutes only The Leclanché cell always has a glass outer containing jar which is of square shape, for convenience of packing to form a battery (see Fig 17), with a large round

mouth furnished with a lip. The cell complete has the top of the mouth, both inside and out, for about an inch down, coated with Brunswick black, paraffin wax, or similar material, that will prevent the salts formed by the contents from creeping over the edge. This coating is applied by thoroughly cleaning the jar, heating it, and either dipping the rim into melted paraffin wax, or giving it two or three coats of Brunswick black The porous pot which goes inside the glass jar contains a carbon plate with a lead cap, on which is a binding-screw with connections. The whole of the space between the carbon and the pot, to within ½ in. of the top, is filled up with a mixture of equal parts by bulk of crushed coke or carbon and peroxide of manganese, crushed to the size of very small peas or rice grains, sifted from the dust and packed in as tightly as possible. So as to allow the gas formed in working to escape, two little pieces of glass tube are embedded in the mixture on each side of the carbon, and then the top should be sealed up with melted pitch, or pitch and resin mixed; the top of one tube is shown in Fig. 17 The whole of the top should have two or three coats of Brunswick black, working well over the lead cap and into the top of the carbon plate, and down the outside of the top of the pot for about 1 in.; dip the bottom of the porous pot for about ¼ in. into melted paraffin wax, and the negative element is ready for use The positive element is generally a rod of drawn zinc; if cast it is crystalline and brittle. A hole should be drilled in the top, and a stout piece of gutta-percha covered copper wire either screwed or soldered in. The joint should be well covered with gutta-percha or several coats of Brunswick black The zinc should be amalgamated by the following method. With a file remove rough excrescences, etc., and have ready two glass jars deep enough to take the zincs:

one of these should be half full of water containing about a tea-spoonful of sulphuric acid, the other a quarter full of the same mixture with a little mercury at the bottom. Dip the rod first in the tube with the acid and water to clean it well, then into the one with the mercury, and by holding it in a slanting position the mercury can be easily flowed all over the zinc by twisting it round Wipe off the superfluous mercury with a rag, and the rod is ready for use.

A Leclanché cell is charged by three-parts filling the outer jar with a strong solution of ordinary sal-ammoniac; if the jar is more than three-parts filled, the salts of the solution will creep up. In a few hours the cell will be ready for use. Should it not be convenient to wait, pour through the little glass tubes in the seal some of the solution into the porous pot, and the cell will be in working order in a minute or so. The chemical action that goes on during the working of the cell is this: The zinc, sal-ammoniac, and peroxide of manganese are changed into zinc chloride, water, and ammonia; and the oxide of manganese is reduced to an oxide less rich in oxygen. Using chemical signs, Zn, $2NH_4Cl$, and $2MnO_2$, become $ZnCl_2$, $H_2O + 2NH_3$, and Mn_2O_3.

Where a good, full current is wanted for short periods at intervals—such as for electric-bell work—a cell of this type is suitable; it is of no use where continuous currents are needed—as in electro-plating—as it polarises quickly, recovering itself, however, equally rapidly. It has another advantage—action does not go on inside the cell unless the circuit is closed and the cell is doing work; therefore it can stand for months always ready charged without any fear of the zincs being eaten away; moreover, it is not affected by changes of temperature, and it does not give off noxious fumes. The E.M.F. of the Leclanché cell is 1·60 volts, and the internal re

sistance varies between ·75 and ·85 ohm in the 3-pint size; 1·1 and 1·2 in the quart size; and 1·5 and 1·6 in the pint size.

With regard to wet batteries in general, cells holding from 1 to 10 gallons each, and elements of a corresponding size, become a necessity when large articles have to be plated, or when a great number of articles has to be plated at the same time. This necessity may be partly met by employing a great number of small cells coupled in multiple arc, but small cells thus coupled up soon run down, because, being placed on short circuit, their charges of acid are soon used up. The best work is generally obtained when the elements of the battery present a slightly larger surface to the liquids within the battery than that of the anodes to the solution in the vat.

Lastly, the current obtainable from a battery may be modified by the manner in which the cells are coupled together. If the E.M.F is too low, the cells may be coupled up in series until the required E.M.F. has been obtained; or, on the other hand, if the E.M.F. is too high, it may be reduced by taking off some of the cells. It is not good practice to couple two or more cells of a different style of battery together to obtain the needed E.M.F., as the weak cells always pull down the current to their own level, and the current from the stronger cells will heat the solutions in the weakest, thus impairing the efficiency of the battery.

Batteries for electro-deposition are fast giving place to dynamos, which yield a current in every respect more suitable to the work of depositing metals than that from the best batteries. They are also more cleanly in working, less costly, and more easily managed.

Success in electro-plating largely depends upon the choice of a suitable dynamo. Dynamos designed for electro-plating differ considerably from

those employed in electric lighting work For electro plating is required a machine capable of giving a large volume of current at a low pressure, and this must be delivered continuously in one direction Machines for electric lighting work are designed to give only a moderate volume of current at a high pressure, and this may be of an alternating character—that is, a kind of see saw, or to and fro movement

The difference in the two classes of machines may be clearly shown by noting in figures the relative value of their output The output of dynamos for plating runs from 30 to 300 ampères, at pressures varying from 5 to 8 volts, whilst the continuous current dynamos used in electric lighting are designed for outputs varying from 3 to 300 ampères, at pressures of from 30 to several hundred volts As 8 volts is the maximum pressure needed to deposit metals from their solutions, a dynamo giving a current having a pressure of 30 volts is manifestly unsuitable

Another characteristic of the plating dynamo is seen in the winding and connection of its coils An electric lighting machine may have its coils connected in series, but an electro plating machine must have the coils so wound as to be shunt connected, or some special means must be devised to prevent the back current from the plating vat going through the coils and reversing the magnetism of the machine Electro plating machines are also run at a slower speed than machines for electric lighting The would be plater should, therefore, avoid all offers of cheap machines that have been used in electric lighting

It is not necessary to specify any particular type of dynamo as being the best, since all makers of dynamos are prepared to design and make plating dynamos from various types of castings Their value does not depend so much on their form as on the perfection of their construction

and fitting from an engineer's point of view, and the proper proportion and winding of their coils. Firms supplying plating requisites are usually prepared to furnish suitable dynamos, and these may be generally relied upon as being the best for the purpose.

Some idea as to the general form of a useful electro-plating dynamo may be gleaned from Fig. 18, which shows a dynamo made by Messrs. J. E. Hartley and Son. It has a heavy bed-plate of iron, on which are two vertical massive iron projections wound with covered copper wire. Between these projections, near the top, in a channel or tunnel hollowed out in the two horns of iron, is an axle or cylinder of iron also wound with coils of wire, with their ends fastened to a ring or wheel of metal divided into segments. This cylinder is called the armature, and the ring is the commutator, whilst the two vertical projections are the field-magnets. When the armature is revolved in the tunnel between these field-magnets, its coils cut through lines of magnetic force, which stream across the tunnel, and this action sets up an electric current in the armature coils. The current is conveyed from these to the segments of the commutator, and is picked up from them by metal pads called brushes, which rest on the segments. From the brushes, part of the current goes around the field-magnet coils to strengthen them, and the remainder is available for the work of depositing metal. The brushes are fixed to a rocker, insulated from the rest of the machine, and wire cables lead from this to stout binding screws or clamps on a board fixed to the top of the field-magnets. Stout wire cables convey the electric current from the binding screws to other screws fixed on rods placed across the tops of the plating vats—that is, the vessels holding the plating solutions. From one of these rods a number of nickel plates are suspended in

the solution; from the opposite rod the goods to be plated are suspended by metal hooks in the solution, and when this is done the electric circuit is completed

The route taken by the current is from the positive or outgoing pole of the dynamo, along one of the wire cables to the rod holding the anodes, down these into the solution, through the

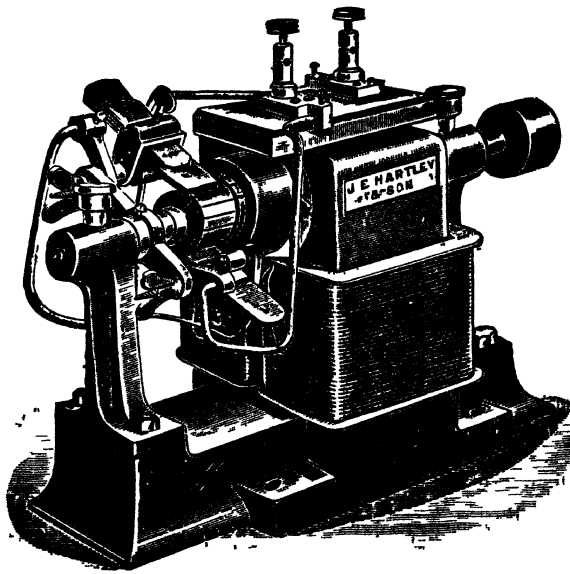

Fig. 18.—Electro-plater's Dynamo.

solution to the articles being plated, then back to the dynamo by the other cable attached to the negative or incoming pole of the machine This route has been explained so that readers may get an intelligent insight into the arrangement of dynamo and vats, in order that no mistake may be made in fixing the machine (see also p. 55).

A useful dynamo for working small quantities

of plating solutions may be made as follows by anyone acquainted with the mechanism of dynamo-electric machinery. Procure castings for a Kapp or over-type form of field, with cores 8 in. in height, 6 in. in length, and 1 in. in thickness, and a laminated drum or shuttle armature 3 in. in diameter and 6 in. long. A shuttle armature is easier to wind, but more current can be got from a drum armature. If a shuttle armature is chosen, wind it with 1½ lb. of No. 16 cotton-covered copper wire, and the fields with 6 lb. of No. 18 cotton-covered wire, connected in shunt with the armature. If a drum armature is chosen, wind it with 2 lb. of No. 16 cotton-covered wire, and the fields with 6 lb. of No. 18 cotton-covered wire, connected in shunt. The speed may be low—say, from 900 to 1,200 revolutions per minute. Copper and nickel will require the higher speed. Any steady-running motor will drive the machine, which will only absorb about 1 man power.

Canning's shunt-wound semi-enclosed plating dynamo with slotted drum armature is shown by Fig. 19. Its entire frame, which is also the magnet yoke, is of cast iron of high permeability, and is in one piece. The shaft is of mild steel of ample strength, and has a keyway for all fixed parts. The bearings are bolted to the frame, and are lubricated automatically by revolving rings running in oil wells. The solid gun-metal bushes are easy of access for inspection, and are provided with the necessary holes for drawing off the oil when it requires renewing. The magnet windings have a high electrical efficiency and are of cotton-covered copper wire wound on formers, built up with ends securely bound with tape, thoroughly insulated and coupled to terminals by lead eyes soldered to ends of wires. Fringe rings are used in all machines above 50 ampères, and are easily removed and arranged to keep windings in place. The armature core is of the slotted

drum type, composed of sheet-iron plates well insulated, clamped between two cast-iron plates and securely fixed to the shaft. The armature is wound with covered wire, thoroughly insulated

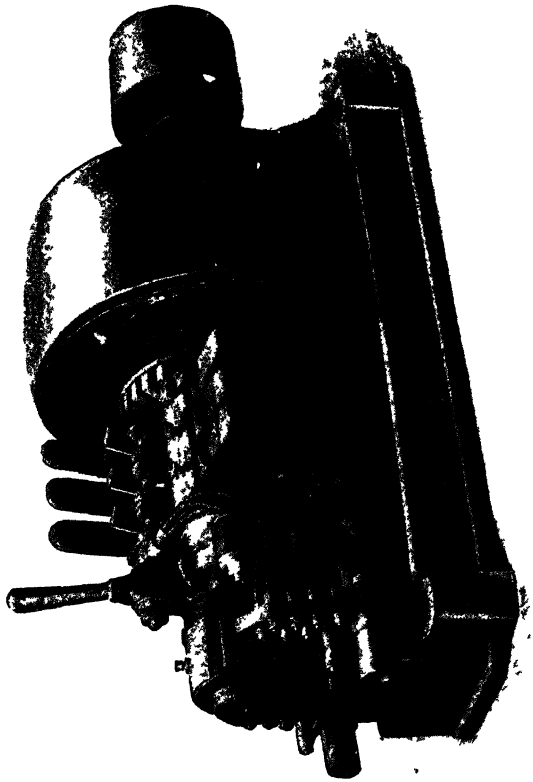

Fig. Semi Flat Dyna

and firmly embedded in the slots of the discs, and held by wire bands which are insulated with mica from any portion of the armature. The armature can be easily taken out by removing the

bearing at the pulley end, and is accurately balanced. The commutators have a deep wearing surface, and are made with copper segments insulated from each other with mica, The brush holders and rockers to carry them are fitted with adjustable springs and hold-off catches, and are connected directly to a bush or by a flexible stranded cable. The rockers are adjustable and fitted with clamping screws enabling them to be set in any position. The brushes are of copper wire encased in gauze. The terminals are placed in a convenient position on the dynamo frame, and are tinned ready for the copper conductor to be soldered in. The driving pulley is of cast iron, rounded on the face, and is securely keyed to the shaft. The dynamo will stand an overload of 25 per cent. for one hour without undue heating or sparking, and a greater overload for short periods.

Having received a dynamo from the maker, its position in the workshop should be determined. It is not necessary to have it close to the plating vat, as the plater can easily look after the machine if it is at one end of the shop and the plating vat at the other. It should not be fixed in another apartment out of sight, or in any position where it is likely to pick up metal dust and other dirt. When it is revolving, a current of air sets in towards the armature, and draws with it any dust that may be flying about the shop. As it is a strong magnet, it will attract to itself any small particles of iron, steel, nickel, or cobalt, such as filings of those metals. It is therefore advisable to bolt it down firmly on a strong bench raised above the floor. As the machine is driven at a high rate of speed, and this sets up a strong vibration of its parts, the bench must be strong and firm to lessen as much as possible the vibration.

The dynamo should be driven from a countershaft furnished with fast and loose pulleys driven at

a lively speed, to obviate the necessity of driving with a tight belt on a large driving wheel. It is also best not to have the driving wheel of the countershaft directly over the dynamo The machine works best when driven with a wide, long belt, as this ensures a better grip of the pulley on the armature spindle Most makers advise the speed at which the machine should be driven, and this may be ascertained by means of a little speed indicator. The direction in which the dynamo armature should revolve is indicated by the position of the brushes; it must never be run against them

Having fixed the machine and started the machinery to work it, an attempt must be made to start the dynamo so as to get the best results from it. See that when turned by hand all its parts move freely without a hitch; see also that the oil cups are provided with oil. Now start the machine and connect it by means of two thick wires to an ammeter—that is, an instrument for measuring the volume of the current. This is a most important instrument, and, if not provided in the outfit in connection with a resistance board, it should be purchased afterwards, as it is to the plater what the foot-rule is to the mechanic. When connected to the ammeter, note the deflection of the needle or hand of this instrument, then alter the position of the brushes until the best effect has been obtained—that is, the largest number of ampères indicated on the dial This alteration may be effected by loosening the screw which holds the rocker to its insulating collar, and moving it, together with the brushes, until the best angle has been obtained, then fixing the screw tightly.

The best materials for brushes are pads of copper gauze, backed with strips of spring brass, which gently press the pads, and keep them in contact with the commutator. The volume of current obtainable from a machine is influenced

by the lead and angle of contact of its brushes on the commutator. From time to time these pads and the commutator must be examined and repaired, and the worn pads being made good, the slits between the bars of the commutator wiped with a piece of card to clear out particles of copper, then oiled, and the oil wiped off again with a piece of rag. Beyond keeping all connections cleaned, and the working parts, bearings, etc., well oiled, it will be found that the machine does not require any more attention than that already indicated.

After the dynamo has been fixed and tested, connect the leading cables to its terminals, and lead them to the positions likely to be occupied by the plating vats. If several of these are likely to be laid down, or even if only two of such vats are to be used, it will be advisable to lead the cables from the machine to a couple of stout copper rods supported in wooden cleats on the walls of the plating shop, these rods being furnished with suitable clamps, and short cables led from these main arteries to the vats, as shown in the illustration.

The plating dynamo should be kept thoroughly clean. The holders should be fitted with springs to ensure a light even pressure of the brushes on the commutator If these press too hard, they will soon wear deep grooves in the commutator bars, and if the springs are too light, the brushes are liable to break contact occasionally, when the sparks will burn both brushes and commutator. Keep the tips of the brushes neatly trimmed square, and free all parts from copper dust before starting the machine. If the bars show signs of grooving, throw off the brushes and work out the grooves with a flat stick covered with emery cloth, whilst the machine is running idle, then wipe the commutator with a rag smeared with vaseline. Always keep the machine well oiled.

Connecting the dynamo with the vat are copper cables, and for these the following sizes may be used. For 10 ampères, seven strands of No. 18 S.W.G.; 20 ampères, seven strands of No. 16 S.W.G.; 30 ampères, nineteen strands of No. 18 S.W.G.; 50 ampères, nineteen strands of No. 17 S.W.G.; 75 ampères, nineteen strands of No. 15 S.W.G.; 100 ampères, nineteen strands of No. 14 S.W.G.; 150 ampères, thirty-seven strands of No 15 S.W.G.; and for 210 ampères, thirty-seven strands of No. 14 S.W.G. from dynamo to vat. One of the cables should be in one length. The other cable should be in two or three lengths, the first from

Fig. 20.—Conducting and Supporting Rod.

the dynamo to a resistance board near the vat; then a short length from the board to the ammeter; and then a short length from the ammeter to the vat. It matters very little which line is thus broken, but it is customary to have the line leading from the positive terminal of the dynamo to the anode system on the vat thus divided. The insulating covering must be stripped from the ends of the cables, the wires soldered together, then soldered into suitable connecting sockets.

As it is possible entirely to neutralise the conducting capacity of a cable by a bad joint or a bad connection, see to it that all joints are well made and soldered, and all parts connected by clamps and under screws made quite clean with broad surfaces of clean metal in contact with clean metal at all points.

Each vat must be furnished with two rods of stout copper or brass (see Fig. 20) running the whole length of the vat, and furnished with brass connecting clamps, to connect with the cable lead-

ing from the dynamo. These rods should be ¾ in in diameter for small vats, increasing to 1 in or 1½ in for larger vats It is advisable to have three such rods when a large quantity of work is in the vat, the articles to be plated being sus pended from the centre rod, and the anodes from the two side rods In this case the two side rods must be connected together by a stout piece of cable across the vat, at the end furthest from the dynamo The rods must be connected to the main leads from the dynamo by stout cables, capable of carrying the full load of current required

The slinging wires mentioned on p 19 depend from the rods, and have at their lower ends the hooks which carry the anodes and articles to be plated

The resistance board (Figs 21 and 22) is a slab of hard wood or slate, furnished with six or more brass studs on the upper edge, and eight or more brass contact pieces screwed on in the position shown Lengths of stout copper wire, graduating in size, are fixed to some of the brass pieces and pass around the studs; then, German silver wires, offering ten or eleven times the resistance of the copper wires, are fixed to the remaining pieces and pass around the other studs, thus forming a zigzag line of wire of graduated resistance from one side of the board to the other, as illustrated. A brass lever is pivoted so as to sweep the semi-circle of brass pieces and make the connection with each in turn This central stud may be connected to a large binding screw at the bottom of the board, and one end of the cable is fixed to this screw At the opposite end of the semicircle, one of the brass pieces is similarly connected to another section of the cable

The resistance board enables the plater to control the current from the machine; when the switch lever rests on the contact piece connected

direct to the cable, the circuit has no additional resistance, but when one of the lengths of copper wire is thrown into the circuit by moving the switch lever, resistance is added, and, when the

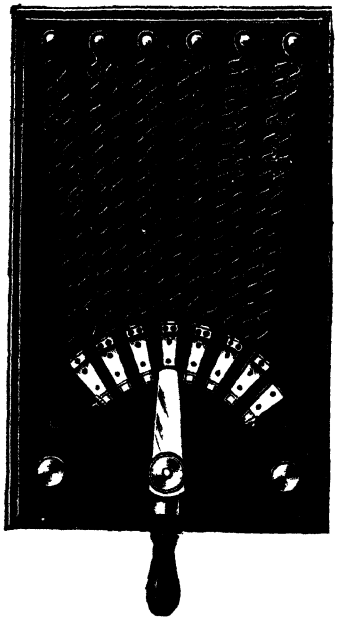

Fig. 21.—Resistance.

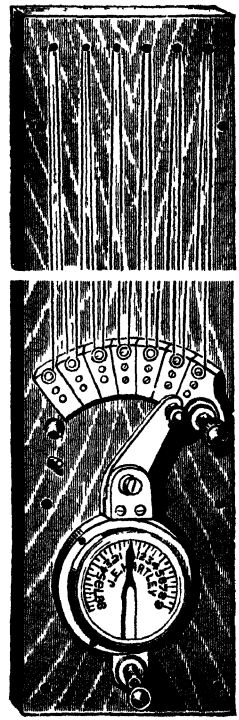

Fig. 22.—Resistance Board, combined with Ammeter.

lever rests on the last brass piece, all the resistances are thrown in. Thus the plater is enabled to silver a small article safely, even with current from a very large dynamo. The switch is equivalent to a tap in a water-pipe, each wire taken in

by it acting like the plug of a tap in narrowing the hole through which the water flows A resistance board must be placed to each vat to control the flow of current through it as required by the plater, and when an ammeter is combined with the board (as shown in Fig. 22), the current passing at any time can be seen at a glance.

The ammeter (Fig. 23) measures the current, and is often fixed to the resistance board for ready reference (see Fig. 22). As the rate at which the silver is deposited depends on the current through the vat, and as the character of the deposit is greatly influenced by the rate of deposit, this instrument is of great importance, for by it the plater can determine how much silver is being deposited. The dial of an ordinary ammeter shows the current in ampères, 1 ampère being that current which will deposit 52 gr. of silver in one hour on 1 sq. ft. of suitable surface, in a fit condition for polishing. Thus, in the special instrument made by T. Morris and Co., Birmingham, and illustrated by Fig. 23, the lower scale shows also the weight of silver deposited per hour.

The voltmeter is similar in external appearance to the ammeter, but the readings on its dial are in volts. From its readings the plater can adjust the brushes of a dynamo and regulate its speed so as to get the right voltage. Experience has proved that the silver in a silver-plating solution may be separated from its salt and deposited in a good condition at as low a pressure as 2 volts; but this may be increased to 3 or even 4 volts without altering the condition of the deposit very much. However, when the pressure exceeds 4 volts, there is a tendency to a loose and powdery deposit, which gets more pronounced as the pressure is increased. A voltmeter is therefore useful, but, its coils being wound with fine wire of high resistance, it must be placed in a shunt bridging the two main lines, and furnished with a switch

to cut the voltmeter out of circuit after the dynamo has been adjusted to the required pressure (see Fig. 24).

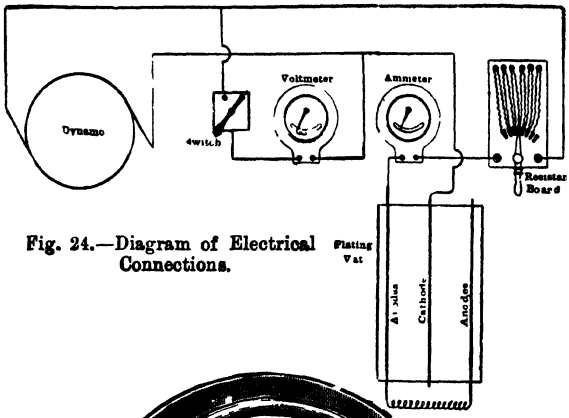

Fig. 24.—Diagram of Electrical Connections.

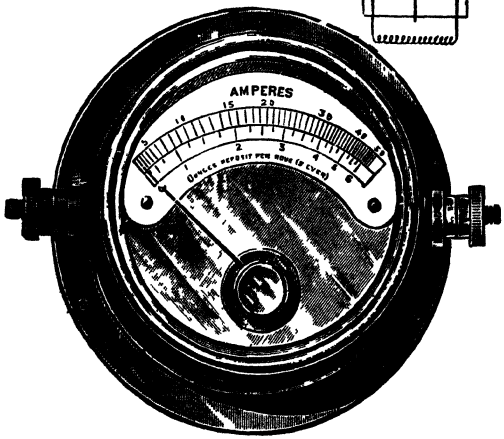

Fig 23.—Ammeter showing Rate of Deposit.

The diagram of electrical connections presented by Fig. 24 should be carefully studied.

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CHAPTER III.

APPLIANCES FOR PREPARING AND FINISHING WORK

CHIEF among the appliances used in preparing metal for plating is the polishing lathe. In order to produce a polish on the work, the first process is by file, scraper, or some similar tool, to remove the rough surface the metal has received in forging or casting; and, to do the work quickly, the instrument taking the place of the scraper or file must move at considerable speed, and the article must be held against it. The same method is required with the further processes of polishing. Figs. 25 to 27 show three kinds of machines suitable for this work.

Fig. 27 illustrates the machine more generally used where steam power can be applied. The cast-iron standard is firmly bolted to a block of wood or stone, and has adjustable bearings at the top for a circular spindle to revolve in; each bearing has a lubricator in the centre to supply the spindle with oil. The spindle has fast and loose pulleys in the centre, and at the ends devices to hold the emery-wheel, grindstone, buff, or dolly, as may be required. The ends of the spindle should be threaded with a coarse taper screw which enters a hole in the boss of the brush or bob, and holds it firm whilst revolving. Large lathes are furnished with flanged plates at one end (see Fig. 27) in addition to the taper screws. These plates support calico mops, and grip the sides of emery wheels.

Polishing lathes must be firmly bolted down on benches not liable to great vibration, and run at a speed of 1,400 revolutions a minute in polishing

silver. For polishing steel or other hard metals they may be run at a higher speed, up to 2,500 revolutions per minute. The brushes used with

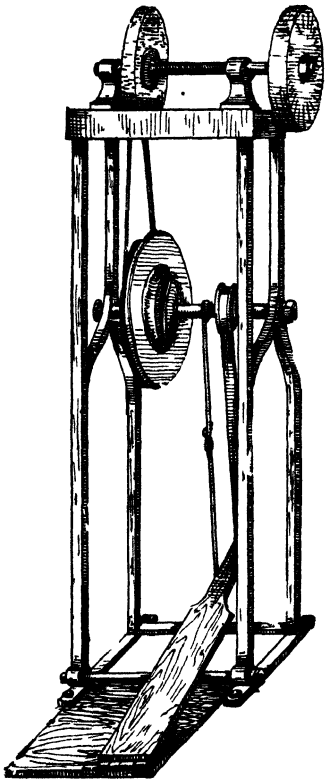

Fig. 25.—Treadle Polishing Machine.

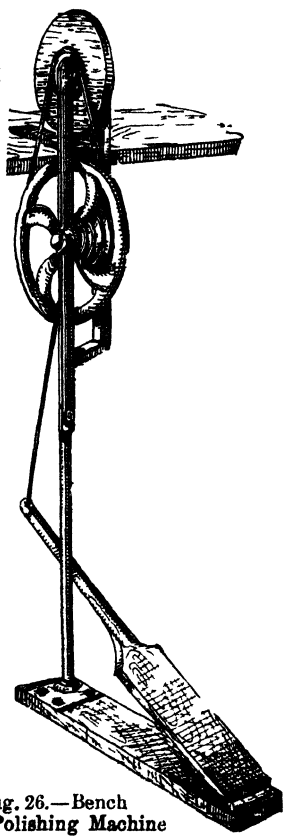

Fig. 26.—Bench Polishing Machine

these lathes differ in size and material according to the work required from them

A simple machine that may be fixed to an ordinary bench and worked by foot is illustrated

by Fig. 26. A treadle device is fixed to the floor and carried by a standard having a plate to secure it to the bench and an upper pillar to take the wheel, buff, or dolly. This is the most simple construction that can be adopted for the work. The wearing portions are few in number, and can

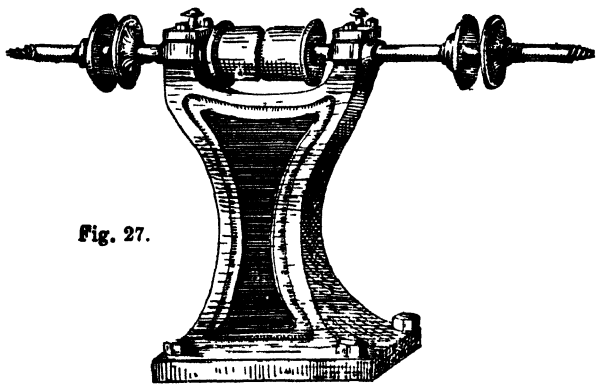

Fig. 27.

Fig. 28.

Fig. 29.

Fig. 27.—Power-driven Polishing Machine.
Figs. 28 and 29.—Spindles for Mops and Dollies.

easily be replaced, but considerable speed, say 3,600 revolutions per minute, is easily obtained Fig. 25 illustrates a grinding or polishing machine, having the same treadle movement fixed between standards, and with a small bench at the top, on which two bearings for the spindle are fixed.

Alternative forms of spindle are illustrated by

Figs 28 and 29, which show the various ways in which the wheels, buffs, etc , may be fixed to suit the work required to be done

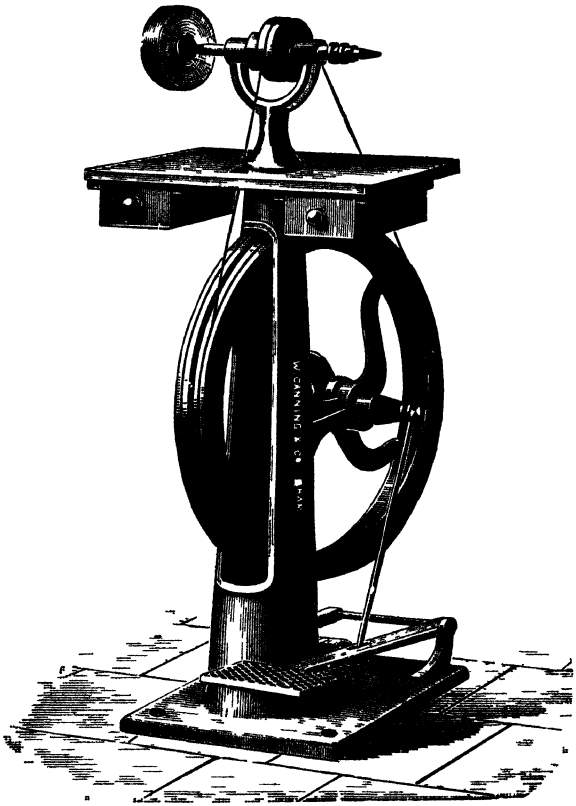

Fig. 30.—Combined Treadle Scratch Brush and Polishing Lathe.

A combined grinding, polishing and scratch-brushing machine is illustrated by Fig 30 The height of the centre of the spindle is 3 ft. 10 in , and there is provision for two speeds.

A powerful emery wheel machine, arranged for power driving, is a most useful tool; it is, indeed, indispensable where much work has first to be surfaced before it can be polished and plated.

The materials used in polishing metals with the lathe are: Emery wheels for grinding down rough forgings and castings; grain emery for use with bobs in taking out rough file marks and scratches in iron and steel; fine emery for getting a better finish; glass-cutter's sand for grinding brass and gun-metal castings; Trent sand for taking out rough file marks and scratches in brass; Sheffield lime for imparting a finish to brass work, etc.; Tripoli composition of three grades for finishing nickel-plated work, and also silver-plated fittings; rouge in several grades and qualities for finishing silver-plated fittings and nickel-plated brass work.

Rottenstone and flour emery together make a good material for polishing iron and steel. The materials should be formed into a cake or slab by mixing with boiling suet and then running into square or oblong moulds, and using cold with the buffs Crocus and rottenstone mixed in the same way with a little rouge form the best combination for brass or copper and kindred materials. Calico dollies and mops are used with the powders dry to give the finishing effects.

In the preparation of articles to be plated, bobs (or buffs) and mops are employed. Bobs are of two kinds: one, formed of a disc of hard-wood, having its edge coated with bull-neck leather (see Fig. 31), while the other is formed of a solid disc of felt. Other varieties have felt or buff leather on their rims, whilst some are made of solid bull-neck, or of walrus leather. The sizes vary from 3 in. to 18 in. in diameter, and from ½ in. to 2 in. in thickness.

To make a wooden bob, first select a piece of hard, well-seasoned wood and turn a true disc in

a lathe. Then get a strip of the required covering material as wide as the wood disc, and long enough to go round and meet with butt edges Next prepare some good glue and roll the edge of the disc in it whilst hot; then put on the leather or the felt, and secure this to the wood with long steel tacks, so driven in as to be easily pulled out when the glue is firm. At the end of twelve hours these tacks may be withdrawn, and wooden pegs dipped in glue driven in the holes;

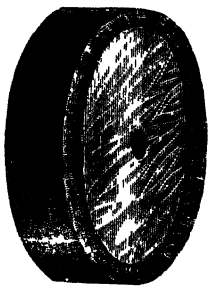

Fig. 31.

Fig. 32.

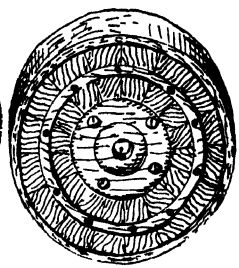

Fig. 33.

Figs. 31 to 33.—Leather-covered Bobs.

then true the whole in a lathe. The bob is then ready for the grinding material, which may be emery, sand, or tripoli, the material and grade being selected to suit the work in hand—emery for iron and steel, and tripoli for copper and brass. The abrasive is spread on paper or in a special trough in an even layer, and the rim of the bob is first rolled in the hot glue, then on the layer of powder until a sufficient thickness has been taken up, then it is set aside for another twelve hours to get firm. Solid leather or solid felt bobs are similarly coated. These bobs are employed to grind down rough surfaces and render them comparatively smooth

Fig. 32 illustrates a better plan of making an

emery bob. Four pieces of wood are glued together with their grains crossing, and then cut out or turned to circular form. Round the edge is securely fixed a thick piece of buff leather, fixed and coated with emery as before. The centre hole carries a brass boss that is screwed to fit the end of the spindle, or has a plain hole to fit on the spindle between the collars, as shown in Fig. 27, p. 58.

Fig. 33 shows the construction of a leather covered bob or buff of large size. The wood is of wedge-shaped sections, securely fitted and fixed together and held by brass or iron rings; the outer edge is covered with leather as before described

A solid leather bob with a rim of thick leather, either bull-neck or sea-horse, may be turned in the lathe to suit various shapes of mouldings and ornaments (see Fig. 34) The central holes in these bobs screw on the point of the spindles shown in Fig. 27. The article to be polished is held against them, and the emery powder held at the point of contact.

A pressed felt bob can be used in place of a leather bob in many cases, and more often for the further polishing with crocus or rottenstone. It is fixed to the spindle in the same way as the leather bobs already illustrated.

Another method of making a bob may be here described. It is of wood covered with felt. Two discs of well-seasoned beech, of the required diameter and half the thickness of the desired disc, are glued together side by side, with their grains opposite, and then left under pressure until quite firm. The disc is then turned true, and a number of small grooves are cut in its circumference. A strip of thick felt of the required width and length is laid out on a bench, the rim of the wood disc is run in some good hot glue until well coated and warm, and is then run along the felt under pres-

sure, the felt being made to cling close to the wood, and afterwards secured to it with long tacks. When the glue has become firm and hard, the tacks are withdrawn, and wooden pegs, dipped in glue, driven into the holes, as already described; then the whole is trimmed true with a sharp knife. The felt-covered disc is rolled in hot glue, and then coated with emery in the usual way.

The emery employed in polishing bobs varies with the work to be done. A bob for the first roughing down is usually coated with No. 60 emery. Then follow bobs coated with Nos. 80, 120, and 140, the last being used to get a finishing polish on steel before employing a mop or dolly Emery-coated bobs cut iron and steel with great rapidity. The friction generates heat, and the article becomes polished, this action being intensified by the pressure.

To polish quickly a number of articles with the aid of emery-coated bobs or buffs, arrange them on a bench at hand, whilst a box, tray, or bench is placed on the other side. As each article gets too hot to be held it is thrown into the box, and another article is reached from the bench, so treating all in succession, and going over them again after they have got cool in the box.

For cycle frames and handle-bars, an emery tape machine (Fig. 35) is preferable to a polishing lathe and bob. The emery-coated tape or band is run over pulleys, and the bars are held to it whilst running; by this means every part of the bar can be reached easily and can be speedily polished. In Fig. 54, A shows the spindle for carrying bob, mop or wheel, B the fast and loose pulleys, and C the emery tape.

When a polishing lathe is not available, and a few small and plain articles have to be surfaced, a buff stick (Fig. 36) may be used. This is a wooden stick with buff leather firmly glued to it,

the most suitable leather being the tough, rough-grained leather used in soldiers' belts. Buff sticks are made in various widths to suit the work in hand, the broad buffs being used for polishing broad plane surfaces; and the narrow, thin buff sticks for giving a polish to grooves and hollows. They are used with finely-powdered rottenstone and oil, or with finely-powdered crocus, to give a finishing polish by hand to articles about to be plated.

For removing the scratches left by emery bobs, emery wheels, or tape machines, revolving mops, known also as dollies, are used. These are of leather or calico (see Fig. 37), and render the surface of the metal quite smooth. They are made chiefly from thin tough leather, such as basil leather, and chamois leather, and from various grades of calico, the finest being the soft variety known as swansdown calico. Basil leather mops may be from 3 in. to 12 in. in diameter and from ½ in. to 4 in. in thickness. They are made of several discs of basil leather, cut and laid true on each other, between two smaller discs of thick leather, to form the bosses, which are then secured by long iron rivets passing through the whole mass of leather. These mops are very useful with tripoli compo in preparing surfaces of copper, brass, and other soft metals.

Chamois leather mops are made in a similar manner, but are chiefly used to produce a high finish on jewellery. Sometimes these leather mops are stitched spirally to keep them more compact whilst revolving.

Calico mops are made similarly The thickest and coarsest calico is employed for mops used in preparing the work with tripoli compo, etc., and the finer grades for finishing the plated articles with rouge compo. The bleached varieties of calico are, as a rule, harsher in texture than the unbleached, and are used in making the mops for

cutting out scratches, and are then followed by mops made of unbleached calico charged with

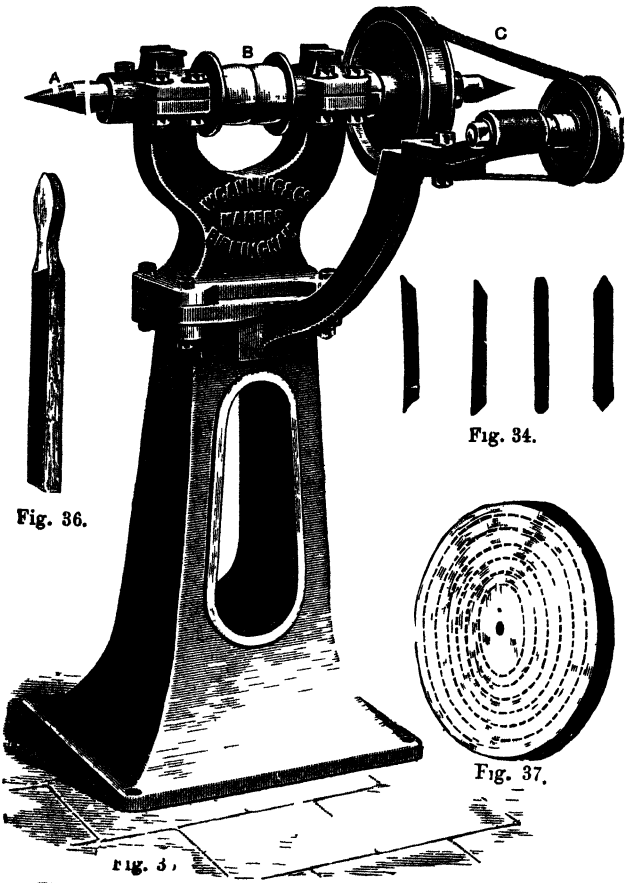

Fig. 34.

Fig. 36.

Fig. 37.

Fig. 35.

Fig. 34.—Sections of Bobs. Fig. 35.—Emery Tape Machine
Fig. 36.—Buff Stick. Fig. 37.—Calico Mop.

rouge compo to give a higher finish Calico mops run from 6 in to 18 in in diameter, and have

from 50 to 105 folds to the inch of thickness according to the quality and thickness of calico employed. Swansdown calico mops run from 6 in. to 12 in. in diameter, and have from 24 to 60 folds in thickness, or about 24 folds to the inch.

The polishing mops and materials used in finishing plated ware should be kept in boxes, to prevent gritty dust getting into them. Each kind of mop and polishing compo. should have a separate box, and special attention should be paid to guard finishing mops and compos. from contamination with those of a lower and coarser grade The same remarks apply to all chamois leather, rags, soap, and burnishers employed in finishing silver-plated articles.

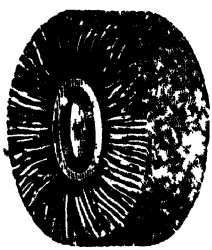

Fig. 38.—Woollen Brush.

The final polish to brass and similar soft metals is given with tripoli in its various grades, and with rouge on calico mops, these also varying in coarseness or fineness with the required finish of the work. Articles to be nickel-plated should be finished off smooth, so as to leave little polishing afterwards, because deposited nickel is very hard and not easily rubbed down with mops. The final polishing is done with fine grade tripoli and with Sheffield lime.

Where the article to be polished is very ornamental and the work very fine, a circular brush may be employed. This brush may be of fibre or mixed fibre and bristle. A woollen brush is shown by Fig. 38. Canning's circular brushes are of special construction, as is evidenced by the sectional view given by Fig. 39.

Scouring brushes employed at the scouring tray are made of coarse bristle or fibre, with

wooden backs and long handles, similar in shape to plate brushes or spoke brushes, or as shown by Fig. 40. They are made in various sizes, from 11 in to 13 in. in length, and with from one to six rows of bristles, which also vary from soft to stiff and "extra stiff," to suit the requirements of the

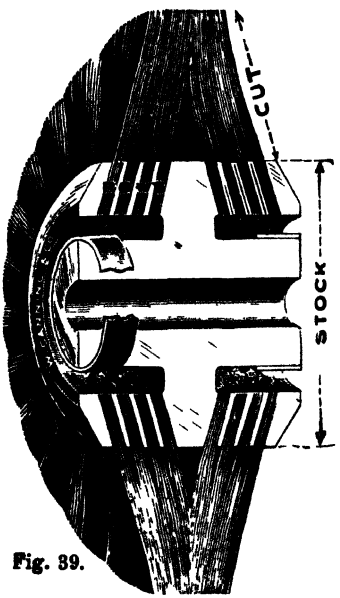

Fig. 39.

Fig. 40

Fig. 41.

Fig. 39.—Section of Circular Brush. Figs. 40 and 41.—Scouring Brushes.

work. A scouring brush without a handle is shown by Fig. 41.

The only brushes admissible in the potash tank are those made of cotton, two forms of which are shown at Figs. 42 and 43. They vary in length from 13 in. to 16 in.

Scratch-brushes are brushes furnished with bunches of brass wire instead of hair or bristles

They are made in a great variety of shapes and sizes, and the wire also varies greatly in softness. The simplest form is a wisp or bunch of the scratch-brush wire bound round with soft copper wire, as shown at Fig 44 The next is the straight or bent hand scratch brush shown by Figs 45 and

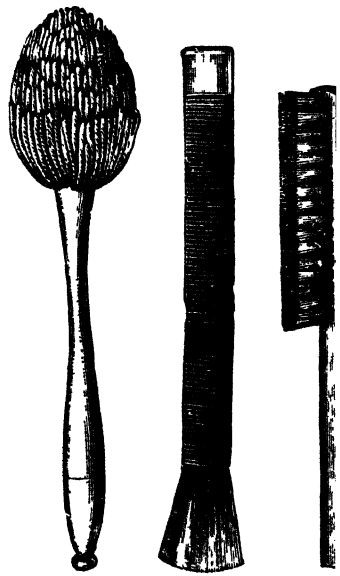

Fig. 42. Fig 43. Fig. 44. Fig. 45. Fig. 46.

Figs. 42 and 43.—Potash Brushes. Fig. 44.—Scratch-knot. Figs. 45 and 46.—Hand Scratch-brushes.

46. Then there are circular brushes in great variety; and attention is directed to Figs. 47 to 56 (see p. 69), the inscription given to each figure being sufficient to explain the purpose of the particular shape.

Large and heavy brushes with coarse wire are used to cleanse the articles from dirt before

plating The smaller ones are for brushing silver deposits when first taken from the vat, and are

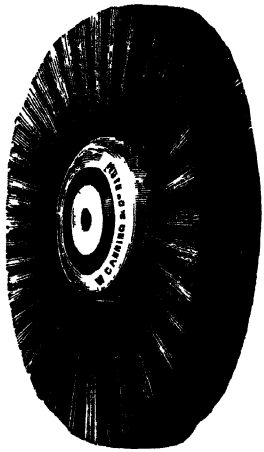

Fig. 47.

Fig. 48.

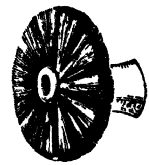

Fig 50.

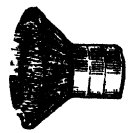

Fig 51.

Fig. 52.

Fig. 53.

Fig. 55.

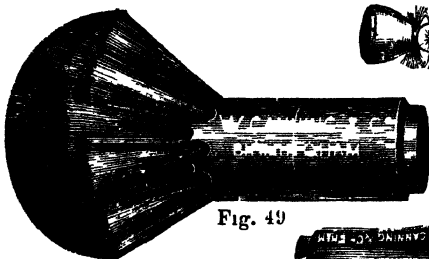

Fig. 49

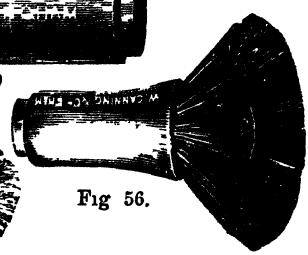

Fig 56.

Fig. 54.

Fig. 47.—Brass Wire Brush. Fig. 48.—Crimped Wire Cup Brush Fig. 49.—Turk's Head Cup Brush. Fig. 50.—End Brush. Figs. 51 and 52.—Watch-case Brush. Fig 53.—Inside Thimble Brush. Fig. 54.—Inside Box Brush. Fig. 55.—Inside Ring Brush. Fig. 56.—Bottom Brush.

made in various shapes to fit peculiarities in outside surfaces, as well as the inside parts of teapots, mugs, thimbles, rings, tubes, etc. Some are furnished with bunches of very fine and soft brass wire, some with bunches of German silver wire, and some have the fine wire crimped to make it more elastic. The softer and finer kinds are used for gold work and for delicate articles.

These brushes are run on the spindle of an ordinary light polishing lathe furnished with a hood or open box over the brush to protect the workman from splashes of the lubricant, this is generally stale beer, or beer diluted with water. Soapy water may be employed as a substitute, but

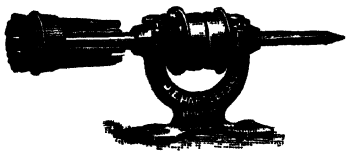

Fig. 57.—Scratch Knot Lathe.

soon becomes offensive after being used; and weak linseed tea and a decoction of marshmallows have been employed. The lubricant may be held in a small cistern over the hood, with a tap and pipe running down immediately over the scratch-brush. A tray beneath the brush catches the surplus drops, which are conveyed by a pipe to a vessel beneath the bench on which the lathe is fixed. The lubricant prevents the fine brass dust worn off the scratch-brush being embedded in the silver and thus giving it a yellow or stained tint, only a few drops applied occasionally being sufficient.

A scratch knot lathe (Fig. 57) is a polishing lathe upon whose spindle has been mounted a chuck holding eight or twelve wire scratch knots, and it forms a most efficient appliance for preparing work.

CHAPTER IV.

SILVER-PLATING.

THE art of silver-plating is an ancient one. Metal workers in olden times learned how to overlay inferior metals with plates of silver, and, later, discovered how to make the silver coat adhere by soldering to the metal beneath, being then able to use thinner plates of silver, which were, however, thick when compared with the thickest electro-silver-plating now done.

To electro-plate with silver, the article must be immersed in a solution of silver, and electricity be passed through this, certain other conditions being also complied with.

More care must be taken in the cleansing of articles to be silver-plated than in those to be electro-gilded. Gold-plating solution is used hot, and will dissolve remaining traces of animal matter, but the silver solution is used cold, and has no such cleansing or detergent effect on dirt left on the surfaces of goods intended to be silver-plated. It is necessary, therefore, to free the surface from the least trace of dirt of any kind, whether in the form of rust, verdigris, tarnish, or any other kind of corrosion, or in the form of oil, grease, lacquer, sweat, or other animal matter. The touch of a soiled finger on the prepared surface is sufficient to cause the silver to strip off from that spot when the scratch-brush or the burnisher is applied.

All deep scratches, dents, cracks, and pits must be removed before goods are plated; all necessary repairs must be done, avoiding an excess of soft solder: and in the case of re-plating,

all the previous coats of silver or of nickel must be removed, and the surface polished. Instructions for stripping electro-deposited metallic coats are given on pp. 145 and 146.

Rust, verdigris, and other metal oxides can generally be loosened, and sometimes removed entirely, by immersing the corroded article in a pickle made of a diluted mineral acid, or a mixture of those acids, and then swilling in clean water. Green verdigris and similar forms of corrosion may be removed by dipping in a mixture of equal parts sulphuric acid and water, to which has been added a half part of nitric acid and a few drops of hydrochloric acid. The articles should be strung on a wire, and swilled in the dipping mixture for a few minutes, until the corrosion has been loosened, and then rinsed in plenty of clean water. After this, they may be brushed with an old scratch-brush, and again swilled in water. If the verdigris is not all off, they must be again swilled in the acid pickle until quite clean.

A mixture of 1 part of sulphuric acid in 20 parts of water will loosen the oxides of copper and zinc on these metals and their alloys. The alloys of these metals may have many names, but are to be regarded by the plater as brass, and treated accordingly If the surface of a copper or brass article is deeply corroded and green, it may be necessary to use a stronger pickle, composed of 3 parts of sulphuric acid, 1¼ parts of nitric acid, and 4 parts of water. Rust on iron and steel may be loosened by immersion in a pickle composed of sulphuric acid 6 parts, muriatic acid 1 part, water 160 parts. The oxides of lead and tin may be loosened from these metals and their alloys (pewter, Britannia metal, soft solder, etc.) by immersion in a hot solution of caustic alkali, such as caustic potash or caustic soda.

Lacquered goods must be steeped for an hour or so in warm methylated spirit, and then trans-

ferred to a strong solution of ammonia, to loosen the lacquer. They should then be well brushed with an old scratch-brush or bristle-brush, and rinsed in hot water. Use old brushes for this purpose, as it will not be advisable to use the same brushes for brushing the surfaces of finished goods.

Mere tarnish may be removed by soaking for a short time in a strong solution of cyanide of potassium, to which has been added a few drops of liquid ammonia.

Metals are often not only corroded, but also dirty with grease, oil, or other animal matter capable of resisting the action of acid pickles; and in such cases it is advisable to swill them first in the hot alkali solution, then in hot water, and rinse in cold water before immersion in the acid pickle. The caustic alkali solution is made by dissolving ½ lb. of caustic soda, or caustic potash, or crude American potash, in each gallon of water contained in a wrought-iron tank.

The acid pickles should be mixed and contained in vessels made of vitrified stoneware. It should be understood that vitrified stoneware is the only suitable material for receptacles for acid pickles, and plain wrought-iron for those for caustic alkalies The mixed acids will undermine and dissolve the glaze from ordinary earthenware, and also the enamel from iron. Caustic alkalies also dissolve enamel, and extract the zinc from galvanised iron, and the tin from tinned vessels

For dipping small articles, baskets of the shapes shown by Figs. 58 to 60 are often very useful. When the basket is in the pickle it should be shaken about well to allow the liquid to get at the entire surface of the work

After all corrosion and dirt has been loosened, the surfaces of the articles to be silver-plated should be well brushed with a hard brush in water to remove loosened dirt from crevices and pits.

This may be done with an old scratch-brush made of wire, if preferred. An examination of the surface will then reveal numerous scratches, dents, and pits, some being due to corrosive action, and many to hard usage. These must all be removed, for the surface must be made like a new surface, all defects being made good before the silver is deposited upon it Dents and misshapen parts can be put right only with the aid of hammers, pliers, etc. At one time all scratches and pits were also laboriously removed by hand, being first filed and scraped, rubbed with sand or emery, then with water-of-Ayr stone, and polished with fine abrading powders. Now the work is nearly all done on polishing lathes with revolving brushes, dollies, etc., resulting in a great saving of time, and in a higher finish (see Chapter III.).

Scratches on the backs of watch-cases and lockets, and pits left from corrosion in other articles, must be taken out with a fine file, and the file marks rubbed out by grinding with water-of-Ayr stone, after which the surface should be scoured with a cork dipped in powdered pumice, then polished bright in the usual way. Spoons and forks should receive similar treatment. Although the cleansing of goods to be silver-plated is so important, there is no need for such a very finely polished surface for silver-plating as for electro-gilding, since the coat of silver can be got up afterwards; but the same care will be needed to get a uniform surface, free from scratches and pits.

After the polishing, the articles will be found to be thinly coated with grease or oil, which is removed by swilling in the hot caustic alkali pickle, and rinsing in water. This process will probably coat copper, brass, and similar soft alloys with a film of black oxide which must be removed by scouring. For this purpose, the article is held on the tray with the plater's left hand, the scour-

ing brush is dipped in water, the surplus shaken out, the brush dipped in the pumice powder, and the article is then brushed to and fro until every trace of oxide is removed. When it is rinsed in water, it should be quite clean, with a uniformly dull surface all over it, which renders the surface suitable to take and hold the silver coat.

The article must now be wired—that is, attached to the wire which will hold it in the plating solution—then rinsed in the mercury pickle to

Fig. 58.

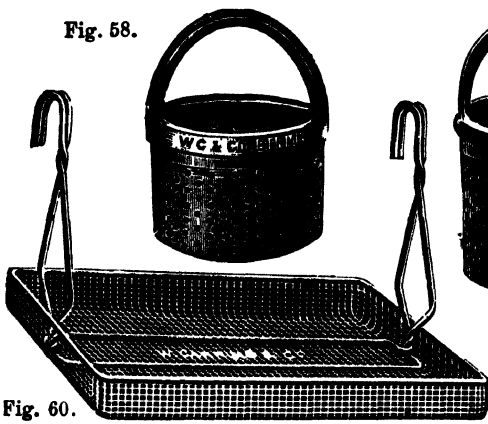

Fig. 59.

Fig. 60.

Figs. 58 to 60.—Dipping Baskets.

impart a thin coat of mercury, again rinsed in water and transferred to the plating bath (for the composition of which, see pp. 79 to 81), where deposition should begin at once. However, in many cases, a preliminary coating with copper is necessary.

Iron, steel, and zinc goods, and, preferably, also those of lead and its alloys, such as pewter and Britannia metal, must be coated with copper after they have been scoured, before they can be made to take an adherent coat of silver. Silver

may be made to adhere to lead alloys with skilful treatment without this coat, but the work is done more easily and better when thus coated The solution employed must be an alkaline one, as acid solutions, by their action on iron, steel, and zinc, undermine the deposit of copper and render it loose. The alkaline coppering solution is prepared by dissolving copper sulphate in hot rainwater in the proportion of 8 oz. of copper sulphate to 1 quart of water. When this has become cold enough, add first liquor ammonia to throw down the copper in the form of green mud, and then an extra quantity of ammonia to dissolve this mud and convert the whole into a bright blue liquid. To this must be added a sufficient quantity of potassium cyanide solution to take all the blue colour out and make the solution amber-tinted, or the colour of old ale. It should then be left exposed to the air for twelve hours, then filtered through calico, and diluted with clean rainwater until each original quart is made up to one gallon of solution. This solution may be worked hot or cold, but gives a fine clear deposit of copper when heated to 160° F. and worked with current from a plating dynamo. Anodes of pure copper must be employed.

When the articles of iron, steel, zinc, lead, pewter, and similar alloys, or those of brass with soft-soldered joints, are lightly coated with copper, they may be removed from the coppering bath to the alkaline mercury solution, and be there given a thin film of mercury, then rinsed and transferred to the silver-plating bath without delay. "Quicking," or coating with quicksilver, is done to secure the perfect adherence of the silver coating. The alkaline quicking solution is made by dissolving mercury slowly in dilute nitric acid, then adding enough strong solution of potassium cyanide to throw down the mercury in the form of black mud, and an extra quantity

(with stirring) to dissolve this mud. Distilled water only must be used in making this solution, and it should contain 1 oz. of mercury in each gallon. Some free cyanide must also be added to act on the copper and ensure a bright film of mercury. Potassium cyanide is a most deadly poison, and should not be held in the naked hand.

The acid solution of mercury proto-nitrate is employed and preferred by some platers. This is the first solution of mercury in nitric acid, largely diluted with distilled water. Its action is more speedy than that of the alkaline solution, but the film of mercury is not so thin and uniform as that from the latter. To prepare the mercury proto-nitrate solution, dissolve a few drops of mercury slowly in a mixture of equal parts nitric acid and distilled water, using only enough acid to dissolve all the mercury; then dilute the whole to twenty times its bulk with distilled water. Swill the articles in this when they are ready for the plating bath, and then rinse in clean water.

In professional plating, it is customary to weigh each article separately, or each group separately, to book the weights, and to determine the weight of silver to be deposited. In all plating, an estimate should be made of the surfaces in square inches, so that the anode surfaces and resistances may be adjusted so as to put on a tough coat of silver that will bear polishing and burnishing. This estimate must be based on experience with the silver solution in use; but, as a commencement, allow two ampères to each 100 sq. in. of surface to be covered, and then find out by actual weighing what quantity of silver has been deposited in an hour. If this deposit is tough, adherent, and in good condition for polishing, the rate of deposit may be increased by lowering the resistance and using more current; but this should be done gradually, until the highest rate of deposit from the solution has been ascertained The

rate, as indicated on the ammeter, will vary with the condition of the solution, the size of the anode surface, the distance of the anode plates from the articles, the voltage, and the character of the surface to be coated. A solution containing only one ounce of silver in the gallon will not yield good results except with feeble currents. If the anode surface is greatly in excess of the surface to be coated, the deposit will be rough and brittle, and a similar result may follow if the anode plates are too close to the articles. If the voltage is too high a similar result will be obtained, and if the articles have many sharp angles, edges, and points, these parts may take on a brittle coat of silver unless the current is kept low. If the anodes can be kept in motion whilst deposition is going on, or if both anodes and cathodes are kept moving, all the conditions previously mentioned will be greatly modified, and the rate of deposition may be safely increased.

The appearance of the silver coat whilst in the solution is a guide to its condition. The surface should momentarily change from grey to white and assume the whiteness of the anode plates in the course of two minutes. If it becomes more grey and bubbles arise from the slinging wire, the silver is going on too fast and the deposit is being "burnt." If it becomes brown it is still going on too fast. If it maintains a milky whiteness (a skim-milk white with a tinge of blue), it may be going on rather more slowly than is necessary. The rate of deposition may be regulated by moving the switch on the resistance board, and in a well-made silver-plating solution a deposit of one ounce of silver per hour can be obtained with a current of eight ampères, two ounces with sixteen ampères, and so on.

Deposition at the proper rate should be allowed to go on for from ten minutes to fifteen minutes, then each article should be taken out

separately, rinsed in water, and scratch-brushed all over to test the adherence of the deposit and its condition. If this is satisfactory, the articles should be swilled in the potash and mercury dips, then rinsed and placed again in the plating bath until a sufficient time has elapsed to get the required coat of silver on them.

The silver-plating solution has been mentioned many times, but the method of preparing it has not yet been explained. This, however, will now be done.

The best solution for silver-plating is the double cyanide of silver and potassium in distilled water. This salt may be made direct from pure silver plates or grains by first dissolving the metal in pure nitric acid diluted with distilled water, then evaporating all excess acid until silver nitrate crystals are obtained; then dissolve these in distilled water, and add a solution of potassium cyanide to form a curdy precipitate of the single cyanide, and finally dissolve this with a strong solution of potassium cyanide to form the double salt of silver and potassium.

But, as the reduction of silver to its nitrate is tedious and noisome, pure silver nitrate is usually obtained from a druggist or drysalter. It is dissolved in distilled water, and then converted into the double cyanide of silver and potassium as above indicated. In doing this, to prevent waste of silver, care must be taken to avoid adding the cyanide solution in large quantities at a time. The precipitate must also be well stirred with a clean smooth stick of wood after each addition of cyanide, and only enough of this added to throw down all the silver. When precipitation is complete, which is shown by all cloudiness disappearing from the liquid above the precipitate, the liquid must be carefully poured off and taken to the waste tub, and the precipitate of silver cyanide well washed by pouring clean water on it

several times, so as to agitate it well; then drain it as dry as possible. To this wet mass of silver curds add a strong solution of the best potassium cyanide in distilled water, until all the curds have been dissolved. The quantity of cyanide in the solution should have been ascertained by weighing the dry salt previous to its dissolution; then add one-fifth in excess to provide enough free cyanide of potassium to dissolve the silver anodes in working and thus maintain the strength of the plating solution. The whole concentrated silver solution must next be filtered through well-washed calico, and added to the distilled water previously placed in the vat intended to contain the silver-plating solution; it will then be ready for use.

The amount of silver in solution needs a word of explanation. Although good silver-plating may be turned out of solutions varying considerably in strength, it is of great importance to the plater to know how much silver is contained in the solution, and this may vary from 2 oz. to 6 oz. per gal. If grain or sheet silver is employed in preparing the solution, its strength may be easily ascertained; but a little calculation is necessary when silver nitrate is used, for in every 170 oz. of silver nitrate there are only 108 oz. of silver.

The method of preparing small quantities of silver-plating solution is as follows: Obtain 2 oz. of the best crystallised silver nitrate and dissolve it in 1 qt. of distilled water. Also obtain 2 oz. of best potassium cyanide and dissolve it in 1 pt. of distilled water Add this a little at a time to the silver nitrate solution, and stir well each time with a glass rod until no white curdy precipitate is caused by the addition of a few drops. Allow the white curds to settle well down, then pour off all the liquid. Pour on clean water, allow the curds to settle again, and repeat the process several times; finally, drain off as much of the water as possible. Dissolve these white curds in a solution

of potassium cyanide and add a little surplus to make it work freely. Use anode plates of pure silver, and work cold in a stoneware or glass vessel with current from two Smee cells, or from two or three Daniell cells.

For making a large quantity (say 150 gal.) of silver-plating solution to contain 3 oz. of silver per gallon, 450 oz. of silver will be required. As there are 108 oz. of metallic silver in 170 oz. of silver nitrate, 45 lb. avoirdupois of silver nitrate will be required, and about 30 lb. or more of best grey potassium cyanide, to convert the silver nitrate into the double cyanide of silver and potassium. About 230 gal. of distilled water will also be required. First well wash the plating vat and carefully sponge out all dirty water, then half fill the vat with distilled water. Next half fill a large stoneware or earthenware pan with distilled water and dissolve therein some of the silver nitrate in the proportion of 1 lb. of the silver salt to each gallon of water. Stir with a glass or clean wood rod until all the silver crystals are dissolved. Then dissolve some of the potassium cyanide in distilled water, in the proportion of ½ lb. to ½ gal., and add this carefully, whilst stirring, to the silver nitrate solution as long as it causes white curds or clouds. Now allow to settle, carefully pour off all the water, and throw this away. Then pour on fresh spring water to wash the silver curds well, and pour all this water away. Next dissolve all the curds in a strong solution of potassium cyanide, and pour this solution into the plating vat through a calico filter. Proceed thus until all has been prepared and added to the first lot in the plating vat. Then add 5 lb more of potassium cyanide, previously dissolved, to form free cyanide. The voltage necessary to work this solution is from four to five volts. The current in ampères is in proportion to the surface of goods immersed in the solution at any one time, so may

range from 1 to 100 ampères. The safe rate is found by experience, and varies with the character of the work in hand.

The plating solution should be kept in good working order. Only distilled water should be allowed in it, and it should always be kept up to a certain mark and thus maintained at the same strength. No chemicals of any kind, except potassium cyanide, should be added to the solution, and this must be used cautiously. A certain quantity of free cyanide must always be present in the plating solution to dissolve the silver anodes at a rate equal to that of the silver deposited. Then the anodes are not coated with black slime, providing all other necessary conditions are fulfilled; but a slimy condition of anodes may be due to an insufficiency of silver in the solution or to an accumulation of dirt. Too much free cyanide in the solution will be shown by a coarse crystalline condition of the anode surface and rapid erosion of the edges of the anode plates, which soon become ragged. In this solution the deposit is liable to become loose on copper, brass, and other metals readily dissolved in cyanide solutions.

In making silver solutions, only the best potassium cyanide should be used; this is sold under the name of best grey potassium, 99 per cent. cyanide. Inferior cyanide may be employed for pickling solutions; but, because it contains a large percentage of uncombined potash salts, it should not be used in plating solutions, as these too soon become charged with an excess of potash salts, caused by a gradual withdrawal of cyanogen from the free potassium cyanide in solution. In process of time this excess of potash renders the old plating solution unfit for use, as shown by its muddy appearance, and by the rough character of the silver deposited from it.

If the muddiness of the plating solution is

caused by dirt, filter the whole solution through good calico. This dirt may consist of dust from the workshop, carbon from the potassium cyanide. and finely divided silver from the anodes; it should therefore be saved and put in with the waste rinsing water to recover the silver.

All water suspected to contain silver should be saved and evaporated in an enamelled iron vessel, the resulting salt being mixed with waste sawdust and sold to a refiner.

If a silver-plating bath is exposed to strong sunlight, a small portion of the free cyanide will absorb carbonic dioxide from the air and part with its cyanogen, and thus become converted into potassium carbonate. The loss of free cyanide may easily be made up by adding a small portion of potassium cyanide dissolved in distilled water When silver-plating baths are not in use, they should be closely covered to prevent this loss, and to keep out dust. They should also be well stirred an hour or two before being used again.

As the silver salts will creep up the sides of the vat, and thus find their way to the floor, it is necessary to wash them back into the vat with a little distilled water applied with a stout brush almost every day. An abundance of clean water must be provided for rinsing, and the rinsing waters must be frequently changed. Failure in securing an adherent deposit of silver may often be traced to the use of dirty rinsing waters.

The anode plates, which serve the double purpose of conveying the current into the solution and also keeping up its strength, must be of pure annealed silver, and their surfaces should always slightly exceed the surfaces of all the articles immersed at any one time. If they fall short of this for any length of time the solution will become impoverished, and, on the other hand, if their surface is excessive, the solution may get too rich. They should be easily removable.

Standard silver must not be employed for the anodes, as it contains 7½ per cent. of copper. French silver coins contain even a higher percentage of copper; therefore coin silver must not be used at all, or the deposited silver will be hard and of a bad colour. The plates may be of any size and length suitable to the vat and work, but should not be less than ⅛ in. in thickness. If kept moving whilst at work, the lower edges rapidly wear thin, and the plates should be reversed to wear both ends equally. This is also necessary if the plates remain stationary, as they are then liable to be cut through at the top of the solution.

Anode plates are usually suspended from the anode rods by hooks of pure silver wire, holes being punched in the upper edges of the plates for this purpose. The anode rods may be kept in motion if they are made to hang on a steel frame moved to and fro by machinery. The frame should have broad steel rollers running on steel rails, and these must be connected to the positive pole of the dynamo. Steel is preferable to other metals because it is not readily corroded by potash salts or cyanide.

Boxwood furnishes the best sawdust for drying silver-plated goods, as it does not contain dye, acid, or resin liable to stain pure silver. But if the sawdust is heated in a vessel by direct contact with flame, it will become charred, and in this condition will stain silver. The pan containing the sawdust should therefore always have a water or steam jacket. The goods may be dried thus in clean boxwood sawdust without spotting or tarnishing, and, in this clean condition, are more easily given a high finish.

Some notes on silver-plating a few particular articles will now be given.

In silver-plating a cruet frame, if it is to be highly polished in every part, it will be necessary to disconnect the parts where they are soft-sol-

dered, and polish each separately. But this is not usually done, as cruet frames thus soldered are of common quality, and best plating is not expected on them. In best quality cruet frames all parts are put together with screws, and by simply withdrawing these, every portion of the cruet can be got at with the polishing mops. The bases of some old cruet frames sent to be re-plated are often so pitted with corrosion as to render a smooth polish impossible If they must be made like new, and there is no other method of doing this, it will be advisable to fill in the pits with solder; then grind the whole level, and polish the surface before plating. This, and all parts coated with soft solder, must be coated with copper before they are silver-plated. Joints may be coated with copper by rubbing with wet copper sulphate and a bunch of fine iron wire. Large surfaces must be coppered in an alkaline coppering bath.

It is not usual to silver-plate tinware, but when it is necessary, it must be cleaned by scouring with potash on a cotton mop; it is then rinsed in a hot solution of potash, and coated with copper in an alkaline coppering solution before it is immersed in the silver-plating solution. Silver does not firmly adhere to tin, but will firmly adhere to copper; hence the advisability of first coating the tin with a thin layer of copper. As tin is a very soft metal, it can be easily scratched, even with a soft cotton brush not quite free from dust and grit. If, therefore, a bright surface is desired on the lightly silvered tinware, this may only be rinsed in the hot potash without scouring, very lightly coppered in a good solution, transferred promptly to the silvering vat and given only a thin coat of silver.

Generally, pure tin, pure lead, and their alloys, irrespective of proportions, such as soft solder, pewter, and Britannia metal, are treated in a special manner in preparing them to receive an

electro-deposited coat of silver. When thoroughly cleaned and ready for plating each article is swilled in a hot solution of potash and transferred at once, without rinsing, to the plating solution, where the deposit is struck by a vigorous current at first, but the current is reduced to finish the deposit slowly. Such metals cannot be quicked in a mercury solution unless they have a coat of copper or of brass deposited on them previous to immersion in the solution. This is sometimes done, and is a safe method for novices in the art, but requires the same preparation as for silver-plating direct. All such metals should be lightly scratch-brushed and polished after they are coated with silver.

For silvering the inside of a tin-plate teapot, well scour it with powdered Bath brick or Trent sand until quite bright; then well rinse in potash water, and fill, whilst still wet, with a good alkaline coppering solution. Connect the teapot by a copper wire to the negative pole of the plating dynamo, and suspend a strip of copper in the pot by a wire connected to the positive pole, and see that this wire does not touch the vessel. In a few minutes the inside should be coated with a thin film of bright copper; then pour out the coppering solution, and substitute a silver-plating solution, and a strip of silver instead of the copper strip. Deposit silver in the teapot until of the required thickness; then pour out the silver solution, rinse with hot water, scratch with a soft wire brush, and polish lightly.

For silver-plating a sword and sheath, two vats, each not less than 4 ft. long and 1 ft. 6 in. wide, will be necessary. Fill one with an alkaline coppering solution, and the other with the silver cyanide plating solution. The sword must be freed from grease, etc., by scouring in the potash pickle, then lightly coated with the alkaline coppering solution, rinsed in clean water, quicked in

a cyanide of mercury solution, and lightly silvered in the silver-plating solution, then scratch-brushed and polished. The sheath must be treated in a similar manner, but care must be taken to remove first the wooden strips which form the lining. To do this, it will probably be necessary to take out a set screw in the collar, and remove this, then loosen the strips of wood with a knife and draw them out. A plug of wood should be put in the screw hole, and the head of the screw should only be lightly plated. Both sword and sheath must be slung horizontally in the baths, and the sheath should be given a heavier plating than the sword.

The insides of tea-pots, coffee-pots, and similar vessels have often to be plated and to be in a bright and finished condition in every part. It is quite possible to reach the insides of ordinary vessels with suitable scratch-brushes, but there are always some interstices in ornamental and chased work that cannot possibly be reached by mechanical means, and it would never do to leave those parts with the dull white or "matt" coating left upon them when finished in an ordinary silver-plating solution. It is, therefore, usual to make up a special brightening solution to deposit a bright coat of silver on the finished article. The solution for bright plating is made up as follows: Take 1 pt. of old silver-plating (cyanide) solution, and add to it from 2 oz. to 3 oz. of bisulphide of carbon. Put this in a glass-stoppered bottle capable of holding ½ gal. of liquid, and add to it 3 pt. more of the old plating solution; then shake the bottle well for a few minutes, and set aside to rest for twenty-four hours or more. Carefully decant the bright liquid into another similar bottle without disturbing the sediment, and add from 2 oz. to 3 oz. of good cyanide of potassium dissolved in distilled water. Shake up the contents of the bottle to mix them, and when all is settled down again, the mixture will be fit

for use The daily dose of this liquid to the bright-plating solution must only be in the proportion of 2 fluid oz. to each 20 gal. of solution This should be added at the close of each day's work, and be well stirred into the plating solution. If too much brightening solution is added, the deposit will be brown, or marked with black or brown streaks, and the solution spoiled. It should never be added to the ordinary plating solutions, since they are apt to be spoiled for other work by the addition of the brightening solution.

The work in course of brightening should be closely watched. The brightening effects will begin at the bottom of the article and spread upwards; when the article is covered, it should be removed at once, and quickly rinsed in warm water. As bisulphide of carbon is an evil-smelling, poisonous liquid, of a volatile nature, great care must be exercised in its use, so as not to breathe the fœtid vapour, the odour of which resembles that of rotting cabbage. The worker is warned against sniffing at the bottle containing bisulphide of carbon or brightening solution.

Some special instructions may be given on the treatment of the various little oddments that come to the country jeweller to be re-plated, such as alberts, charms, lockets, brooches, buckles, scarf-pins, rings, and one or two spoons or sugar-tongs. The small jeweller is not advised to undertake the job of plating spoons and forks in dozens, or anything larger than a dessert spoon, as larger articles demand more room than can be found in the small vat of a working jeweller, and more anode surface than he has at his command; but there is no reason why he should not profitably engage in the plating of small articles. If he does, he will find the following notes particularly useful. The preparation of the articles by boiling in alkali, rinsing, scratch-brushing, scouring, and quicking has already been described. Each article

must be hung to a long hook made of copper wire, and suspended by this in the solution whilst receiving its coat of silver. For very small articles this hook may be made of No. 28, whilst for larger articles it may be made of No. 20. This hook is made in the form of an S, the lower end hooking behind a pin, into a bow, into a link, or to some projecting part of the trinket. The articles should be wired with wet hands before the final dips, and not touched with the hands afterwards, but placed straight away into the plating solution, suspended to the cathode rod attached to the zinc of the battery. Two or three cells in series will be enough to force current through the wires and deposit the silver in good condition. The articles should be coated white with silver within a few minutes of placing them in the depositing vat. They should then be taken out and brushed with a clean scratch-brush in clean water, to test the adherence of the deposit If this does not strip, the article must be rinsed in clean water, and restored to the vat to receive a finish coat. The time taken to do this will depend upon the price to be paid for plating, since a longer time in the vat represents a thicker coat of silver. By carefully weighing the article after it is polished, preparatory to plating, and weighing again when dried, after it has been plated, the weight of silver deposited upon it can be found. A thick coat of good adherent silver may be deposited in two hours; but the time taken will always depend upon the condition of battery and solution. It may be said that for sixpence a trinket only a mere blush of silver over and above the scratch-brush coat can be allowed, and this may be laid on in a few minutes.

CHAPTER V.

COPPER-PLATING.

COPPER is a highly malleable, ductile, and tenaceous red metal very largely used in the industrial arts. It does not resist the action of acids, and even moisture affects it, causing it to form an oxide known as verdigris; this, under the action of carbonic acid, turns to green copper carbonate. Copper is also caused to oxidise by heat; it is volatile only at a great heat. It has a specific gravity of 8·9, and melts at 2,000° F. Commercial copper contains many impurities, amongst them being iron, silver, bismuth, antimony, arsenic, cuprous oxide, lead, tin, and sulphur. Copper is much used in its commercially pure state, but is greatly in demand as the chief ingredient of the important brass and bronze alloys.

The metals on which a coat of copper is deposited by electricity are lead and its alloys; tin and its alloys; iron, tinned iron; zinc; and steel. When articles made of these metals are to be silver-plated, nickel-plated, or gilded, it is always advisable and sometimes necessary previously to coat them with copper. This cannot be done in a copper sulphate solution, because the acid in this dissolves the metals.

The merits and demerits of copper-plating as part of a preparatory process to nickel-plating for cycle work may be discussed briefly. Skilful hands, old in the trade and experienced, ridicule the idea of having to coat with copper before putting on a coat of nickel. An experienced hand can deposit nickel direct on iron and steel, and the nickel will adhere firmly, but the novice is

advised first to copper all steel and iron parts of cycles, and thus save himself much after-trouble. The reason for this lies in the fact that copper will adhere to iron and steel more firmly than nickel does, and nickel will adhere firmly to copper. Another point in favour of copper-plating is, that it enables the plater to see whether the articles are perfectly clean or not, for copper will not deposit firmly on dirty iron or steel, and the coat strips off (when subjected to scratch-brushing) from all dirty patches. The nickel deposit can also be better seen on copper than on iron, and the progress of the depositing process watched. Copper will also enter into fine pinholes and cracks, and stop them, whilst nickel goes on around such spots, and leaves them open to the action of damp. A coat of copper, then, after the work has been scoured, is recommended, and this coat should be well scratch-brushed, dipped in the cyanide dip, and rinsed before placing the article in the nickel-plating solution. If a special job is in hand, a thick coat of copper should be deposited, and this well burnished all over to make sure of perfect adherence, then scoured to give a slight roughness to the burnished surface. A coat of brass will do quite as well as copper if a good brassing solution happens to be available.

When articles are badly pitted with deep rust-spots and scale from forgings, or castings have their surfaces full of small sand-holes, this previous coppering process enables the plater to fill in all such defects with solder, get a smooth surface on the defective spots, and coat the whole with copper. The best way of soldering such pits is by means of a chloride of zinc flux, applied with a spoon of copper wire which is always left in the flux, and thus contaminates it with a little chloride of copper. A slight film of copper is thus deposited on iron and steel, to which the solder adheres perfectly. This patching must be done

before the articles are polished, in order that the patches may be made quite smooth before placing them in the coppering solution. Articles thus patched must not be left long in the potash-vat, because this alkali will dissolve solder readily, although it has no action on iron.

Only a thin film of copper is necessary to form a basis for the deposit of nickel. When this has been obtained uniformly all over the article, remove it from the coppering solution, and test its adherence with the brass wire scratch-brush lubricated with water. If the copper comes off from any part, give the faulty spot a good scouring with whiting; rinse well in clean water, and give the whole article an extra coat of copper, placing one of the anodes near the fault, so as to cover it at once with copper If the coat of copper is good and perfect, rinse it well in clean water, and place the article at once in the nickel-plating solution, unless it has been determined to burnish the coat If the coat has been burnished, give the article a dip in the cyanide solution, to remove any tarnish caused by the action of the air; then rinse it, and place it in the nickel solution.

Although copper can be easily deposited from an alkaline solution, it requires some amount of skill to deposit the metal in a tough condition fit for burnishing.

Various solutions have been used for copper-plating; but the most successful one is made as explained on p. 76 of the previous chapter. Its usual proportions are: Copper sulphate, 4 oz.; potassium cyanide, 12 oz.; liquid ammonia, 4 oz.; rainwater, 4 gal. Distilled water may be used instead of rainwater, but spring and river waters are not suitable because of the earthy matters held by them. The solution should be held in an enamelled iron vessel.

The following is a typical copper-plating solution: Dissolve 1 lb. of copper sulphate in 1 gal.

of rainwater, then stir in enough liquor ammonia to throw down the copper in the form of a green precipitate, and dissolve this to make a blue liquid. Dilute this with an equal bulk of rainwater, then add sufficient potassium cyanide to destroy the blue tint and produce the colour of old ale. Filter the whole through calico and expose to the action of air for twenty-four hours, when it should be ready for use. Work it cold or hot.

Enough free cyanide should be present in the coppering solution to dissolve the copper anodes easily, but an excess of free cyanide should be avoided when the tension of the current is high, and the copper solution is impoverished. It is necessary to add some good cyanide of potassium to the solution from time to time, as found necessary, to keep up the supply of free cyanide; but as cyanide itself does not freely dissolve the oxide of copper formed on the anodes, a little liquor ammonia also should be added occasionally to assist the action of the cyanide. This is preferable to a large excess of free cyanide in the solution.

Anode plates of pure copper must be employed; these are connected by No. 16 S.W.G copper wire to the positive pole of the generator If the plates do not dissolve freely, but become encrusted with a green slime, a small quantity of potassium cyanide and of liquid ammonia should be added to the solution. The best electro-deposited pure copper should be selected for anode plates. Discarded Daniell battery-plates will serve the purpose very well. All other conditions being equal, employ an anode surface slightly in excess of that of the articles being plated. The rate of deposit can be regulated by exposing more or less anode surface. Too little anode surface may result in a hard, dark deposit of copper, if the tension of the current is high. Too much

anode surface may result in a loose, soft deposit of copper, which will peel off when scratch-brushed. This may be remedied by altering the resistance board, and interposing a higher resistance in circuit. Too much anode surface tends to make the solution rich in copper, and this condition also favours a rapid deposit, which may be loose under certain other conditions, such as too much free cyanide and too much current. On the other hand, too little anode surface tends to an impoverishment of the solution, and consequent hard, dark, and unequal deposits of metal. Unfavourable conditions may be remedied by moving the articles nearer to or farther from the anodes, in addition to the means already proposed.

If the solution is kept supplied with free cyanide and free ammonia it may be worked with a current at from 6 to 8 volts; but the deposit may be improved by heating the solution to from 150° F. to 170° F., and the vat may then be worked at from 4 to 6 volts. The best generator is a plating dynamo, the next a three-cell accumulator; and among primary batteries the next best would be four ½ gal. Bunsen cells.

The surfaces of all articles to be copper-plated must be cleaned and prepared. Iron and steel articles may be cleaned from rust by steeping and swilling in a pickle composed of 6 fluid oz. of sulphuric acid and ½ oz. of muriatic acid in each gallon of water. They must then be rinsed in clean water and immersed in a pickle composed of ½ lb. of American potash dissolved in each gallon of hot water. If the surfaces have been pitted, the corroded parts must be polished with emery held on a mop in a polishing lathe, after which the articles must be well swilled in the hot potash pickle to free them from oil or grease. All surfaces must be well polished before the copper is deposited, because the thin coat will not permit much polishing afterwards.

Articles made of lead and tin, or their alloys, must be first scoured with sand and water, using a hard brush for the purpose, to free them from oxide; then rinsed in the hot potash pickle; again scoured with finer sand to polish them; wired with short lengths of No. 24 s.w.g. soft copper wire; again rinsed in the hot potash pickle, and transferred direct to the plating vat. The potash pickle will prevent rust forming on iron and steel articles, and will clear oxide from lead and tin and their alloys; but it is advisable to transfer the articles quickly to the plating vat, and not to rinse them in water on the way.

Zinc articles are cleansed in a similar manner; but very fine sand or finely powdered bath brick must be used in scouring. If articles are bright and free from rust and tarnish, only a light brushing with a vegetable fibre brush in the potash pickle will be necessary to prepare them.

The actual process of copper-plating will now be described. Each article must be attached to a short length of copper wire, which suspends it in the vat. Use No. 24 s.w.g. for small articles, and No 18 s.w.g. for heavy ones. Each article should be held by the slinging wire during the final rinse, and the free end of this wire is bent over a brass rod on the plating vat, attached to the negative pole of the generator. Move each article to and fro with a rinsing movement when placing it in the vat, to remove any air bubbles on the surface. The current should be regulated by a resistance, usually a long length of German silver wire furnished with a switch. The resistance can also be increased by diminishing the surface of the anode exposed to the plating solution, and by placing the anode further from the article being plated. If the current is too strong, the deposited copper will be dark in colour and loose in character, and this will also happen if the solution contains too much copper. Move-

ment of the articles whilst being plated will assist in securing a bright and smooth deposit. Some gas is given off from the articles whilst deposition is going on, but this should be regulated by adjusting the current. Only a few minutes is required for plating each article.

The plated articles should be rinsed in plenty of clean water to free them from cyanide and copper salts. If the surface is to remain coppery, the article should be rinsed in hot water, placed at once in hot bran or hot sawdust, and moved about in it until quite dry and bright. Pure copper readily tarnishes in the air when damp, but may be brightened with a scratch-brush.

If the surface is to be nickel-plated, the articles must be rinsed and transferred at once to the nickel-plating vat. If a thicker deposit of copper is desired, use an electrotyping solution, after depositing a thin film of copper in the alkaline solution above mentioned. If the plated articles are to be gilded, get a very thin and bright deposit of copper, or brighten it with a scratch-brush; then rinse and transfer at once to the gilding vat If they are to be silver-plated, coat with a thin film of mercury before placing them in the silver-plating solution; give a brisk swill in the quicking solution (p. 76), and then rinse in clean water.

For copper-plating sheet lead, first scour the lead plates clean with sand and water, then briskly rinse them in a solution of pearlash (1 lb. to the gallon), and transfer from this direct to the copper-plating solution without handling or previous rinsing in water Use a current at from 6 to 8 volts. If the first deposit is coarse and loose. remove the plates and well brush them in water with a hard fibre brush, again rinse in the potash or pearlash solution, and return to the copper-plating bath, using a reduced anode surface, or keep the plates moving whilst being plated. In this way a bright facing of copper may

be obtained, which must be well rinsed and dried quickly to prevent tarnishing. Electro-deposited copper rapidly tarnishes in air when damp.

Occasionally, a piece of carbon has to be copper-plated for the purpose of soldering something to it. The coppering is easily done by the following process: Dissolve copper sulphate in warm water until the water will not dissolve any more. Place this copper solution in a large battery jar, or similar stoneware vessel, and select a porous battery jar to stand up in the centre. In the porous pot place a rod or plate of amalgamated zinc in a solution of sulphuric acid (1 part acid to 12 parts water), and suspend the carbons from a wire attached to this zinc with their ends only dipping in the copper solution. See that the ends to be coppered are quite clean and specially free from grease. In the course of half an hour enough copper will be electro-deposited on the carbons to take a coat of solder. Rinse each in hot water, and do the soldering whilst the copper is new

A special bath for copper-plating iron has been recommended as under, but it is not thought to have any advantage over the alkaline bath already given. For use cold, the bath is made of bisulphate of soda and cyanide of potassium, 18 oz. each, carbonate of soda 36 oz., acetate of copper 17 oz., liquid ammonia 12½ oz., and water 5½ gal. If the bath is to be used warm, make it as follows: Bisulphate of soda 7 oz., cyanide of potassium 25 oz., carbonate of soda and acetate of copper 18 oz. each, ammonia 10 oz., and water 5½ gal.

So that copper can be electro-deposited on terra-cotta, earthenware, etc., the surface of these materials must be first rendered conductive to electricity. This is done by coating with blacklead, bronze powder, or some other finely divided metal. Blacklead is brushed into the pores of the material in a dry condition until the whole sur-

face is evenly coated and well polished. Bronze powders are mixed with methylated spirit and applied in the form of a paste. If the surface is briskly brushed with a new brass-wire brush, it will become coated with brass and thus made conductive. A copper wire must then be tightly twisted around some part of the article and connected to the conductive surface by a liberal application of the powder. Thus prepared, the article is immersed in an electrotype solution, connected to a battery or dynamo, and copper deposited in the usual manner. Only a very thin coat must be applied if the pattern is to be retained or smoothness is desired. If the surface of a flat object is only covered, this coating may be afterwards peeled off; but if the object is surrounded with copper, as a vase or statue, the coat will be adherent.

In depositing a copper coating on a plaster statue, coat the statue several times with linseed oil or saturate with melted stearin to render the plaster non-absorbent to the copper salts; these would destroy the statue. When the surface is dry and firm, apply a coat of paint made of bronze powder mixed with methylated spirit only. Work this into every crevice with a soft brush, and when it is dry well brush every part with blacklead to get a smooth surface Brush with an alcoholic solution of phosphorus, and then with an ammoniate solution of silver, prepared by dissolving silver nitrate to saturation in strong ammonia. To ensure conduction to all parts of the statue, several fine wires should be led to the deeper crevices. A battery of Daniell cells should be used, and deposition should proceed slowly to obtain a smooth coat of copper.

The carved work, relief decorations, and other enrichments of wooden doors, etc., may by electroplating be given a coat of copper, brass, nickel, or other metal that will in certain circumstances

have a very rich appearance. Before plating, the wood is preserved and prevented warping by being coated with a good linseed oil varnish. When it is varnished, metal strips as conductors are fixed around the edges, and the whole surface is rendered conductive by blackleading. A big plating vat is required, and the operation of depositing the metal is carried out as usual. The excellent fire-resisting qualities of a wooden door covered with tinplate are recognised, the metal preventing the wood taking fire and the wood framing preventing the door warping from the heat and allowing flames to pass though, this last being a defect of doors made wholly of iron. A tinplate covered door has a poor appearance, however, and is suitable only for workshops and warehouses. An electrically deposited coat of metal serves the same purpose as the tinplate, and the process is suitable for doors in all situations.

The copper-plating of aluminium has many difficulties. This metal cannot be nickel-plated, as nickel must be deposited in an alkaline bath, using ammonia and the salt ammonium sulphate, and all alkaline salts rapidly corrode and dissolve aluminium. So before nickel can be deposited, the aluminium must be copper-plated, and even this method is very troublesome, since the small ingress of gas or a slight development of hydrogen at the cathode, though very feeble and perhaps scarcely visible to the naked eye, will be a hindrance to the setting of the deposit. But if a salt solution is used, the acid part of this will not dissolve the aluminium, but it will oxidise any hydrogen developed during operation in the nascent state. The salt solution recommended is nitrate of copper, whose effect can be further enhanced by using an excess of nitric acid. A solution of 100 grammes of sulphate of copper and 60 cubic centimetres of concentrated nitric acid of specific gravity 1·3334 per 32 oz. of solution is

recommended. The aluminium must be first roughened, preferably by sand-blasting (although it may be roughened by rubbing with emery), and then dipped in a weak solution of caustic soda or potash until a considerable gassing takes place. Next wash in concentrated nitric acid and place in a copper bath. The copper anode should have about the same surface as that of the article being coppered. Constant moving either of the article or solution is essential. Use current at a pressure of about 4 volts, with a distance between the electrodes of about 2 in. The opening and closing of the circuit is made by dipping in and taking out the objects. The length of time taken in coppering will be from ten to twenty minutes. Too thick deposits will strip off. When the surface has been coppered, the article can be covered with nickel in the usual way (see Chapter VII.).

The best method of plating aluminium is the mechanical, not the electrical, one. The mechanical method consists of laying over it a sheet of clean nickel, fastening the two closely together, and placing them between two large cast-iron blocks previously heated to a dark red, a pressure of 6½ tons to the square inch beng exerted on the blocks, this pressure being applied gradually and sustained for about fifteen minutes. The sweated plate can now be rolled as an ordinary plate.

CHAPTER VI.

GOLD-PLATING.

GOLD may easily be deposited in good condition on a large variety of metals and alloys from a solution of the double cyanide of gold and potassium. This may be made and kept warm in an enamelled iron saucepan over the flame of a gas-burner or of an oil lamp, the saucepan serving as the vat. One cell of any of the many suitable varieties may be used, even one dry cell being suitable. It is only necessary, therefore, to get such a cell, and some gold solution heated to a temperature of 160° F. in a saucepan, to connect the trinket to be gilded by a length of No. 24 S.W.G. copper wire to the negative (zinc) pole of the cell, and a strip of pure gold by a similar length of wire to the positive (copper or carbon) pole of the battery, and then to suspend both trinket and gold in the hot solution for a few moments to coat the trinket with gold.

A country jeweller often recognises the advantage of the possession of a small plating outfit, if only in the saving of time required in sending the job to be done in town. Now, nearly all firms supplying electro-platers' outfits and materials for electro-platers also supply as a speciality a small outfit suitable to the wants of watchmakers, opticians, country jewellers, etc. The following lists are selected from two catalogues, and these will show the materials in general use for the purpose. Canning and Co. supply the following: One gilding vessel and portable stand complete; ½ gal. rich gold solution; one Bunsen burner and tube: two 7-in. rectangular Bunsen batteries;

1 pt sulphuric acid, or one tin of Canning's B or negative battery powder; 2 pt. nitric acid, or one tin of Canning's A or positive battery powder; one sawdust pan and boxwood sawdust; one plate brush; ½ lb best rouge; 1 lb mercury; one amalgamating brush; 1 lb No 22 B W G. copper wire, for connections; two hand scratch-brushes For a silver-plating plant they supply extra: one 1-gal enamelled vessel; 1 gal of rich concentrated silver solution; two rods, 10 in long and ½ in. in diameter; two connectors for the ½-in rods If a coppering plant is also required, they supply an extra enamelled iron vessel and 1 gal of copper solution, together with the necessary connecting rods It may be stated as a commentary on this list, that the Bunsen battery charged with nitric acid emits most acrid noxious fumes, and should be kept in an outside shed or in a cupboard ventilated into a chimney with a good up draught Covered bell wires of No. 20 S W G may be employed as conductors from the battery to the plating vats The Bunsen cells may also be charged with other excitants which do not emit such noxious fumes. The zinc elements in a Bunsen battery whilst at work must be kept coated with mercury, which, with a suitable brush to apply it, is also provided. If the jeweller has not a lathe which can be utilised, he should obtain a combined scratch-brush and polishing lathe, with assorted finishing mops and brushes

J. E. Hartley and Sons supply the following small outfits: Gilding outfit Q:—Enamelled iron gilding vessel, with tripod stand and Bunsen burner as shown by Fig. 61; one 6-in Bunsen battery; 1 qt. gold solution; gold anode; 6 ft of connecting wire; and one hand scratch-brush. Gilding outfit R:—Enamelled iron gilding vessel, tripod stand and burner; one 8-in. Bunsen battery; 1 gal. gold solution; gold anode; 6 ft. of connecting wire; one hand scratch-brush of fine wire, and one of

medium wire. They also supply an optician's and watchmaker's outfit, which comprises an enamelled iron vessel (with stand) for the gilding solution as above; 1 qt. gold solution and gold anode; also suitable vessels for silver and for copper, with 1 gal of silver solution and 1 gal of copper solution, together with silver and copper anodes; also three 6-in Bunsen batteries, 10 ft. of covered connecting wires; wire for slings; three hand scratch-brushes; three assorted scouring brushes; 2 lb. pumice; and 2 lb. whiting.

In a regular plating shop, the gilding vats are

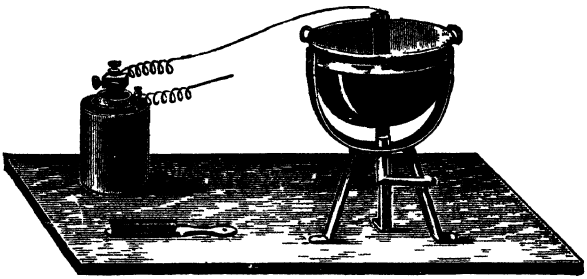

Fig. 61.—Small Gilding Outfit.

generally of enamelled iron, mounted in iron frames furnished with iron legs and heated with Bunsen burners, as in the model outfits above enumerated. In large establishments rectangular vats hold from 10 to 30 gal. of gold solution, and are fitted with steam jackets, as it is prejudicial to health to have the vats heated by gas jets, and with the use of the steam jackets the temperature of the solutions can be regulated better.

The preparation of articles to be electro-gilded is much the same as for those to be coated with silver, with a few exceptions. It is not necessary first to coat bright iron and steel with copper, as gold may be firmly deposited in a hot solution of the double cyanide of gold and potassium. But

it is advisable to copper-plate articles of zinc, lead, pewter, and other soft alloys before they are electro-gilded, because gold goes on them loosely. Copper, silver, brass, German silver, and similar hard metals with their alloys form suitable materials for articles to be gilded. Gilding metal, a kind of gunmetal, and the various kinds of brass which are sold under grand names for sham jewellery, all form excellent bases on which to deposit gold, taking a very fine polish in their preparation. The articles should always be highly polished before they are gilded, this greatly affecting the nature of the surface after gilding.

One method of producing a matt or frosted appearance on gilded articles is to make the surface rough by means of frosting brushes, by the sand blast, or by the action of acid, before the article is gilded.

It is not necessary in gold-plating to coat the surface with mercury before gold is deposited on it, except in the case when a very thick deposit is required on bare copper.

The gilding solution can be made in one of three ways.

(*a*) The best and the one chiefly used by professional platers is composed of the double cyanide of gold and potassium in distilled water. The single cyanide of gold is a very light yellow powder, 223 gr. containing 197 gr. of gold. This is added to a strong solution of potassium cyanide and stirred until dissolved, then made up to the required strength with distilled water. The strength varies from 5 gr. to 15 dwt. of gold in the gallon, the richer quality being used where large quantities of heavy gilding are done each day, and the poor solution for merely blushing the surfaces of trinkets with a gold tint.

(*b*) The solution may be made by dissolving gold direct into a heated solution of potassium cyanide, and passing an electric current through the solu-

tion from one strip of gold to another until sufficient of the metal has been acquired. This method is the most economical for small operations, but as the solution thus made contains an excess of potash, it is not to be recommended for large operations.

(*c*) The solution may also be made by the chemical method in a laboratory attached to the workshop if the necessary skill is available, but not otherwise, as unskilled attempts at making cyanide of gold usually result in much loss of gold. By the chemical method, the gold salt is precipitated from its solution of gold terchloride by cautiously adding a weak solution of potassium cyanide; the resulting yellow powder is well washed, and then dissolved in a strong solution of potassium cyanide to form the gilding solution. But, as the signs of complete precipitation are not well defined, and as the single cyanide of gold is so easily dissolved in a very slight excess of potassium cyanide, there is danger of great loss of gold in the making of the gilding solution by this method

Gold-plating solutions are generally heated for use, and the repeated heating drives off the solvent property of the solution; consequently, gas having a noxious odour is given off, cyanogen (prussic acid gas) is separated from the potassium cyanide, and leaves potash alone in the solution. As potash alone will not dissolve gold, more of this precious metal is withdrawn from the solution than is dissolved from the gold strip (anode) to make up the loss. As a consequence, the gilding becomes more and more poor in colour, because the strength of the solvent has diminshed, and the quantity of gold in the solution has also decreased. Experienced electro-gilders add a small quantity of potassium cyanide occasionally to make up this loss, and also regulate the surface of gold anode to the work in hand so as to prevent

impoverishment of the solution. The addition of cyanide to a gilding solution must be made carefully to avoid a great excess, as this will spoil the colour of the gilding, giving it a foxy-brown tint.

Pure gold (fine gold) must be employed in making gilding solutions and for the anodes. Coin gold and standard, or sterling, gold, being alloys of gold with copper or silver, should not be employed. If silver is present in the gilding solution, the deposit will be of a pale tint, grading to a greenish yellow with each increase of silver. If copper is present in the solution, the deposit will have a ruddy tint, deepening to a reddish brown, and then to a dark bronze with an increase of copper The effect of copper in deepening the tint of gold deposits has been used in fancy jewellery, slight additions of the inferior metal being made to the gilding bath from time to time, and small copper anodes employed to secure ruddy tints in the gilding; but solutions thus alloyed require more skill to work them successfully than those made of pure gold, and are always more or less uncertain in their action. The proportion of copper to gold is not determined by the proportions of these metals in the solutions and in the anodes, but by the selective power of the current working the solution. As this varies with the resistance of the circuit, which alters with each variation in temperature and change of metal to be gilded, so does the proportion of the two metals, and the consequent colour of the deposit.

The solution (*b*) described briefly on p. 104 is recommended as being the cheapest and best for the amateur gilder and the jeweller in a small way of business. To prepare it, get 1 pt. of distilled water, and ½ lb. of best 95 per cent. cyanide of potassium. The latter is a deadly poison, and will injure health even if handled with

the naked hand; it should be kept locked-up in a wide-mouthed glass-stoppered bottle. Dissolve 2 oz. of the potassium cyanide in one pint of hot distilled water, and place it in the vessel intended to serve as a vat. Get two strips or plates of pure gold, weighing from 7 to 10 dwt. each; punch a small hole in the upper edge of each, and hang each strip on a hook made of No. 20 platinum wire. Hang one strip in the vat connected to the wire leading from one pole of the battery (say, the zinc plate), and the other strip of gold to the wire leading from the other pole. See that the gold dips only deep enough in the cyanide solution just to touch the platinum hooks, but do not allow the copper wires to hang in the solution. Copper and gold will dissolve in cyanide solutions, but platinum will not dissolve in them. The gold is to be dissolved to make up a gilding solution, but copper is not desired in the solution. If all has been done right, an electric current will pass from the zinc plates in the battery to the copper plates, and from these along the wire to the gold strip in the cyanide solution, through this, and back to the battery by way of the other gold strip and the wire leading to the zinc plate, thus completing the electrical circuit. Whilst current is passing in this way, gold will be dissolved off from the strip of gold hanging to the wire leading from the copper of the battery, and will be taken up by the cyanide of potassium to form the double cyanide of gold and potassium solution. Keep the solution heated up to 160° F., and keep the battery connected to it for one or two hours. At the end of this time hang a German silver wire for a moment or two in the vat, connected to the wire leading from the zinc of the battery. If the wire takes on a coat of a satisfactory character, hang both strips of gold to the opposite wire, and call them gold anodes, and connect the work to be gilded to the cathode wire—that is, the wire from the zinc

of the battery. The action of the battery may be carried on until 5 dwt. of gold has been dissolved into the solution, or gilding may be begun with only 1 dwt. of gold to the pint of solution. The quantity of gold in the solution can always be increased if the surface of the articles to be gilded is less than the surface of the anodes, and there is an excess of cyanide in the solution. The contrary condition will result, of course, in an impoverishment of the solution. A solution rich in gold deposits a rich-looking coat of gold in a short time, whilst one poor in gold works slowly, and deposits a poor-looking coat.

A full battery of at least three Wollaston, Smee, or Daniell cells, or two Bunsen cells, should be used in making the gilding solution, but it can be worked afterwards with a battery of one cell. The Gassner or the Leclanché are both unsuitable to use in making up the solution, but may be used in working it after it has been made up.

Gilding solution prepared by the chemical method (see *c*, p. 105) will be found inferior to that produced by method *b*, for though it will deposit a coat of gold of a fairly good colour, the coat is apt to strip off whilst being polished or burnished. A further objection is the loss of gold involved. This solution is best made up to the strength of 8 dwt. to the gallon. To make it, proceed as follows: Take 8 dwt. of fine gold and put it in a porcelain dish of about 40 oz. capacity—an enamelled saucepan will do if the dish is not attainable—then pour upon this, gently, about 4 oz. of aqua regia, which is a mixture of 2 parts of hydrochloric acid and 1 part of nitric acid. Another aqua regia composition is 3 parts pure hydrochloric acid, 1 part pure nitric acid, and 1 part distilled water. Gently heat the vessel containing the gold and aqua regia over a Bunsen burner to accelerate the chemical action, and when the gold is dissolved, pour the resultant solution

of chloride of gold into another vessel and evaporate the acid. If too much heat is used the gold will be reduced to the metallic state; if this should be the case, add a little more aqua regia to redissolve, and then re-evaporate. When the acid has been driven off, add to the resultant chloride of gold about one pint of distilled water, or failing this, use water that has been vigorously boiled and filtered. If, when the chloride of gold is added to the water, a white precipitate is formed, the chloride of gold solution should be carefully decanted; this precipitate is chloride of silver, which should never, on any account, be allowed to get into the gilding solution. To the solution of chloride of gold, a strong solution of cyanide of potassium should be added (this need not be of any specific strength); a brown precipitate of cyanide of gold is produced The solution of cyanide should be carefully added, so that a drop at last should have no effect upon the clear solution Too much cyanide will re-dissolve the cyanide of gold. Allow the solution to stand for about fifteen minutes, pour the clear liquor off, and wash the precipitate two or three times with distilled water. For this purpose, a quantity of distilled water is poured upon the precipitate; this is then allowed to settle and the water run off; this is done two or three times. When the cyanide of gold is sufficiently washed, a solution of strong cyanide of potassium is added to dissolve it. To the solution thus produced, some more of the cyanide of potassium solution is added to form free cyanide. Then add sufficient distilled water to make up to one gallon This solution must be worked with a pure gold anode, and a battery power of two Bunsens or their equivalent, holding about a pint and a half each. If the solution works a bit slowly, add a little fresh cyanide. The solution must be worked at a temperature of 125° to 135° F. A solution of the same strength as above, and worked at a

temperature of 132° F. with two quart Bunsens, has produced work of first-class colour, far better than with other heats and strengths of solutions and currents

There is a number of other baths that may be used, but those already given are the ones in common employment. The following four baths require the addition of one gallon of distilled water, and are used hot. For use with iron and steel, take bisulphite of soda, 2 oz.; crystals of phosphate of soda, 8 oz.; pure potassium cyanide, ½ dr.; gold chloride, 160 gr. Dissolve the phosphate of soda in a portion of the water heated. In another portion of the water dissolve the bisulphite and potassium cyanide, and in the remainder of the water dissolve the gold chloride. Stir the latter slowly into the phosphate solution when cold, and then add the bisulphite and cyanide solution. The bath should be heated to about 180° F. A strong current is required.

For bronze and brass the following has been used: Bisulphite of soda, 1½ oz.; crystals of phosphate of soda, 6½ oz; bicarbonate of potash, ¾ oz.; caustic soda, ¾ oz.; pure potassium cyanide, ¼ oz.; gold chloride, ½ oz. Dissolve all, except the gold chloride, in hot water. Then filter, and, when cool, stir in the gold chloride, dissolved in water. The bath should be heated to about 130° F.

A bath, which is simple in preparation, but which cannot be recommended owing to the want of uniformity in the results obtained, is made as follows: Potassium cyanide, 3 oz. (nearly); gold chloride, 1 oz. Dissolve the chloride in the gallon of water mentioned above, and then stir in the cyanide.

The following bath is for silver or copper or similar alloys: Bisulphite of soda, 1½ oz.; crystals of phosphate of soda, 9½ oz.; pure cyanide of potassium, ½ oz.; gold chloride, 160 gr. This is prepared in the same way as the baths for iron and

steel. The vessels containing the bath should be of glass, porcelain, or enamelled iron. Before electro-gilding lead, zinc, or tin articles, it is best to give them a coat of silver. A bichromate battery is preferable when using these hot baths.

Roseleur's cold gilding solution is made up of fine gold, 10 parts; cyanide of potassium, 30 parts; liquid ammonia, 50 parts; distilled water, 1,000 parts. The gold is converted into the terchloride of gold, and this is dissolved in distilled water. The liquid ammonia is added to this, and fulminating gold is thrown down as a brown precipitate. This precipitate is washed on a paper filter, and dissolved at once with the cyanide of potassium solution. The water is now added, and the solution boiled for an hour to drive off excess of ammonia. Care must be taken in making this solution not to dry any of the precipitate, as it is a dangerously explosive substance.

Another cold gold-plating bath is made with pure potassium cyanide, 3¼ oz.; gold chloride, 3⅛ oz. Dissolve the cyanide in part of the water and the gold chloride in the remainder of the water. Then add the latter solution to the first. This solution should be boiled for about half an hour before use.

Several attempts have been made, but without success, to invent a cheap electro-gilding solution for metal jewellery. Much, however, may be done with copper anodes; these may be so worked in the ordinary gold cyanide solution as slightly to alloy the deposit of gold with copper, and thus give a pleasing blush to a thin film of the precious metal. The cheapest method of preparing these solutions is to dissolve pure sheet gold in a solution of potassium cyanide by means of current from a battery until a test sample receives a nice blush of gold in a few moments' treatment. The articles must be clean and well polished, lightly scratch-brushed, strung on wires attached to the

negative pole of the battery, and dipped for a few moments in the gilding solution; then rinsed in clean hot water, and brushed with a scratch-brush of very fine, soft wire.

Alloyed gold may be deposited from an alloyed solution of the double cyanide of gold and potassium, but the process is not easily managed, and the deposit not always certain. The following process has been recommended: Dissolve 8 dwt. of gold alloy in each gallon of solution containing 4 oz. of commercially pure cyanide by the usual battery process Work the solution at a temperature of from 160° to 170° F., using the alloyed anodes. If the colour is too dark, reduce the density of the current. The colour of this alloyed gilding has been found to vary with each slight variation in current density brought about by a different size of anode or of article being gilded, or of slinging wire employed, or by a change in the temperature of the solution.

Enough has now been said on the preparation of the solution.

Fine soft copper wire should be employed to connect the articles with the cathode rod of the gilding vat, and the lengths of wire thus used are named slinging wires. These may be inserted in any holes in the articles, or twined round any obscure projections, or formed into slings for the suspension of coins and medals. In gilding some patterns of long thin chains it is advisable to take the chain in loops, and insert the wire in several links, and if the chain is a bad conductor it will be necessary to twine it around the slinging wire. If this is not done, there will be patches of links imperfectly gilded, or left ungilded.

Gold anodes should be made of pure gold plate or ribbon, not less than $\frac{1}{16}$ in. in thickness. Thin gold leaf or sheet is apt to become ragged at the edges as the anode gets worn; these ragged edges drop tiny pieces of gold to the bottom of the

bath, and thus the solution, or the gilded goods, gets credited with an undue portion of the wasted anode. Plates of pure gold $\frac{1}{16}$ in. in thickness can be easily bent over a platinum wire, and this forms the best support for the anode, since it is not acted upon at all by the gilding solution or its fumes. Copper, silver, or brass wires dissolve and contaminate the solution with an alloy. If alloyed gold is used for the anodes, the deposited metal will soon become an alloy of gold instead of pure gold; and the alloy is as likely to be as variable in composition as most deposited alloys are, and thus give trouble to the gilder. If gold anodes have been hardened by hammering, they should be annealed before being used. As a rule, the surface of anode presented to the solution should be slightly in excess of the surface to be coated with gold. As anodes are more quickly worn away at the surface of the solution, because of the action of the air on them, they should be lifted out when not in work, and their position frequently changed.

The green slime on a gold anode when in a plating solution is caused by an insufficiency of free cyanide in the solution in proportion to the other ingredients and the current employed. The green slime may indicate a deficiency in gold cyanide, and in this case much careful building up of the solution will be necessary whilst small quantities of cyanide are added. It may indicate excess of current for the work in hand or a larger anode surface than is necessary. Exhausted and over-worked gold solutions are frequently indicated by green slime on the anodes.

It might be supposed that because the gilding solutions in general use are made with pure gold, and because the anode plates also are of pure gold, that the metal deposited would also be pure, and of the same colour as the original gold. But this is not always the case.

A newly made solution of the double cyanide of gold and potassium invariably deposits a lemon-tinted gold when worked under ordinary conditions. As the solution ages, its deposit darkens, until it resembles heavily alloyed gold. This darkening is sometimes due to an accumulation of copper dissolved from the slinging wires, and from the articles that have been gilded in the solution; but it may occur in solutions that have been carefully protected, and is then due to impurities contained in the added potassium cyanide, and to an accumulation of free potash in the solution.

The working temperature of an electro-gilding solution ranges from 120° to 180° F. Within this variation the temperature greatly affects the colour of the deposit. Below 120° F. a pale brassy-coloured deposit is obtained; from 120° F. upwards the colour improves until 160° F. is reached; then, as the internal resistance of the bath is reduced, the gold goes on faster, and the colour darkens.

Gold in good condition can be deposited with a very feeble current, even from one cell of the simplest battery. A very good deposit can be obtained from a rich solution working at ½ volt, with only a fraction of an ampère. If the solution has but a small quantity of gold in it, the deposit will be very pale, but may be darkened by increasing the voltage. If the solution is in good condition, this darkening disappears in scratch-brushing the deposit, but does not disappear if the deposit is foxy, as when deposited from a defective solution. Gold deposited fast, with a high current density, soon assumes a brown tint, and much of it is in a loose powdery condition; but the brown appearance can be removed by brushing the surface.

Gold can be deposited in good condition from very weak solutions if attention be paid to their

temperature and to the current. With only a few grains of gold per gallon of solution, a good colour can be obtained when worked at a temperature of 160° F. and from 1 to 2 volts. As the quantity of gold per gallon is increased, the resistance of the solution decreases, and gold is deposited faster with the same voltage. This alters the colour, though not to any great extent, in newly made solutions; in fact, the colour indications may deceive the worker, for heavy deposits at low pressure from a rich solution may be very pale, and thin deposits of a high colour may be obtained from attenuated solutions worked at from 5 to 7 volts. As the density of the solution increases owing to the accumulation of potash and impurities, the colour of the deposited gold becomes darker, and this high colour is permanent.

When a cyanide of gold solution is being prepared, the worker adds a quantity of potassium cyanide more than is required to dissolve the gold cyanide, and this excess is named "free cyanide." It dissolves the pure gold anode, and thus feeds the solution with gold. If this is deficient, the deposit will soon become pale, and have an impoverished appearance. If it is excessive, the colour of the deposit will be too high, and a great excess will cause it to assume a foxy-brown tint, which will be permanent, and not removable by brushing.

When the electric current is too strong, a silver-plating solution deposits its metal in the form of a dirty grey loose powder, or the coat may have the appearance of pewter. This is called "burning" the work. When gold is deposited under similar conditions, the deposit may vary in appearance between a loose brown powder to a foxy red, and from this to a dark bronze, resembling in colour that of a dirty penny. Brown deposits of gold may be improved by a judicious use of colouring mixtures, but those of a foxy red and bronze

tint are usually intractable, and the workman will find that they can only be restored by freshly cleaning and re-gilding the article. As "burning" is caused by too great a density of current delivered at a high voltage, it may be avoided by using a resistance board in circuit with the vat, and throwing in sufficient resistance to stop back the excess volume of current.

A very dark brown deposit of gold from an electro-gilding bath may also be due to excessive free cyanide and to a deficiency of gold in the solution. This may be remedied by dissolving more gold in the bath, or by adding cyanide of gold until the excess cyanide of potassium has been taken up.

The condition of the surface to be gilded affects the colour of the gold deposited upon it. On bare copper, the deposit has a ruddy tint; on a bare silver surface, all thin deposits of gold have a pale tint, the thinnest having a greenish-yellow hue. Nickel and German silver surfaces impart a warm tint to thin deposits of gold. Pale brass gives a pale tint; but brasses and bronzes containing higher percentages of copper, such as gilding metal, impart a warm tint to thin deposits of gold. A rough and dull copper surface will impart a foxy-brown hue to thin deposits, whereas, if the same copper article has its surface highly polished, the deposit will have a warm, bright tint.

A matt or frosted surface on silver imparts a pleasing yellow tint to a thin deposit of gold if the minute silver points are clean and bright. Another effect may be produced by depositing a thin layer of gold on freshly deposited copper, and still another by depositing gold on a thin layer of freshly deposited silver. When the colour is affected by the condition of surface, gold deposits are rarely improved by scratch-brushing.

When gold solutions are alloyed with copper or with silver, an alloyed deposit results; but its

colour cannot be predetermined by employing anode plates of the desired alloy. The deposited alloy does not always contain the same proportions of the mixed metals as the anode plates. This is due to the varying rates of deposit of the metals employed. Pleasing effects may be obtained by adding a small quantity of copper to a gold solution, when a peculiar ruddy tint is imparted to the gold deposit. Various pale shades may also be obtained from a gold solution alloyed with silver, a greenish deposit being thus obtainable. Such gilding solutions are not suitable for ordinary gilding work, and cannot be afterwards restored to their former pure condition.

For gold-plating in colours there must be a separate bath for each separate colour. For green gilding add silver-plating solution to the gilding solution in very small quantities at a time until the required tint has been obtained; too much silver solution will cause a whitish deposit, known as white gold. To gild red, add a solution of copper cyanide, or use a copper anode until the desired colour is deposited. To gild rose pink, first gild the article and scratch-brush it, then deposit a mere flash of silver on the surface; on this deposit a mere tint of copper from an alkaline copper bath, and then just a blush of gold to tint the copper The process is a delicate one.

A thick deposit of gold is obtained in the following manner: The articles are frequently taken from the gilding bath and scratch-brushed to remove the brownish appearance, then rinsed and returned to the bath. If this is not done the gold will not adhere, but will simply surround the article in the form of brown mud, and this condition is soon observed when the solution is poor, and when the current is too strong.

Highly polished small steel articles, free from grease and oil, may be gilded in an electro-gilding solution of gold cyanide. When a quantity of

such articles is to be gilded, they may be done in dozens at a time if suspended in the solution in a basket of platinum gauze; this basket must be shaken whilst the gilding process is going on Any gold deposited on the platinum may be afterwards dissolved off in the gilding solution without doing it any injury. The steel articles are scratch-brushed and polished in the usual manner.

Articles made of aluminium cannot be gilded direct in a solution of the double cyanide of gold and potassium, because the alkali therein attacks and rapidly dissolves the aluminium. They should therefore be first coated with copper in a solution of copper sulphate, and then transferred to the gilding bath.

The insides of mugs, spoons, salt cellars, etc., are gilded by means of a special arrangement in which the articles are connected to the cathode system; then they are filled with gilding solution, and gold is deposited from a gold anode held in the solution by hand. If the vessel will hold any gold solution, fill it and connect it with the negative pole of the battery or dynamo, and for an anode use a strip of gold on the end of a wire connected to the positive pole. The anode is held in the gilding solution contained in the vessel, or moved about in it as required. If the vessel will not hold liquid, it may be gilded with a rag mop wrapped around the anode and repeatedly dipped in the gilding solution, connection being made with the battery as before.

The scratch-brushes used in brushing gilded work are made with very fine brass wire, some being crimped for extra elasticity combined with softness. Special shapes are required for such goods as rings and watch cases, so that the insides may be brushed and polished. Sometimes a good brushing with a scratch-brush is all the finish required for the insides of goods. When chains are heavily gilt, each link must be twisted

around and brushed, whilst only a short length of chain is held between the fingers and thumbs of both hands.

Gilt articles are polished on soft mops made of swansdown, soft felt, and chamois leather, using finest rouge composition as the polishing material. The insides of rings are polished on felt fingers so tapered as to fit any size of ring. Chains are polished on broad-shaped bobs covered with soft leather on the convex sides. Thimbles and similar hollow ware have specially formed bobs made with wooden stocks of the required shape covered with fine soft felt.

Contrasts in the various grades of finish are sometimes resorted to for effect. A frosted appearance is secured by using a coarse scratch-brush having long bunches sparsely set in the boss, and holding a stick to the revolving brush just before it strikes the gilded articles. Raised parts are burnished with suitable burnishers made of steel, bloodstone, and agate. A final yellow blush is often imparted by a momentary dip in a new gilding solution, after which the article is rinsed in hot water and dried.

Gold is deposited rapidly from ordinary electro-gilding solutions, and a sufficiently strong coat may be deposited in the course of a few minutes, the rate being about 37 gr. an hour per ampère. Weigh the articles after they have been cleaned and after they have been gilded to ascertain the quantity of gold on them. When, therefore, by calculation of time and current, it has been estimated that enough gold is deposited, the article must be rinsed in clean water, scratch-brushed to remove the brown appearance, dried by rubbing in sawdust or otherwise, and then weighed. If there is not enough gold on the article, return it to the gilding bath.

Professionally, the weight of gold and silver deposited is according to the charge to be made

for the job. The article should therefore be weighed in a balance when it has been dry-finished for plating, and the weight entered in a book. If it is a ring, for instance, weighing 50 gr., and the price will allow of 2 gr. of gold being put on, it is immersed in the gilding solution for a few minutes, then rinsed, scratch-brushed, and dried, and again weighed. If it weighs 51 gr., it must be again put into the gilding solution for a few minutes, and the foregoing process repeated until it weighs 52 gr. The price per grain is easily ascertained by dividing the price of pure gold per ounce by 480, the number of grains in an ounce. Silver is reckoned by the pennyweight, taking ½ dwt. as the lowest fraction. To the cost of metal must be added the cost of labour in preparing and finishing, and a small addition to cover the cost of deposition. This gives the prime cost.

In gilding lockets, light brooches, and similar light trinkets, the solution will get inside and remain there during the process of scratch-brushing. This must be taken into consideration when weighing the goods, and care must be taken to have them dry. Some of the hollow ware is filled with a waxy composition which oozes out in the course of gilding, and this falsifies the calculations made to determine the deposit of gold.

The amateur and small professional plater are interested more in the gilding of such trinkets as brooches, chains, coins, rings, etc., than in larger and more ambitious work; so it is proposed here to treat this branch of the gilder's art in greater detail. A brass ring could be taken from a man's finger, and, seeing that it is bright and clean, a person might conclude it would not need cleaning before hanging it in the gilding bath. Assume it to be merely wiped with a scrap of rag, a bit of copper wire tied to it, and hung in the gilding bath In a few moments it receives a coat of gold all over, and may be rinsed in warm water to free

it from the cyanide salts, wiped dry with a rag, and handed back to the owner, gilded. The ring looks fairly well, but by rubbing it with the palm of the hand the very thin coat of gold can be removed in a few moments, leaving the brass bare. All trinkets may be thinly gilt in a similar manner, and the thin coat of gold can be as easily rubbed off. If the ring is left in the gold bath for a few minutes, it will take on a brown coat instead of a golden tint. This brown coat is merely the matt appearance assumed by electro-deposited gold, and this will entirely disappear on brushing the coat with a brush of fine brass wire kept lubri cated with stale beer But on brushing in this way an imperfectly cleaned ring as it comes from a person's finger, the ring assumes a brassy appearance, because the gold went on loosely over the sweaty parts of the ring, and these loose particles of gold are readily detached from the imperfectly cleaned spots by the wire brush, and this non-adherence of electro-deposited coats becomes more apparent with thick coats than with thin ones. To get a perfectly adherent coat of electro-deposited metal, the article must be thoroughly cleaned. Let it appear to be ever so clean to the eye, it must have contracted a trace of animal grease, or sweat, if it has been handled or worn, and this film of animal matter must be taken off in a solution of strong alkali, such as soda, potash, or ammonia, before a coat of adherent metal can be deposited on the article. A strong solution of washing soda may be used if nothing better can be obtained. Pearlash is a better cleanser; American pearlash, or potash, is still stronger; and the best cleansers (in general use by professional platers) are commercial caustic soda and caustic potash. A piece of either of these, about the size of a walnut, dissolved in half a pint of hot water, will be enough to clean a dozen or two of small trinkets or chains. First

dissolve the potash or soda in hot water, then string a few trinkets on about 6 in. of No. 20 or No. 22 copper wire, and swill the bunch for a few minutes in the hot liquor Transfer from the hot caustic solution to some clean warm water, and well rinse the trinkets in this to clear off the loosened grease. When the caustic liquid is cool, put it in a closely stoppered bottle to exclude the air, and thus preserve it for future use. After the grease has been loosened, if there is no corrosion on the article, it must be briskly brushed with a little whiting, or prepared chalk, or finely powdered pumice, again rinsed, and then hung in the gilding solution.

If the trinkets are corroded, the corrosion must be removed in a pickle made of two parts sulphuric acid, two parts water, and one part nitric acid, after which the articles must be rinsed in clean water.

Chains of a strong pattern may be rolled up in a mass between the two hands with a little whiting, and rubbed until polished; but those of more delicate construction may not be treated in this way, but must be carefully brushed. Filigree work will require very careful treatment in cleaning, and the gold should be deposited on it with low battery power, to prevent browning the deposit, since it cannot be well brushed bright afterwards. Long chains of a delicate pattern should be threaded on a long thin copper wire passed through the links at intervals of from 2 in to 3 in., or the wire should be wound spirally around the chain, to assist in conducting the current to all parts equally.

Ear-rings and brooch pendants made of metal beads strung on silk should be suspended in a small basket of platinum gauze, in order that the beads may be placed in connection with a conductor of electricity, since silk will not conduct the electric current. Such goods should not be put

in the caustic solution, as this will dissolve silk, and cause the beads to drop off. All trinkets containing hair, photos, and other material likely to be injured by the hot gilding solution, must not be put in the caustic solution until the hair, photo, etc., has been removed. It is also advisable to remove glass and stones liable to injury from this cause, and to re-set them when the work is finished. Trinkets made of aluminium only will not receive a coat of gold, but will dissolve in caustic solution and in the gilding solution (see p. 118). The brush used in brushing articles before gilding may be an old, but clean, tooth-brush, or any clean brush with stiff bristles.

Special care must be taken with common jewellery. Bits of coloured glass, called "stones," are inserted in cheap brooches, rings, etc., under the names of rubies, diamonds, pearls, etc. In the commonest goods these stones are merely attached with gum or some soluble cement, which is dissolved in the solution, and thus the stones come off. An examination of the goods before gilding will soon detect these, and, if the "stones" are not held firmly in claws, they should be taken out by steeping the articles in hot water before they are prepared for gilding. They must be re-set after the goods are gilded.

Whilst preparing the trinkets, the condition of their surface must be noted. If this is scratched, dented, bruised, or pitted with corrosion, the marks cannot be obliterated by polishing and burnishing after gilding. All such blemishes must be removed before the articles are cleaned, if they are to be removed at all, and this can only be done by hand, either by pressing out the dents with suitable pieces of wood, or removing the scratches with a fine file and burnishing the filed spot. All repairs must be done first, as it will be difficult to repair electro-gilt goods when finished.

Joints made with soft solder are difficult to coat with gold, but small joints may be doctored up by rubbing over them a wet piece of bluestone (sulphate of copper) and then touching the place with a piece of bright iron or steel. Both the iron and the joint will take on a coat of copper and cover the solder. Rinse the joint in clean water, and hang the article in the gilding solution.

If there are several soldered joints or much soft solder about the trinket, or if it is desired to coat a pewter medal, lead casting, zinc ornament, piece of tinned iron, or article composed wholly or partly of iron, tin, lead, or zinc, it is advisable first to coat it with copper in an alkaline coppering solution, made up as described on p. 76. At least three battery cells will be needed to deposit copper from this solution, and perhaps four cells, arranged in series, may be required to force the copper on a soldered joint; but the copper thus deposited will be firm and adherent, and may be well polished. Use a piece of good copper, such as electrotype copper, as an anode. A mere film of copper is all that is required to protect the article from the action of the gilding solution. If the film does not go on evenly in a few minutes, take the article out of the bath, briskly brush it with a brass wire brush, and return it to the coppering solution. This solution may be worked cold or hot, as may be desired; but the deposit is brighter from a hot solution than from a cold one. This solution is also useful to give an 18-carat gold appearance to gilded or pure gold goods. This is done by merely flashing a film of copper over the surface when finished, then flashing a film of gold on this, rinsing at once in hot water, and drying off in clean sawdust. By careful working in this way, a clever workman can get any desired tint of gold on the surface.

CHAPTER VII

NICKEL-PLATING AND CYCLE-PLATING.

To facilitate the reader's mastery of the information about to be presented, it may be said that this chapter conforms to the following arrangement: The nickel-plater's and cycle-plater's plant; the necessary solutions; the preparation of the work; the preliminary coppering of cycle parts; the actual process of nickel-plating; the finishing of nickel-plated work; re-plating; the working of nickel-plating solutions in general; and special applications of nickel-plating

In the cycle trade large firms have a plating shop as a branch of their business; but small repairers are content to send their work to professional platers, though, as business increases, they naturally wish to do all the work on their own premises, and so save time and intermediate profits To this end they seek to do the plating at home, and they look about them for the information necessary to guide them in laying down a plating plant This chapter is intended as an aid to tradesmen desirous of expanding their business in this way, but the information given will be of value to all who are interested in electro-plating

The cycle maker's nickel and copper plating outfit, supplied by Messrs J. E Hartley & Son of Birmingham, includes the following appliances and materials.—

Shunt wound dynamo (4½ volts, 40 ampères, 3½ in pulley, speed, 1,700 revolutions per minute),

Resistance board for regulating current.

Plating vat (6 ft. by 2 ft. by 1 ft. 6 in.), lead-lined, burnt joints, bolted and match-boarded.

Salts for making 100 gal. of nickel solution.

Twelve nickel anodes (total weight 31 lb.) and hooks.

Cable, three rods, five connections, and copper wire.

Wrought-iron, potash, and hot-water tanks —the latter galvanised.

Galvanised wrought-iron sawdust pan.

Lead-lined scouring trough and twelve assorted scouring brushes.

28 lb. of potash, bag of boxwood sawdust, and 28 lb. of pumice powder.

A dynamo of 5 volts and 80 ampères, the pulley diameter being 3½ in. and the speed 1,100 revolutions per minute. is supplied in the place of the dynamo mentioned above at extra cost. To the above plant must be added the following items if electro-coppering is to be undertaken:—

Resistance board.

Vat, 4ft. by 2 ft. by 1 ft. 6 in.

Chemicals for making 50 gal. of copper solution.

Four copper anodes and hooks.

Three rods and connections.

Twaddell hydrometer.

Five pounds of cyanide of potassium.

The output of such a plant (with the larger dynamo) if under the control of an efficient plater is estimated at 100 sets of cycle fittings per week.

A nickel-plating outfit suitable for repairers, etc., is now obtainable; it has an output of 40 sets of cycle fittings per week, and differs from the nickeling plant already specified in having a vat measuring 4 ft. by 2 ft. by 1 ft. 6 in., eight anodes, and smaller quantities of chemicals and

materials, no coppering appliances and materials being included.

Similar outfits are supplied by other makers, whose lists should be obtained.

The above will be found sufficient for those who have facilities for preparing and polishing the cycle fittings, but if unprovided with a good polishing lathe and its accessories, the cost of this must be added, since nothing can be well done without it.

If a battery of large Bunsen cells is employed instead of a small dynamo, the total cost will be a few pounds less; but a battery is not advised if power can be obtained for driving the dynamos. Batteries are messy, and the daily work of keeping them in order is something considerable, whilst the cost of their maintenance is a very serious item. To compete with professional platers, it is necessary to have polishing lathes driven by steam, water, gas, or some similar power, and the same source of power can be used for driving the dynamos.

Directions are sometimes given for making nickel-plating solution by dissolving grain nickel in acid. As these home-made salts are inferior to those obtainable from a good dealer in nickel-plating outfits, and the quality of a nickel deposit largely depends on the purity of the salts used in making the solution, intending platers are advised to purchase the salt direct, instead of attempting to make it in the workshop.

The salt of nickel in general use for making nickel-plating solutions is the double sulphate of nickel and ammonia. This is a beautiful clear sea-green salt when pure, and takes the form of crystals, ranging in size from that of peas to that of chestnuts. The salt is merely dissolved in boiling water in the proportion of 1 lb. to each gallon, and poured into the vat when cool. Fairly good solutions may be made with 12 oz. of nickel

salt to the gallon; but weak solutions offer a high resistance to the current, and the deposit is liable to be powdery and loose. Rainwater is preferable to spring-water in making the solution, and it is advisable to pass it through a calico filter into the vat, to remove any loose dirt accidentally acquired by the nickel salt. If best nickel salt is used, it will not be necessary to add either ammonia or table salt, these being employed to correct some fault in old and poor solutions.

If for some special reason it is desired to make the double salt of nickel and ammonia at home, proceed as follows: Take of nickel 14 oz., dissolve it in a mixture of three parts of strong nitric acid, one part of strong sulphuric acid, and four parts water. When dissolved, which is indicated by the fumes (caused by chemical action) ceasing, add a little hot water and filter; the deep green liquid obtained is a strong solution of nickel sulphate. Then make up a strong solution of ammonium sulphate by dissolving 4 lb. of the salt in a gallon of water. For preparing the plating solution mix about half of ammonium sulphate solution with the sulphate of nickel, and make up with water to one gallon.

In working nickel solutions, they become too acid when insufficient anode surface has been provided. To correct this excess acidity, add liquor ammonia in small quantities until the solution ceases to redden blue litmus paper. When a solution ceases to deposit white nickel, a very small quantity of common salt is added, say ½ oz. to the gallon of solution.

Messrs. Hartley point out that if the nickel solution be weak, it offers too much resistance to the flow of the current; whilst if it is too acid, the deposit is pulverulent and peels off. The brilliant whiteness of American nickel plating is due mainly to the quality and purity of the salts

used. A slightly acid bath is best for iron, this giving a beautiful white deposit, whereas an alkaline or neutral solution gives a darker shade. A yellow sediment in the plating solution is due to the bath being too alkaline.

Litmus paper for testing the solution should be kept handy; an acid solution turns blue litmus to red; an alkaline solution turns red litmus to blue. The use of cast nickel anodes soon causes a bath to become alkaline.

A form of hydrometer with a heavily loaded bulb at the bottom can be used if desired for testing a nickel-plating solution, the instrument being appropriately termed a nickelometer. To test a solution pour a quantity into a testing glass (any long, slender glass vessel will do) and gently lower the instrument into the sample. The nickelometer has a graduated stem, and the nickel solution should not register less than seven degrees on this. If it does, more nickel salts must be added until the density of the solution is correct.

Nickel anodes should invariably be made of pure rolled nickel plates of a thickness suitable to the work in hand. Small anodes for small operations should be thin, the thickness increasing with the superficial size of anode required. Plates of cast nickel are always clumsy, because heavy and thick; they are also brittle and porous, whilst the pores are apt to contain impurities. Loose carbon, in the form of graphite, has been found interspersed with badly cast nickel. Rolled-nickel anodes give off the metal constantly and steadily; they do not become soft or fall to pieces while in the bath as cast-nickel anodes do; they may be light and thin to begin with, and they last a long time. Anodes of nickel may be suspended from strong hooks of copper, inserted in holes punched or drilled in the nickel plates. A suitable hook is illustrated by Fig. 5 (p. 19), but Messrs. Canning and Co. offer the hook shown by

Fig. 62 as an improvement. This slides along the rods, and is very secure.

It is advisable to coat all cycle fittings with copper before placing them in the nickel-plating vat. Copper will adhere firmly to all metals if properly deposited, and fill in all cracks and blemishes, whilst nickel will adhere well to copper. It therefore performs the part of a solder in uniting nickel to other metals. Nickel may be deposited firmly on iron and steel without the help of copper, but the process demands more skill, and the beginner does not produce such good results as when a coat of copper is first deposited on the fittings. The matter is fully discussed on pp. 90 to 92. Copper may be readily deposited on iron and steel from an acid solution of sulphate of copper, but the deposit of copper thus obtained will be useless for the present purpose, because it will not adhere firmly to the plated articles. When copper is deposited on iron and steel from an alkaline solution of copper, the deposit has a fine grain, and is firmly adherent to the article. The best alkaline solution for cycle plating is made as follows:—Estimate ½ lb. of copper sulphate for each gallon of solution required, and dissolve this salt in enough hot rainwater to form a solution. This will be about half a gallon of water to each pound of salt. Set this aside to cool, and when cold, add enough liquid ammonia, whilst stirring with a stick, first to throw down the copper in the form of green mud, and then dissolve this to form a beautiful blue liquid, free from sediment. Add to this enough cyanide of potassium dissolved in rainwater to destroy all the fine blue colour, and give the colour of old

Fig. 62. Improved Hook for Nickel Anode.

ale to the solution. The quantity of liquid ammonia and of cyanide of potassium cannot be definitely stated here, as these materials vary very much in strength and quality; hence, it is safest to follow the above colour indications, being careful to stir the solutions well after each addition of ammonia and of cyanide.

For purposes of estimation take equal weights of each salt and the ammonia, as both are used for other purposes, if there should be a surplus. The solution thus formed should be well stirred, allowed to rest for a night, and then filtered through calico into the vat, where it is made up to the required quantity with rainwater.

The coppering vat must be furnished with rods, anodes, cables, resistance-board, and other fittings, as before mentioned.

In preparing new work intended to be plated, the work of the smith and fitter may be found either a help or a hindrance to the polisher and plater. Rough forgings, weldings, and brazings by an unskilled or careless smith cause an immense amount of extra labour to the plater's polisher. It may be stated emphatically here that all notions respecting the filling up and covering over properties of nickel are entirely erroneous and false. Nickel will not fill up cracks and deep pits, cuts, or file marks; it will not cover defective forgings and rough welds. If the fitter does not file these out, they will be shown in the finished work, unless the polisher grinds out the flaws on the emery-wheel, and thereby weakens the part; thus a defective machine is the result of a polisher's attempt to make good the faults of the smith. The smith should therefore aim at turning out his part of the work in as smooth and finished condition as he can. The fitter should also be careful to avoid bruising or denting the surfaces of the parts, and leaving rough file-marks on them. He also should aim at turning out the

machine in a finished condition, remembering that the polisher's duty is to put on a higher finish, but not to make good the fitter's defects.

The preparatory polishing of iron and steel parts of cycles may be done by hand with different grades of emery-cloth, but the work is best done in a polishing lathe or on an emery tape machine (see Chapter III.). When it is known that the surfaces of parts to be nickel-plated must be made as smooth and bright as iron and steel can be made before they are plated, the use of a machine to do this will be appreciated. The smallest scratch left by the smoothing file, or even by fine emery-cloth, will be plainly visible in the nickel coat even when this has been polished, for nickel is too hard and intractable to be scratch-brushed and burnished like copper, silver, or brass.

If the forgings are rough, the rough parts must be taken down on an emery-wheel fastened to the spindle of the polishing lathe between suitable collars. Some skill is required in the use of these powerful tools, as they soon grind and cut their way into wrought-iron. The work must therefore be kept well alive in front of the wheel, and not allowed to lie long enough for the emery to cut into the metal. Different shapes and sizes may be necessary to suit different forms of parts.

When the rough patches are reduced, the work must next be submitted to the action of an emery-bob. If the work is not very rough, an emery-bob may be used from the first. For cycle work it is advisable to have an assortment of bobs, varying from 12 in. in diameter down to 9 in., 6 in., and 4 in., and in various thicknesses, from 2 in. to 1 in.; also some solid bobs made of bull-neck or sea-horse, some of them only ½ in. in thickness, and turned round on their edges to fit curves and hollows (see Fig. 34, p. 65). Coarse

grain emery, such as No. 90, is used on bobs intended for the first grinding, then No. 120, or a finer grade, to take out marks made by the first; then the work must be finished off or "coloured" with flour-emery on a plain uncoated bob. The flour-emery must be mixed with a little oil, just enough to keep it from flying about, and allowed to pass between the work and the bob whilst this is revolving.

The bobs are made to revolve toward the workman, who stands in front, a little on one side, and holds the work to the revolving bob. The work must be kept well alive whilst polishing—that is, must be kept in continual movement, either from side to side or round and round in front of the bob, to prevent lines from being cut in the metal. It is somewhat difficult to guide a novice by instructions on paper, for there are many little acquired knacks known only to the practical polisher, and called up on the spur of the moment to meet some little requirement; these knacks can only be obtained by practice. Polishing metal is generally designated dirty work, and the workman should protect his clothes by wearing a canvas apron or blouse overall; but he may avoid much dirt by standing a little out of the line of particles flying off from the bobs.

Copper, German silver, brass, and alloys of soft metals are not prepared with emery, but with a fine sand, sold under the name of Trent sand, applied on a clean bob. When the rough surface has been worn down with this sand, it is next subjected to the action of Tripoli composition applied by a calico mop run on the spindle of the polishing lathe. Tripoli composition is a composition of Tripoli powder and tallow, and is sold in three grades—A, a fine grade for polishing nickel-plated goods, and putting the finishing polish on German silver, brass, copper, and other soft metals; B is a grade not so fine as the pre-

ceding, but will do for the same purpose where a highly-finished surface is not desired; H is a harder and rougher grade, very useful in taking scratches and file-marks out of brass and copper before using the finer grades. These compositions are superior in every way to loose powder for polishing purposes.

Surfaces about to be nickel-plated are given the finishing touch with a 9-in. calico mop charged with rouge composition, or with rouge powder mixed with water, or with fine powdered lime specially prepared for the purpose, and sold under the name of Sheffield lime.

When the articles to be plated leave the polisher's hands, they are apparently as clean as it is possible to make them; not a spot can be seen on the surface, which is clear and bright as a mirror. But this mirror-like surface will not receive a coat of nickel, or, strictly speaking, will not retain the coat even should the plater get it on the article. This surface is coated with a very thin transparent film of animal matter, such as grease or oil, although it may have been finished with rouge and water or with lime, and this film will be quite enough to prevent the coat of nickel from uniting with the surface of the metal. Even one little spot in an obscure angle untouched by the scourer, will take on a loose coat of nickel, and form a blister, which will strip in the finish polishing, or after the article has been in wear for a few days.

When the articles leave the polisher, they must therefore be first soaked in the hot potash solution, to loosen and saponise the film of grease contracted whilst being polished, then rinsed in hot water to remove any loose soap and potash, and passed on to the scouring trough. A hold may be maintained on them during the dipping and rinsing processes by first twisting a stout wire, or two wires, if necessary, around them. Nuts,

collars, rings, and similar articles with holes in them, may be strung on wires, but it is not advisable to bunch too many, as they are liable to scratch whilst being rinsed.

The work to be scoured is held by the workman in his left hand on the edge of the scouring tray, or on a board provided for the purpose, whilst he scours it all over with a brush dipped in finely-powdered pumice-stone or finely-powdered whiting. Whiting is to be preferred, because it is not so rough as powdered pumice. Some workmen peg pieces of buff leather to the edges of the trays and scouring boards, to prevent scratching by the wood. Be sure to scour every little crevice of the article, and leave no part untouched, for it will be just this unscoured part which will strip after being plated. The work requires merely a brisk light brushing. Keep the left hand well coated with whiting, or handle the work with a clean linen rag to prevent soiling by sweat, for this will cause the nickel coat to strip.

When every part has been well scoured, attach the slinging wires to each article as it is finished, rinse off all the whiting in one division of the trough, then in clean water contained in the next division, then in the hydrochloric dip for a few moments, again in clean water, and transfer at once to the copper-plating vat to receive a coat of copper, after which rinse and place in the nickel-plating vat.

After the articles are scoured and rinsed—if made of iron, steel, zinc, Britannia metal, or pewter, and if the work of scouring has been done speedily—they may be transferred at once to the coppering vat. Whilst scouring large articles made of iron and steel, it is almost impossible to prevent some parts from contracting a thin film of rust; and this, if left on, would spoil the work by preventing close adherence of the deposited coat. It is therefore advisable to dip

them for an instant in a solution of hydrochloric acid to remove the film of oxide thus contracted, then rinse them before placing them in the coppering vat. The vessel to contain this solution may be made of wood lined with lead, similar in all respects to the plating vat already described. The solution is composed of 1 part commercial hydrochloric acid (spirits of salts) in 5 parts of water.

While brass, German silver, gun-metal, and similar alloys are being scoured, they also are liable to become tarnished on exposure to the air. It is therefore advisable to dip them in a solution of cyanide of potassium before placing them in the plating vat. There are not many or very large articles made for cycles in these metals, and so a small stoneware vessel will hold all the solution required for this purpose. The solution contains ½ lb. of commercial cyanide of potassium in each gallon of water. The cleaned articles are first swilled for a minute or two in this dip, then rinsed, and transferred at once to the plating vat. Copper must be treated in a similar manner.

Lead alloys, such as pewter, Britannia metal, etc., are but seldom if ever used in the cycle trade; when they are used, they are rinsed in the potash tank, and transferred from this direct to the coppering vat.

The dynamo must be going, and the vat already connected with it, before the articles are suspended in the nickel solution, for no time must be lost in starting the deposit after the final rinsing. Wherever practicable, each article should be suspended in the bath, so as to have the same quantity of solution above and below it—that is to say, it must be well below the surface, but not touching the bottom or the sides of the vat. It should also be slung with its surface facing two rows of anode plates—that is, with the nickel anodes all round, but not too close to the article.

The switch on the resistance board should be well over, to include a high resistance when the first article is placed in the vat, then moved to a lower resistance when more articles are put in, because then more current is required. Put in large articles first, then sling smaller articles, such as nuts, collars, and screws, between them. If this order is not observed, the smaller things may strip whilst being polished. Steel should thus be flanked with iron, but it is not desirable to attempt plating copper, brass, German silver, and like alloys in a vat with iron and steel. These are best done by themselves. Small goods, when wired together, should have quite ¼ in. of space between each article, and screws are best wired with fine copper wire twisted around each, to form a long string of them.

The work of deposition must go on without interruption for a period of from 1½ to 3 hours, according to the class of work to be done. It is sometimes necessary to turn the articles and move the slinging wires to prevent marking by the wires, but the goods should not be taken out of the solution.

When the article has been in the nickel-plating solution long enough to acquire the desired thickness of nickel, it is lifted out of the solution by means of the slinging wires, rinsed at once in the hot water tank, and immediately placed in the hot sawdust pan to dry off quickly. This celerity is necessary to prevent unsightly blotches and spots on the nickel-plated surface, as these show after the work has been polished. When a good deposit of nickel comes out of the vat, it has a creamy white or a dull grey appearance, which passes to a creamy white when rinsed in hot water. Nickel deposited too fast or from an inferior solution may have a dirty grey appearance, which does not alter very much even when rinsed in hot water. To remedy this, add from one to

two per cent. of common salt (sodium chloride) to the solution, and stir well together, then allow the disturbed sediment to subside during the next twelve hours. If the solution is allowed to dry on the surface, or if this is touched with the fingers whilst wet, dirty spots will be formed.

The dried plated goods are now polished by means of suitable mops, dollies, and polishing materials. Nickel-plated articles may have their surface finished by polishing them with mops and dollies charged with Sheffield lime, with fine Tripoli composition, or with rouge composition. The lime employed for this purpose is a picked material, procured from Sheffield, where it is packed in casks and jars, from which air is excluded, for transportation to other towns. It may be applied in the first place for polishing plane surfaces, together with a little oil, on a buff bob. When the rough surface has been brightened in this way, the bob may be removed, and replaced by a calico mop charged with lime, by holding a lump to it whilst it revolves. A good polish is thus obtained, which may be still further improved by using a dolly made of swan's-down calico, charged with dry lime from a lump held in the hand. An assortment of bobs, mops, and dollies should be kept on hand, including various sizes and varieties in shape, to go easily into curves and narrow grooves.

A very good polish can be imparted to nickel by using first a basil leather mop charged with fine Tripoli composition, then a calico mop charged with rouge composition, and finally a swansdown calico dolly charged with rouge. This imparts a fine steely lustre to nickel-plated goods; but the use of rouge on a lathe for polishing nickel-plated and silver-plated work has the disadvantage that the rouge flies about the shop, and gets into cracks and crannies, where the appearance of the red powder is objectionable,

and from which it is with difficulty removed. It also penetrates the clothing of the workman, and gets into his hair.

The work must be kept well alive in front of the bob, mop, or dolly whilst polishing its surface—that is, it must be kept moving to and fro or up and down all the time, so as to prevent the tool from grinding into one spot, and cutting through the deposit. Special care must be observed when approaching sharp angles, the edges of holes, and sharp corners, as the nickel deposit is soon cut through at these points, and the work spoiled. The aim throughout is to get a bright mirror-like surface on the nickel; and this is not very difficult if the work has been properly prepared for plating. If, however, the work has not been properly prepared, no amount of labour or skill will enable the finisher to turn out a polished surface; and for doing the work over again, all the old nickel must be removed. One method of doing this is to steep it for a short time in commercial sulphuric acid, to which is added, from time to time, a small quantity of nitric acid. However, owing to the corrosive nature and fumes of the acid, the nickel is generally removed with emery bobs, the work being polished ready for plating at the same time.

A large portion of the plating work to be done in repairing shops consists of replating the parts of cycles from which the nickel has been worn. This is not such easy work as plating new fittings, for the old parts are generally worn unevenly, dented, and bruised, and sometimes deeply pitted with rust. From the preceding instructions for plating new work, it will be clearly understood that all parts to be plated must be thoroughly cleaned; and to do this, it is necessary to take the machine apart wherever a nut can be unscrewed, a screw withdrawn, or a key driven. All nuts, screws, collars, pins, and similar small

articles, must be done apart from the larger fittings. Handles must be removed from handle-bars, and rubber from pedals and brakes, if these are to be plated, since the solutions will spoil all materials made of ivory, bone, horn, wood, rubber, vulcanite, ebonite, etc., and the hot potash will loosen all handles.

The loose dirt may be removed with a wisp of cotton-waste, and stiff grease should be taken off with some of the same waste dipped in turps. All parts to be plated should be thus roughly cleaned before they are sent to the polisher. If several parts of more than one cycle have to be re-plated, the smaller things, such as nuts, collars, pins, and small bolts, should be bunched together, tied with strings, and attached to the handle-bar of the machine to which they belong.

As nickel-plated fittings are more or less tarnished or stained with rust-marks when sent to the plater, it is advisable to first submit them to a leather mop, charged with emery or with coarse Tripoli composition, to clear the surface from stains and rust. It can then be seen whether they have been nickel-plated or not, and measures taken accordingly. If they have not been plated, and are merely polished iron or steel, rusted and stained, the polishing process must go on as for new parts, special attention being paid to rust-marks, which are sometimes very deep. If the parts to be nickelled have been previously nickel-plated, all the previous coat of nickel must be stripped off clean before a new coat can be firmly deposited on them. Nickel will not firmly adhere to a coat of nickel, even when freshly deposited and polished: hence the necessity of stripping it off before a new coat is laid thereon.

A very thin coat of nickel may be ground off on an emery-wheel whilst preparing the article for polishing, but it is usual to take off nickel by means of an acid which will dissolve this metal

without injuriously affecting the metal on which it is deposited. The stripping acid is composed of sulphuric acid, nitric acid, and water, mixed in the following manner:—In a stoneware vessel, capable of holding more than 12 gallons of liquid, first place 2 gallons of water; then add to this, in a cautious manner, 8 gallons of strong sulphuric acid, pouring it into the water in a thin stream, and stirring the mixture with a glass rod. This precaution is necessary, because the addition of this acid to water is always attended with an evolution of heat, and a consequent raising of the temperature of the liquid to almost boiling point. If water is added to the acid, instead of acid being added to water, the mixture will bubble as if boiling, and some of the scalding liquid will be spurted from the surface, with possibly serious results. After the sulphuric acid and water have been mixed, add to the mixture 2 gallons of commercial nitric acid, and stir all well together. As the heat generated in a mixture of sulphuric acid and water is liable to crack stoneware vessels, a lead-lined tank is preferable to stoneware for mixing the acids in; but they must be transferred to a stoneware vessel afterwards, because the mixture of nitric acid with sulphuric acid will dissolve lead. It will even dissolve enamel from iron vessels, and then violently attack the exposed iron.

The articles to be stripped should be first cleaned free from grease and oil, swilled in the potash solution, and then in the hot-water tank, then wired with stout copper wires, and dipped in the stripping acid. If the coat of nickel is thin, it will be dissolved in a few moments. Thicker coats will take several minutes' immersion, and very thick coats may require half an hour's immersion. The work must therefore be closely watched, and lifted out occasionally for examination, as each article should be removed from the

stripping acid, and plunged at once in clean cold water when the nickel has all been stripped off.

As noxious fumes arise from the acid during the stripping process, this should be conducted in the open air, or in a recess provided with a flue and strong up-draught, to carry the fumes off from the operator. After the articles have been stripped and rinsed in cold water, they should be rinsed in hot water, dried in hot sawdust, and then prepared for plating in the manner already described. The subsequent operations for replating and finishing are the same as for new work.

Some notes on the working of nickel-plating solutions will now be given. Nickel-plating solutions are always worked cold.

The solution is at its proper working strength when it contains 1 lb. of nickel sulphate to the gallon of water. To maintain it at this strength attention must be paid to the anodes and their condition. As a rule, the surface of anodes exposed to the action of the solution should exceed by one-half the surface of the goods being plated. The anodes should also freely dissolve in the solution, and therefore should not be too hard.

If nickel has been drawn from the solution too fast, it will be liable to become too acid, and this condition may be ascertained by testing it with blue litmus paper, which will quickly redden if acid is in excess. But a slight excess is permissible when plating iron and steel. An excess of acidity may be corrected by adding a small quantity of liquid ammonia; but an addition of nickel sulphate will be required also if the normal strength of the solution has been reduced. The hydrometer will show this reduction by comparing it with a sample of known correct strength. The readings on the hydrometer scale show the density of the solution, but not its temperature.

Sulphuric acid should not be added to a nickel-plating solution without previously testing the

solution with litmus paper and finding it alkaline. Even then the acid should be added in very small quantities, and the solution stirred after each addition, then tested with litmus paper. The same caution should be exercised in adding ammonia if the solution is found to contain an excess of acid. Neutral solutions may be employed in plating copper and brass.

If slimy yellow feathers appear on the anodes and on the sides of the vat, the solution is foul, deficient in nickel salts and their solvent. To alter this, filter all the solution through good calico, add one fluid ounce of sulphuric acid to each gallon, test for acidity with litmus paper, and add enough liquor ammonia to render the solution neutral. Work with nickel anodes greatly in excess of the surface to be coated.

Pinholes in nickel plating are caused by small air bubbles left on the surface of the articles when immersed in the plating solution. These bubbles may be held in pinholes existing in the surface of the metal, or may form on the smooth surface itself. They may be broken by a smart tap on the edge of the article, by shaking it in the solution, or by sweeping the point of a feather over the surface. If the solution holds particles of dust, these may settle on the articles being plated and cause pinholes. To avoid this, keep the solution clean by filtering it occasionally through clean calico.

Black streaks in deposits of nickel are caused by bubbles of hydrogen gas, which form in clusters on the surfaces of articles and then burst. They may be prevented by gently agitating the articles whilst being plated, or by stroking the clusters with a stout feather and thus bursting them.

All electro-deposits of metal are slightly porous, and so when a thin deposit of nickel on steel or iron is exposed to moisture the tiny drops penetrate these pores to the metal beneath and cause

rust. A thicker deposit offers a better protection, or better still is a coat of copper deposited on the parts and well burnished previous to being coated with nickel.

Aluminium may be treated much the same as zinc in preparing it to receive an electro-deposit of nickel or silver. After it has been well scoured with Trent sand, it must receive a coat of copper in a sulphate of copper solution, and be transferred direct from this to the nickel-plating solution. Solutions for nickel-plating on aluminium should not contain any free alkali, but be slightly acid, since alkalis act on aluminium.

Nickel can be deposited on wax moulds, but previously the mould must be prepared with black-lead or with bronze powder as for the electrotype process, and a thin film of copper deposited upon it in an electrotype solution (1 lb. of copper sulphate and 4 oz. of sulphuric acid in 1 gal. of rain-water). If the object desired is a copy of a design impressed on the face of the mould, it will be advisable to remove the mould to the nickel vat when it has become coated with a very thin film of copper, and deposit the nickel on this film. If the design is not undercut, it may be possible to peel off the film of copper from the nickel; but some difficulty may be experienced in getting a deposit of nickel thick enough to form a plate or sheet, as thick deposits have a tendency to crack, curl up, and peel off. To get a tough coat, the nickel should be deposited slowly with a low-tension current.

CHAPTER VIII

FINISHING ELECTRO-PLATED GOODS.

PROPERLY electro-deposited silver leaves the plating solution with a pleasing, rough, creamy-white surface, much like fine unglazed porcelain. It should be rinsed in clean hot water to free it from silver salts, and may be dried in clean hot boxwood sawdust, or scratch-brushed first, then washed in warm soapsuds, rinsed, and dried to prepare it for the polisher. Great care must be taken of the surface, as it is easily soiled and readily tarnished, and then causes much trouble to the polisher and finisher, who will have some difficulty in cleaning the surface. The rinsing waters must therefore be clean, and the sawdust free from dirt and burnt or brown particles. Should the article have a yellowish tinge when taken from the vat or from the hot sawdust, swill it at once in a warm dilute solution of potassium cyanide and rinse and dry

If the silver-plated surface is to have a higher polish than that imparted by scratch-brushing, it must next be held against a revolving swansdown mop charged with fine rouge. This may be applied in the form of powder to a mop previously greased or oiled; but rouge compositions do the work better, and in working are far more cleanly than powdered rouge. Avoid rubbing the silver off angles and projections, and apply pressure moderately, the surfaces being kept moving to and fro to prevent the mop cutting into one spot. This movement is specially necessary when polishing the coat on soft metals, to prevent blistering, as

the heat generated by friction is liable to cause buckling of the underlying metal.

Deeply impressed or engraved designs to be highly polished must be held against a revolving hair-brush charged with rouge powder.

When a sufficiently high polish has been obtained, it is advisable to wash out any rouge that may have lodged in crevices by steeping the articles in hot soapy water and mopping with a soft woollen mop. After this they should be rinsed in hot water and dried, then mopped with a clean swansdown mop. With great care in keeping mops free from grit, dust, dirt, etc., and the use of best quality compositions, a high lustre can be got on silver-plate by mopping alone.

If the deposit blisters and breaks away whilst being scratch-brushed, the loose silver must be all got off, either by means of a rough bob or in a stripping solution, and the surface again prepared by polishing, scouring, and quicking as before. The thin preparatory coat may be thus ground off easily without blotching the surface; but if the deposit blisters at a later stage it will be necessary to strip off all the silver in acid and begin afresh to get a good surface. The articles to be stripped must be quite dry and attached to stout wires, then gently moved in ordinary undiluted sulphuric acid made hot in a stoneware vessel, and grain saltpetre added in small quantities at a time until all the silver has been dissolved. If this is done carefully the acid will do very little injury to the article. For large articles a cold stripping solution may be employed; this is composed of sulphuric acid with a little nitric acid added from time to time as required.

Small articles, such as buckles, buttons, metal beads, hooks and eyes, etc., are treated in a special manner in preparing, silvering, and finishing. They are prepared by shaking some hundreds at a time with grit and sawdust in a revolving

barrel or in a stout sack. If it is necessary to pickle them, they are massed together in a perforated acid-proof vessel and shaken in this whilst immersed in the pickles and rinsing waters. Whilst being plated they are held in a basket made of brass or copper wire, and this is also to be kept moving by shaking to prevent contact for a long time; if this is not done, the articles will be blotched where they touch each other. By automatic machines the articles are so kept in motion whilst being plated that they are in a polished condition when the silvering is finished. If these machines are not employed, the articles must be rinsed and dried, and then polished by shaking together with sawdust or bran.

With regard to finishing gold-plated work, strongly gilt articles just taken from the gilding solution will be found to be coated with a brown powder. This powder is finely divided gold in a crystalline condition, the mass of crystals absorbing, instead of reflecting, the light. To remove this brown appearance, the articles are briskly scratch-brushed, the scratch-knot lathe being a convenient appliance for this purpose. The ends of the brass wires wear down the points of the gold crystals, and render the whole surface smooth To prevent the brass from wearing off in the shape of dust and cutting the gold coat, the brush is kept lubricated with stale beer, and is covered with a hood, to prevent the lubricant from being splashed over other things in the workshop. Rest the work on a sloping piece of board over a vessel placed so as to catch the drips of stale beer, and work the brush from left to right, away from the workman, going over all the surface until all the brown appearance has been removed. Do not leave any of this in the crevices. Lastly, rinse the work in warm water, and dry it in hot boxwood sawdust. Then polish with dry rouge on a plate brush, or burnish with a highly polished steel

burnisher, or one of highly polished bloodstone, using newly made soapsuds as a lubricant.

Stale beer, as stated on the preceding page, is employed as a lubricant whilst scratch-brushing electro-plated articles. Unless a lubricant is used, the brass of the brush wire gets worn off as fine dust and becomes embedded in the surface of the plated article, rendering it more or less brassy in appearance. A tea made of marsh mallows, or weak linseed tea, can be used instead of the beer.

A still higher polish on electro-plated work results from the use of steel, agate, and bloodstone burnishers. These tools are made in a large variety of shapes to suit all possible surfaces. The steel burnishers have very highly polished rubbing surfaces, which must be maintained in this condition by frequent rubbings on a pad of buff leather charged with putty powder. Skill in burnishing is acquired only by practice. The article is held on a soft pad with one hand, whilst the burnisher is held firmly by its handle with the other hand, and pressed hard on the surface with uniform straight strokes slightly overlapping each other. The surface of the burnisher may be kept moist with soapsuds, made either with best soap or with special burnishing soap. After the steel burnishing, the finish is imparted with either agate or bloodstone burnishers, and the whole article afterwards rinsed in hot water, then dried by rubbing with a soft linen cloth free from dust. The mirror-like surface of burnished silver is easily scratched and soiled, and should not be wiped or handled more than necessary Soft metals, such as pewter, must be burnished very lightly, if at all.

Burnishers in their least expensive form are made of steel blades varying in shape, running into the wood. Straight burnishers, shaped as shown at Fig. 63, and in section at A, are used for burnishing stems of spoons and forks, and plane surfaces generally. Curved burnishers, such as

those shown in Figs 64 to 68, and in section at B, C, D, E, and F, are used for burnishing the insides of the bowls of spoons and for hollow curves. Burnishers made of chips of agate, and of bloodstone or hæmatite, set in brass ferrules and mounted on wood, are more costly than those made of steel, and they also impart to the goods a more finished surface Some further forms of

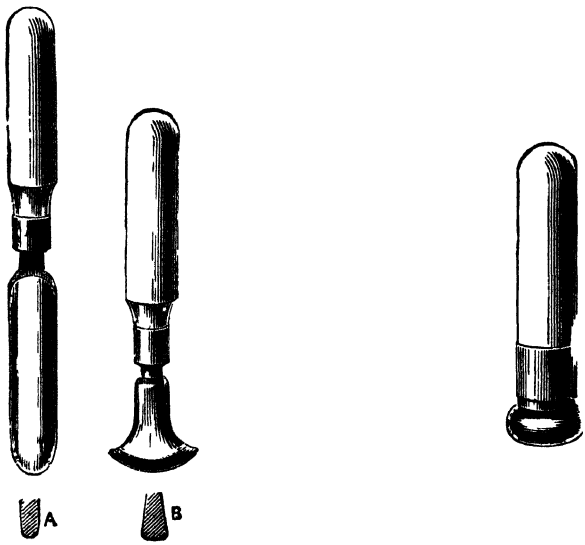

Fig. 63. Fig. 64. Fig. 65. Fig. 66. Fig. 67.
Fig. 63.—Straight Burnisher. Figs. 64 to 66.—Curved Burnishers. Fig. 67.—Round Burnisher.

burnishers in everyday use are shown in Figs. 69 to 72. Special agate burnishers are illustrated by Figs. 73 to 76.

Buffs are used to impart a perfectly smooth polish to steel and bloodstone burnishers. When used for this purpose, the strip of buff leather is first boiled in water and dried quickly, then glued to a flat piece of wood a little larger than itself,

and weighted with heavy weights until quite firm. The buff then resembles a mounted hone or oil-stone, such as is used by carpenters (see Fig. 77).

It is most important that the work to be burnished should have been prepared properly for plating, as on this depends the perfection of the burnished surface. In the first place, all scratches, lines, indentations, and corroded pits must be re-

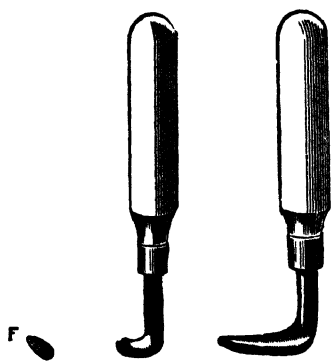

Fig. 68. Fig. 69. Fig. 70. Fig. 71. Fig. 72.

Fig. 68.—Hooked Burnisher. Fig. 69.—Curved Burnisher. Fig. 70.—Burnisher for Corners, etc. Fig. 71.—Hooked Burnisher. Fig. 72.—Pointed Burnisher.

moved by filing, rubbing down with water of Ayr stone, polishing, and burnishing, before the article is pickled and quicked with mercury preparatory to being placed in the plating vat. The slight roughness imparted to the surface by the action of the acid pickle is not in any way detrimental, but should a stain be left on the brass or German silver surface, or should the operator leave his finger-marks upon it, these will be dis-

tinctly traceable in the surface of the finished article, even if the spot does not strip under the burnisher. The utmost cleanliness must be observed in the preparation of the articles to be burnished, and care must be taken to put the quicking coat of mercury on evenly, or the silver will be apt to strip from slightly soiled spots, as also from those where thick blotches of mercury have been left on the surface.

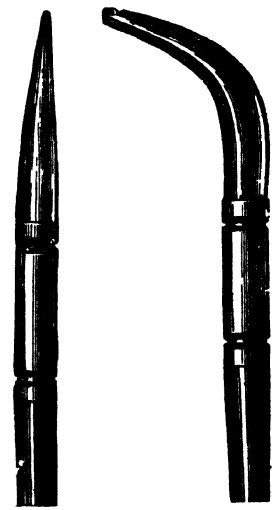

Fig. 73. Fig. 74. Fig. 75. Fig. 76.

Figs. 73 to 76.—Agate Burnishers.

Articles made of pewter, Britannia metal, and similar alloys are usually difficult to burnish because they are softer than the overlying coat of silver, but they are made worse by lack of care in their preparation; they should be transferred at once from a clean potash dip to the plating solution (after being properly cleaned and prepared) without any intervening rinsing, because such alloys are readily tarnished when exposed

to the air whilst wet. Potash dissolves the tarnish.

Silver will strip under the burnisher when it is deposited too fast or too slow, since its hardness is greatly affected by its rate of deposition. The plater should, therefore, find out by trial the best rate at which to deposit a coat for burnishing on the several metals or alloys likely to be employed. Silver will also strip when a plating bath has been made up by dissolving chloride of silver in a solution of cyanide of potassium, or when chloride of silver has been used in building or faking up a plating solution. A similar result will follow on the use of too much brightening solution in the plating bath. Plating solutions thus ruined should be set aside for the most common work, allowed to work out, and then treated for recovery of silver.

Work that is to be burnished should be laid on a clean soft pad of rag, on which it will be held during the process.

If an attempt were made to burnish articles whilst the surface and the burnisher were dry, the tool would heat and drag off the silver in the form of fine dust. A lubricant is, therefore, essential; linseed tea or a decoction of marsh mallows answer this purpose, as both of these are of a slippery nature, and are harmless when applied to silver. Soap-suds are sometimes used, and these form a fairly good substitute when freshly made, but they should never be set aside for use a second time, as they are apt, whilst standing exposed to the air, to undergo chemical changes which result in the formation of acids injurious to the silver coating.

The burnisher must first be polished to a dead black lustre, by rubbing its edge or face briskly along a groove worn in a polishing buff charged with jeweller's rouge. A thin burnisher is first selected to ground the work, which is afterwards

gone over with one having a broader surface, finally finishing off with a broad bloodstone burnisher. The tool is held in the right hand, the lower part of the handle resting on the outside of the little finger, and the upper part resting against the inside of the three other fingers, with the ball of the thumb on the top of the handle. In this position great pressure can be brought to bear upon the tool, if required

The strokes of the burnisher always should be given in one direction, since cross strokes will spoil the appearance of the burnished surface. Each stroke must be applied with some pressure, and the burnisher must be kept supplied freely

Fig. 77.—Buff for Polishing Burnishers.

with the lubricant, to prevent heating. Each succeeding stroke should slightly overlap that of its predecessor, so as not to leave unburnished metal between the strokes, and a clear, mirror-like surface behind. As the surface or the edge of the burnisher gets dull by use, polish it up on the buff, which is charged with rouge or with the finest putty powder. Very pleasing effects on ornamental goods are sometimes obtained by burnishing certain parts, such as bands and raised parts, whilst others are left matt. Gold-plated articles are treated in a similar manner to those of silver, but it is not usual to burnish nickel, since this metal is somewhat hard and intractable under the burnisher. When articles have been burnished, the finishing polish is put on by hand with soft rags, charged with a suitable plate powder, or by a dolly of soft linen revolving in a lathe.

CHAPTER IX.

ELECTRO-PLATING WITH VARIOUS METALS AND ALLOYS.

To make an electro-tinning solution suitable for small brass and iron articles, dissolve 1 lb. of common washing soda, ½ lb. of best pearlash, 1½ oz. of caustic potash, and 1 dr. of potassium cyanide in 1½ gal. of warm rainwater; then add ¼ lb. of tin peroxide and 1 dr. of zinc acetate, well stir until all is dissolved, and filter through a piece of calico. This solution should be kept in a stoneware vessel immersed in hot water in an outer vessel of metal, as it will have to be kept at a temperature of 75° F. whilst working. Use an anode of pure tin and work with a current at not more than 4 volts. Add small quantities of caustic potash and potassium cyanide as may be required to keep the anode and solution in working order.

A solution for the electrical deposition of iron has been made by dissolving, in 200 cubic centimetres of distilled water, 10 gram. of yellow prussiate of potash and 20 gram. of Rochelle salts. Then add a solution consisting of 3 gram. of persulphate of iron and 50 cubic centimetres of water. To make this ready for use, a solution of caustic soda is added very slowly, keeping the whole well stirred, until a clear yellowish liquid is obtained. Another solution, also due to Boettger, is prepared by evaporating and crystallising equal parts of sulphate of iron and sulphate of ammonia. A solution of the double salt is made, which, when current is passed, yields a good white deposit of iron.

Iron-plating solutions may become exhausted of metal from insufficient anode surface and the oxidising effect of the atmosphere. The anode surface should be very greatly in excess of apparent requirements, best soft charcoal iron being used. This is necessary because the solution does not readily dissolve iron, and even a faint current deposits the iron on the cathode faster than it can be dissolved from the anodes. Again, iron solutions exposed to the action of air absorb oxygen from the atmosphere, and the oxidised iron falls to the bottom of the vat. Covering the surface with a film of glycerine helps to protect it from atmospheric effects. Keeping a faint current passing through the solution to a small cathode counteracts these effects.

A solution for the electro-deposition of platinum is not easy to work, but may be made thus: In a porcelain capsule dissolve 1 oz. of platinum scrap in a hot mixture of 1 part nitric acid and 2½ parts of hydrochloric acid. Continue with a gentle heat until all excess acid has been evaporated, and the solution assumes the consistency of thick blood-red syrup, then allow this to cool and solidify. Next dissolve this deep red salt (platinum tetrachloride) in hot distilled water, allow the solution to cool, and filter through blotting-paper. Add a strong solution of potassium cyanide to this until it acquires a clear amber tint, then make up to 1 gal. with distilled water Make up the bath in a vessel of enamelled iron, commence working at a temperature of 112° F. with current from one cell of any battery, and note results. If good platinum is obtained from this moderately warm solution with a feeble current, continue to work it; but if the deposit is not satisfactory, raise the temperature and increase the current by using two cells in series.

Platinum solutions demand attention and careful adjustment of temperature and current. As a

rule, they work best when they contain 1 oz. of platinum in each gallon of liquid; but, as the platinum anodes do not dissolve to feed the solutions and thus make up for metal withdrawn from them in deposition, they are continually altering in strength and density. To counteract the effects of this alteration, it is necessary to increase the current and raise the temperature of the solution, or to add enough concentrated solution of the double salt of platinum and cyanide to keep the bath up to its original strength

To make a solution for depositing lead, dissolve 1 lb. of acetate of lead in 1 gal. of water, and add cyanide of potassium to precipitate the lead as lead cyanide, and then enough cyanide to re-dissolve this, and also to form free cyanide. Work with a pure lead anode and two Bunsens.

A brassing solution for use cold is made with 4 oz. each of carbonate of copper and carbonate of zinc recently prepared; 8 oz. each of carbonate of soda in crystals, bisulphate of soda, and pure cyanide of potassium; $\frac{1}{10}$ oz. of white arsenic; and about 2 gal. of water. Dissolve in water the copper carbonate and the zinc carbonate, and then add the soda carbonate and soda bisulphate. Dissolve in warm water the cyanide of potassium and the white arsenic, and pour this liquid into the other, which becomes rapidly decolorised; add distilled water to make 2 gal. or slightly more

The following is another method of making an electro-brassing solution. Procure 4 fluid oz. of nitric acid and dilute it with 2 fluid oz. of distilled water; heat the mixture in a glass or porcelain vessel under the influence of a good draught, and add cuttings of sheet brass until the acid ceases to dissolve. Dilute this with four times its bulk of rainwater, and add liquid ammonia, stirring until the green precipitate first formed has been all dissolved, and a clear blue liquid only remains. To this add a strong solution of potassium cyanide

until the liquid changes in colour from blue to pink; then add more cyanide cautiously, stirring until it assumes an amber tint. Allow it to stand like this for twenty-four hours; then filter the clear liquid through calico into the vat in which it is to be used. Work with a good sheet brass anode.

Electro-brassing solutions are known in great variety, the two just given being among the best of twenty or more.

The electro-deposition of bronze itself is rarely practised, since most brassing solutions can be made to yield a deposit resembling real bronze in tint, by merely increasing the quantity of copper in the deposit. Electro-bronzing can also be done with an alkaline coppering solution made as follows: Dissolve 2 oz. of copper sulphate in 1 qt. of hot water; add this to ½ gal. of rainwater containing 4 oz. of potassium carbonate; then add 2 oz. of liquid ammonia, and stir until the green precipitate has been dissolved; mix this liquid with a solution of 6 oz. of potassium cyanide in ½ gal. of rainwater, and filter for use. This solution is best worked at a temperature of 100° F., but can be worked cold, with current at a pressure of from 6 to 9 volts. It deposits a bronze-coloured copper at low temperatures with the higher voltage. The bronze tint may be deepened by rinsing the coppered goods in a solution of sal-ammoniac.

[Many of the blocks in this book illustrating electro-platers' appliances have been kindly lent by Messrs. W. Canning and Co., Great Hampton Street, Birmingham, and Messrs. J. E. Hartley and Son, St. Paul's Square, Birmingham.]

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