which has to be guaranteed, but in the formation of an alloy composed of precious and base metals in definite proportions. The accuracy of the "standard fineness" of the alloy after melting must be absolutely ascertained; the alloy must be protected during manufacture against a change of standard, and finally its correctness must be verified after it has been converted into coin.

The precious metals are weighed on entering the mint, as well as during various stages in the manufacture of coin. The finished coins are also weighed in bulk before they are issued to the public.

The operations incidental to the coinage of bronze and silver differ from those described in relation to gold in some unimportant details only; and the weight and composition of the bronze coins are not so carefully guarded as is the case with gold and silver.

Subjoined are the details of the operations involved in the conversion of bullion into coin at the British mint.

After being assayed and weighed in the manner already described the bullion is taken to the melting-house, where the details of treatment for silver and gold respectively differ somewhat. (The subsequent operations are nearly identical for both metals.) The silver melting-house (see fig. 1) contains eight furnaces, of the kind shown at A fig. 2, the part of the furnace containing the crucibles being below the lids B, B. Crucibles of cast iron were formerly employed, but these were replaced in 1853 by wrought iron pots, which have since 1870 been in turn abandoned in favour of crucibles made of a mixture of clay and graphite, each crucible being capable of containing about 3000 oz. Such crucibles are very generally adopted throughout the Indian and Continental mints, but the form and dimensions given to them vary. The fuel employed in England is coke, about 75 lb of which are required to melt 3000 oz. of standard silver. Sufficient draught is afforded by the flue C and by a chimney about 35 feet high which communicates with it. The silver and copper are melted together;

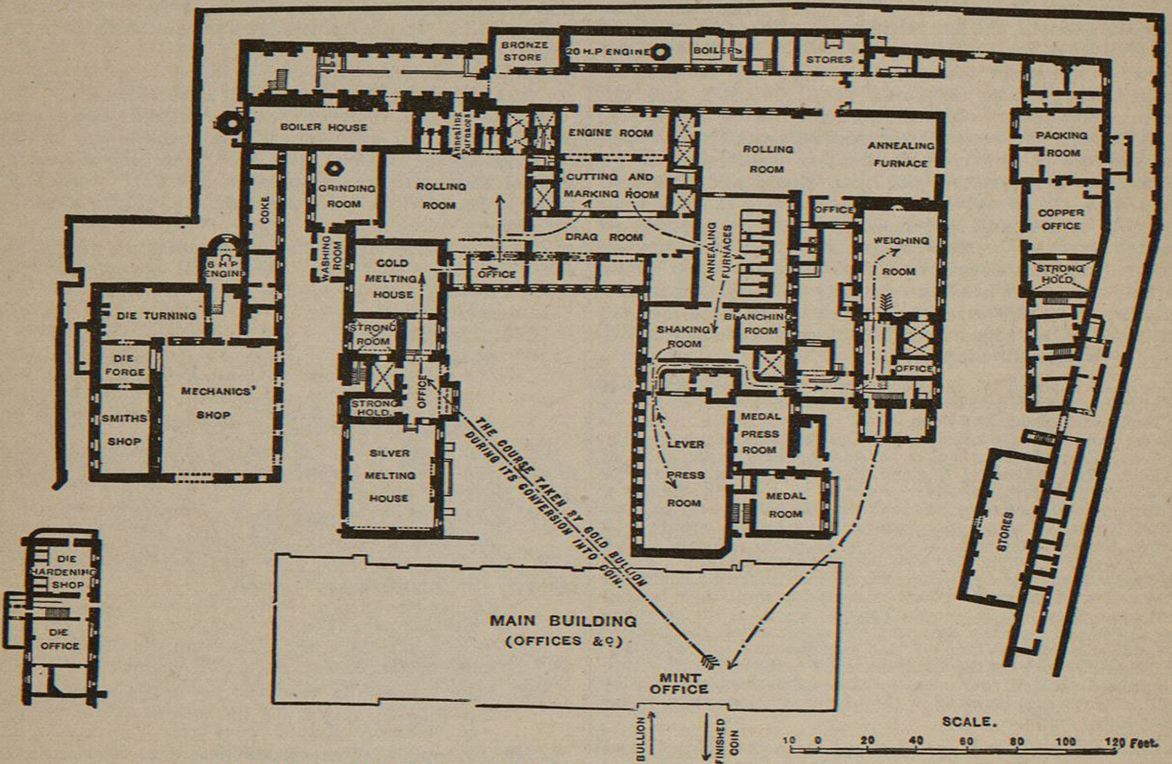


Fig. 1.—Royal Mint, Tower Hill, London. Plan showing the Operative Department as rearranged in 1881–82.

and before the metal is poured into moulds it is stirred with an iron rod having a flattened end. The surface of the molten metal is covered with a layer of charcoal to prevent oxidation of the copper. The crucible with its contents is then removed from the furnace by the aid of a crane and tongs W, and is placed in a cradle M, which can be tilted by means of a handle D. By the intervention of toothed wheels E, F, G, H, and K acting on a rack the handle turns the crucible on the fulcrum formed by a spindle, so that the contents of the crucible may be poured into the moulds N mounted on a carriage OP, running on rails Q, Q. The moulds now in use in London are of such dimensions as to enable bars to be cast 12 inches long and ⅜ inch thick. The width of the bars varies, according to the coin to be produced, from 1¾ to 2⅝ inches.

When the metal has solidified in the moulds it is removed, and the bars are trimmed by the aid of a revolving circular file, their ends being cut off and returned to the melting pot. Portions of metal are then cut from certain of the bars, and sent to the assay department. The bars are weighed before they pass to the subsequent operations of coinage, in order that the amount of metal retained by the crucibles or carried into the flues may be ascertained. Gold bullion is melted in a similar way, but the crucibles are smaller, and contain only 1200 oz. Their contents are poured by hand into moulds, one end of the tongs by which the crucible is grasped being supported by a chain and suspended from the roof.[1] In many Continental mints it is very generally the practice to leave the crucible containing the precious metals in the furnace, and to pour the contents into the moulds by the aid of small ladles of wrought iron lined with clay.

It has been pointed out in GOLD (vol. x. p. 751) that minute quantities of certain metals render standard gold extremely brittle and unfit for coinage. If either the gold bullion or the copper used as an alloying metal should be impure, brittle bars will be the result. Should this prove to be the case, the bars are re-

[1] A new form of furnace devised by M. A. Piat of Paris has recently been introduced. In these furnaces the portion which contains the crucible may be detached from the flue, so as to admit of the molten metal being poured into moulds without removing the crucible from the incandescent fuel. Four of such furnaces have been fitted up in the gold melting-house, but have not as yet been used for gold melting; in the melting of silver and bronze, however, they are known to effect considerable economy in labour, fuel, and crucibles.

melted and chlorine gas is passed through the molten mass in the manner described in GOLD, vol. x. p. 750.

The engine-room (shown in fig. 1) contains three 60-horse-power vertical condensing engines, which are provided with Corliss valves, and are specially devised for meeting the constantly varying strain to which they are subjected by the machinery, the whole of which they are capable of driving. The central engine acts directly on either or both of the rolling rooms placed on each side of the engine-house. There is, however, an additional 20-horse-power compound beam engine usually employed, in connexion with the pumps of a deep artesian well.

Into one or other of these rooms the bars which have been cast in the melting-house are brought, and are rolled into strips the thickness of which depends on the kind of coins to be produced. Gold is rolled in one room and silver or bronze in the other. The details of manipulation involved in the conversion of gold, silver, or bronze bars into coin, however, do not differ materially, and the coinage of sovereigns will therefore be taken as typical.

Each room contains six pairs of rolls, the diameter of the rolls varying from 10 to 14 inches. Smaller diameters are employed in most European mints, but on the other hand the use of very narrow rolls of far larger diameter has often been suggested, and there appears to be good ground for the belief that the rigidity of such rolls would enable strips or fillets of more uniform thickness to be

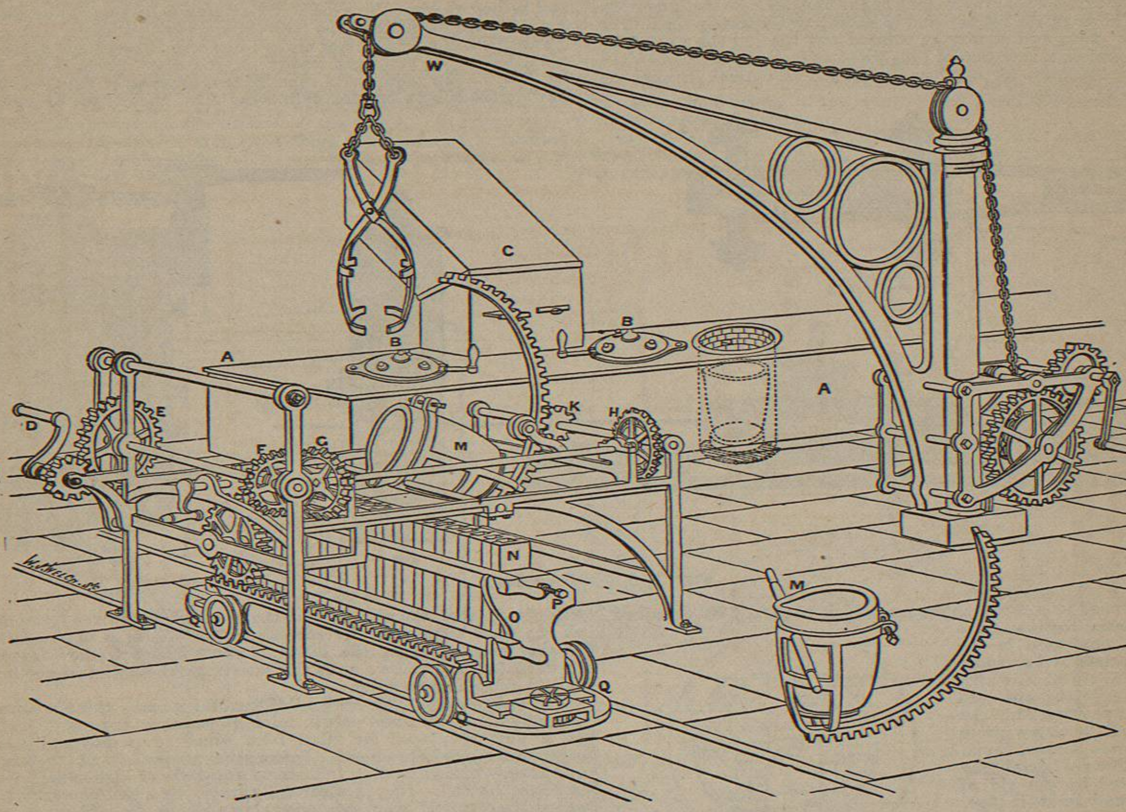


Fig. 2.—Furnace Apparatus.

produced than is the case at present. The iron frame CC (fig. 3) is firmly bolted to the stone D, which rests on a solid foundation EE. This frame supports the two rolls A, B, the lower of which B revolves, but is not like the upper, capable of adjustment in a ver-

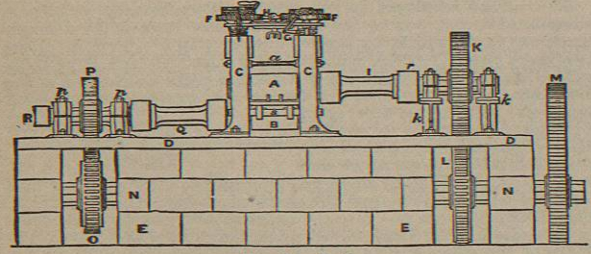


Fig. 3.—Rolls.

tical plane. The upper roll is centred in bearings, and may be raised or lowered by means of screws connected with toothed wheels F, F, which are turned by a handle G, both wheels being moved simultaneously by worms on the rod H. The bearings of the upper roll are connected by vertical rods with weights below the level of the floor; and, as it rises with the screws, it can thus be readily adjusted in a line exactly parallel with the lower roll, at a sufficient distance from it to admit the bar which is to be reduced to a strip or fillet. The rolls are turned by the shaft NN, the main wheel M, and the gearing K, L, O, P. The sockets *r* by which the upper roll is connected with the gearing by the shaft I are not rigid, as is the case with the shaft Q of the lower roll, but admit of the adjustment of the roll. The portion of the roll used is determined by a guide a little wider than the bar.[1] The rolls throughout this department are driven at the rate of about 32 revolutions in a minute. The iron frame CC is braced by rods *a*, *s*: and blocks bearing the driving shafts are shown at *k*, *k*, *p*, *p*.

The initial thickness of a sovereign bar is ⅜ths of an inch. The bars are weighed out to the workmen in batches of about sixty bars, an entire batch being passed through the rolls under precisely the same conditions of adjustment. The bars are only slightly reduced in width by repeated passages through the rolls, but are successively reduced in thickness in the first stages of the rolling by $\frac{1}{16}$th of an

[1] In the second rolling room, shown in the plan on the right of the engine-house, the frames and gearing of the rolls are of newer pattern than those in the first room. In some of the six pairs the bottom rolls revolve and drive the upper ones. In the pair of "breaking-down" rolls in this room,—that is, the roll by which the fillets are first treated,—the upper roll is stationary, the lower roll alone revolving. The necessary "bite" is given to the fillet, when its end is introduced, by slightly turning the upper roll by means of a ratchet-wheel and lever.

inch, while in the later stages the reduction in thickness at each passage through the rolls is less than $\frac{1}{100}$th of an inch, and finally one or two "spring pinches" are given to the bars by simply passing them through the rolls without altering the adjustment. The testing of the fillets, to ascertain whether they are of the accurate thickness, is effected by the aid of the gauge plate (fig. 4), which consists of two steel bars set at a low angle in relation to each other and graduated to $\frac{1}{1000}$th of an inch.

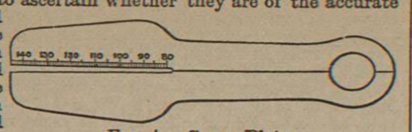
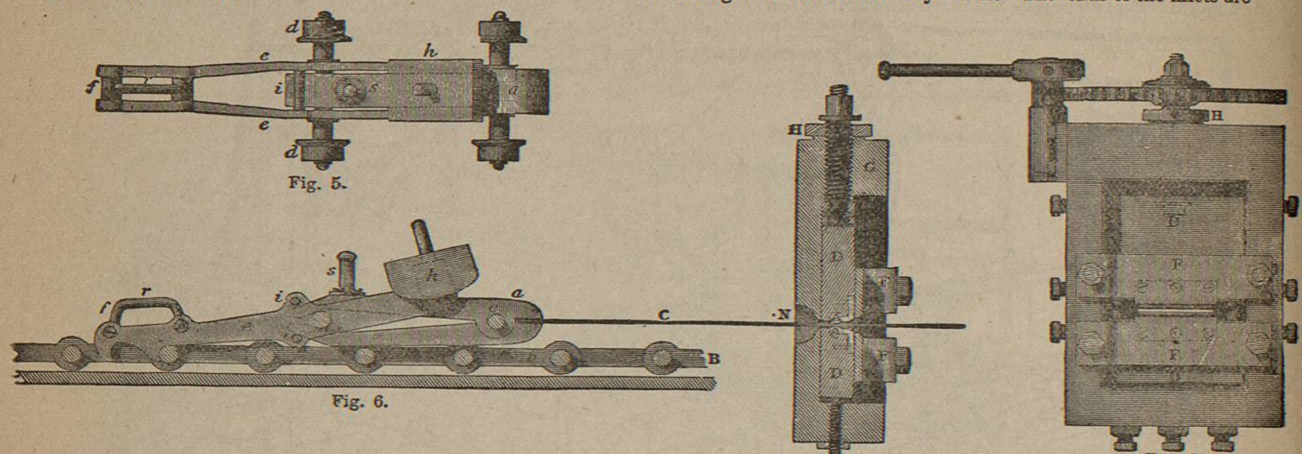


FIG. 4.—Gauge Plate.

It will be evident that the weight of the finished coin depends upon the thickness of the fillets; and to show how accurately the rolling must be performed it may be pointed out that, in the case of the half-sovereign, a variation of $\frac{1}{20000}$th of an inch above or below the accurate thickness (or a range of $\frac{1}{10000}$th of an inch) throws the coin out of "remedy."

The repeated passage through the rolls is attended by a considerable increase of hardness in the metal, and it is therefore in some cases necessary to anneal the fillets repeatedly during the rolling. In the case of fillets for sovereigns the annealing may be entirely dispensed with if the initial thickness of the bars does not exceed $\frac{3}{8}$ths of an inch. Fillets for half-sovereigns have only to be annealed once. In some European mints the fillets are annealed frequently; in one mint the operation is performed after each passage through the rolls. The furnace used for the purpose is generally so arranged as to permit the flame to play over the fillets, which are sometimes freely exposed to its action, but are more often enclosed in cases or tubes. Muffle furnaces are frequently used. The furnace used in the Royal Mint is a simple form of reverberatory furnace. The final rolling is given by a pair of finishing rolls capable of more accurate adjustment than the "breaking-down" rolls.

The fillets of gold or silver are in some cases, though not always, submitted to an appliance known as the drag bench, shown in figs. 5, 6, 7. Its object is to equalize the thickness of the fillets by drawing them between steel cylinders. The ends of the fillets are



FIGS. 5, 6, 7.—Drag Bench.

first flattened in a little appliance, which need not be described. The essential feature of the machine now used in the mint consists of two small steel cylinders A, A, which do not revolve, and are held in position in the plates D, D by clamp pieces F, F screwed against them. The portions of metal may be adjusted by the aid of a wheel and screw H (figs. 6, 7), and by small adjusting screws *f*, *f*. The part of the machine containing the steel cylinders is fixed at the end of a long bench, and gearing at the other end of this bench drives an endless chain BB (fig. 6), one link or other of which catches the carriage, shown in plan in fig. 5, and drags it along as soon as its end *f* is depressed by the handle *r*. The carriage runs on the wheels *d*, *d*. The drawing of the fillet C is conducted as follows. Its flattened end is introduced between the steel cylinders, and is grasped by the jaws *a*. The jaws turn on the pin *c*, and while the fillet is being dragged through the cylinders the axle of the wheels *d*, *d* tends to increase the grip of the jaws by acting on their inclined ends. Directly the strain on the

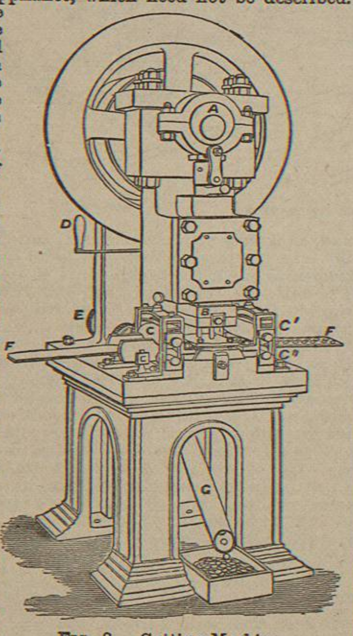


FIG. 8.—Cutting Machine.

fillet is released, the pins *i*, *i* and the weight *h* loosen the jaws and at the same time raise the end of the carriage so as to arrest its further progress along the bench. The carriage is then moved forward by the handle *s* until the jaws enter the hollowed portion N and grasp another fillet.

Formerly—when fillets were rolled from thick bars—this appliance played a more important part in coining operations than at present. It is now only used for fillets from which sovereigns and half-sovereigns are to be produced. Before fillets are passed on to the next operation—that of cutting from them the disks or blanks destined to form the coin—they are carefully tested by a skilful workman called the "tryer," who cuts one or two blanks from the sides of each fillet by the aid of a cutter worked by hand. These blanks are weighed on a delicate balance against a standard weight, and the experience of the operator enables him to determine whether the variation from the exact weight will justify his sending the fillets forward to the cutting room. In any case he divides the fillets into two or more classes for a reason that will be explained presently. Trying.

The cutters employed in the mint until quite recently were of complicated construction, but these have been replaced by a simple machine (fig. 8) which, by the revolution of an excentric A, causes two short steel cylinders, mounted on a block of iron B suitably guided, to enter two holes firmly fixed in a plate on the bed of the machine. When the fillet FF is interposed between the short cylinders and the holes, the former force disks of metal through the holes, the fillet being advanced at each stroke of the machine by small gripping rolls C, C′, C″ actuated by a ratchet-wheel E, driven from the shaft which bears the excentric A. The disks pass down the tube G to a receptacle placed on the floor. In the case of very large silver coins, only one disk is cut in the width of the fillet, and in some few mints disks for gold coin are also cut in this way, but it is far more usual to cut two disks in the width of the fillet, the position of the cutters being so arranged as to remove blanks in the manner shown in fig. 9. In cutting disks for bronze coin extreme precision is not necessary, and it has therefore been found possible to obtain five at each stroke of the machine.

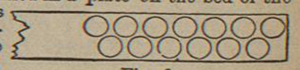


Fig. 9.

It will be evident that the rough classification of the fillets according to their thickness, to which reference has already been made, renders it easy to compensate for slight irregularities in thickness caused by rolling, by employing cutters of a slightly larger diameter than the standard size for fillets which are too thin.

The fillets after the removal of the disks present the perforated appearance shown in fig. 9. The residual metal, called "scissel," which amounts to from 25 to 30 per cent. of the metal operated upon, is returned to the melting-house in bundles weighing 180 oz. It may be mentioned here that all attempts to cut disks or blanks for coinage from the ends of rods or cylinders, and thus to avoid the production of scissel, have hitherto failed.

The next operation to which the blanks are submitted varies in different mints. In some, each blank is weighed by hand or by automatic machinery, and each blank that is too heavy is adjusted either to an exact weight or to within the remedy prescribed by law. On the Continent it is very generally the practice to adjust blanks by the aid of a file, or by a machine that removes a fine shaving of metal from the surface of the blank. In mints where mechanical adjustment is adopted there is a tendency to produce "too heavy" blanks in the rolling and cutting departments, as it is impossible to adjust blanks which are too light.[1]

In the London mint finished coin alone is weighed, so that the blanks after leaving the cutting room pass directly to an edge-rolling machine, which thickens the edge of each blank so as to form a rim intended to protect the impression on the finished coin. The operation of edge-rolling is called "marking," and the method of conducting it varies considerably in different mints.

In the Royal Mint the blanks are made to pass in quick succession, at the rate of six hundred a minute, between a circular groove in the face of a revolving steel disk and a groove in a fixed block placed parallel to the face of the revolving disk. The groove in the block exactly corresponds to that on the disk; and, as the distance between the block and the disk is slightly less than the diameter of the blank submitted to the operation, the result is that before the blank escapes from the machine its edge has been thickened. The operation may be varied by admitting the blanks between a groove in the periphery of a revolving wheel and a groove in a segmented block, placed at a distance from the wheel rather less than the diameter of the blank. The wheel and block may be either vertical or horizontal.

In some cases the edges of the blanks, at the same time that they are thickened, receive the impression of a legend, or inscription, or an ornamental device. When this is the case the blank is rolled

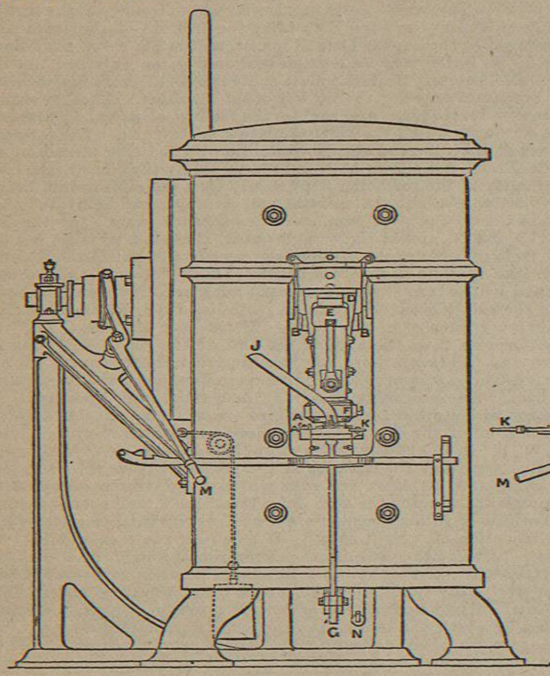


Fig. 10.

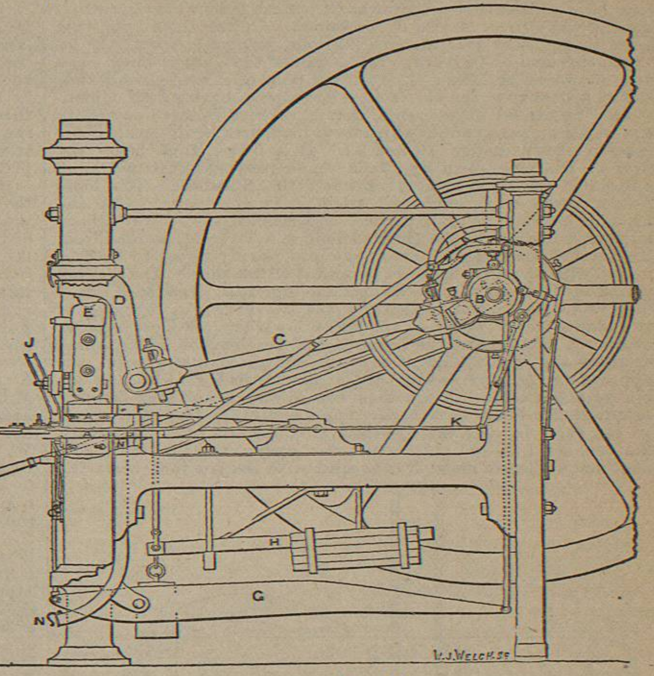


Fig. 11.

between two planes, one of which is fixed and bears the device, while the other has a reciprocating motion imparted to it, or the edge of the blank receives the impression, which may be either raised or sunk, from a collar surrounding the blank in the coining press, as will be afterwards explained.

Before passing to the coining press the blanks either of gold or silver are annealed. In many mints the object of the heating is not only to soften the blanks before they receive the impression, but also to produce a film of oxide of copper on their surface. This is attained in various ways. In England gold blanks are placed in cylindrical crucibles of plumbago and covered with a layer of charcoal, heated in a reverberatory furnace, and when the blanks reach cherry-redness they are cooled by plunging them in water. The thin film of oxide of copper thus formed on the surface of the gold or silver blanks is readily soluble in dilute sulphuric acid, and the removal of a small portion of the alloying metal in this way constitutes "blanching" or "pickling" the coin. The method of conducting the operation varies somewhat in different mints, mainly, however, in the strength of the acid used, which varies from 3° to 5° of the hydrometer of Baumé. The solution is sometimes heated to 96° to 98° C., while in other cases the blanks are introduced into the solution while at a red heat. The latter method is, however, objectionable, as a dense layer of pure metal is found at the surface of the blank which is apt to protect the underlying oxide of copper from the action of the acid. The blanks are afterwards washed in pure water and dried either in sawdust or in copper vessels heated by steam jackets. The object of the process is to

[1] A description of a machine used for the adjustment of blanks will be found in *Dingler's Polytechnisches Journal* (1882, ccxlv. 61, pl. 6); and some years ago Mr J. M. Napier devised for the Indian mints a beautiful machine which first ascertains how much it is necessary to cut from each blank in order to reduce it to the standard weight, and then removes the necessary amount of metal and no more. The initial cost of such machinery, however, is considerable. In 1849 M. Dierck, director of the mint in Paris, endeavoured to substitute a chemical for a mechanical treatment by submitting the heavy gold blanks to aqua regia, which it was anticipated would bring them within the prescribed limits of accuracy. The results were not satisfactory, and the attempt was abandoned. In 1870 the present chemist of the mint, Professor W. Chandler Roberts, showed that gold alloyed with copper might be removed from heavy blanks with singular regularity by means of a suitable solvent aided by a battery. The blanks are arranged in a frame of wood and submitted to the action of a solution of cyanide of potassium, the heavy blanks forming the dissolving pole of the battery. The process was not used in the London mint, as it became evident that it could not profitably replace the present system, under which finished coins alone are weighed and the manufacture of good coin only is paid for. It was, however, introduced into the Bombay mint in 1870 by the late Mr L. G. Hines, who extended its usefulness by transferring the metal dissolved from the heavy blanks to blanks which are too light, the latter being by this means raised to the prescribed weight. The process has now fairly taken its place as an ordinary operation of coining, and its importance to the mints where it is used may be gathered from the fact that in the Indian mints no less than 1300 tons of silver were converted into coin in one year (1879), so that the saving effected by its introduction must be considerable.