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The Manufacture of Rolled Sterling-Silver.

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Within the past twenty-five years the manufacture of sterling-silver has undergone a remarkable change. It is not difficult to remember when an article of this metal was considered a household luxury and only the wealthy could afford it. Well-to-do people possessed a small quantity, handed down as an heirloom, perhaps; and people in moderate circumstances had to be content with pewter or tin-ware for common use, with a meagre assortment of plated-ware for special occasions. On particular occasions, the family heirlooms of sterling-silver, which usually consisted of one or two table-spoons and half a dozen tea-spoons, were carefully cleaned and polished and arranged on the table so that they would make the best showing. After such service they were returned to their former hiding place to prevent theft.

This unique condition has now changed. Instead of being confined to the wealthy or well-to-do people, sterling-silver is found in even large quantities in families who in former times would have been considered extravagant had they possessed the stock which they now have. The reason for this apparent paradox is not the reduction in the price of silver, but in the cost of manufacture.

The method pursued by the old-time silversmith for making spoons or forks was to hammer them out by hand from a rod. By means of files and saws the article was made to assume its shape. No doubt, the reader has seen examples of this early silversmithing and has noticed the marks of the hammer upon

them. Costly operation that it is, our British friends still continue to use it for the manufacture of their wares. Even in our own progressive country, a few manufacturers continue to manufacture goods in this manner, but only upon work which will warrant it. Such work is always upon special designs which would not warrant the necessary expense for dies.

The change which has been responsible for the cheapening of sterling-silver wares is the use of *rolled sheet metal* for its manufacture. Articles which heretofore were made from rods are now made by stamping from sheet metal and with the employment of modern machinery instead of hand labor. This sheet metal is the foundation of the manufacture of modern sterling-silver ware, and it is my intention to describe the various operations employed for its production.

Trade conditions at the present time are such that it hardly pays the manufacturer of sterling-silver wares to make his own sheet metal, and nearly all of the establishments of this nature in the United States now purchase the sheet from mills that make a specialty of rolling. The condition is analogous to that which exists in the brass trade. It has been found that the manufacture of the sheet metal and the production of finished wares are quite distinct, so that the present policy of the sterling-silver manufacturer is to purchase his sheet metal and not manufacture it. The fact that a large and extensive equipment is required for the manufacture of rolled sheet metal is usually a sufficient reason why the majority of manufacturers do not care to make it.

Sterling-silver, as now made in the United States, consists of 925 parts of pure (fine) silver and 75 parts of copper. Pure silver itself is too soft for use in articles which are to hold their shape. At the beginning of the so-called "cheap silver era," or when sterling-silver ware began to be manufactured by modern methods, a manufacturer occasionally was found who cheated the purchaser by making ware with less than 925 parts of silver in it. To-day, however, no one would dare to do this. Laws in several States regulate the quantity of silver which an article stamped *sterling-silver* must contain. These laws do not stipulate the alloy nor the exact proportions, but state that not less than 925 parts of fine silver shall be present in 1000 parts of metal.

The silver which is used in the manufacture of sterling-silver sheet is known as *fine silver bars*. It is also called *bullion*, but as bullion may mean impure silver as well as the pure material, it is now customary to designate the metal that is employed for sheet rolling by the former name. These fine silver bars are purchased from the various smelting works that smelt silver ores. The electrolytic copper industry also furnishes a supply. These bars are received from the express company (all bullion is transported by express) in a loose condition, as

Fig. 1. 500 Oz. Bars of Fine Silver Valued at Over \$12,000.

it has been found easier to watch or verify them if sent in this manner. When the bars are received from the express company they are loaded upon a mill truck as shown in Fig. 1 and immediately counted. Any loss, therefore, is detected at once.

The fine silver bars which are shown in Fig. 1 are known as "500 oz. bars," on account of their weight. Such bars have been found to be the most convenient. Bars may also be obtained weighing 1000 and 200 ounces. The value of silver needs no explanation and every precaution is taken to prevent theft. The bars which are shown in Fig. 1 have a value of over \$10,000.

The bars are now immediately weighed upon bullion balances, as shown in Fig. 2, in order to ascertain whether the correct amount has been received. If any bar has been tampered with the loss is at once apparent. The balances are capable of weighing as small an amount as 0.01 oz. Troy, which is sufficiently accurate for the ordinary weighing of silver.

The storing of large quantities of silver, both in the form of

Fig. 2. Weighing the Fine Silver Bars When Received.

bullion or in process of manufacture, is a problem which has had to be solved, as it is not unusual for silver to the value of several hundred thousand dollars to be partially completed. This problem has been solved by the use of a vault. The vault which is commonly used for this purpose closely resembles a bank vault. It is both fire and burglar proof. The inside brick walls are filled with fine copper wires so that the rupture of any one of them, that would take place should an attempt

be made to enter the vault, is at once made known at some central station.

The "fine silver bars" which are used for the manufacture of sterling-silver and which are shown in Fig. 1 are always stamped on the bottom with the weight, number and fineness. The mark used to designate the fineness is always the same and no attempt is made to raise the fineness of the silver beyond 999 parts in a thousand. It has been found not only quite expensive but unnecessary to raise the fineness beyond the 999 point, and silver of this purity answers every requirement. It is such silver, 999 fine, that is used in the manufacture of sterling-silver sheet.

In Fig. 1 are shown 500 oz. bars. Bars weighing 1000 oz. and 200 oz. may also be obtained, but it has been found that the 500 oz. bars are the most convenient for use. The 1000 oz. bars are too large for crucible melting. The 200 oz. bars are satisfactory, but more handling is required in using them, and, therefore, they are not extensively employed.

The fine silver bars shown in Fig. 1 are frequently known as *Commercial Silver Bars* to distinguish them from *Assay Bars* made by the United States Government. *Assay Bars*, however, are no better than *Commercial Bars* and experience has demonstrated that no better results can be obtained by their use. Our Government does not sell silver, and in order to obtain *Assay Bars* it is necessary to place a certain amount of silver in the Assay Office in New York City for refining. The quantity of silver, 999 fine, which is obtained from it is returned to the depositor and a refining charge is made. The Government stamp upon them, to many persons, would seem to indicate that the silver is better than *Commercial Bars*, but such is not the case. The Government makes no attempt to raise the fineness above 999.

In the manufacture of sterling-silver which, as previously mentioned, consists of 925 parts of fine silver and 75 parts of copper, it is customary to use shot copper. This variety of copper is made by melting the purest copper that is obtainable (Lake copper) in a graphite crucible and then pouring it at a considerable height into cold water. The copper cools in the form of shot. In Fig. 3 is shown a batch of shot copper ready for use. The fine state of division of this variety of copper

renders it a simple matter to make up any given weight. The copper which is used in making sterling-silver is called the "alloy."

The fine silver and the shot copper are now weighed upon accurate bullion balances in the proportions which are necessary to produce sterling-silver. In the majority of sterling-silver mills it is customary to use a No. 40 graphite crucible for melting the silver and this holds about 1200 oz. As a large amount of scrap constantly accumulates, the amount of fine silver and shot copper that are weighed are sufficient to fill

Fig. 3. Shot Copper Used in Making Sterling-Silver.

only half the crucible. The remainder is filled with scrap. A small amount of copper oxidizes in melting so that while the original fineness may have been 925, after the sterling has been cast, the fineness will frequently be found to reach 926 or even 927. Allowance is made for this oxidation. One or two thousandths, however, are usually considered as close at it is possible to make sterling-silver when considerable scrap is used.

The copper is placed in the bottom of the crucible and the silver on top. No scrap is put in at this period but is with-

held until the copper has melted. The silver having a lower melting point than copper, melts first. When the silver begins to melt, charcoal is added to the crucible so that it completely covers the metal. This is imperative, as without it the copper would oxidize.

The crucibles which are used are of the ordinary variety employed for brass melting. In some establishments a crucible known as a "Tube-Nosed Pot" is used. This is a crucible with a tube down the side which renders it self-skimming. Beyond the advantage of skimming they have no value and silver

Fig. 4. Oil Furnaces Used for Melting Sterling-Silver.

manufacturers seem to differ about their value in melting. Personally, I have found them quite advantageous, but many silver makers have not found them so.

For melting the silver, crude oil has been found to be very satisfactory. Its freedom from sulphur and the fact that it produces no ashes have greatly appealed to the sterling-silver maker and at the present time nearly every one in the United Stats uses it for this purpose. It is cheaper than gas, although not as convenient. The cost of a good quantity of gas has prevented its use in the manufacture of sterling-silver. The fact

that coal or coke leaves ashes to be ground has brought about the use of oil for melting. The value of silver is so great that every particle must be saved. The constant accumulation of ashes, therefore, which invariably contain more or less silver, has always been a difficult problem, but the use of oil has solved it.

The furnaces used for melting sterling-silver are a shell of cast iron lined with fire brick. A burner enters at the bottom and strikes at a tangent so that the flame does not directly impinge upon the crucible. These furnaces are shown in Fig. 4. When everything is in good working condition, the melting operation usually takes about forty minutes. Air is used for spraying the oil and the noise which this blast produces is one of the objections to the use of oil. The melters, however, soon become used to it.

As the silver melts before the copper and settles to the bottom of the crucible, great care is required in ascertaining whether all the copper has melted. A rod of graphite crucible mixture is used for stirring the mixture, and this is frequently done by the melter to make sure that all the copper has melted and alloyed with the silver. Charcoal is added to the crucible when needed and care is taken to see that the surface is not exposed at any time. When the copper has melted and the mixture has reached the required temperature, it is ready for pouring. The determination of this "pouring heat" is an operation which requires skill, and unless the melter understands his business good sterling-silver cannot be made. Too low a temperature will result in a cast plate full of "cold-shots," while one poured when the heat is too high will result in blow-holes and the cracking of the metal in rolling. Pyrometers have not been extensively used for the determination of the pouring temperature, but they will undoubtedly be largely employed as soon as one is found which is capable of giving accurate and uniform results in inexperienced hands.

When the sterling-silver is ready for pouring, the crucible is lifted from the furnace by two men by means of basket tongs and is immediately poured. In Fig. 5 the operation of pouring a sterling-silver plate is shown. The crucible which is shown is of the "tube-nosed" variety.

The mold that is used is of cast iron and in halves so that the

plate may readily be removed. It is held together by means of an iron band and wedge. The mold is coated with whale oil before using. A good sized stream is used in pouring so that the mold is rapidly filled. No attempt is made, as it is in the brass industry, to fill the "shrink" at the top of the mold. Sterling-silver shrinks very little in cooling and only a slight depression is found on the top of the plate.

This pouring operation is supposed to be one of the

Fig. 5. Pouring a Sterling-Silver Bar or Slab to be Used for Rolling.

"secrets" in the manufacture of sterling-silver; but, as a matter of fact, the only "secret," if it can be called such, is in the determination of the pouring temperature. At the present time this point is determined by the eye, but it is quite probable that the advent of a suitable pyrometer will reduce the operation to a business basis.

One of the former "secrets" in the manufacture of sterling-silver, but now common property, is the use of cadmium for imparting soundness and malleability to the metal. It is customary to add 5 parts of metallic cadmium to 1000 parts of

sterling mixture. This amount is deducted from the copper so that the actual mixture becomes:

Fine Silver	925 parts
Shot Copper	70 parts
Metallic Cadmium	5 parts

The cadmium is added after the copper and silver have melted. It is pushed down under the metal with tongs so that it will not rise to the surface and burn. The function of cadmium is to remove the oxygen from the silver and in this respect it has been found so advantageous that it has replaced every other deoxidant and practically every manufacturer of

Fig. 6. The Bar or Slab of Sterling-Silver as Cast.

sterling-silver in the United States now uses it for this purpose.

The cooling of a large mass of silver in the air is a slow operation, so it is customary to plunge the plates after they have "set" and are removed from the mold, into cold water. This sudden chilling of the plate does not seem to have any bad influence on the rolling qualities of the silver, and by thus quickly cooling it work may be commenced upon it at once.

It is customary in the sterling-silver industry to cast one size of plate and then widen it if a wide sheet is required. In Fig. 6 a cast plate of sterling-silver is shown. This plate is $1\frac{1}{4}$ inches in thickness, 10 inches wide and 12 inches long. The

plate shown in Fig. 6 is just as it came from the mold. After the fins have been removed the top end is cut off on large alligator shears. The object of cutting this end is to remove the imperfect portion of the metal. The top is not so dense and sound as other portions, and if the plate is rolled without cutting off this end, imperfect sheet would be produced. It is quite difficult to detect such imperfect metal after the sheet has been rolled, so that the practice of cutting off the end before rolling has been adopted. This is called "cutting-off the gate." Usually one cut is all that is required, but now and then when the center of the plate is quite crystalline another cut has to be taken. The center of the plate is usually crystalline near the top and the object of the cutting of the end is to remove it. Dross, too, frequently rises and this is likewise removed when the gate is cut off.

The plate is now ready for "overhauling." This operation has long been used for removing the surface of a plate before rolling. No one has yet devised a process for casting perfect metal, and although sterling-silver runs freely and without oxide, the surface of the plate is never clean. Charcoal, slag, or pieces of crucible are always found on the surface of the cast plate.

The overhauling machine consists of a bed similar to a planer bed upon which the plate is clamped. An overhanging arm carries a tool which is made to scrape the surface of the plate by means of a crank and cam. The tool may be made to take a heavy or light cut by means of a treadle manipulated by the operator. The fact that any particular portion of the plate may be scraped more than another is wherein the overhauling machine differs from a planer. A planer removes an equal amount of metal from one end of the plate to the other, while the overhauling machine enables the operator to remove the metal from any particular portion which may require it. It often happens that certain portions of the plate require no scraping while others have to be scraped deeply in order to thoroughly remove an imperfection.

After the plate has been overhauled, it is ready for the first rolling operation called "breaking-down." The rolls which are used for this purpose are of chilled iron and ground with a smooth surface. As the object of this breaking-down pro-

cess is to reduce the metal as rapidly as possible, the rolls and housings are made sufficiently strong to bear the strain which is put upon them. This "breaking-down" process does not require as skilled labor as finishing the metal and the wages are correspondingly less.

All sterling-silver is rolled cold and the plate is passed through the rolls with as heavy "pinches" as can be given it. A "catcher" stands behind the rolls and passes the plate back to the roller after it issues from them. In Fig. 7 is shown the

Fig. 7. "Breaking-Down" the Sterling Silver. First Operation in Rolling.

breaking-down operation. The plate is rolled to a thickness of $\frac{3}{8}$ of an inch in this "breaking-down" operation. If a wide sheet is required, the plate is passed through the rolls diagonally so that the metal is widened and lengthened at the same time. This widening operation is called "cross-rolling."

The rolls shown in Fig. 7 are 18 inches in diameter and 30 inches long. The adjustment is by means of a crank at the left hand side of the rolls. Both ends of the rolls are raised and lowered at the same time. This adjusting mechanism

answers very well for "breaking-down" rolls, but for finishing rolls, an overhead adjustment by means of screws and "spanners" are the best.

After the plate has been "broken-down" to $\frac{3}{4}$ -inch the metal has reached the limit of rolling and any further reduction would tend to injure or fatigue it. In order to overcome the hardness which the rolling has imparted to the plate and to

Fig. 8. Annealing Muffle.

soften it so that further rolling may be done, the plate is annealed.

The annealing is carried out in a muffle (shown in Fig. 8) lined with fire brick and heated with oil. As soon as redness has been reached the plate or sheet, which it now is, is plunged into a sulphuric acid pickle. This pickle is composed of sulphuric acid (oil of vitriol)

and water in the proportion of about one part of acid to sixteen of water. The sheet is plunged while it is red hot into the hot pickle and in this manner the black oxide of copper which forms on the surface during the annealing is removed in a few seconds. The sheet is then rinsed in water and dried. As it has been found that silver is injured by allowing it to remain too long while red hot, great care is required in annealing to avoid excessive heating. The simple heating to a red heat is all that is required. The pickle which is used dissolves some of the silver as well as the oxide of copper which is on the surface. At frequent intervals salt is added to the pickle, and the precipitated chloride of silver is allowed to settle and is then removed.

The pickled sheet now presents a uniformly white surface and without lustre. Any imperfections which have developed during the "breaking-down" are now plainly revealed and are removed by a second overhauling and an operation called "chipping." This "chipping" operation consists in removing small particles of charcoal or similar imperfections which have become bedded in the surface. A hammer and chisel are used for the purpose, but care must be taken so that the hole which is produced will not fold over on itself in the next rolling. By making the hole dish shaped the edges will not fold over.

The sheet of sterling-silver after it has been annealed and pickled is warped so that it will not lie flat upon the table of the overhauling machine. The sheet is therefore straightened upon a machine known as a "three-roll straightener." This appliance consists of three rolls arranged in pyramid form, that is, with two rolls at the bottom and one at the top. In order to use them it is first necessary to curve the sheet and then adjust the top roll so that the sheet is flattened. This operation is frequently explained by saying that the sheet is "first made sick before it is made well."

After the sheet has again been overhauled, it is ready for the next rolling operation, called "running-down." The rolls which are used for this purpose are the counterpart of the "breaking-down" rolls but are kept in a better condition. The "running-down" process consists in rolling the sheet to No. 10 B. & S. gauge. The sheet is then elongated so that it requires coiling before it can again be annealed. The sheet is usually

10 or 12 feet long. Another annealing is then given it followed by pickling, and the sheet is then carefully inspected for further imperfections. If any are found they are removed by means of a hammer or chisel. Deep chipping must now be avoided, however, and only superficial imperfections can be advantageously treated. In this manner the elimination of the chipping marks is assured, but deep holes will not be removed by the subsequent rolling.

The sheet is now ready for the final rolling process called

Fig. 9. The Finishing Roll.

“finishing.” The rolls that are used for this purpose are chilled iron, but the surfaces are kept in a more highly polished condition than either the “breaking-down” or “running-down” rolls. The adjustment is by means of overhead screws operated by long spanners so that one side of the roll may be raised or lowered independently of the other end. Any tendency towards crookedness in the sheet as it issues from the rolls may, therefore, be corrected. In Fig. 9 is shown a pair of finishing rolls in operation.

It is in the finishing of sheet metal that the skill in rolling is displayed. All spinning or drawing operations, in which sheet metal is used, demand that an accurate gauge shall be furnished. For this reason, the finishing roller must understand his business or great inaccuracy will follow. A device called a "bridle" is used for straining the sheet as it passes through the rolls. If this is not done the sheet cannot be kept straight. In wide sheets a "wedge" is used; this may be seen between the rolls and bridle in Fig. 9. The wedge and bridle are frequently used together, but the bridle can only be used for thin sheet. Neither can the wedge be used for thin sheet as the strain cannot be accurately adjusted and the sheet will tear. The bridle, however, enables the roller to adjust the tension so that the thinnest sheet may be rolled.

Back of the rolls is a wooden cylinder attached to a revolving shaft. The sheet as it comes from the rolls is attached to this "block" and a coil is thus produced. A band of copper wire prevents it from springing apart. As practically all sterling-silver sheet is sold in the annealed form, the coil is now returned to the annealing muffle and again annealed and pickled. More care is now exercised in the handling to avoid scratches or dents and when the coil comes from the rinse water it is dried in maple sawdust so that a uniform surface is produced. An appliance called a "drying-out machine" is employed for this purpose. It consists of a long box in which sawdust is placed. On one end is a coiling drum operated by a belt. The sheet is started through the sawdust and attached to the drum which draws it rapidly through. Revolving brushes remove the surplus sawdust from the sheet after it issues from the box. Pine sawdust cannot be used for this purpose, as the pitch which it contains leaves streaks upon the surface of the silver. In order to obtain the best results, the sawdust is used warm and a steam coil underneath the box heats it to the required temperature.

As the various articles which are made from sterling-silver require varying widths, it is necessary to slit the sheet to the required dimensions. A rotary slitting machine is used for this purpose and both sides of the sheet are trimmed at once. If great accuracy is not required in the width of a sheet, it is preferable to slit the sheet before it goes to the finishing rolls.

FIG. 10. Inspecting the Sheet.

The object of this procedure is to avoid scratches or dents, which invariably are produced when a soft metal like sterling-silver is handled. The surface after annealing and pickling is dead white and is particularly susceptible to abrasion. In Fig. 11 the finished sheet may be seen and the dead white surface is quite apparent. The need for careful treatment is, therefore, far greater than in brass or german-silver.

The final operation is the inspection of the sheet, and as no requirement is more severe upon a metal than spinning or

Fig. 11. The Finished Sterling-Silver Sheet Ready for Shipment.

drawing, nothing but perfect sheet can be allowed to go to the customer. In Fig. 10 the inspecting operation is seen. The sheet is unrolled upon a bench and every part of the surface is searched for imperfections. The specks of dirt often deceive the inspector, but a little scraping with a knife will reveal their true nature. If it is found that the imperfections are such that the sheet is injured, the whole is cut up and remelted. It usually happens, however, that sheet is sold in short lengths, so that by judicious slitting or trimming the imperfections may

be removed. The sheet is now rolled into coils as shown in Fig. 11 and is ready for shipment.

A word about the grinding of the rolls may be of interest. This operation is one of the most peculiar in the rolling mill industry. One would naturally think that an emery wheel could be rigged so the rolls could be ground in place, or if not, it is a simple matter to remove them and grind them in a lathe. While both of these methods are used for grinding the rolls before they are inserted in the housings, they do not answer for the production of the required surface. The method which is now pursued for grinding a pair of chilled rolls that are used for cold rolling silver, brass, or copper is by means of a hard wood stick and emery. The stick is covered with oil and emery, inserted between the rolls and moved gradually from end to end. The object of this apparently primitive method is not to produce a polished surface upon the rolls as one might naturally think, but to impart the necessary "crown" to the rolls. Although chilled rolls seem proof against any bending, it is an actual fact that they do spring when a piece of metal is rolled. If, therefore, a pair of rolls were used with a "flat" surface, i. e., straight from end to end, the "spring" would cause the rolls to become concave and a sheet would thus be produced which would be thicker in the middle than on the edges. In order to guard against this unevenness of gauge, the rolls are ground so as to allow for the amount which they "spring."

As the thickness, width, and hardness of the sheet which is to be rolled, cause the rolls to "spring" to a varying amount, it is obvious that a uniform "crown" cannot be given to them. It is in the grinding of the rolls that the skill in rolling is displayed and a roller who can grind a pair so that a sheet of metal will have a "lay" to it and with uniform gauge, is worthy of the name of an "expert roller." The most difficulty arises in rolling wide sheets and only those who are highly skilled in the art of rolling can roll sheet of this character.

MEASUREMENT OF NATURAL GAS.

Statistics of the quantity of natural gas consumed in the United States will be taken next year by the United States Geological Survey. Up to the present time, only the value of the gas has been ascertained. The adoption of this method will make it inconvenient, if not impossible, to refer back for purposes of comparison to the figures of previous years, but it will result in more direct knowledge of the capacity of gas areas to maintain a commercial supply of gas for a certain number of years.

An effort will be made to collect and publish statistics showing the total acreage held by natural gas companies and the acreage operated by them, with the total quantity of gas consumed in the different States. Owing to the fact that gas wells from different fields are connected to the main pipe lines, and that gas is only measured where consumed, it is now almost impossible to procure exact figures as to the quantity of gas produced from any particular district.

When natural gas was first brought into use an idea prevailed that the supply was inexhaustible. It was sold at low rates and usually without measurement. This method encouraged waste in the consumption of natural gas and was shortly abandoned by the larger companies. They introduced meters and sold their gas at a rate per thousand feet by measurement. There were, however, so many smaller companies that did not measure the gas consumed that it was impossible to secure reliable figures of the production and consumption of natural gas in thousands of cubic feet. For this reason the statistics of this valuable product have been collected in terms of value.

In taking only the value of the product, however, as a basis for statistical record an incorrect idea is given of the actual production of the gas fields, for with the diminution in volume the price has been increased, and in recent years in some cases an increased value is shown where there has been a decided falling off in the production of gas. Experience has demonstrated that there is a limit to the production of all fields, and those who handle the gas have learned that the unnecessary waste of this valuable resource must be prevented. To-day nearly all consumption is sold by measurement. It is believed that the time has come when it is possible to procure statistics of the quantity of gas consumed. Announcement of the Survey's intention to make the endeavor next year is contained in the recently published report by Mr. W. T. Griswold entitled "The Production of Natural Gas in 1905."

PRODUCTION OF LEAD IN 1905.

The production of lead in 1905 was 302,000 short tons, as against 307,000 short tons in 1904 and 282,000 short tons in 1903. The value of the production in 1905 was \$28,690,000, as compared with \$26,402,000 in 1904, and with \$23,520,000 in 1903.