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FLOW OF METALS IN THE DRAWING-PROCESS.

BY OBERLIN SMITH.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *January 29, 1886.*]

LADIES AND GENTLEMEN:—In introducing the subject upon which I have been asked to address you this evening, "The Flow of Sheet-Metals in the Drawing-Process," I will refer briefly to *flowing*, in general, and to this motion as it occurs in various metallic and other solid materials. Webster defines "flowing" as moving "with a continual change of place among the particles or parts, etc., as in a liquid," and to many people the idea is connected only with liquids and other fluids. A further flow of the brain molecules which are supposed to represent their inner consciousness, however, will soon show them that such motion is a very common phenomenon in all the events transpiring in daily life before their eyes, both in semi-fluids and in solids; also, that this flow may be *elastic* or *non-elastic*.

Common instances of elastic flow may be found in the wonderful stretching of a piece of india-rubber to perhaps ten times its normal length, and its indignant return to exactly its original form;

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or in the bending or twisting of any wooden or metallic springs, etc., etc.

Instances of non-elastic flow are observed most frequently perhaps in connection with semi-solids, such as the clay upon the potter's wheel, the dough in the hands of the house-wife, or the putty under the glazier's knife. In the apparently rigid solids, such action is not popularly conceivable, but a little observation will show that the cold-forging of a piece of iron, or, indeed, any bending or other permanent distortion of any piece of metal, could not occur without this flowing of its molecules among themselves. Such flowing is shown on the grandest scale known to our present experience (whatever may have happened in the mighty work-shops of geological science) in the glaciers of the Alps, where great masses of solid ice flow slowly down their confining channels, changing their shape of cross-section as needs be, without being crushed or suffering any disintegration of their substance. This has been well described by Professor Tyndall, and it is, if I remember rightly, the same distinguished prowler about Nature's portals who tried the very interesting experiments regarding the flow of foreign objects through solid pitch, without leaving any holes in it. I could not find the description of this experiment, the other day, in any books that I had at hand, but I believe it was as follows: A number of stones were placed upon the top of, and a number of corks underneath, a mass of pitch several inches thick, and abandoned to their fate. After several months of silent disappearance, the corks arrived at the top and the stones at the bottom of the pitch, having floated and sunk respectively to their natural destinations.

In looking for the flow of solids in the metallic arts, it will be well to omit all *hot* processes as dealing with semi-fluids; but familiar examples of cold flow may be seen in wire-drawing, tube-drawing, cold-rolling and hammering, lead-pipe making, sheet metal-spinning, etc.

The first two mentioned are obviously analogous, about the only difference being that the tube is hollow (usually with a mandrel inside of it), while the wire is solid. Very similar to these operations, as respects the direction of flow of the particles of metal, is the reducing of a rod in grooved rolls, the chief difference being that the metal is coaxed along by friction, so to speak,

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instead of being pulled by its finished end. In hammering a bar, the tensile stresses are entirely omitted and the action is wholly compressive, in a lateral direction, of course.

In lead-pipe making we have also an entirely compressive action, but one very different from that in the last-named process. Here the lead is *squirted* out, as it were, much after the manner of a syringe, or a sausage-stuffer, or one of those curious, but really excellent, squirting brick machines, the only thing about which I could not understand being that it should figure (if I remember aright) as a *mechanical* novelty at the "Centennial," and an *electrical* novelty at a certain well-known exposition of later date.

In the spinning process, there is a great variety in the method of flow, as the shapes produced from a flat disc (though sometimes from a tube or cup) are of many kinds, and the metal is, by the action of the burnisher, stretched in some places and forced into a smaller diameter in others. This process, by the way, is a tedious and expensive one, and requires a treatise to properly describe it in all its variations. Happily, it is much less practised than formerly, and is for many purposes being superseded by the very much quicker, cheaper and more uniform drawing-process and its modifications. Spinning is, however, often useful as a supplementary operation in finishing some shape which cannot be made in the dies. Part way in principle, between tube-drawing and the process referred to in our title, is such work as cartridge-drawing, where a "cup," made in a drawing press proper, is afterwards "broached" at several subsequent successive operations by being pushed through a female die that is a little too small for it. This is, in effect, the same as tube-drawing, the male-die, or "punch," acting as the mandrel. The only difference is that the tube is comparatively short, and has an *end* in it. The end is usually, in the case of cartridge shells, left thicker than the sides. This is not, however, necessarily the case, as the proportional thickness of the sides depends upon the space between the punch and die relatively to the original thickness of the sheet-metal.

Coming nearer to the process which forms our subject proper to-night, we find that its immediate predecessor as a cheap substitute for spinning was the "stamping process." I have no correct data regarding its history, but its practice does not to much extent reach back into the last century. Its object was chiefly the

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production of seamless utensils from tin-plate, sheet-iron, brass, zinc, etc. These comprised such articles, as pie- and jelly-plates, milk-pans, dish-pans, dippers, cups, shallow sauce-pans, wash-bowls, colanders, wash-boiler bottoms and other articles of approximately conical and hemispherical forms. A general idea of such work in its finished state is given by the pictures, which Mr. Hiltebrand will now kindly throw upon the screen. As will be seen,

FIG. 1.

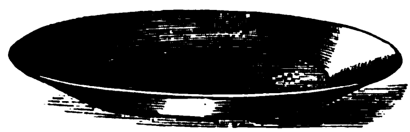

FIG. 2.

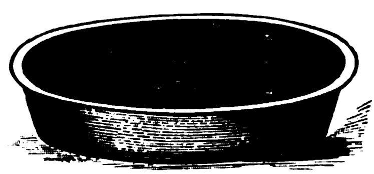

FIG 3.

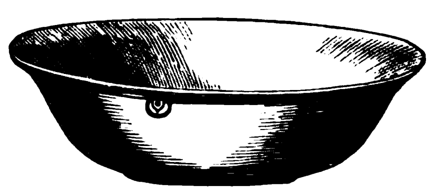

FIG. 4.

Fig. 1 is a bake-pan, *2* a pie-plate, *3* a milk-pan, and *4* a wash-basin. *Fig. 5* is a tea-kettle, in which there are three drawn pieces, namely, the cover and the upper and lower sections of the body. *Fig. 6* is a dish-pan. *Fig. 7* is an oil-can, in which the spout and bottom are, of course, separate pieces. *Fig. 8* is a ladle, to which the handle is riveted afterwards. *Fig. 9* is the bottom or well of

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an ordinary wash-boiler. *Fig. 10* shows a screw-nozzle and cap, such as is used upon fruit-jars, oil-cans and other utensils. These

Fig. 5.

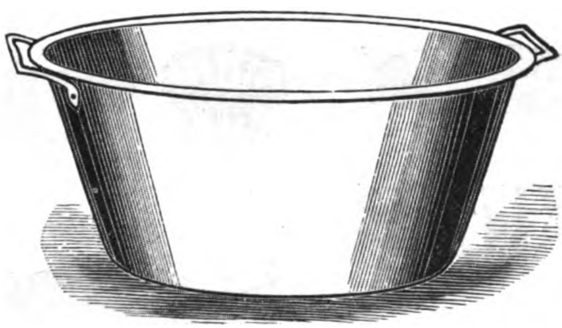
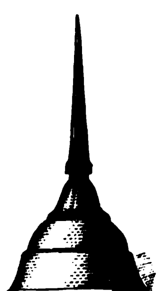


Fig. 6.

Fig. 8.



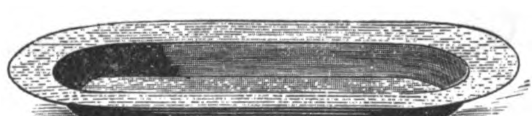


Fig. 7. Fig. 9.

have the screw-thread automatically spun upon them after being drawn. *Fig. 11* is a tin-cup, and *12* an oval bake-pan. *Figs. 13*,

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14, *16* and *17* are not properly drawn work, as the wrinkles have not been taken out, but only thrown into symmetrical forms, to answer as ornamental corrugations. *Fig. 15* is a shallow-plate,

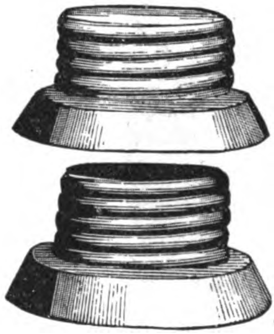


FIG. 11.

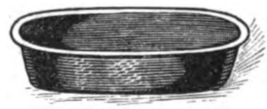
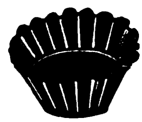


FIG. 10.

FIG. 12.

FIG. 13.



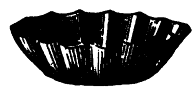
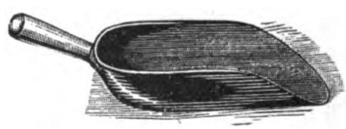


FIG. 16.

FIG. 17.

FIG. 14.



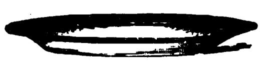


FIG. 15.

FIG. 18.

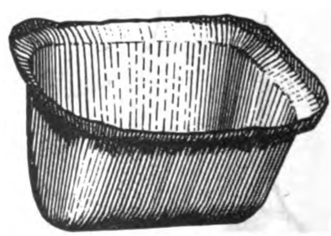


FIG. 19.

FIG. 20.

and *18* a dust-pan, to which, of course, the handle is attached afterwards. In *Fig. 19* is shown a rectangular box with rounded corners. In such work as this, the drawing-process proper applies only to the corners, and not to the straight sides, which obviously have no flow of particles within them. These are simply bent up at right angles to the bottom, while in the corners, especially if of small curvature, the flow is very violent, making this one of the most difficult shapes to draw. In *Fig. 20* is shown a second operation, in which *Fig. 19* has been deepened and made smaller in diameter by a process, which will be explained further on. In

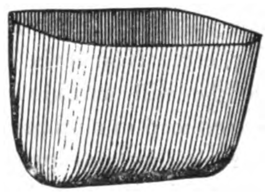


FIG. 21.

Fig. 21 is shown a third operation upon *Fig. 19*, where the flange has been turned up and trimmed. This turning up of the flange is not properly drawing, although the metal has to be upset, or crowded together. It is done by forcing the article down through a die, and can only be applied where the reduction in diameter is quite small, as otherwise the wrinkles would fold upon one another and the work be ruined. The article shown, as completed in *Fig. 21*, is intended for a seamless elevator bucket. In comparing *Figs. 13* to *17* with drawn work, and in describing the genesis of *Figs. 19* to *21*, I have digressed a little from "stamping" in order to explain these pictures while on the screen.

All the other work mentioned was usually done in a drop-press, although a crank-, lever- or screw-press could be employed, as far as the proper motion of the dies was concerned, had force enough been applied. The lower die was the female, or intaglio, and fitted the outside of the work before the wired or curled rim at the top was made; that is to say, the top of the die was a flat, smooth surface, extending some distance out, so that its outer diameter was fully as great as that of the blank. "Blank," it may be explained, is the technical name of the flat disc of sheet-metal which is to be formed to shape. The upper die was the cameo, technically the male-die, punch or "force," as in this process it was generally termed, and was usually made of an alloy of lead and tin which could be cast into the lower die while in the press, and thus a perfect fit be cheaply made. It had a flat flange, extending over

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the flat top of the lower die, which served to mash the wrinkles out from the flange of the work—it being understood that the work is usually *hat*-shaped, with a flat projecting flange. This was afterwards wholly or partly trimmed off true, and was often curled over a wire ring, or else over the place where the wire ought to be—somewhat upon the principle of the Irishman's "empty bag with praties in it." This latter process is known as "false-wiring" or "curling." The appearance of either this or real "wiring" is shown at *Figs. 4, 11, 15*, etc. Now it is obvious that a flat disc formed into a concave die will wrinkle near its periphery on account of being there reduced in circumference. This principle is taken advantage of in making cake-pans and such work. See *Figs. 13, 14, 16* and *17*. Such shapes can easily be made perfect at one blow, because the corrugations are systemized wrinkles, of the proper amplitude to just take up the surplus metal. If the work must be smooth, the wrinkles can be mostly, but not wholly, mashed out by a heavy enough blow, *providing* the wrinkles are quite shallow, so that one cannot possibly fold over upon another. Of course, in so doing the metal must be "upset," or crowded together in a circumferential direction. In order that the wrinkles may be thus shallow, the work must be shallow relatively to its diameter, say as one to fifteen or twenty, in ordinary sizes of tinware, with a metal as thin as tin-plate, which averages perhaps only about one-sixty-fourth-inch thick. (It may be said, *en passant*, that with much thicker metals, *e. g.*, a piece of one-fourth-inch boiler plate made into a pie-dish, the metal is so braced within itself that it "upsets" to a great extent *before* the wrinkles form, and they are apt to be almost *nil.*) To make deep work by the stamping process, it became necessary to *coax* the metal down, so to speak, by several successive operations—sometimes as many as eight or ten. For these, the same "die" was used with several "forces," each one having its convex part projecting below its flat flange a little further than the last, say from one-half inch to one inch. This flange beat out the newly-formed "flange-wrinkles" at each operation, while the same thing was done for the "body wrinkles" (those in the conical surface) by the nearly touching sides of die and force. An incidental advantage about such soft-metal "forces" as we have been considering, besides their cheapness and facility for fitting, is their capacity for a ready internal

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flow of their particles by the force of the press's blow, thus forging themselves to exact shape each time, in spite of their tendency to wear and mash out of shape. This is especially the case when they are used in a drop-press, where there is great force and rapidity of percussion at the extreme bottom of the stroke.

The *drawing-process* proper, which we are especially to consider to-night, and which will be more fully described further on, was designed as a substitute for stamping, and consists in confining the flange of the work between two parallel surfaces so tightly that wrinkles have *no room to form*, and its molecules consequently flow outward radially to compensate for what they must flow together circumferentially, as their diameter at any given place is reduced. Its products show deeper and better work in one operation than could be obtained in several successive ones by stamping. Curiously enough, the *name* of the last-mentioned process has been retained by many of the manufacturers who make nearly all their work by drawing, using only an occasional drop-press for auxiliary operations. It should be understood, then, that when we read in the newspapers of the "Great American Conglomerated Association for the Diffusion of Good Prices Among Stampers," or see the market quotations for "stamped ware," we must interpret the term in a commercial, and not in a technically mechanical, sense. It is now generally supposed to comprise all seamless sheet-metal household utensils, as deep as a pie-plate, or deeper. These are usually made of tin-plate (the best qualities of goods being re-tinned after being brought to shape) or else of sheet-iron or steel coated with tin or with some porcelain-like material, of which there are several excellent varieties in the market. This term "stamped" seems to have its chief individuality as in contradistinction to "pieced"-ware, which is soldered together in sections.

Of the *history* of the drawing-process I have not been able, in a somewhat casual search, to find any printed record, except an encyclopædic statement that it was first practised by a Mr. T. Griffiths, in 1841. Mr. Grosjean, of New York, who probably first used it in this country, and has been one of its largest users ever since, informs me that he thinks it was practised in France as much as fifty years ago, but cannot be sure of the date. I am indebted to my friend, Mr. F. G. Niedringhaus, of St. Louis, for some valuable information upon this subject. He tells me that the

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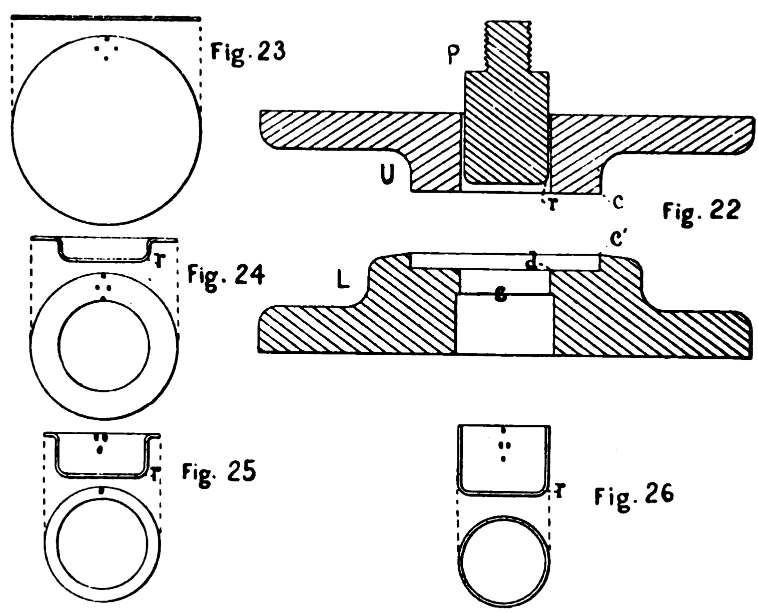
"Prussian system" of metal-drawing was invented by the Strouvelle Brothers, at Saarlouis, Rhenish Prussia, and was practised by them there, and, later, at Ars, Alsace. From there skilled artisans introduced it into this country early in 1866, it being put into practical working shape by the Lalance & Grosjean Manufacturing Company, and a little later by the St. Louis Stamping Company. Soon after this, one Marchand, who had been employed by the first-named company, and had learned something of the process, made it prematurely public, and commenced to build presses adapted to its practice. These bore his name, and were for a time the only ones in the American market. As their maker has long been out of the business, and is, I believe, now dead, I do not feel that I am unduly advertising his wares by thus making him a factor in history. Since his time various improvements have been made in the details of the process, and in the strength and convenience of the presses used. Many of the minor improvements in the manipulation of the metal have been kept secret by their inventors, and are practised only in a few large factories.



Proceeding to describe in detail the process in question, we see upon the screen in *Fig. 22*, a vertical section through the axis of a

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pair of drawing-dies for plain cylindrical work, *L* being the lower die, *U* the upper die (sometimes termed blank-holder), and *P* the punch. Such a die may both cut and form the work at one stroke, *c* being the male cutting edge and *c'* the female cutting edge, or it may be used for blanks already cut, which are merely thrown into the recess formed by *c'*, it acting as a guide to hold them central. When the operations of cutting and forming are thus combined, it is usually termed a "combination drawing-die," and this type is very generally used for all small work, say up to twelve inches in diameter, while for larger work, it is often the practice to cut the blanks separately and make the dies of a cheap material, like cast-iron, which would not answer for cutting edges. There can now be purchased in the market, circles of tin-plate, which are tinned in that form, thereby saving the wastage which occurs from having the scrap-metal left at the corners of the rectangular sheet, uselessly coated with tin. Where, however, such circles are not used, the tendency is, I think, more and more towards the use of combination-dies, so as to do the whole work in as few operations as possible. Whichever way the blank may have been cut, the operation is as follows: The die *U* descends until the blank is firmly held between the two flat surfaces, when *U* remains stationary until the punch *P*, which has so far descended with it, continues its descent, drawing the metal into a cylindrical form, as shown in *Fig. 26*, and stripping it from the punch against the stripping-corner *s*, when the latter rises to its original position. The slight expansion of the top edge of the cup by the elasticity of the metal, is usually sufficient to prevent it from pulling up into the die again, although sometimes trouble is experienced unless the corner *s* is kept very sharp and hard. It is usually necessary to "vent" the punch by a small hole, running up through it, not shown in the drawing, in order that the suction of the air cannot help to pull the cup upward. The rising to a normal position of the upper-die may occur at any time after the flange of the work has disappeared around and below the corner *d*, but this rising usually takes place at the last part of the stroke and simultaneously with the last part of the upward motion of *P*.

In *Fig. 23* is shown a section and top view of the blank before being drawn. In *Fig. 24* is the same as it appears when it has been drawn to about one-third of its depth, and in *Fig. 25*, when

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about two-thirds. In *Fig. 26* is shown the completed cup, the flange having entirely disappeared. The direction in which the metal is forced to flow, is shown graphically by the four dots in the form of a square upon *Fig. 23*. In the subsequent figures, these dots will be seen to have assumed the form of a diamond, whose axis, lying in a radial line, continuously lengthens, while its other axis, lying in a tangent, is to about the same extent shortened, thus showing that the metal is stretched radially with its particles flowing away from each other, while circumferentially it is upsetting, and the particles are approaching.

The question naturally occurring to the uninitiated is, what is the limit of depth to which an article can be drawn from a flat sheet of metal? This depends upon a variety of circumstances, such as the kind and quality of metal, its thickness relatively to the size of the work, etc. A good quality of "one-cross" (I-X) tin-plate, which is about one-sixty-fourth-inch thick, can, in small articles, say under eight inches across, be drawn to a depth equal to about one-half of its diameter, although I have known frequent cases where this depth has reached two-thirds; for instance, a 3-inch box, 2 inches deep, etc. With soft brass and copper, a somewhat greater depth can be obtained, while with zinc, the proportional depth is considerably less. I have had but little experience in drawing gold and silver, but as far as I know, they act much in the same way as does brass.

A little study of the work which is being done in a die like this will show why a limit of depth is soon reached. The actual work consists, firstly, of molecular friction, or the causing to flow among themselves of the particles of metal in the flange before it turns the corner *d*; and secondly, in overcoming the friction between the upper and lower sides of the metal, and the flat surfaces of the dies. If we imagine the part of the work which has become cylindrical to be a series of little ropes (forming the elements of the cylinder), which are attached to the punch by running across under the bottom of it, and thence up its sides to the corner *d*, we will see that all the resistance offered in the flange is being overcome by the punch pulling these ropes downward over the corner *d*, it acting as a stationary pulley-block. Hence, if the united tensile strength of all these little ropes is great enough to overcome the resistance at its maximum, which is soon after the

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metal begins to flow, when the flange is at its widest, perfect work will be the result. If, however, there are not enough ropes to do this work, which is the case when the diameter at *s* is too small, the flange will not start to move, but the punch will simply go down and tear the bottom out of the work. Thus, if we try for too great a depth relatively to the proposed diameter, the work will be spoiled, because this means a wide flange and more resistance.

It is evident that the little ropes spoken of will "render" more easily about a large corner than a small one, and that therefore a better result may be obtained by increasing the radius of the drawing-corner *d*. If, however, this is carried too far, a considerable part of the flat holding-surface of the lower die is lost, and a new

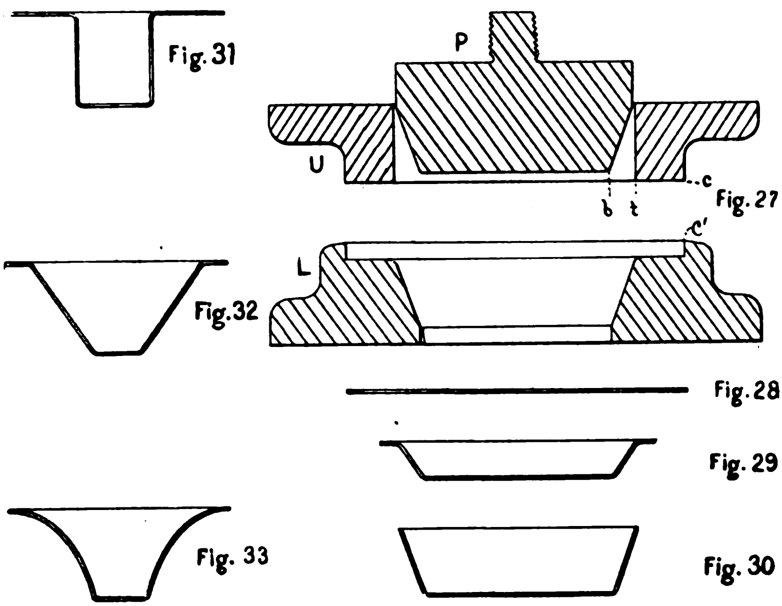

Fig. 27 Fig. 28 Fig. 29 Fig. 30 Fig. 31 Fig. 32 Fig. 33

evil arises, known as body-wrinkles, which will be explained further on. Practically, for working tin-plate, the radius of the corner *d* is made from one-eighth to one-quarter inch. The curvature of the corner *r* upon the punch also affects the result. If it is made perfectly sharp, it tends to cut the metal which is pulled around it, and practically ought not to be less than of one-sixteenth inch radius. It is often much larger than this to suit shape

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of work desired, but if made very large, causes the trouble of body-wrinkles before referred to, on account of there being a certain zone of the blank which is unconfined by the flat holding-surfaces.

You will now see upon the screen, a new diagram, marked *Fig. 27*. This is a vertical axial section of a pair of conical drawing-dies, similar to the last shown, except that they produce conical instead of cylindrical work. They, like the others, may either be "combination," or may work blanks already cut. In *Fig. 28* is shown a section of a blank and in *Figs. 29* and *30*, successive stages of the work while being drawn. The radical difference between this and cylindrical work consists in the blank being unconfined over a certain space which lies between the lower face of the punch and the upper holding surface of lower die, and this is represented by the distance *b*, *t*, *Fig. 27*. When the drawing actually commences, the inner portions of the flange as they flow inward, enter this zone and constantly have to become smaller in circumference. Now as there are no holding-surfaces to prevent, wrinkles are formed which are carried down into the conical portion of the work and are known as "body-wrinkles," in contradistinction to the "flange-wrinkles" which sometimes occur when the upper die is not set down hard enough upon the lower. These are usually removed by roller-spinning. The same difficulty with regard to getting sufficient tensile strength of metal around the punch to pull down the flange as occurs in cylindrical work, appears in still greater force in conical, as the hypothetical little ropes spoken of are still fewer in number around the small circle bounded by *b* than they would be in the larger one bounded by *t*, were the punch cylindrical. It may be said generally, therefore, that any work with a small diameter of bottom in proportion to extreme diameter of flange is difficult to draw. This type is illustrated in *Figs. 31*, *32*, and *33*, which are the most troublesome of all shapes to deal with.

I have before shown that the resistance to be overcome consists of both molecular and surface friction. In drawing conical articles, such as bowls, pans, etc., which do not require absolute uniformity and accuracy, advantage is taken of this fact by drawing two or more together, sometimes even as many as four. In such a case, the surface-friction is no greater for four than for one,

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while the molecular friction is four times as great. The sum of these frictions is, however, obviously less in proportion to the tensile strength of work surrounding the punch, which is as the number of thicknesses therein. There is, therefore, a great gain in strength, and much deeper work may be made than by drawing one at a time.

These several thicknesses can also be removed from the press and spun and trimmed all at a time, after which they easily drop apart. This method is only applicable to work with considerable taper. Obviously, it would not answer with cylindrical articles, as they could not be separated one from the other easily, and their difference in diameter would be too apparent.

FIG. 34.

In *Fig. 34* is shown a photograph of a wash-basin just as it leaves the dies, where the body-wrinkles are very apparent, and where also the unevenness in contour of the flange plainly appears. This is caused by slight variations in the thickness and ductility of the metal, and also in the flatness of the holding-surfaces of the dies. As regards the latter, the variation from a perfect plane is partly caused by imperfect construction, but is in a greater degree due to their springing or bending out of flat by the unequal yielding of different parts of the press when the holding-pressure is brought upon it. Incidentally, it will be well to mention that the proper action of the drawing-surfaces depends not only upon their flatness, but upon extreme smoothness, and upon the grain of the polish of the metal being in a radial rather than in a circumferential direction. Referring again to body-wrinkles, I will mention that they may be partially avoided by an extra heavy pressure upon the flange, in which case the tensile strains upon the metal surrounding the punch tend to partly pull them out, as it were.

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As upon the screen before you there happens to appear two photographs germain to the direction of the flow of particles from the flange to the body, I will here recur to the subject, explaining

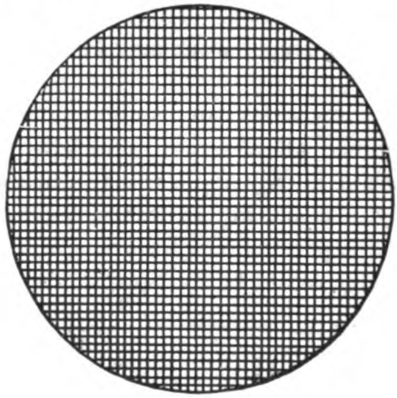


FIG. 35.

that *Fig.* 35 is a blank cut from so-called "decorated tin," where a series of lines divide the surface into a number of small squares. The appearance of these squares after the metal has flowed to its

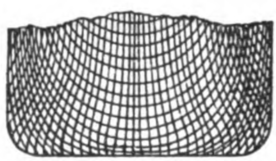
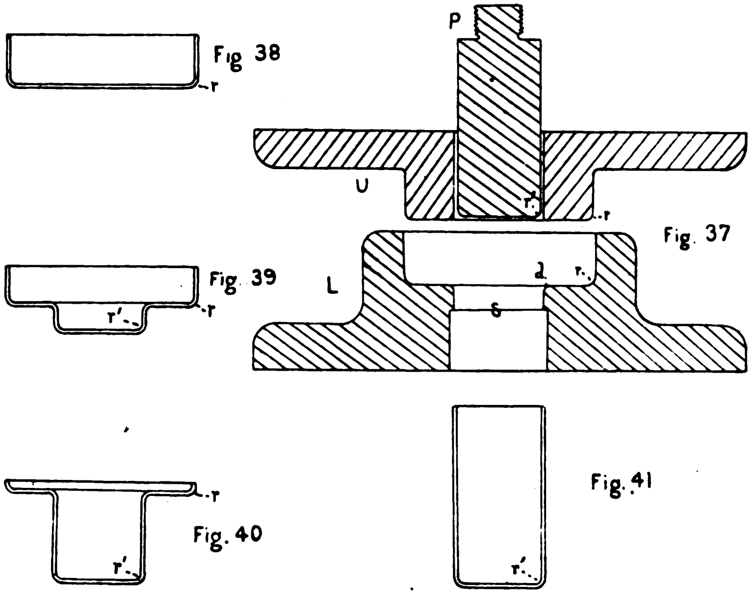


FIG. 36.

new shape is beautifully shown in *Fig.* 36, which is photographed direct from a piece of cylindrical work made from a blank like *Fig.* 35. This cup is shown in side view, and at the upper edge is seen the effect of uneven drawing incident especially to deep work. Such an edge needs trimming, but where the depth is not over about one-sixth of the diameter, it is usually good enough for commercial purposes without.

In *Fig.* 37 is shown a pair of cylindrical "deepening" dies. They are in principle exactly like the plain dies, *Fig.* 22, except that instead of working a plain blank, they receive a cup which has been previously drawn at a first operation. Such a cup is shown in *Fig.* 38. It is placed within a recess in the lower die, which guides it exactly to place. The upper die is made of such a diameter as to exactly fit inside of it, and the rounded corners upon both dies and punch, as shown at *r*, *r* and *r′*, *r′*, are made of such a curvature as to fit the work at the points marked by the same letters. Successive stages of this work, while being drawn deeper at this operation, are shown at *Figs. 39* and *40*, while at *Fig. 41* it is shown com-



pleted, as dropped through the die *L*. This process is known as "deepening," and can obviously be carried on in successive operations without limit, provided the metal does not harden, or can be annealed between operations. Thus, with brass, copper, black-iron and steel, etc., long tubes may be drawn from a flat sheet, as is instanced in some of the operations of cartridge-drawing, etc., these metals allowing the necessary annealing to be performed. With tin-plate, however, the coating of which would be spoiled by annealing, not more than two operations can usually be performed. With such material, a box may be obtained of a depth about equal to its own diameter, but not much deeper, and in such a case, the metal is made very brittle.

There are not many data available regarding the pressure per square inch for holding various kinds of metal between the surfaces of drawing-dies. I hope at some future time to make a systematic course of experiments, but so far have the records of only a few

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informal ones. One of these showed that it took 4,600 pounds to hold without wrinkling the flange of a $5\frac{3}{4}$ x $1\frac{5}{8}$-inch milk-pan. This had about twenty-three square inches of drawing-surface, and therefore required about 200 pounds per square inch. Another case was that of a small seamless blacking-box with two and one-half square inches of drawing-surface, where a pressure of 800 pounds was applied, making it 320 per square inch. In a third case, a $1\frac{9}{16}$ x $\frac{3}{8}$-inch box had 1·35 inches of drawing-surface, and took 648 pounds pressure, being 480 pounds per square inch. This stood over 4,000 pounds, however, without breaking, showing for such shallow work a great excess of drawing capacity. It will be seen that the average of the above experiments is something over 400 pounds per square inch; the average pressure really necessary, however, will probably run somewhere between 200 and 400 pounds.

Regarding the maximum limit of speed in drawing, there is the same lack of data based upon systematic experiments. The presses in use, run from say ten strokes per minute in the larger sizes, to 200 in the smallest. This gives a maximum punch speed (counting on twenty inches in the former case and one in the latter) of about fifty feet per minute. At this rate, the metals used seem to flow properly without tearing, though probably in some cases a slower speed would be better. Iron, I believe, will flow faster than brass, but how much beyond the above speed it is practicable to go, must be left to the verdict of some future very interesting experiments.

In *Fig. 42*, now upon the screen, you will see a perspective view of an ordinary type of drawing-press, such as is usually employed for small work, say not over ten or twelve inches in diameter. In this the dies are shown set, the upper die at *U* and the lower at *L*. The "outer-slide-bar," carrying the upper die, is pushed downward until the latter is in contact with the blank, by means of cams upon the main-shaft, working against rollers in the slide-bar. These cams have a cylindrical portion of their surface so arranged as to hold the upper die perfectly still during the latter half of the descent of the punch and the first half of its upward return. The punch is attached to the "inner-slide-bar," which is driven by a crank and pitman in the usual way. Such presses are arranged with accurate adjustments for giving the proper pressure upon the

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blanks and for making the punch descend to exactly the proper point. The outer-slide-bar is raised, in this case, by springs, which

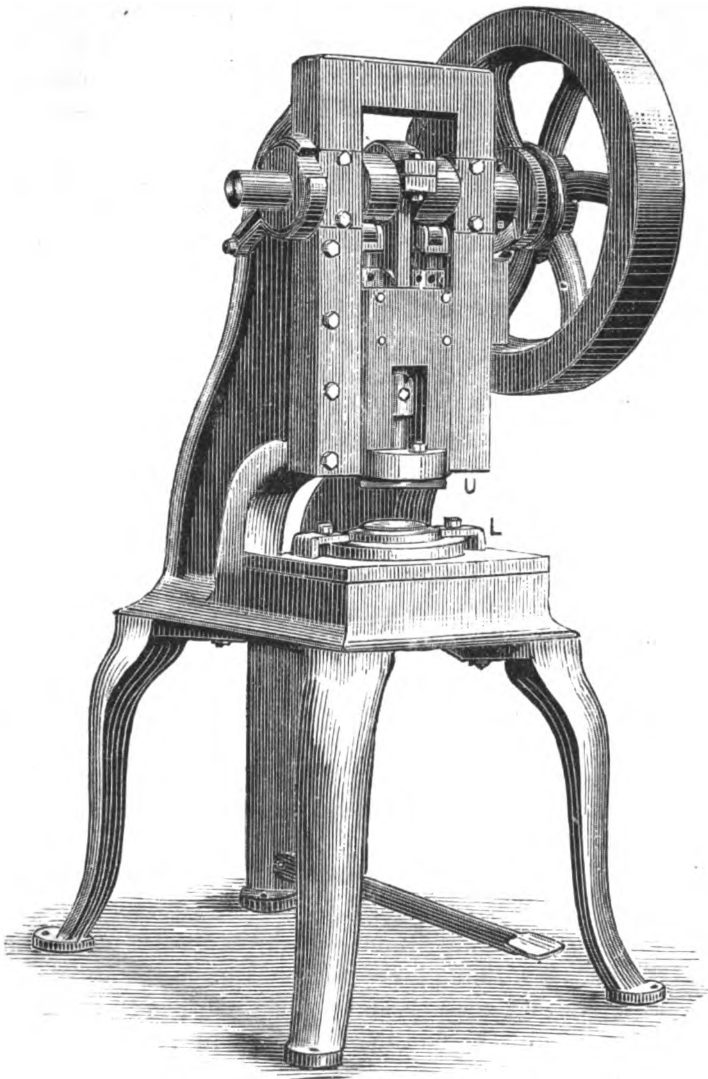

FIG. 42.

do not show in the picture. Sometimes "return" cams are used for this lifting. This view, *Fig. 42*, shows a press made in England. In *Fig. 43* is shown a much larger drawing-press, made in

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Germany. For obvious reasons, of a non-advertising nature, I have not shown views of any American presses, although some of them are of much better design than these before you. It may be said, however, in favor of the German presses, that they are usually fitted with more conveniences than are those made in this country, in the way of extensive and rapid adjustments, which adapt them to a great variety of shapes and sizes of dies. In this particular point we may well copy the Germans, who, perhaps, have arrived at a greater state of perfection than we, on account of having been longer at the business. The machine represented in *Fig. 43* differs from the smaller one shown, and from many large ones in the market, by having the bed which carries the lower die to slide upward to meet the upper die, which is stationary. One advantage of this "bottom-slide" construction is that said bed, which is very heavy, can be returned to position by gravity, without any lifting arrangements, actuated either by cams, weighted levers, springs or steam-cylinders—all of which methods are used in "top-slide" presses. Another advantage is that the slide working the punch need only move through a distance necessary for doing its actual work, while with the other plan it must move this distance *plus* the waste space through which the blank-holder moves until the work is held—this space being necessary for removing conical and flanged work that cannot drop through lower die. This wastes a good deal of its stroke, and necessitates a much greater radius of crank, with the accompanying increased strength in shaft and gearing. Before leaving the subject of presses, I want to call attention to a fact which even yet is not fully realized by drawing-press makers, and that is, the immense importance of making the bed and the outer-slide, which carries the drawing-dies, of enormous *depth* relatively to their width. These members are really beams, usually supported at their ends, with the greatest working pressure occurring in the middle. It is very necessary that these beams should not bend to any appreciable degree, and therefore their depth must be great. A press otherwise abundantly strong enough, will utterly fail to make good work if these cross-members are allowed to spring so as to throw the face of the dies out of true when the pressure is brought upon them. In such cases, flange-wrinkles will commence to form in certain parts where the holding-surfaces happen to recede from each

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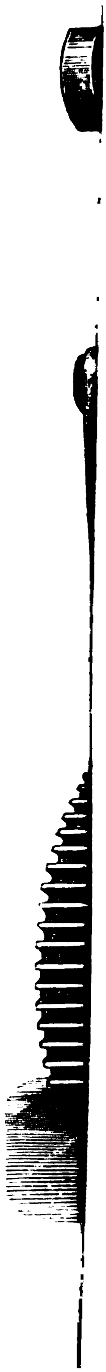

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other; and, when once formed, cannot possibly be removed. Worse than this, these wrinkles tend to force the dies still further apart and throw them into undulations of "springiness," so to speak, which is apt to entirely spoil the work.

While on the subject of presses, it may be well to mention a sort of mongrel drawing-press that is used for small work in some brass factories; where the outer-slide is driven by *cranks* instead of *cams*. This gives a simpler construction, but fails to properly "hold" the blank—except for an instant when the crank is passing its dead-centre. In the best modern practice such presses are giving way to those of the type shown in *Fig. 42*.

Recurring again to dies, I will mention that a certain method is frequently practised for drawing small articles, which are comparatively shallow, in an ordinary single-action press. This consists in using a strong spring-pressure for holding the flange of the metal from wrinkling. The dies used are generally constructed with a holding-ring surrounding the punch, and within the female cutting-die, which is pushed up by heavy springs, and answers as the lower holding-surface. The punch and female cutting-ring are fast in the lower die, while the upper die is the male cutting-die, with a recess in it, which does duty as the female forming-die. The flat lower face of this is the upper holding-surface. These are known as "spring drawing-dies," and answer a very good purpose, when small enough to make the power which they waste of little practical account.

It will naturally occur to the student of this subject that some easy method is desirable for determining the diameter of the blank for any given piece of drawn work, especially if its dies are to cut; as cutting edges are expensive to make—and to *alter* if guessed at and made wrong at first. Aside from lucky guessing, somewhat guided, perhaps by analogies from other approximately similar work that dies have been made for before, I have in my own practice used three principal methods to obtain this measurement of blank diameter.

The first of these methods is the *tentative* one. It is the surest, but, in many cases, the most expensive. It consists in cutting blanks of as near as possible the right size and shape by guess, and trying them successively, modifying the shape of each to suit circumstances, until the proper shape of drawn work is produced.

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For dies that do not cut, this isn't difficult, as the flat holding-surfaces can be made plenty large enough, and whatever gauging arrangements are to guide the blank, can be put on afterwards when its correct proportions are decided upon. In cutting dies, the female cutting-ring must be made separately, and left unfinished until the size and shape is ascertained. The male cutting-ring, which forms part of the upper holding-surface, must of course be made, but can be left plenty large enough until this trial has been completed.

The second method referred to, may be called the *gravitative*. It depends for its accuracy upon the principle, that the thickness of the metal in a piece of drawn work, is the same as it was in the original blank, which is in fact usually the case. My own method is to carefully weigh the sample piece of drawn work which is to be reproduced, and then, knowing the weight of one square inch of a piece of similar sheet-metal of exactly the same measured thickness, to calculate the number of square inches necessary in the blank and make its diameter to suit this given area. This method can obviously be practised only where a sample of the work is at hand, and where the blanks are circular in form. Certain inaccuracies may arise in the practise of this method, where there are sundry beads, corrugations, etc., near the centre of the piece of drawn work, which tend to let the metal stretch when the punch comes home in the die. Such action is properly embossing, rather than drawing, and stretches the metal thinner in certain places, which of course invalidates the accuracy of this system. It is, however, often useful for work whose contour is simple in form, near the central portions, where a drawing action does not take place.

The third method spoken of may be called the *mensurative*. This, too, depends upon equal areas and upon the thickness of the metal remaining the same. In the case of plain cylindrical work, a very simple formula, which I have worked out for the purpose, may be used. This is given in *Fig. 44*, equation III, for a box or cup whose corner at m is sharp, or nearly so, and in equation VI, for a round-cornered box. The latter formula is not theoretically accurate as regards equal areas, but serves an excellent practical purpose where the corner is not of too large a curvature—say with a radius not more than one-fourth the depth of the cup. The

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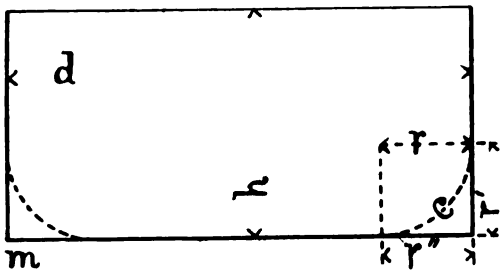
FIG. 44.



Let, (in inches.)
d = Diam. of cup.
h = Height of cup.
r = Radius of corner.
c = Arc of 90°, with radius r.
a = Area bottom + sides
a = Area blank, also.
x = Diam. blank is to be cut.

$$a = \cdot785\, d^2 + \pi dh., \qquad (1.)$$

$$x = \sqrt{\frac{a}{\cdot785}} = \sqrt{\frac{\cdot785\, d^2 + \pi dh.,}{\cdot785}} \qquad (2.)$$

$$x = \sqrt{d^2 + 4dh}, \text{ for sharp-cornered cup,} \qquad (3.)$$

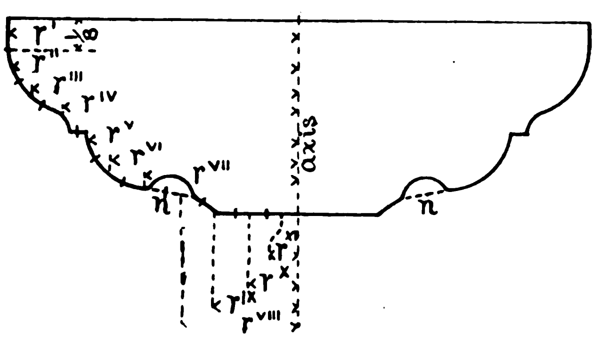
$$r' + r'' - c = \frac{r}{2} - \qquad (4.)$$

$$2 = (r' + r'') - 2c = r - \qquad (5.)$$

$$x = (\sqrt{d^2 + 4dh}) - r, \text{ about, for round-cornered cup; with small corner, say where } r < \frac{h}{4} \qquad (6.)$$

diagram given in *Fig. 44* is a vertical axial section of a cylindrical box or cup, the same as was shown in *Fig. 26.* It is not worth while here to give the working-out of the formulæ, as by a close inspection, the figures will explain themselves.

FIG. 45.



Let (in inches.)
r^{i}, r^{ii}, r^{iii}, r^{iv}, etc. = Radii drawn to axis from centres-of-gravity of ⅛ inch segments of contour line.
s = $r^{i} + r^{ii} + r^{iii} + r^{iv}$, etc.; that is, the sum of the radii.
a = Area bottom + sides.
a = Area blank, also.
a^1 = Area of one zone whose average radius is r^{i}, r^{ii}, r^{iii}, etc.
x = Diam. blank is to be cut.

$$a' = 2\, r^1\, \pi\, \tfrac{1}{8}, \qquad (1.)$$

$$a = 2\, s\, \pi\, \tfrac{1}{8} = \cdot785\, s, \qquad (2.)$$

$$x = \sqrt{\frac{a}{\cdot785}} = \sqrt{\frac{\cdot785 s}{\cdot785}} = \sqrt{s} \qquad (3.)$$

In *Fig. 45* is shown a method which I have devised for ascertaining the area of a piece of drawn work of irregular contour as regards its vertical section. This method is a graphic one, an exact profile of the work being drawn to scale of real size, and this contour-line being laid off, from its axis outward, into sections each exactly one-eighth inch long. From the centres of these sections, at the points marked r', r'', r''', etc., horizontal measurements are taken to the axis. These measurements, of course, represent various radii of the piece of drawn work in question. If we let the sum of them be called s, we then get the very simple formula given in equation III. The reason that just one-eighth of an inch was taken for the length of these segments of the contour-line was that it happened to reduce the equation to the simple form given, while any other length would have made it more complicated. The principle here involved is, obviously, that of the area of any zone being its width, multiplied by its circumference at a point representing the centre of gravity of its single cross-section. The points marked r', r'', etc., are, of course, not accurately in the centre of gravity of each of the little segments, but they are practically near enough so. The same principle occurs in this method as in the last-mentioned one regarding places in the metal which will stretch thinner when formed to shape, like deep beads, or other indentations. This trouble may be mostly neutralized, however, by bridging over them, so to speak, in making the contour-line; that is, by running the latter across from point to point of the corrugations instead of following their curves, wherever it is judged that stretching will take place. This amended contour is shown at n, n, *Fig. 45*, by dotted lines, and on it the segments should be laid out.

In making drawn work whose top view is elliptical, instead of round, the formulæ above given may be used with some modifications. To do this, the ellipse is treated separately, as regards its short and long axes, and values are inserted in the two equations which would be used for circles which approximately coincide with the sides and ends of the ellipse, at the terminii of its respective axes.

In making rectangular work with round corners, some idea of the shape of the blank may be obtained by treating the corners as belonging to a circle of the proper diameter, while the sides of

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the rectangle (which properly are not drawn at all, but only bent to shape), may be treated nearly by actual measurement, as in them very little stretching takes place. As regards the corners, however, the tentative method is the safest wherever it is possible to use it.

It may be of interest to state that certain kinds of work are drawn from whole sheets of metal, wherever such sheets are only a little larger than the blank which would otherwise be used, and the cutting to shape is done in a pair of "trimming"-dies afterward. This method is frequently used for such work as wash-boiler bottoms, dust-pans, halves of toy animals, etc, and gives an accuracy of edge contour not attainable the other way.

As an accessory to the process of drawing, the old-fashioned process of spinning is sometimes used, for finishing certain details of shape which cannot be done in the dies. The drop-press is also occasionally brought into requisition for finishing certain shapes. Much more common than either of these, however, is the process of roller-spinning before referred to. This is very much more rapid than the old-fashioned hand-spinning with a burnisher, and is done very quickly by a cheap quality of labor. It is used for crushing out such body-wrinkles as were shown you in *Fig. 34;* in wash-bowls, conical pans and such work. One or more of these articles are placed upon a steel chuck, without even stopping its revolution, and being pushed up solidly by a loose pad upon the dead-spindle of the lathe, so that they are driven by the friction of the chuck, a hardened steel roller, mounted upon a slide rest is rapidly passed once over them, under considerable pressure, and thus the wrinkles are entirely removed.

On the table before me, you will see a large number of specimens of drawn work of various proportions and of several materials. These I shall be glad to show in detail to anyone interested, after the lecture is over. The larger articles on my right were kindly loaned me by Mr. George Melloy, of this city, and very well represent the general line of commercial stamped-ware hinted at in *Figs. 1* to *18*. Perhaps the most interesting among them is this milk-can, the lower part of which is drawn seamless in one piece. It is about a foot in diameter by nearly two feet deep, and was drawn and deepened at three or four operations with annealings between and the tinning afterward.

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With regard to the future possibilities of this interesting process of drawing metals, we probably can form but a primitive idea. Already, articles as large as soda-water fountains and the halves of kitchen-boilers are drawn from a flat sheet; and it would be simply a matter of first cost for plant, to draw large steam-boilers in the same way. There would certainly be no real difficulties, except the expense of plant, in drawing such things as bath-tubs, boats of small sizes, etc., by precisely similar methods to those I have indicated this evening.

Of the real value of this invention, I think the public have a very inadequate idea—perhaps because there is so little generally known about it, the practise of the art being mostly confined to a few large and very secretive-minded factories. To it mainly, however, we owe the wonderful cheapness, abundance and variety of the household utensils, which help in some degree to lighten the burdens of toiling millions of wives and mothers the world around. If, like Abou-Ben-Ahdem, the man who makes to grow two blades of grass where grew one before, is a lover of his fellow-men, with what laurels shall we crown the brow of him, who in so many a busy kitchen has placed, not *two*, but *ten* pots, and kettles, and dishes, and pans, where but one might have been attainable, were it not for this scientific and beautiful art.

'Tis true, we may take another view and wonder how much this process has also contributed to human misery by producing cheap *cartridges*, but shall we not, with optimistic mind, think of those things that make war more deadly, as warnings which will teach men to go to war no more, and thus help forward the reign of universal peace?

AN INTERESTING MONUMENT.—M. Clermont-Ganneau has communicated to the Academy of Inscriptions and Belles-Lettres a note relative to a discovery made by him in an old building at Jerusalem. It was a block of stone, with a Greek inscription signifying that any stranger who should have passed that limit would be condemned to death. It is evidently a fragment of one of the posts which formed, in the temple built by Herod, a dividing line between the exterior enclosure of the Gentiles and the inner precinct reserved for the Jews. It will be remembered that St. Paul barely escaped stoning when he was accused of having introduced Greeks into the inner circle with himself. The stone has been removed to Constantinople, but a cast has been taken, which will be preserved in the Museum of the Louvre. —*Cosmos, Aug. 24, 1885.*

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