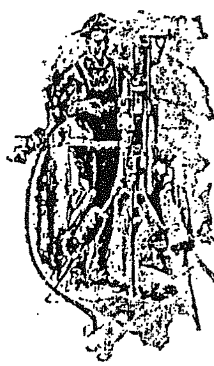
7:2 Cassier's Dec 1894

MANUFACTURING MACHINERY—OR BUILDING IT.

By Oberlin Smith.



IN Adam Smith's well-known illustration of the economy attained by the principle of division of labor, as applied to the art of pin-making, written over a century ago, he estimates the daily product of one artisan as about five hundred pins. He compares this work with a product of one pin per day, if made in the old-fashioned way, the various operations all being performed by one person, without special training or appliances, presumably including all the work from the crude pig metal onward. Had he lived to examine modern methods he would doubtless have introduced a new principle into his political economy, that of the multiplication of brain work. By its application he could have shown, perhaps, another five-hundred-fold increase in the per-man-per-day output of that very useful implement, the common pin. In the wonderful automatic machines used for the production of this and other small articles, he would have seen also the embodiment of still another important principle, which is so large a factor in our modern industrial life, namely, the controlled distribution of mechanical power. By this I mean the application of force in a machine, just where, when and how it is required.

In the construction of machinery any or all of the three principles above mentioned may be carried out to a greater or less extent, usually dependent upon how many individual articles of one kind are required to be made at one time. Where they are all so applied we have an example of manufacturing proper, in contra distinction to mere making or building, as implied in the title of this article.

The cheap and systematic manufacturing of simple articles of daily use, such as the pins of Adam Smith's time and earlier, was naturally developed as fast as current civilization enabled and demanded the cheapening of its implements for the convenience and happiness of mankind. The tools or machines, however, with which these articles were made, were themselves built "piece meal," as it were, usually being designed by a gradual process of evolution. This went on for a long time, and is still going on, in regard to the great majority of intricate machines.

Within a comparatively short time, however, measured chiefly by the latter half of this century, wonderful cheapening processes have been applied to the production of certain machines by the thousands and tens of thousands whose function, in their turn, is the production of the various articles in common use by millions and tens of millions. Familiar examples of this are seen in the modern American system of manufacturing clocks and watches, whose product, so to speak, is hours, minutes and seconds; sewing machines, whose product is clothing; guns and pistols, with a product of defunct soldiers, exterminated wild animals and mutilated small boys; mowers and reapers, producing hay and grain; together with a great variety of other improved devices whose number and ingenuity is constantly increasing.

There is not space in this article to dwell in detail upon the character and the enormous importance to our civilization of this great system of manufacture that has almost imperceptibly been engrafted upon our modern existence and which has so wonderfully cheapened the necessaries, and often luxuries, of our lives. Recurring to the three before-mentioned principles involved in the rapid production in question, division of labor is not the least important. This is, of course, applicable only to cases where similar articles are made in large quantities, as such a division would only add to the cost of a single article, or a small "batch" thereof. The principle, however, is not new, as it was undoubtedly carried out to a greater or less degree of perfection among the pyramid, temple and aqueduct builders of ancient times. The third principle mentioned, of the exactly controlled distribution of force, which has, perhaps, reached its highest development in some of the modern automatic machinery, is also of hoary age in certain of its applications, as is witnessed by the water-wheels, pumping apparatus and other devices of centuries long past.

Power thus controlled, even in an intricate machine, need not necessarily be derived from the so-called mechanical forces, operating such motors as steam engines, water-wheels, etc., as muscular force derived from men, horses, or other animals and applied to a prime distributor, as a rotating shaft, could not, if properly governed, be distinguished from any other prime-mover. When distributed, however, among the various grippers and cutters, grinders and swedgers of a pin machine, for instance, each steel lever, finger and pawl moving in exact time and with exactly measured force and distance in relation to all its fellows, any force derived from the prime-mover becomes strictly mechanical and can be applied with a precision and rapidity unattainable by the fingers of workmen, no matter how skillful. In heavy work, however, where powerful forces are required, it would in some cases be impossible to substitute for the steam engine muscular energy in the space required for its application. An instance of this may be seen in the driving of a great steamship at twenty-five miles an hour, or a Pullman train at seventy-five.

We see, therefore, in modern manufacturing the application, to a more or less degree, of properly divided human labor and of properly controlled mechanical force, whencesoever derived, as two essential principles which, in some form or other, are almost as old as the world's history. The second principle before-mentioned, the one tending to upset all of Adam Smith's calculations in regard to pin making, that of the multiplication of brain work, as I have called it for want of a better and briefer name, seems, however, to be of comparatively modern origin, except possibly in the Chinese Empire. The most notable example of this principle is shown in the art of printing, where the brain work used to prepare and arrange the types for printing a copy of a given manuscript is duplicated a thousand or a million-fold by means of cheap labor, which needs absolutely none of the original brain power, but only the necessary experience for the routine management of the apparatus. The same principle is, of course, used in the production of pictures of all sorts, from chromo-lithographs down, "chromos" being mentioned first, not because of their necessarily artistic merits, but because they require, with their many colors, a more complex process than do any prints embodying merely blacks and whites.

Numerous other examples of this principle can be found in various branches of industrial life. The most modern and most important use of it is exemplified in the "special tools," so-called, which have been the most vital factors in the cheap, accurate and uniform productions of the various machines mentioned in the former paragraphs. These special tools consist chiefly of gauges, templets, cradles and jigs. A gauge may obviously be made in many forms, its function in any case being to measure the size of some part of the object to which it is applied, either externally or internally, or to determine the distance apart between certain holes, flanges, or other characteristic features. It usually is of fixed dimensions and serves to identify and keep standardized measurements and locations which are determined in the first place by templets or jigs.

The word *templet* is not very well defined, but is usually applied to a tool which not only partakes somewhat of the nature of a gauge, but which locates certain holes and other details of construction by directing, scribing or other marking tools which are slid against the internal or external edges of said templet. The tool itself usually consists of a thin plate of metal, having, in some cases, certain lugs or pins projecting from it wherewith to locate it upon the work to be templeted; and having, furthermore, various holes, notches and other working edges which serve as guides for a scribing tool. The use of a templet does not locate holes, etc., with extreme accuracy, because of errors afterward occurring with drilling or other cutting tools by not strictly following the lines which are scribed by the templet. It often answers a sufficiently accurate purpose, however, and will enable a group of holes to be quickly marked out upon any number of surfaces to which it may be applied, these markings all being in duplicate. A familiar application of the templet principle is seen in stencils of various kinds, a paint brush being substituted for a scriber. In this form a templet can scarcely be called a modern device.

The term *cradle* is usually applied to a tool in which a number of similar pieces of irregular-shaped work can be successively inserted and brought to a given location, being secured by proper clamping devices. This cradle usually has a base which is exteriorly flat or otherwise adapted to fit the machine, as a planer or drill-press, in which the work is to be treated, its function being to form a false base for work not in itself provided with a true and flat bottom, or group of legs, upon which it can firmly rest.

The tool familiarly known as a *jig* is by far the most important in its nature and functions of all the special-tools in question. It is usually employed for the accurate locating of a hole, or a group of holes, to be drilled or bored in the piece of metal or other material to be operated upon—technically known as "the work." It is sometimes provided, however, with locating edges for guiding certain tools which produce planes and other definite surfaces, as well as cylindrical holes. In its simplest form it consists of a flat plate of metal which can be clamped upon, or otherwise secured to, the upper surface of the work, being perforated with round holes, through, and guided by which, a vertical revolving drilling tool is passed, to drill the required holes. Sometimes this jig is located in reference to the work simply by the eye; but more generally it is guided by flanges, pins or other projections, partly or wholly surrounding the work, and either fitting it tightly, or being brought to a fit by movable jaws or other devices. When such a jig is intended to locate a group of holes, either of the same or different sizes, it is, of course, perforated to agree therewith. Such a tool as this is obviously suited for lying upon a true horizontal surface, with its pins or flanges projecting below, just as the lid of a pasteboard box might be slipped over the broad surface of a brick, and is, moreover, generally used on work having a flat base of its own, the brick being an analogy therefor. Obviously, work having such a plane surface for a base, or provided with a false base of some sort, can be laid upon the horizontal table of a vertical drilling machine and quickly slid by hand, if not too heavy, to the different positions required for the various holes which are to be drilled, the jig itself determining the location of the combined structure of work and jig, by allowing the drill to enter each of its holes successively.

A more complex form of jig is adapted not only for drilling a group of parallel holes as above described, but other holes in any of the other sides of the work, and these at any desired angle with, as well as distance from, each other. In such case, if the work is cubical or of any rectangular form, after the fashion of our supposititious brick, it is evident that its jig may be in the shape of a rectangular box which, with its lid, will completely enclose it, that is, providing all of its six sides are to be operated upon. The brick, when thus enclosed, would have the six planes bounding the jig for its temporary bases, and could evidently thus be perforated with a large number of holes, all agreeing with those in the jig, and all of which would be located in exactly the same relative positions as would those in the thousand or million other bricks which might be successively inserted in the jig. Strictly speaking, this is true only when assuming that the jig holes do not wear larger, or the drills wear smaller, so as to be appreciably loose in fitting each other. In practice such looseness is, of course, cumulative, and is allowed to produce its inevitable errors up to a certain limit of accuracy which is regulated by more or less frequent inspections with master gauges which are used to keep the jig and boring tools up to a certain standard. These master gauges are usually made with extreme care and accuracy, and when not in use are kept securely locked up, as a safeguard against accidents or malicious tampering. In some cases grand master gauges are provided, preserved with still more care, to test the master gauges.

It often, and indeed most frequently, happens that work is not cubical in its general form, being sometimes extremely irregular—as, for instance, in the case of a frame of a sewing machine. Furthermore, holes and other surfaces are often desired at other angles with each other than those of ninety degrees, as was assumed for our imaginary brick. In such cases it is only necessary that some exterior flat base be provided upon the side of the jig opposite to any given hole to be drilled, the plane of said base being perpendicular to the axis of such hole. In cases where a horizontal drilling tool is used, with its axis parallel to the bed of the drilling machine, a jig is, of course, constructed to suit, having its temporary base arranged to rest upon the machine bed in question.

In actual practice, a jig for drilling a few dozen holes, some of them perhaps being of two or three different sizes, or countersunk at their ends, or tapped with a screw-thread all or a part of their length, consists of an accurately made iron box, sometimes with partly open sides, having perhaps a hinged lid, which, when closed down, clamps the work securely in place, with the bearing points against it at certain definite locations which will give the best average position, even though the rough surfaces of the casting are accidentally somewhat varied in position and form. To suit these variations, the clamping devices are adjustable. This box is perforated upon its various sides with the proper number of holes, each of which is bushed with a hardened steel bushing accurately ground to size. These guide the drills and other boring tools until worn loose, when they are cheaply taken out and replaced with new bushings, thus enabling the jig proper to last an indefinite time and yet maintain its original accuracy.

With such a tool sliding freely upon the truly planed horizontal bed of a gang drilling machine, above which are constantly revolving a number of properly made drills, each capable of being fed down to a fixed position, and no farther, by an accurately adjusted stop gauge (or, as in some cases, with the drill vertically fixed and the bed fed upward toward it) a boy or other low-priced operative can, with great rapidity, produce a group of holes, which are located with practically the same accuracy as are those in the jig. Furthermore, he can do it a thousand or ten thousand or ten million times with the same uniformity and certainty that he can once. He is thus, without appreciable brain labor, doing as accurate and almost infinitely quicker work than did the educated engineer who designed the jig and the drilling machine, and the careful high-priced machinist who made them, such a jig having cost perhaps hundreds of dollars, and the locating and drilling of the holes in it having occupied hundreds of hours, the measuring often being done in thousandths and even ten-thousandths of an inch. In this comparatively simple tool, therefore, we see exemplified the same grand and universal principle of duplicating and multiplying valuable and tedious brain work that is seen in that epitome of civilization, the printing press. The process of thus multiplying certain pieces of work by jig-drilling them is to the hand-drilling of one such piece (which it would be almost as much trouble to drill as the jig itself) as is the printing of a large edition of a book to the elaborate writing of one copy with a pen, after the fashion of the Middle Ages. There are, of course, many other processes other than those mentioned which have been greatly cheapened by a high degree of specialization. Among these are special forms of turning, planing, milling, etc. Hole-making seems, however, to take the lead, because, perhaps, by its means chiefly the individual members of a structure are attached to each other.

Mention has already been made of the general character of the machinery produced in this nineteenth century fashion. Such processes are truly manufacturing. They are, however, evidently not suited to the construction of steamship hulls, bridges and large sizes of engines, pumps, lathes, planers, etc., simply because these articles are usually built one at a time, or at any rate in very small batches. Obviously, the enormous expense of special tools for producing them would, in this age of the world, even if they were standardized enough to create a large demand, prove entirely prohibitory. We must, therefore, in this generation at least, expect to see all such machinery made in the old-fashioned way, that is, simply built, and not manufactured. A partial exception to this occurs in connection with certain detailed members of the structures in question, as, for instance, many of the beams, link-bars, pins, etc., in a bridge, or the bolts and nuts in an engine, which members can often be made in duplicate, with the advantage of using special tools.

Between the large structures mentioned, which, on the whole, are merely built, and in quantities of but one or two at a time, and the small machinery before alluded to, which can be made in lots or batches of from a hundred to a million at a time, there is a large class of medium sized machines, such as small lathes, planers and other machine tools, high-speed engines, dynamos, steam pumps, presses and shears, etc., etc., which are made in batches of from five to fifty at once, and to which some of the cheapening processes in question can be applied. In building such constructions the wise machine-shop owner will, and often does, use the principle of division of labor, to a greater or less extent, according somewhat to the number of his employees. He also in these days uses the controlled power principle in almost all his work, as the admirable general tools now in use in most shops leave little to be desired upon this point, from the operations of planing, turning, boring, etc., down to the rapid handling of heavy pieces by electrical and other quick-moving cranes. These, happily, are now becoming fashionable.

In the vital principle of multiplying brain-power, as exemplified in the jig-work, etc., shop-owners still fall a good deal short of the high standard which they might reach, greatly to the benefit of themselves and their customers. The main object of this article, though the reader, in perusing the long preamble, may hardly have suspected it, is to urge the importance of this intermediate class of machinery, which is usually built in comparatively small batches, being manufactured, rather than thus built, by means of the obviously sensible and enormously money-saving tools, consisting chiefly of gauges, cradles and jigs, which have been described in the preceding paragraphs.

It must be remembered also that the cheapening of a piece of work in the actual formation is not the only advantage of making it with a jig, rather than by hand. The incidental advantage of uniformity in all parts, which enables machines to be assembled with almost infinitely less fitting, and which, moreover, enables them to be afterward repaired by the substitution for broken and worn pieces of duplicates from the same maker, has proved of tremendous, and at first unthought-of, advantage, this uniformity being indeed the leading characteristic of what is frequently known as the American interchangeable system of manufacturing. Of course, in the small-sized batches in question, averaging perhaps not more than ten made at one time, we cannot expect the great saving of cost obtained in an article like a sewing-machine, which is now produced complete and of first-class quality for less than ten dollars, against a cost of perhaps twenty times as much were it made singly, but with good tools and workmen, in an ordinary machine-shop.

The reverse of the above picture should obviously be shown, and this would teach that much caution must be observed before going too extensively and expensively into the procuring of special tools for the manufacturing of any machine regarding which there is any doubt whatever as to commercial demand, in reasonably large quantities. Great care should be taken not to design jigs and other such tools for any article which is not thoroughly standardized and really ready for the market, not only mechanically but commercially. In average shop practice it is by far too often the case that a machine will seem to be all right and ready for manufacturing, when in reality it is not entirely out of the experimental stage. Under such conditions important changes are very likely to be required, either as the result of a salesman finding out that customers think they want something changed; or, more likely, from the maker finding out that something must be altered to suit the severe requirements pertaining to actual operation, month in and month out—such hard work having shown imperfections which were not developed in a mere shop trial, but which must be duly remedied. In still other cases the machine itself may run well enough and suit its purchaser, but the maker may find that something can be so improved in action and simplified in construction as to make the machine enough better or cheaper, or both, to justify him in wholly or partially re-designing it. Then, again, a competitor's machine may appear with additional speed or more comprehensive functions which must be met—and beaten.

In all the cases mentioned there is danger that a set of special tools, or a part thereof, will have to be thrown away before they have been used long enough to anywhere near pay for themselves. Much circumspection is, therefore, necessary in looking carefully at both sides of the question before making rash outlays for tools which, when really desirable, are of such extreme value, but which, on the contrary, are worth something less than a cent a pound when not exactly adapted to their environment. In this respect they are vastly different from general machine tools, which, when out of use for one purpose, can easily be turned to account for something else, and which, moreover, have usually a definite market value. Jigs, but for the tender mercies of the junk man, have, under such circumstances, a valuation absolutely *nil.*