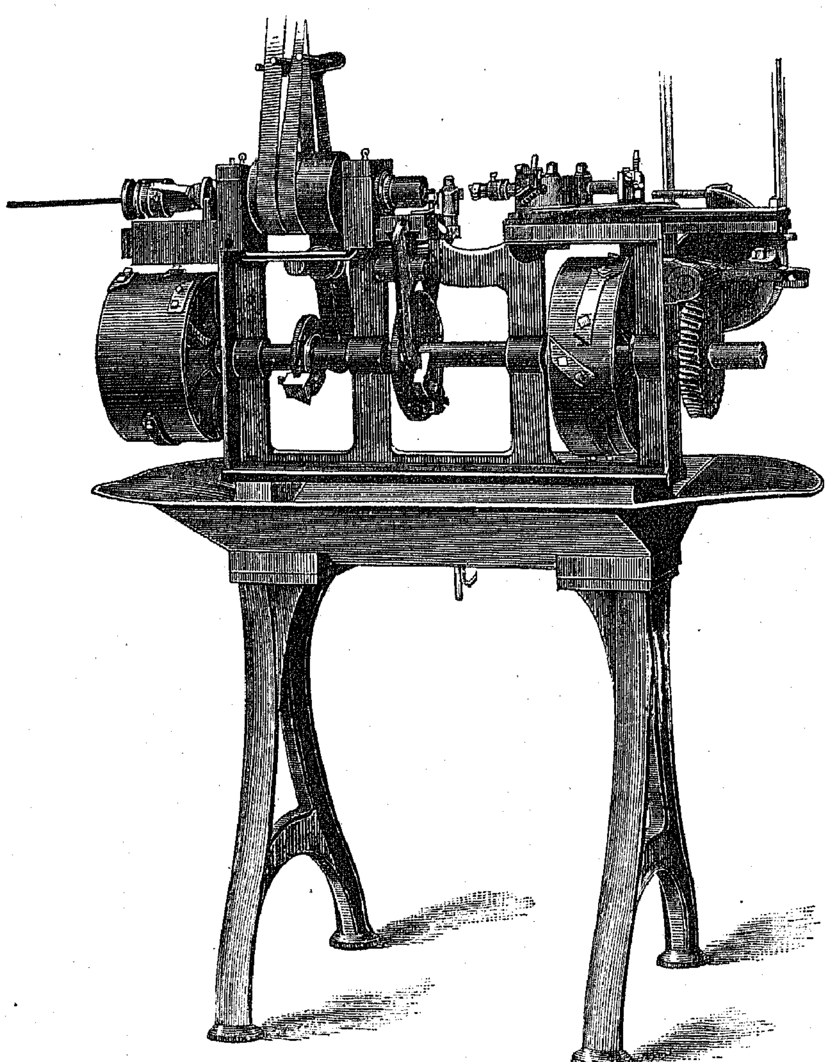
of which a detailed description is not permissible; but it is essentially wireworking machinery, involving, perhaps, no new principles of metal-working, but with features of special adaptation which have resulted from costly experiment and experience.

The steel wire is first straightened, then turned to taper, cut off and passed between two small mills, that groove it; but as the groove does not extend the full length after grooving, the rough needle is in automatic machines grasped by a small lever with jaws, withdrawn, and deposited in a tray. This grooving is sometimes done in a separate machine.

The punching of the eye is done with great rapidity, either by a small punch press or by a miniature drop. In polishing the needle and the needle eye, rolling, burring, and other finishing operations, ingenious contrivances are used, but the straightening after annealing has still to be done by hand-hammer and anvil.

The productive efficiency in needle-making has been greatly increased by automatic movements, and by combining mechanism so as to effect a transfer of the piece from one operation to the next without resetting by the human hand. In these respects needle-making has simply kept pace with other wire-working processes, in which such great development has been made within the past ten or fifteen years. From 6 to 8 per cent. of all the operative labor on sewing-machines may be considered to be employed in needle-making.

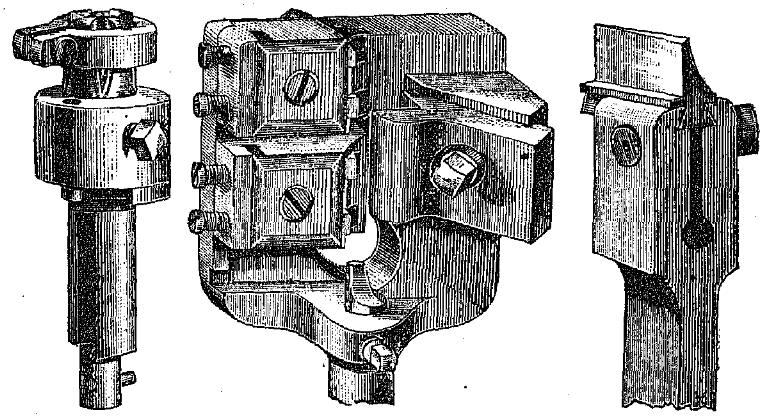


No. 10.

WOOD-WORKING.—Case-making for sewing-machines is a manufacture which, it is most obvious, may be entirely different from and independent of the manufacture of the sewing-machine movement; but since it is embraced among the departments of a complete sewing-machine factory, under one common system and management, it is here briefly considered. In sewing-machine work proper the value of product per operative is but little more than in the case work, but in the former the value of material used is about one-fourth, while in the latter it is about two-fifths the value of the product. In the former the horse-power required is about one-fourth of one horse-power, while in the latter it is upward of two-thirds of a horse-power per operative, and in the cruder operations of wood-working as much as four or five horse-power per operative. About six times as much power per machine is required for the wood-working as for the other machinery. While in sewing-machine work proper ten machine-tenders on the average attend seventeen to twenty machines, in case-making ten machine-tenders on the average attend eleven or twelve machines. In cabinet-shops the machine-tenders are less than half of all the hands. In the other departments of sewing-machine work (including the foundery and other non-machine work) the machine-tenders constitute as many as 60 per cent. of all the hands, and of the machine-shop work alone a very much larger proportion.

Of the machine plant required for case-making nearly 50 per cent. of the whole number of machines are sawing-machines, about 12 per cent. drilling and boring, 10 per cent. molding and carving, 10 per cent. sand-papering and polishing, 6 per cent. turning, 6 per cent. planing, and the rest machines for jointing, matching, dovetailing, sticking, and so on. But it is obvious that the numbers of many wood-working machines are increased for convenience of access rather than for anything like continuous use, and the output, as a measure of mechanical efficiency, becomes an impracticable consideration, as is the case with many machine tools. One saw-table, with an attendant, might, for example, suffice for doing the saw-table work on a vast number of table-tops of a specified pattern, but such figures might convey distorted ideas of the actual product and methods of manufacture. Wood-working machines require, when in use, an attendant to a machine, excepting in a few machines, such as surface planers, where two men are required to handle the stock. The machinery used in cabinet work exhibits some notable improvements, especially that of the molding and dovetailing class, and that used in the shaping of knobs, fancy moldings, and ornaments. In one case, in a nice operation of molding formerly done by hand, one man tending a special machine does a work equal to the hand-work of fifteen men.

Between metal- and wood-working machinery there may be stated this prime distinction: In metal-working the man has most frequently to wait for the machine, but in wood-working the operation is so much more rapid, and the material requires so much more handling, that the machine may be said to wait for the man. In the former case the problem is to devise rapid or semi-automatic machinery which will enable a man to utilize all his time; in the latter case the problem is to give a higher value to time already fully occupied, which may be best done by a wholesale manufacture, in which each man, by devoting himself to a single kind of work in repetition, insures a great saving of cost as compared with ordinary mixed cabinet work, a saving often four- or five-fold. A special machine will, for example, turn knobs faster than a boy can place them. Its highest efficiency is attained when the boy is fully occupied, and its productiveness is then so great as to reduce the cost to a very small sum compared with other portions of the work. It will not be profitable to introduce expensive mechanism for setting knobs faster than a boy can do it. This is cited to explain the absence of automatic machinery in wood-working and in many kinds of metal-working. In order to make it profitable to save labor by expensive machinery there must be a large principal of labor to be saved, and if this labor is already slight, by reason of the expedition of methods in use, the subject becomes less interesting to the capitalist than to the ingenious mechanic. The cost of other labor, and of handling, marketing, tariff duties, and so on, becomes so disproportionately large relative to the item of labor to be saved that the saving will not secure such a reduction of price as will, by an increased demand for the product, warrant the expenditure.



No. 11.

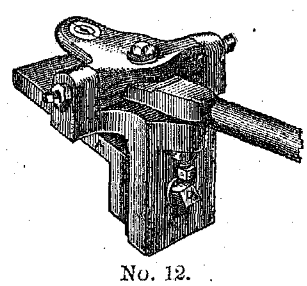
No one who examines the fitting and jointing of a piece of fine wood-work can fail to see the importance of interchangeability in the manufacturing system, although the parts may not be designed to be separated after finishing. Interchangeability saves a great amount of fitting and job work in the manufacture, and by careful kiln-drying and the filling and finishing of the wood, so as to prevent dessication or reabsorption of moisture with the consequent shrinkage or expansion of the finished wood-work, a high and enduring degree of interchangeability is attained in the most careful and substantial work.

OTHER WORK.—The small working parts of sewing-machines are annealed in oil. Being heated in furnaces, in iron boxes, the boxes are removed by suitable tongs from the furnaces, the lids are struck off, and the small pieces are poured into an oil-tank with a sieve-bottom, which can be raised for their removal.

In japanning, the legs of the stand are usually dip-japanned, the head being painted with japan of a different quality. Dip-japanning saves a great deal of labor, and in some cases, by special methods, it is applied to the finest work with results unexcelled by brush-work.

Until within five or six years past ornamenting has for the most part been done by skilled labor, some of the operatives attaining great efficiency in the work; but at some factories the work, by a process analogous to stencil work, is done by boys.

The assembling, setting up, and running of machines occupies a man on the average, with the division of labor, to from two to four machines per day. A girl employed in testing machines by stitching will try upward of twenty machines a day. In the matter of boxing, with the division of labor, one man will make and pack boxes for as many as twenty machines a day, using about 200 feet of lumber. For all the work about one foreman to thirty-five operatives and one clerk to fifty operatives may be considered average ratios. Teaming, porterage, and common labor occupy a considerable number of men, the common labor being partly general and partly divided among the several departments. Such figures as the foregoing are intended to convey average ideas of the division and efficiency of labor in large factories. As such, they are offered without apology, although for different factories such ratios will often vary greatly.



No. 12.

For the information embodied in this section of the report, the writer is indebted to many parties; but for courtesies extended, especial acknowledgment is due to Hon. Nathaniel Wheeler, of Bridgeport, and Mr. F. A. Platt, of Hartford, Connecticut.

IV.—THE MANUFACTURE OF LOCOMOTIVES AND RAILROAD MACHINERY.

A report on the manufacture of locomotives must needs be prefaced by some account of the product, and this may best be defined by briefly recounting the changes in that product from the earliest days until, by years of experience and by changed requirements, there have been gradually developed the salient features of the present types of American locomotives.

It is nearly fifty years since locomotive building was inaugurated, and when fairly beyond the experimental stage more men were required in the work per locomotive per annum than are now required. The locomotive of that time cost nearly as much as a standard passenger locomotive of the present day, while the latter is, on the average, three or four times as heavy, even more powerful in proportion, and incomparably superior in finish to the former.

In 1832 the "Old Ironsides" was built by Mr. M. W. Baldwin. It was modeled after the English "Planet" type, with a stiff wooden frame and inside connections. Up to 1840 most of the Baldwin engines were built with inside connections, as were also the earlier Rogers engines; but outside connections afterward became more generally approved, inside-connected engines having now become practically obsolete. Mr. Thomas Rogers was an early advocate of outside connections, and in 1837 filed in the patent office a specification for counterbalancing, which was not in general use until some years later, and even then was considered less essential to the inside- than to the outside-connected engines. In 1839, in Mr. Baldwin's practice, the outside frame was abandoned, and the machinery, truck, and pedestals of the driving-axles were attached directly to the boiler. From that time the wood parts of the frame were gradually displaced by iron. About 1837 equalizing beams were used on the Eastwick and Harrison engines, some method of equalizing being necessary to distribute the weight upon the two pairs of drivers then introduced. In 1841 Mr. Baldwin built some engines for freight traffic with the drivers geared, but in 1842 his six-wheel connected engine met with more general favor. In this the four forward wheels had inside journals running in boxes held by wide and deep wrought-iron beams, one on each side and disconnected, the engine frame on each side having a spherical pin bearing in a socket midway between the axles of the frame. The cylindrical boxes used could also turn in the pedestals, and the connecting-rods had ball-and-socket joints, with play enough to enable the engine to pass short curves.

The driving-wheels of "Old Ironsides" had cast-iron hubs, wooden spokes, and wrought-iron tires, and the driving-axle was placed in front of the fire-box. The "half-crank" for inside-connected engines was patented by Mr. Baldwin in 1834. The "E. L. Miller" (1834) had driving-wheels of solid bell-metal, which soon wore out, but later driving-wheels were built with hubs and spokes in a single iron casting, and wood fellies, breaking joint in thicknesses, and bound with wrought-iron tires, secured by bolts. In 1834 Mr. Baldwin built his engines with the driving-axle back of the fire-box, and Mr. Norris built engines with drivers in front. The latter plan gave the greater adhesion, and the former the longer wheel-base. To obtain the necessary adhesion, Mr. Baldwin had recourse to the Miller patent for throwing part of the weight of the tender upon the driving-wheels of the engine. It was at this time considered impracticable to cast a chilled car- or truck-wheel in one solid piece, and the hubs were cast in three pieces and banded together with wrought-iron, the interstices being filled with lead or spelter. The "Brandywine", Baldwin's eighteenth engine (1835), had brass tires, to give more adhesion, but they soon wore out. Mr. Rogers began the manufacture of wrought-iron tires in 1834, but in 1838 S. Vail & Co., Morristown, New Jersey, are said to have been the only American manufacturers of tires, which were then made only 1½ inches thick. In 1838 Mr. Baldwin began using chilled wheels for trucks, the truck-wheels having previously been made with tires; and in 1836 Mr. H. R. Campbell patented an eight-wheel engine with two pairs of driving-axles, one before and one behind the fire-box. This combined the plans of Messrs. Norris and Baldwin, and, with the addition of equalizing springs, was substantially of the same type as the standard American locomotive of to-day. The last half-crank engine was built at the Baldwin works in 1849. Steel axles were tried as an experiment about this time, and chilled tires for drivers began to be used a few years later. The use of steel tires shrunk upon the wheel centers was not begun until after 1860. These tires were then imported. In 1863 the Rogers works built their first engine of the "Mogul" type (three pairs of drivers with a pony truck), and the first engine of the "Consolidation" type (four pairs of drivers with a pony truck) was built by the Baldwin works in 1866. In these large freight locomotives some of the many drivers are made without flanges, to facilitate the turning of curves. In 1870 the practice of shrinking on steel tires, without the use of bolts or rivets, was begun at the Baldwin works in building some locomotives for the Kansas Pacific railroad.

In 1868 the introduction of narrow-gauge roads began to create a demand for suitable locomotives. Some of these narrow-gauge locomotives have been built of a weight of not less than 25 net tons, and within the past decade the manufacture of steam and compressed-air street cars and motors has been fairly inaugurated.

The use of four-wheeled swiveling-trucks was one of the features which characterized the early American as distinguished from the English locomotives; but one of the most notable improvements of American practice was in the invention by Mr. Baldwin of ground steam-joints, instead of joints made with canvas and red lead, then the English practice. With this change the steam pressure employed was raised from 60 to 120 pounds.

"Old Ironsides" had a loose eccentric for each cylinder. These loose eccentrics were reversed by a pin in a stop on the axle working in a half-circular slot. This was changed to a fixed eccentric for each cylinder, with rods extending from the eccentric straps to the arms of a rock-shaft beneath the foot-board of the engine, the reversal being effected by shifting the connection between the rods and the rock-shaft arms. In these early engines fixed eccentrics were commonly used, but Seth Boyden's "Essex" (1838) had valves worked without eccentrics, moving by levers from the cross-heads, each cross-head communicating motion to the valve of the opposite cylinder. In 1838 Mr. Baldwin adopted the use of double eccentrics, each terminated by a straight hook and reversed by a lever. He used, under specification, a form of link motion in 1840, and in 1842 a link motion similar to that used by Stephenson. (The link motion had been used by William T. James, of New York, in 1832.) In 1845 Mr. Baldwin adopted the half-stroke cut-off, in which there were two slides operated by separate eccentrics, the cut-off eccentrics being set at half-stroke. The same year Mr. Rogers began using independent cut-off valves, operated by various combinations of links and V-hooks, and in 1850 he introduced the present form of shifting link. Meanwhile Mr. Baldwin continued experimenting, introducing several forms of variable cut-off, one of which had a wrapping connection on a quadrant and curved link, for varying the position of the block. He then used the "Cuyahoga" cut-off, with lever and shifting link. Finally, in 1857, after putting on a number of them, under specification, he adopted the present form of link motion.

The "Old Ironsides" had a D-shaped smoke-box with sides concaved, to make room for the cylinder. The boiler was 30 inches in diameter, with 72 one and one-half inch copper tubes 7 feet long. The "Sandusky" (Rogers, 1837) had a bonnet smoke-stack with deflecting cone. Most of the early engines had high domes over the fire-boxes. In 1835 Mr. Baldwin commenced the practice of driving copper ferrules on the outside of the copper tubes, to make a tight joint with the tube-sheet, instead of, as before, driving the ferrule or thimble inside the tube. At present, with iron tubes and copper ferrules, the end is swaged down, the copper ferrule brazed on, and the iron projecting end turned or riveted over against the ferrule and tube-sheet. For copper tubes wrought-iron thimbles had also been used. These were found liable to leak, but about 1850 this defect was obviated by the use of cast-iron thimbles, a device of Mr. W. S. Hudson. In 1844 iron flues or tubes were first used in the Baldwin engines. Morris, Tasker & Co. had made lap-welded tubes in 1838, and butt-welded tubes prior to that year; and Ross Winans had also made iron tubes by hand for his locomotives. Experiment showed no appreciable advantage in copper over iron tubes. Mr. Rogers first used expansion plates to provide for the lengthening of the boiler under steam, and about 1850 the wagon-top was substituted for the dome boiler. Prior to this time there had been many experiments, with the view of burning anthracite coal, and in 1854 deflectors in the fire-box began to be used, sheet-iron, water-leg, and fire-brick deflectors being tried. In 1856 there were built at the Baldwin works for the Pennsylvania railroad locomotives having straight boilers with two domes, and in 1859 locomotives having "Dimpfel" water-tube boilers were built for the Philadelphia, Wilmington and Baltimore railroad. Fire-boxes of low steel began to be built in 1861, and had come into very general use by 1866; and in 1868 all-steel boilers (fire-boxes, barrels, and tubes) were built for the Pennsylvania railroad. In present practice both straight and wagon-top boilers are built. In 1876 steel boilers, with corrugated sides, were built at the Baldwin works for the Central railroad of New Jersey.

The "Old Ironsides" had $9\frac{1}{2}$ by 18 inch cylinders, the "Sandusky" 11 by 16 inch cylinders; in 1840 the largest Baldwin pattern had $12\frac{1}{2}$ by 16 inch cylinders. The "Gov. Paine", a fast passenger engine (1849), had $17\frac{1}{4}$ by 20 inch cylinders, and in 1852 a freight locomotive, weighing 56,000 pounds, had 18 by 22 inch cylinders. The first "Consolidation" engine (1866) had 20 by 24 inch cylinders, and the "Uncle Dick" (1878) had 20 by 26 inch cylinders. The cylinders of the early engines were generally inclined, but by 1865 horizontal cylinders had become the rule. Mr. Baldwin was the first American builder to use an outside cylinder, which was made with a circular flange, bolted to the boiler. In 1852, on some engines for the Mine Hill railroad, these flanges were brought around, nearly meeting, with only a spark-box between, and later each cylinder and half saddle was cast in one piece, and the saddles set face to face, and when horizontal cylinders came into general use the rights and lefts were made interchangeable.

The early engines had neither cabs nor sand-boxes. Cabs were first used in New England, and the first Baldwin engines provided with sand-boxes were built in 1846.

"Old Ironsides" was estimated to draw 30 tons gross 40 miles an hour on a level. In 1838 Mr. Baldwin believed that an engine weighing 26,000 pounds, loaded, and with $12\frac{1}{2}$ by 16 inch cylinders, was as heavy as would ever be called for; but the requirements of heavy freight and passenger service demanded, for economy no less than for convenience, larger and stronger engines, the heaviest ever built at the Baldwin works ("Uncle Dick", 1878) weighing, with water in the tank, 115,000 pounds. In 1849, at the Baldwin works, there were built a number of fast passenger engines of the type of the "Gov. Paine" (Vermont Central railroad), which could start from rest and run a mile in 43 seconds; but these engines lacked sufficient adhesion. Within the past few years some attention has been given to the manufacture of fast passenger locomotives, a number having been built which, with light trains, will run 60 miles or more an hour. Of these, a locomotive for the Bound Brook line has a single pair of 6½-foot drivers and a patented arrangement for varying the distribution of the weight between the drivers and a pair of trailing-wheels.

At the Brooks locomotive works the average weight of locomotives built in 1869 was 28 tons for passenger and 30 tons for freight engines; but the average is now 35 tons for passenger and 42 tons for freight engines, showing a rapid increase in weight, and it is believed by many that 50-ton consolidation engines will soon become the prevailing type and size for American freight service.

Examples of the performance of engines might be given at great length and in great variety. For the Baldwin engines the loads are calculated on the basis of the utilization for adhesion of fully one-fourth the weight on the driving-wheels. A standard "American type" passenger locomotive, with 35,000 pounds on the driving-wheels, will pull 1,000 tons gross on a level, and on 1, 2, and 3 per cent. grades will pull 25½, 12½, and 7½ per cent. of that load respectively; a consolidation engine, with 94,000 pounds on the driving-wheels, will pull 2,740 tons gross on a level, and on 1, 2, and 3 per cent. grades will pull 26¼, 13½, and 8 per cent. of that load respectively. In some heavy freight- and switching-engines the entire load is upon the driving-wheels, consolidation locomotives having usually 85 to 88 per cent., Moguls 80 to 85 per cent., standard American passenger locomotives 60 to 70 per cent., "double-enders" about 50 per cent., and fast passenger locomotives as little as 35 to 40 per cent. of their total weight upon the driving-wheels.

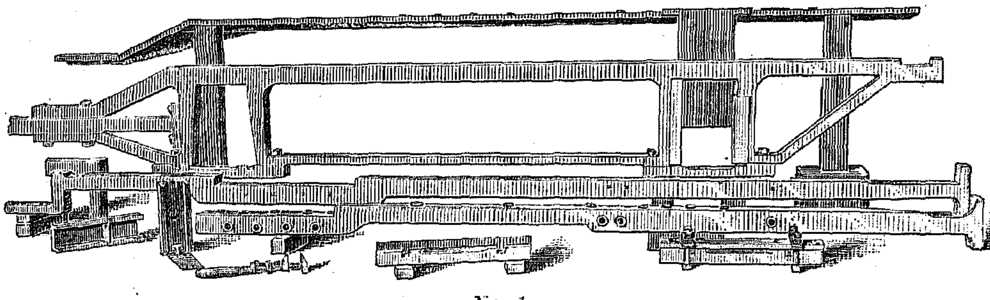
The endurance of an engine in service is very great, but the necessary repairs will average from 1½ to 6 or 7 cents per mile, according to service. Steel tires last six or seven years before wearing out. In the transitional stage of locomotive building, engines capable of much longer service were not infrequently broken up, laid aside, or made over on account of the introduction of improvements in design. At present the high quality of material and of workmanship promises a degree of endurance which will require many years to ascertain, and the uniformity of parts cannot fail to lessen the cost of repairs. It must, however, be remembered that the service required of a locomotive is much heavier and more exacting than it was ten years ago, cars often being loaded twice as heavily, and the weight of trains actually drawn averaging nearly twice as heavy for the same size of locomotive.

The present American locomotive may be fairly considered an established criterion of excellence. It is characterized by accuracy and beauty of workmanship and strength, combined with flexibility and adaptability to many difficult conditions of service—an adaptability which has given it the precedence where such conditions have to be met. Although the great demands of railroad traffic and travel in this country have absorbed the greater part of the product, American locomotives have been supplied to foreign countries using railroads in such numbers as to make them an important factor in the extension of facilities of travel and communication abroad.

The manufacture of locomotives in locomotive-works is so far based upon the use of costly and partly-finished materials that the additional labor and expense involve less than half the value of the final product. The iron and steel plates, steel tires, sheet-brass and iron, copper pipe, smoke- and feed-pipes, chilled wheels, bolts, rivets, hardware, fittings, boiler-tubes, flues, and other materials are in themselves costly products, and some of the forgings and the steel and iron castings are often produced for the work by separate establishments having special facilities. On the whole, the raw material, properly speaking, has its value more than trebled before it is brought into the locomotive-works as material for the manufacture. In comparing the manufacture of locomotives with the manufacture of small engines or of sewing-machines, where the value of material in locomotive manufacture is doubled, in that of small engines it is nearly trebled, and in sewing-machines quadrupled; but in locomotive building the same increment of added value requires the employment of a considerably greater number of artisans (at similar rates of wages) than are employed in the manufacture of small engines; principally because the prices of locomotives are ruled by the wholesale purchases of large railroad corporations, while the prices of small engines and machinery are ruled to a great degree by small buyers making single purchases. In short, in the manufacture of locomotives, the cost of putting the product upon the market is reduced to a minimum, and of the same added value given in the manufacture and marketings about 50 per cent. additional goes for the employment of artisans in locomotive building, as compared with the general manufacture of steam-engines. The composition by weight of the various crude and finished materials in a locomotive and tender weighing about 45 tons (net) may be stated as follows: About 32 per cent. pig-iron, 18 per cent. bar- and hammered-iron, 9 per cent. boiler-iron and steel (about one-fifth of which is for the fire-box), 8½ per cent. steel tires, slides, springs, and the like, 7 per cent. wheels, 7 per cent. wood for cab, tender, and lagging, 5 per cent. axles and connecting-rods, 4 per cent. flues, 3½ per cent. tank-iron, 2 per cent. lead, tin, copper, smoke-pipe, glass, hardware, and fittings, 1½ per cent. bolts and rivets, 1½ per cent. cast- and sheet-brass, and 1 per cent. sheet-iron.

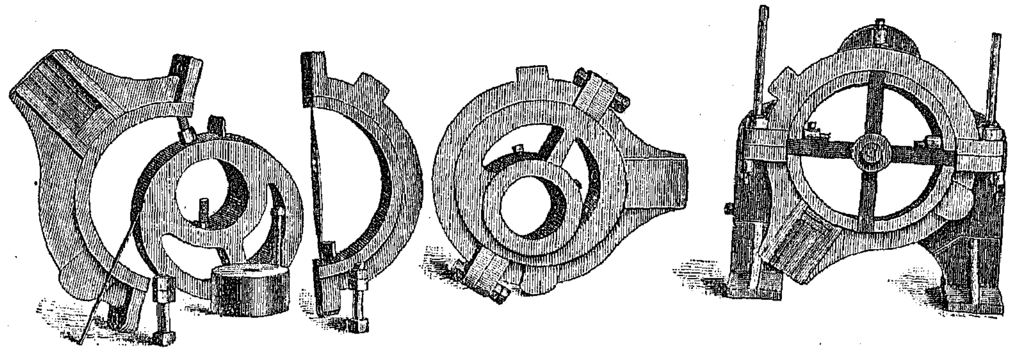
The market value of a locomotive in 1880 was less than three-fourths as great as it was in 1870, the descent in value being very gradual, with the exception of a very notable rise in 1873 and a slighter appreciation in value after 1879.

These fluctuations have mainly followed the general shrinkage of money values and the fluctuations in the cost of material, influences great enough to conceal any evidences of improvement in the methods of manufacture such as might here be looked for. Nevertheless, there has been a very general advance in the details of system and machinery, which is confirmed in aggregate results of the capability of a given number of men to perform a given work. Locomotive-works have each their individual status, some having had less room for improvement at the beginning of the decade. Although interchangeability of parts is coming to be so general in almost every line of machinery, the system of gauging may still lack thoroughness, partly requiring measuring-rods and adjustable calipers, till a well-maintained system of standard gauges is secured. The character of such standard gauges is very well shown in some illustrations here adduced from the practice of the Grant locomotive works, of Paterson, New Jersey. There is shown (No. 1) a locomotive frame, with pedestals and fittings and a number of the gauges, the most



No. 1.

noticeable of which is a long gauge with hardened bearings for drilling. In the second illustration (No. 2), showing eccentrics, eccentric straps and gauges, there is on the right a jig-frame, which is of the nature of a gauge, being a frame designed to hold a machine part while certain exact operations are performed upon it. In planing, the



No. 2.

hardened templates used are of the sections of the forms to be planed, and limit the operation. In turning, collars and rigid calipers are commonly used. Now, while by such devices there is secured a practical uniformity in all the proper machine parts of a locomotive of the same class and make, yet, if there was not such a multiplicity of standards or different designs of locomotive, the advantages of the system would be much greater. As nearly every leading railroad and nearly every locomotive establishment has its special designs, the system is largely impaired, not through any lack of standard sizes or accuracy of workmanship, but because standard is opposed to standard, and the expense of changing designs is an obstacle to uniform standards. Thus it is the uniform system that stands in the way of its own advancement. If the locomotives of a great railroad were built without reference to any close degree of uniformity, it would be comparatively easy to gradually effect the introduction of any uniform system; but if, as is the case, that railroad already has great numbers of locomotives of a specified design and standard, the effort to bring its standard into conformity with that of any other road or of any locomotive-works meets at once another standard and a standing obstacle. On a great railroad the slightest changes in equipment are usually the subject of careful and conservative thought, because a small innovation, running through the whole equipment, becomes a serious matter of expense.

But when we consider how large a proportion of the whole railroad service is engaged in the work of railroad repair-shops the importance of a uniform system of standard locomotives becomes sufficiently obvious. On this subject I quote the following from the circular of the Baldwin locomotive works:

> By its means the expense of maintenance and repairs can be reduced to a minimum. A limited stock of duplicate parts, either ordered with the locomotive or at any time thereafter, can be kept on hand by the purchaser and drawn from to replace any worn-out or broken part when required. Repairs can thus be made in the shortest possible time, and the use of the locomotive lost for only a few hours or days, or not at all. The first cost of duplicates will be much less than the cost of manufacture in the shop of the railroad company; in many cases it will be less than the cost of carrying the stock of raw material necessary for the purpose; while if the line is equipped with a limited number of classes of standard interchangeable locomotives, the quantity of duplicates necessarily carried in stock will be small and comparatively inconsiderable in the amount of capital represented. Much of the ordinary outlay for shops, machinery, drawings, and patterns can be saved, and the necessity of maintaining for the purpose of repairs a large force of skilled workmen at a constant expense may be in great measure obviated.

Without uniformity of parts repairs of locomotives, like any other species of tinkering, are costly out of proportion to the original expense of manufacture. As the requirements of a railroad in the matter of repairs vary greatly from time to time, the surplus force of skilled workmen, which must be maintained to meet contingencies, is usually employed in the building of locomotives, many repair-shops turning out a few locomotives per month or per year.

But while the advantages of the uniform system might be of still greater avail in the economy of railroad management in the manufacture of locomotives, this system has within the past twenty years wrought a great change, improving the product both in quantity and in quality, securing a more economical division of labor, putting the more skilled work into the hands of fewer men, and preserving administrative conditions of order and simplicity.

The advantages derived may not appear great in descriptive detail, but they are by no means small in the aggregate. It may be said of machine work in general that the following were some of the evils to which the old methods of working were strongly liable: The lack of uniformity began in the drawing-room. The drawings were of various shapes, sizes, and scales, and when sent to the blacksmith-shop would often become so singed and discolored that new ones had to be made. In the machine-shop the machinist would need to be skillful in interpreting the drawings, and when in doubt as to the meaning of lines or figures intended for other parts of the work, or as to discrepancies between figures and scale, he would need to consult the foreman or the draughtsman. No two men will measure exactly alike with a graduated rule or an adjustable pair of calipers capable of being sprung, and when these are used slight discrepancies will occur. And so when it came to the erection of the work, filing and fitting and making over, and perhaps conferences of the various fallible parties to apportion the blame for mistakes, were not unusual. Old castings and materials were often left lying about the shops, to the inconvenience of skilled workmen, and the whole work was carried on with trial and fitting and the apprehension of occasional mistakes.

In contrast is presented the following outline of the system pursued at the Baldwin locomotive works, where the interchangeable system was introduced about 1860. Standard office drawings to a uniform scale, with all parts figured, are first made of any new design proposed to be manufactured. Small sketch drawings, mounted on pasteboard and shellacked, are furnished to the pattern-makers for castings, to the machinists for each finished part, and to the erecting shops to show the relative positions of parts only. These cardboard sketches are on uniform sheets, and are carefully numbered and recorded, with all necessary reference to the engine to which they refer, in a considerable system of book-keeping. They are given out as the work demands, and are required to be promptly returned to the accountant on its completion. But the drawings for the blacksmith-shop are so liable to become destroyed that, with a view to this, they are made on tracing material, and the record is preserved in the original of the tracing. Each sketch, before being given out, is examined and verified by three men, the measurements which concern the work of each class, and these only, being figured on the sketch, which is not generally drawn to scale. The gauges are made in a gauge-tool shop, which constitutes a separate department. From this shop the gauges are furnished as drawings are furnished from the draughting-room, and to it they are returned for comparison with standards. The calipers, rods, and templets made for the work in the gauge-tool shop are the only standards of measurement allowed in the machine-shops, no graduated rules or scales being used. Most of the machinists have only to work to the templets given them, and cannot possibly misunderstand or make errors. All the bolts, fittings, and small parts for a particular engine are kept in a separate cupboard, in readiness for assembling, and are interchangeable for the same class of engines. It is the duty of one class of laborers to remove to their proper places all refuse pieces of material which may be left about on the floors of the shops, and to keep all material stowed away with economy of space. In short, the whole system is so ordered that each man has a simple work to do, in which he is unfettered and unhampered, and in which it is scarcely possible for him to err. No mistakes are made, nor is time or material wasted. These considerations are so valuable that in large works the saving in such a system, displacing less thorough and orderly methods, may be rated in the labor of hundreds of men.

At the Baldwin locomotive works all parts of the locomotive are made interchangeable, except the fitting strips for the boilers. It was formerly regarded impracticable to make check-pipes and valves interchange, on account of the variation in the length of the boiler; but they are now made interchangeable by starting measurements uniformly from one end of the boiler. Valve-gears are made interchangeable to the setting of the valve. The eccentric straps are drilled to templet, and the work would generally interchange, but as a precaution the eccentric is drilled with the strap fitted. The frames are planed and slotted to gauges and drilled to steel-bushed templets; the cylinders are bored and planed to gauges; the steam-ports, valves, and chests are finished and fitted to gauges; and the tires are bored to gauges. The centers are turned, and the axles are finished to gauges; every bolt is made to gauge, every hole is drilled and reamed to templet, and the cross-heads, guides, guide-bearers, pistons, connecting-reds, and parallel rods are finished in a similar manner.

At the Grant works the ports in the valve-seat are milled to size by a cutter from a gauge which is bolted upon the valve-seat. This cutter works in a block, which slides in slots in the gauge corresponding to the ports. The guide-blocks also are faced off in a special chuck (which receives a full set) to an exact thickness. Some parts of the work are finished by jig-filing to hardened templets.

In respect to capital required, it will be found in general, although with the exceptions to which this item is specially liable, that if the number of operatives be taken as a basis of comparison the capital reported will range somewhat less for locomotive building than for the wholesale manufacture of certain classes of smaller mechanism, such as sewing-machines, fire-arms, and small steam-engines. The capital required in a manufacturing business may be classified into that necessary for carrying stocks of material and finished goods, for the cost of real-estate plant and of machine plant and power and the floating capital necessary to cover the conditions of trade, and the payments for labor and expenses until the avails are realized.

In locomotive building the cost of carrying material is a large item, but in point of fact, as far as the mere weight is concerned, a single operative will on the average turn out nearly as many thousand pounds product in a large sewing-machine factory as in the locomotive-works, and although the material is more costly in the latter case no finished stock has to be carried.

As to machine plant, the power per operative will not average much greater for the locomotive-works than for a sewing-machine factory (perhaps one-third horse-power per operative in one case and one-fourth horse-power per operative in the other). The estimated value of machinery per operative is often greater in sewing-machine than in locomotive work. As to real estate, where a given acreage suffices for the turning out of a given weight of locomotives, the same acreage is found to be utilized by the larger sewing-machine factories in turning out a less weight of sewing-machines, and in some instances a less value and less than half the weight for the same area of floor space.

And, finally, in the marketing of goods, the maintenance of agencies and city offices, and the contingencies of trade, the manufactures of smaller mechanism often require a capital which places the aggregate beyond the requirement for locomotive building.

Taking as an approximate unit of comparison a standard eight-wheeled engine of the American type, with tender, the engine weighing about 30 tons net, and being worth in 1880 about $8,000, we may estimate for the various functions of locomotive manufacture under the usual range of work that to make 100 locomotives per annum will, on the average, require about six (generally between five and seven) men per locomotive, and that about 28 per cent. of the operatives will be occupied in erecting (including some fitting, finishing, wood-working, cab-making and common labor, but not including boiler-shop work), about 17 per cent. in the foundery (including the laborers, who will constitute a large proportion), about 22 per cent. in the machining (including machine-tool work in the erecting-shop, but not the machining of boilers), about 10 per cent. in the forging (exclusive of boiler work), about 14 per cent. in boiler and tank making, and about 9 per cent. in clerking, teaming, and general and unspecified service. It should be said, however, that these proportions vary greatly from the different ranges of work and conditions embraced in the manufacture, and that it is not easy to draw a definite line between some of the departments, nor to eliminate the uncertain factor of common labor. Increased efficiency appears to result more from improved general system than from devices of mechanism, the gain in erecting and some other branches of the work being so great in some cases as to leave the machining a greater percentage than before. But the saving in labor in some actual cases has been from one-fifth to one-third, as evidenced by various methods of comparison.

The number of locomotives produced per annum per acre of plant is found to range from 20 to as high as 50, and three or four operatives (all included) may be estimated per piece of power machinery and about one horse-power per power machine, about two-fifths of the power being for steam-hammers.

FOUNDERY WORK.—In heavy foundery work there has been no such notable improvement as in the casting of light hardware. In locomotive-works comparisons between the same foundery in 1870 and in 1880 are not always significant, since steel and other castings may be manufactured at separate establishments, and while the output in locomotives is increased the foundery may not be proportionately enlarged. Cast-steel, which is usually made by separate concerns, is coming into more extended use, displacing cast-iron, on the one hand, on account of its threefold greater strength, and displacing difficult wrought-iron forgings on the other, on account of its less expense. Cross-heads, rocker-arms, wrist-pins, links, and blocks are very commonly made of cast-steel and purchased as material for the work in the form of manufactured castings, not costing half as much as forgings for the same parts, and being so much closer to size that there is also an economy in the machining. Steel castings for these purposes range at about 10 cents per pound. Within the past few years steel cross-heads have very generally displaced cast-iron cross-heads. Springs are of cast-steel. Tires were formerly made of wrought-iron, turned and welded; but cast-steel tires are now used, being first cast, then punched and hammered under the steam-hammer, then hammered upon the beak of an anvil to bring them to size for rolling, three rolls being employed, the central and largest one carrying the tire, while the others roll upon it. The advance in the use of cast-steel, it may be here observed, has been common to many manufactures. In 1831 it displaced double shear-steel for sword blades (in the practice of the Ames Company), and over ten years later began to be used in the manufacture of fire-arms, in which it has now displaced wrought-iron to a great extent. In agricultural implements (notably in plows, in which it was used at an early date) and in machine parts its use has been continually advanced, and since 1860 it has had a steady growth in locomotive building, as in other manufacturing.

In some cases the foundery facilities of locomotive-works are partly applied in making heavy castings for turn-tables and other work, so that the weight of lump coal and pig-iron (with due allowance for wastage) appears in excess of the weights that would be required in the castings of the locomotives turned out. For a standard passenger locomotive the weight of iron castings may be reckoned at a little over a third of the total weight, or, to give it roundly, for a 30-ton locomotive the weight is 11 tons net, of which a large proportion is in the wheels and the two cylinders and half-saddles, the balance being made up in the weight of eccentrics and straps, mud-hole plates, smoke-box front, dome and sand-box bases and tops, smoke-stack base, pedestal wedges, saddles and seats for springs and trucks, glands, steam-chests and covers, piston-heads and followers, shaft stands and brackets, axle-collars, boxes, counterbalance weights, dry pipes, T-pipes in smoke-box, slide- and throttle-valves, coupling castings, mud-rings, grates, roof-ribs and furnace castings, and sometimes pumps, cross-heads, and other parts. The average weight of metal cast per day in locomotive founderies is observed to be about 75 pounds per operative per day, which would require about 100 men to make the castings for 100 locomotives per annum.

Cylinder iron is sometimes specified as Lake Superior charcoal. Grades of American iron from native ore furnish castings of great excellence for various purposes. Cylinder iron is hard, being commonly of a mixture of the grades known as No. 2 and mottled, No. 3 being the hardest grade usually run out of the furnaces, which will sometimes run one grade of iron and sometimes another. The pig-iron is sorted to insure the flowing of the desired grade from the foundery cupola.

FORGING.—Of the wrought-iron used in locomotives, the heavier parts, such as the frames, axles, and connecting and piston rods, are commonly of hammered iron, the lighter parts, such as truck-frames, roof ribs, bolts, and rock-shafts, being made of bar-iron. But of the aggregate weight of wrought-iron, exclusive of plates, sheets, bolts, rivets, and tubes, the greater part is of bar-iron. In the early history of locomotive manufacture a blacksmith was not able to weld a piece of iron upward of 2½ inches in diameter, but since that time there has been a great growth in the facilities for forging.

Some parts of locomotives are, as staple goods, largely merchantable in a more or less finished form, and improved facilities may sometimes not only effect a greater division of labor among the men of a factory, but in a wider commercial sense among parties and companies. This, however, for locomotive building, should not be overstated, as the great body of the work remains intact, and any diminution of work which may result from such causes is more than compensated for by the greater requirements of finish and workmanship. Each manufacturer is disposed to make all the parts of his machine, where a specially large investment is not required. If, for example, locomotive-works were capable of consuming the entire product of a rolling-mill, it might profitably be established as a department of the works; but since such an establishment would generally involve the general manufacture of boiler-plate and sheet- and merchant-iron, it is left in separate hands. The manufacture of cold-rolled iron, which illustrates this point, deserves some mention in this connection. The superiority of this material as compared with ordinary turned and machined wrought-iron is sufficiently established by a series of tests made by Messrs. Whipple, Fairbairn and Wade, and more fully by Professor Thurston, showing it to be from 25 to 40 per cent. more tenacious, 50 to 80 per cent. stronger in ultimate resistance under transverse stress, 80 to 125 per cent. stronger in resistance to permanent set, whether of twisting, tension, or bending, and much more capable of enduring shocks, and more uniform in strength and density. While the introduction of steel, cold-rolled iron, and other improved materials is, so far as these materials are made by outside parties in partly-finished form, a guarantee of the better quality and endurance of locomotive work, the manufactory is obviously relieved of this portion of its duty. The use of cold-rolled iron saves some forging, and even lessens the work of machining, as it may be more easily worked than hot-rolled iron, and for round section and other forms of bar may be rolled exactly to gauge, requiring little further preparation. It is now made as large as 4½ inches round, and is applied for a few locomotive parts, such as guide-bars and pump- and piston-rods.

While in the special manufacture of large forgings, such as axles, upward of 400 pounds of forgings are sometimes turned out per operative per day, in the forging-shops of locomotive-works the forgings, large and small, will average about 80 or 90 pounds per operative, and there are about two-thirds as many fires as blacksmiths. Such forgings as axles, rods, and shafts, which, from their regularity of form, can be easily hammered or rolled, are made cheaper than steel castings.

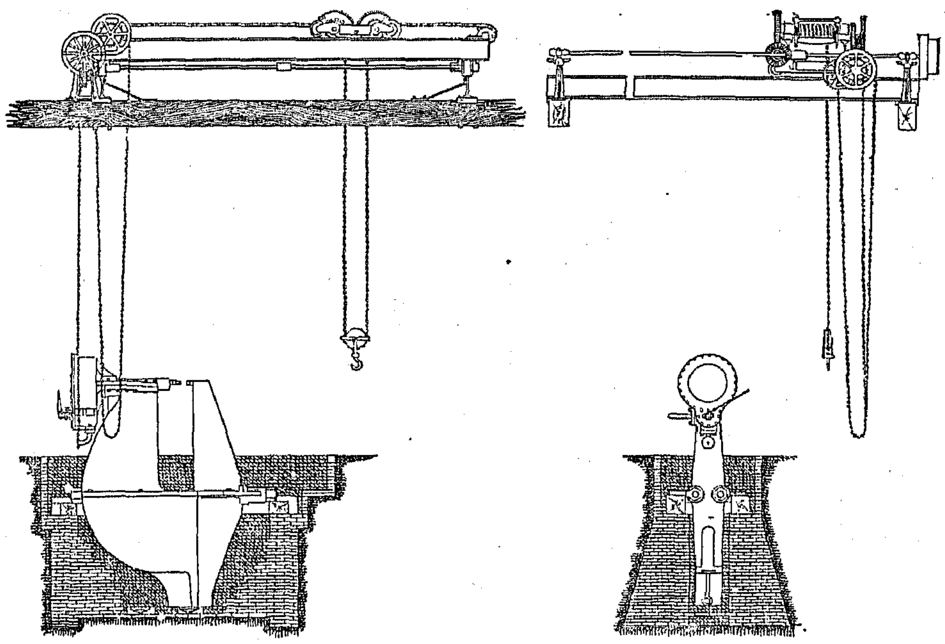
Blacksmithing, on the whole, involves more skilled labor than any other department of the work. The weight of steam-hammers in active use ranges near 145 pounds per operative in the blacksmith-shop for a number of works, 10 or 12 horse-power being required per ton of hammers, and about 24 tons of soft coal, for blacksmithing and boiler-making, are required per locomotive produced. Such statements as these may serve to convey tolerably correct ideas, but the conditions are so diverse in all this class of work that it is difficult to find any fact or ratio which can be stated as the invariable rule. Of two locomotive-works of almost the same capacity, one may, for example, be equipped with much heavier hammers than the other, and, so far as can be estimated, may, from the character and condition of its machinery, consume a very different amount of power.

BOILER AND TANK WORK.—In boiler and tank making about 60 pounds of material, boiler- and furnace-plate, tank-iron, tubes, bolts, and rivets, will be handled per operative per day. The barrel of the boiler is usually specified to be of the best cold-blast charcoal-iron, although sometimes it is of flange-iron or of steel. English locomotives are generally built with fire-boxes of copper, which, although more costly, is considered by American builders as inferior to a proper steel. Steel fire-boxes began to come into general use ten or twelve years ago.

Formerly either copper or laminated iron (made by rolling three plates together) was used. Such iron had a sufficient tensile strength, and was used in wood-burning locomotives, but would not suffice for the fire-boxes of coal-burning locomotives, on account of the imperfect welding, unequal expansion, and the strain between the plates. This was in some degree remedied by hammering the iron before rolling, but steel was found to answer the purpose better. Crucible steel was first used, afterward Siemens-Martin steel. The foreign steel was found to work less satisfactorily than the American, being of too high a grade and containing too much carbon (about one-fourth of 1 per cent.); but the American manufacturers began to produce a low steel, containing from one-sixth to one-tenth of 1 per cent. of carbon, and sometimes called homogeneous iron, which, on account of its uniformity and excellence of quality, was found especially adapted to the requirements of locomotive work.

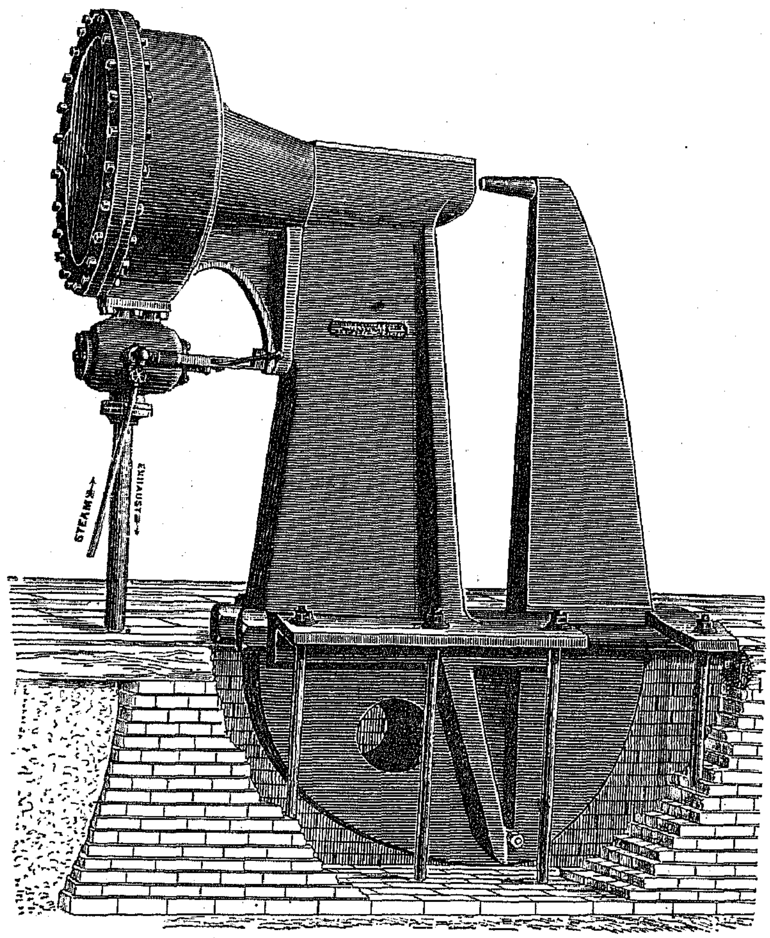
While all steel sheets for fire-boxes or boilers are required to be thoroughly annealed before delivery, those which are flanged or worked in the process of boiler construction are usually annealed a second time before riveting. Longitudinal joints are generally double, bias joints triple, and straight cylindrical joints single riveted, the spacing ranging from $1\frac{3}{4}$ to 2 inches for $\frac{1}{4}$ to $\frac{3}{8}$ inch boiler-iron and $\frac{5}{8}$ to $\frac{3}{4}$ inch rivets.

The plate work is principally comprised in the machine work of rolling and shearing plate, punching, drilling, riveting, and plate-planing, and the bending, flange-turning, rivet-heating, and hand-riveting, the fitting and setting up of the boiler, and the calking. The skilled trades in the work may be esteemed of two grades, the boiler-making, or fitting, and the flange-turning ranking first in point of skill required, and the hand-riveting and calking second. In hand-riveted work the riveters and calkers will each outnumber the flange-turners three or more to one, and there will be one rivet heater (usually a boy) to every two riveters, and about as many ordinary helpers or laborers as rivet heaters. Locomotive boilers are, for the most part, riveted by power. The boiler is suspended from a traversing crane or hoist, and upward of five or six rivets may be placed in a minute. With a permanent steam riveting-machine on light bridge iron thirteen or fourteen rivets can be placed in a minute, but this is too fast for boiler work, and the boiler cannot be swung into place and the rivets set with any such rapidity. In the plain work on boilers, when done by hand, the boiler is rested horizontally in chains over a beak, and shifted from rivet hole to rivet hole by moving the chains. Two men will in this way place a rivet in two minutes. In other special hand-riveting, with one man holding a heavy hammer as anvil within the boiler and two men striking, as much as five minutes is observed to be occupied in placing and hammering the rivet. In general, as compared with hand-riveting, the advantage of power-riveting is upward of fivefold in the matter of speed, beside producing a better quality of work. An illustration is given (No. 3) of a steam riveting-machine, with crane or hoist, and fixtures for hanging a locomotive boiler. An illustration is also given (No. 4) of a riveter built by William Sellers & Co. Compressed-air riveters are used with similar advantage.


No. 3.

An illustration is given (No. 5) of a labor-saving arrangement for punching plates. This machine is driven by fast and loose pulleys, and has a clutch for starting and stopping the head. The punch-lever is actuated by a cam moving on a friction roller, and is connected with the punching slide by vibrating links, with adjustment for wear. A device called a stripper, adjustable to any thickness of iron, holds the sheet while being punched. The table, as shown, will hold iron under 15 feet long, and of any practicable width. The automatic movement of the table is effected by a screw, placed diagonally in the bed, moving the table by a nut fitted to slide in a transverse groove, the obliquity of which may be changed at pleasure, so that any spacing under 3 inches can be obtained automatically, and so correctly that two sheets so punched may be rolled into cylindrical form and the holes will exactly coincide for the fitting. This machine will punch 14 or 15 holes per minute in $\frac{3}{4}$-inch iron. In punching heavy plates some form of table, chain support, or rest is necessary, but the plate is often moved by hand. Plates are often held by chains from a crane and fed forward by hand. Five men thus holding a rather small $\frac{3}{8}$-inch plate (one of them also throwing the punch-press in and out of gear) were observed to punch 18 holes in a minute.

An illustration is given (No. 6) of a multiple drill for drilling boiler-plate. These multiple drills are built with from 12 to 20 spindles, and with this amount of spindles will, upon plain work, drill the holes about as fast as they can be punched, leaving a smooth, clean cut, and the strength of the iron unimpaired. The drills may be accurately spaced by means of stop-gauges, and the spindles may be adjusted separately for different lengths of drills, although all are brought into action and reversed by the movement of a single lever.

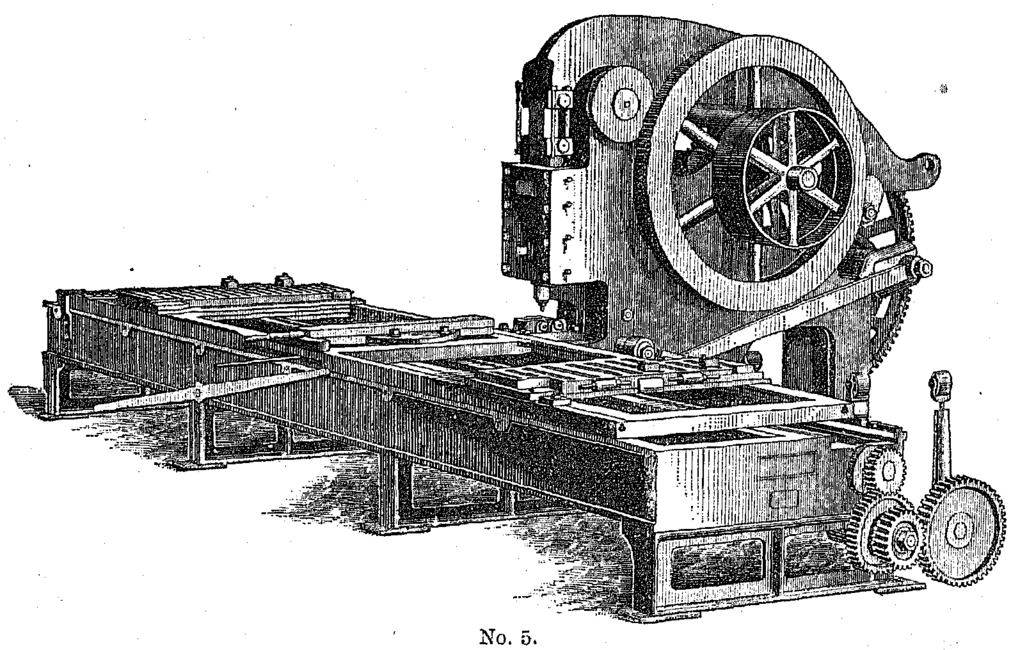


No. 4.

One of the most notable labor-saving machines that has been introduced into locomotive work is the Bement plate-planing machine, shown in the illustration (No. 7). It is necessary to chamfer or bevel the boiler-plates before calking. Prior to the introduction of this machine the work was done by workmen chipping with hammers and chisels. This machine, with one attendant, will plane plates 15 feet long and 1 inch thick, from one to three tools being carried on the traversing carriage, and will do the work formerly done by fifteen men with hammers and chisels. A 15-foot plate may be planed in ten minutes, and on rough work three or four plates are planed in an hour.

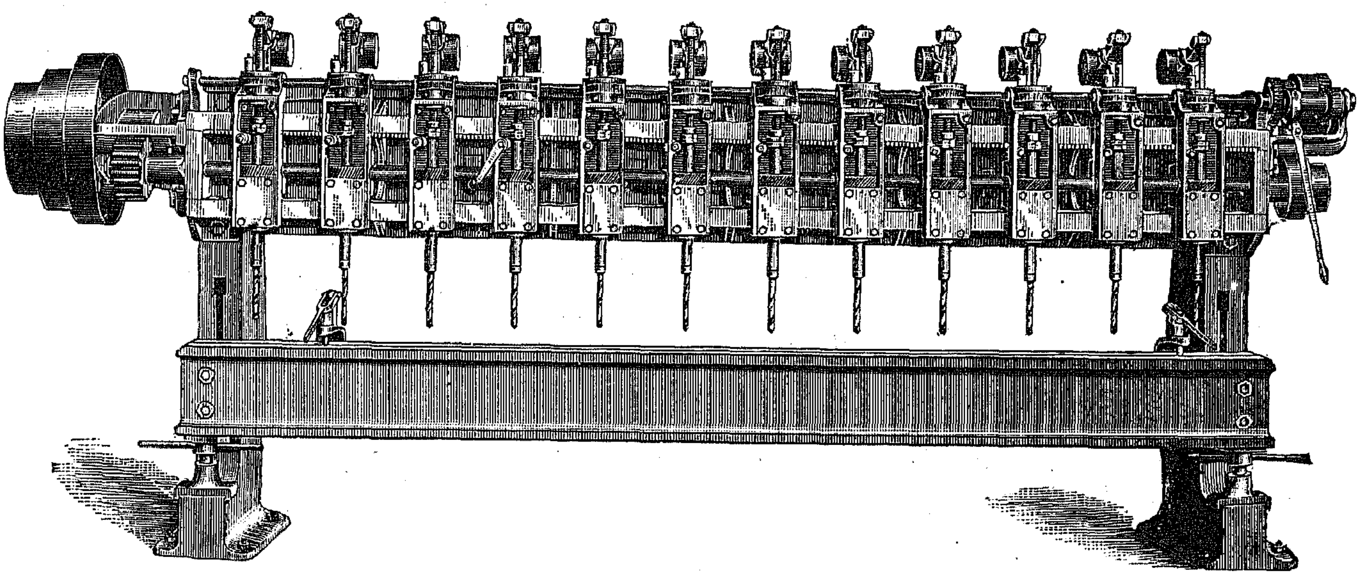
MACHINING.—While in some species of forged work, where dies and rolls can be conveniently used, the forgings are made closer to the required form than was the previous practice, in common shop forgings the reverse is the case, the metal-working machinery now in use handling and working the material with so much greater facility that the forgings need not be brought so closely to size. Thus it is, within limits, more profitable to machine them than to forge them down to size, and we have an economy in one department effected at the expense of another, although in the multiplicity of other conditions it might be useless to seek for the evidences of such minor tendencies in any general statistics.

A piece of mechanism is not a precise unit, and statements regarding the numbers of machines constituting a plant are of little account without a pretty full understanding of the nature and efficiency of the machinery thus enumerated. The number of operating tools is another basis of enumeration, but is scarcely more definite. A tool to a machine is the common ratio, but many of the improved planing- and turning-machines rest their essential merit upon the labor-saving and the speed resulting from the simultaneous operation of from two to five tools. The percentages of the different classes of machinery constituting a large plant are found to be 28 per cent. planing- and slotting-machines, comprising large, medium, and small power planers, pony planers, link-curve planers (which might be rated as turning-machines), slotting-machines, and special frame-slotting machines; 26 per cent. turning- and boring-machines, comprising wheel lathes, axle lathes, large, small, and medium power-feed lathes, hand-feed lathes, cylinder-boring and vertical turning- and


No. 5.

boring-machines; 13 per cent. drilling-machines, comprising drill presses and traverse drills; 12 per cent. power presses (exclusive of shearing, punching, and riveting), cranes and hoists; 5 per cent. punching and riveting presses; 5 per cent. screw-cutting machines; 3 per cent. grinding and polishing apparatus; 3 per cent. forging machinery, comprising steam-hammers, sets of rolls, and bending and bolt-forging machines; 2 per cent. power shears; 2 per cent. wood-working machinery; 1 per cent. milling machinery. In many cases the turning- and boring-machines would outnumber the planing- and slotting-machines.

The number of operatives per power-machine in locomotive-works ranges from five to three. The number of men per machine in the machine-shops has in some shops been greatly reduced within the decade on account of

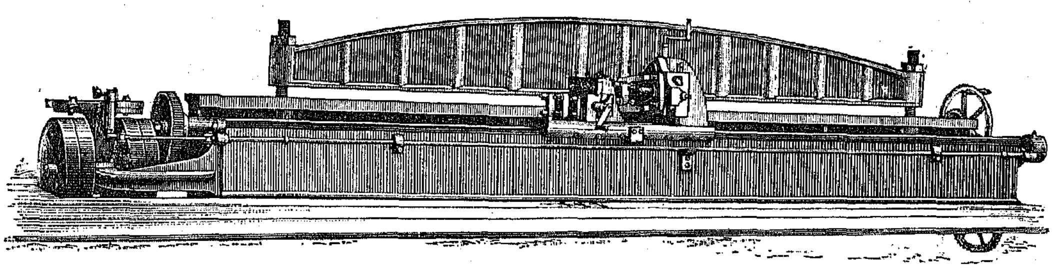


No. 6.

improved machinery and system, and the introduction of improved machinery has been a source of increased productive efficiency. The power required will usually average about three-fourths of one horse-power per power machine, exclusive of steam-hammers.

In the planer, of which an illustration is presented (No. 8), three or four tools operate simultaneously, and in some instances, in actual practice, three times as much is done as can be done with an ordinary single-tool planer.

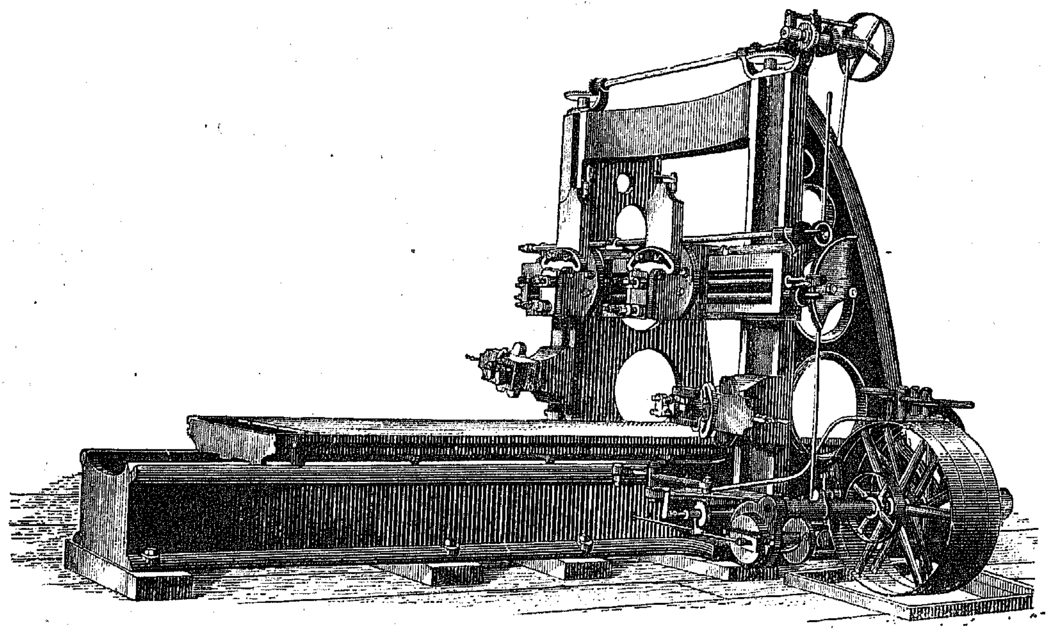
A machine more specially characteristic of locomotive work is the locomotive frame slotting-machine, shown in the illustration (No. 9), and which may be seen at any of the large locomotive-works. This standard machine has two opposite heads and saddles traversing a 24 to 36 foot bed. The maximum stroke is 16½ inches, and each head may be independently driven with two speeds, the movement of the saddles upon the bed being independent of the driving and feeding. The longitudinal and cross feeds are independent and variable, and the cross-slide can be set at a sufficient angle for slotting the inclined edges of jaws and pedestals. The saddle has a clear area of 34½ inches across by 17 inches vertically, so that two frames may be piled together and slotted at one operation.



No. 7.

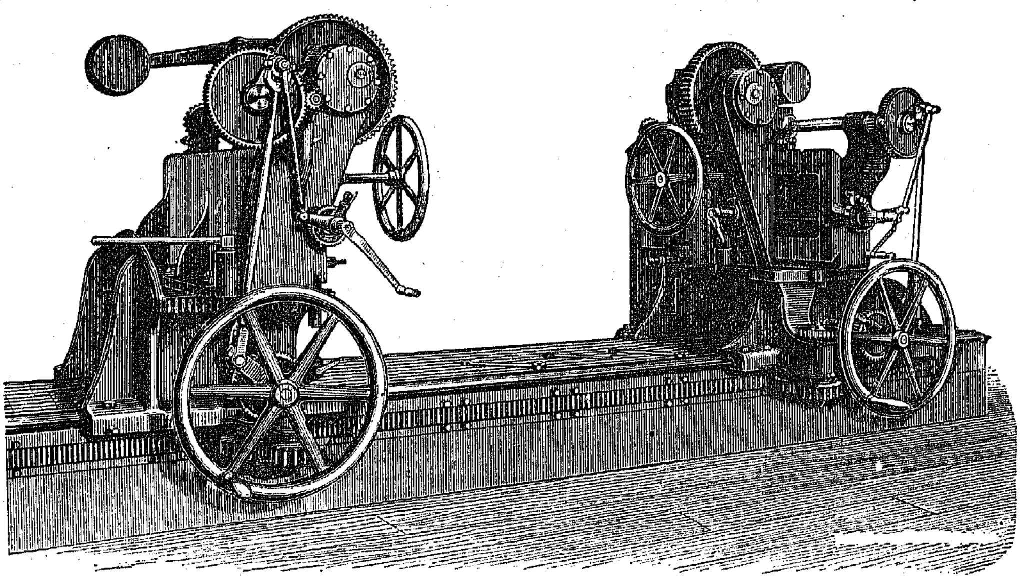
In slotting locomotive frames the advantage in the use of this machine is at least four to one, as compared with the use of ordinary slotting-machines. One of these machines has a capacity of one pair of frames for an engine, class 8 to 30 D (Baldwin's locomotive works' designation for an eight-wheel, 18-inch cylinder engine, with six driving-wheels, "Mogul" type), in twenty-one hours, and for an engine of class 8 to 30 C ("American" type) in fifteen hours. In general, it may be said that locomotive frames are more solidly built than formerly, although the front end of the frame is commonly made fast to the pedestals by bolts, so as to facilitate taking apart for repairs. The frames are first planed to templets in horizontal planers, and are then slotted.

As locomotive building antedates the introduction of power planers into this country, the plane work on the earliest locomotives had to be done by chipping and filing, hand-planing, and slabbing. Probably the earliest power planer built in the United States was in the fall of 1839, at Chelmsford, Massachusetts, where it is still doing good service at the shops of Messrs. Silver & Gay. This great tool was justly considered a wonder of the time, planing 22 feet long, 3½ feet wide, and 3½ feet high, and was used in making machinery for the Concord railroad shops and for the shops of the Erie railroad at Dunkirk. The slides were set upon stone blocks faced with iron plate, there being one V-ridge and one plane-slide, as it was then out of the question to make two V-guides true enough



No. 8.

to work together. The V-guide was itself planed by the use of a temporary wooden carriage. The upright slides were chipped and filed, and as it was impracticable to make both sides parallel one pair of slides was brought to a true plane, while the variations in the other were compensated by heavy semi-elliptic springs upon the vertical carriage, which springs yielded to the inequalities as they slid over the less even slides. There was a heavy chain-feed, the links being of wrought-iron, with steel studs. The belt shipper was operated by a dog, acting through a long connecting rod and levers. On the reversal of the chain movement, the end arbors, on which the chain was

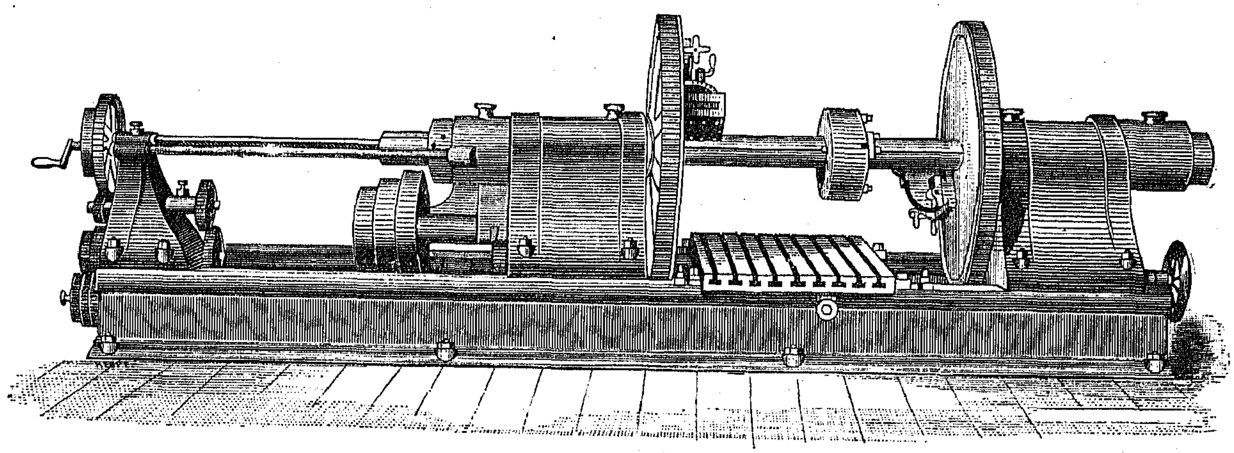


No. 9.

carried, began to move in the opposite direction, which movement was shared by a halved arm, bolted upon one of them, until it struck a stud of the frame, when it slipped and stopped. This movement, by means of a connecting rod, drove a wheel, which, as a pulley, drove a tool-flip by a train of small pulleys with an endless cord, and as a disk-crank, with slot, pin, and connecting rod, actuated a vertical rack with two sets of teeth, whose gears, by click motion, effected the vertical and horizontal feeds. In all the earlier planers the V-slides were made as ridges, instead of being, as now, grooves capable of holding oil.

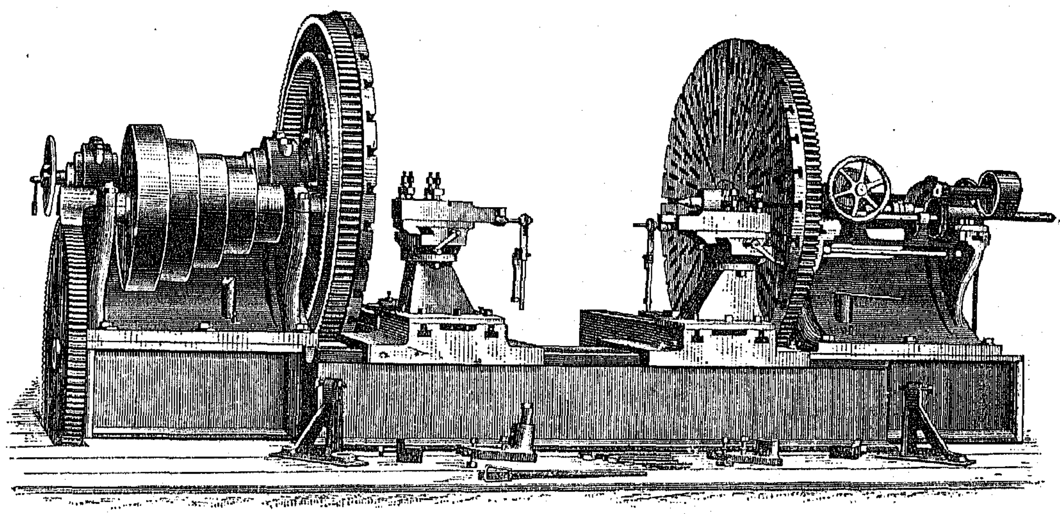
The account of this machine is introduced not only as a remarkable example of early achievement, but in illustration of the difficulties of workmanship in the earlier stages of the work. The advantage in labor-saving and in quickness and quality of work derived from the use of the close-fitted, accurate, and conveniently designed special tools, of which some examples are given, will then appear more manifest.

In turning and boring machinery the most notable improvement is in the Sellers cylinder-boring and facing-machine. This being a special machine for performing the special work of boring locomotive cylinders, its work may be satisfactorily compared with former and less effective methods in terms of piece-work, being capable of boring, facing up the flanges, and counterboring the largest sized cylinder commonly used in express passenger engines, viz, 18 by 24 inches, in three and a half hours. Before the construction of this machine the quickest known time for



No. 10.

this work was nine hours, and the usual time was upward of thirteen hours in this country, while from two to four days were occupied in the work in the practice at some foreign shops, where the statements of its performance were received with positive incredulity. One cut with a fine feed takes out the greater part of the metal. While this roughing cut is being made, the sinking-head of the casting is cut off by independent slide-rests provided for facing off both ends of the cylinder, and the flanges are turned. Two finishing cuts are then run through with a feed one-half an inch broad, and the cylinder is afterward counterbored at the ends for the clearance of the piston. If the flanges are turned up separately, when no other cut is in operation, the whole work can still be done inside of five hours. The machine which is shown in the illustration (No. 10) has six changes of boring



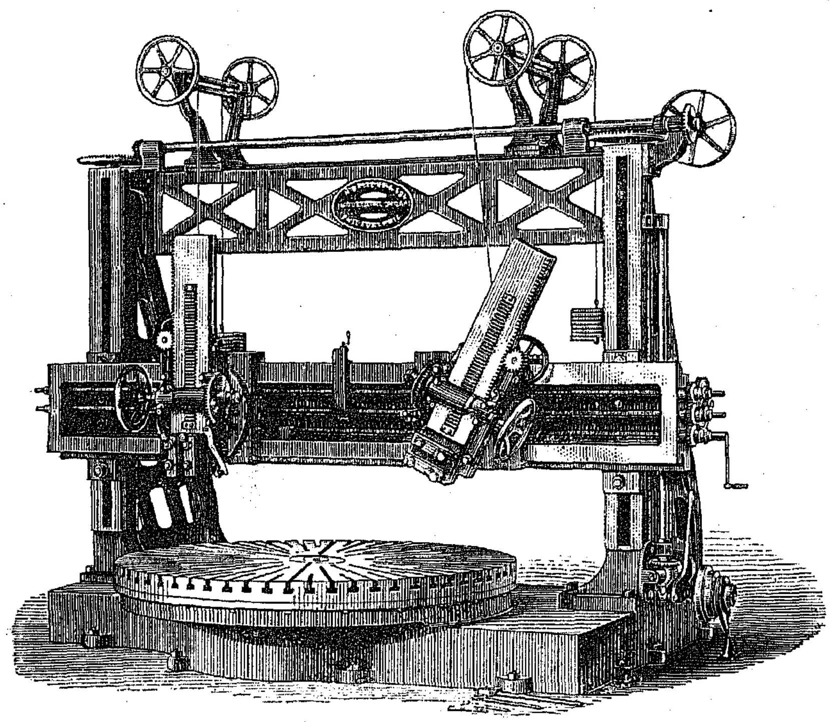
No. 11.

feed, with a quick hand-feed, cutter-heads to bore from 10 to 22 inches. The speed of cut on a 22-inch cylinder is 18 feet a minute for 140 revolutions per minute of 18-inch pulleys on the counter-shaft. John Anderson, LL. D., C. E., Woolwich arsenal, Great Britain, in the report accompanying an award at the international exhibition of 1876, says of the above machine:

> This grand tool is an embodiment of all the tool virtues that can be enumerated, resulting in the transmission of mathematical truth and accuracy to the work performed, combined with great rapidity of execution and subsequent economy, thus realizing the highest ideal conditions. Still more, this machine is constructed in such a manner as will enable it to maintain its inherent faculties unimpaired for a long time.

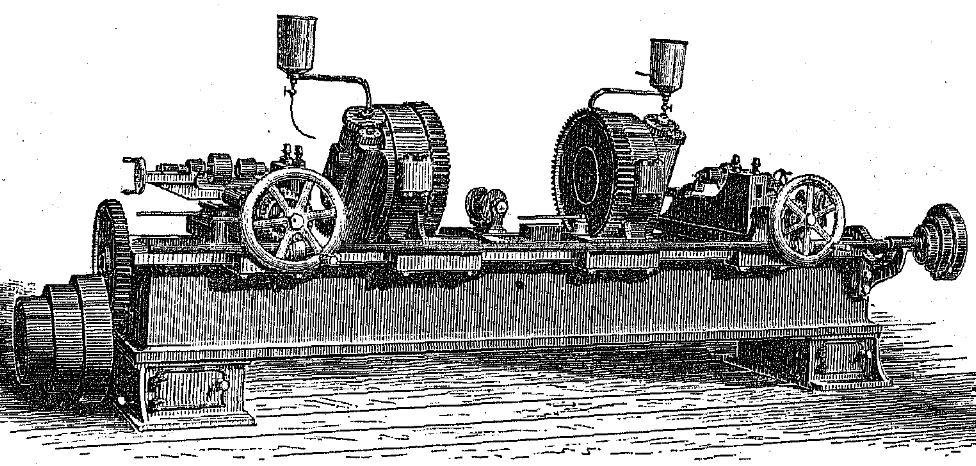
An illustration is given (No. 11) of a double-wheel lathe, practically two lathes and a quartering machine in one construction. The quartering device is particularly designed for repair-shops, in which it obviates the use of a separate quartering machine. This machine has a 79-inch swing, ten changes of speed to one and five to the other face-plate, the face-plates being driven separately or together at the same or at different speeds, and the feeds being variable and self-acting at any angle, and are derived from an overhead rock-shaft, in connection with the gearing shown upon the tool-rests. This machine suffices for the turning of the wheels and tires.

The vertical turning- and boring-machine shown in an illustration (No. 12) is a tool almost indispensable in locomotive work. The face-plate has twenty changes of speed, and the feed is self-acting at all angles with four changes. An economy may generally be effected by having several tool-slides upon the cross-head, but the nature and position of the work usually limit the number of tools to two, or three at most. This class of machines dates back as early as 1850. A vertical turning- and boring-machine, capable of operating three tools at once and turning 16 feet diameter work, was built at Chelmsford, Massachusetts, in 1850, and is still in active service. The machinery at Chelmsford was at the time considerably in advance of the general usage. In 1848 horizontal lathes were used in boring car-wheels, and by this means two or three wheels were bored in a day. About this time a vertical boring-mill was introduced at Windsor, Vermont, by which three times as great an output was obtained, the present output being still greater.



No. 12.

The double cutting-off and centering machine for axles, here illustrated (No. 13), is a labor-saving machine, which, from its special application, can be compared in efficiency with the piece-work of former practice. With an attendance of two men forty car-axles can be cut off and centered in a day, both ends of the axle being operated upon simultaneously, the axle revolving in self-centering jaws. There are three changes of speed, and each has an acceleration of speed as the tools approach the center of the axis. As compared with cutting off and centering axles in a common lathe, the advantage to be derived from the use of this machine is at least fivefold.



No. 13.

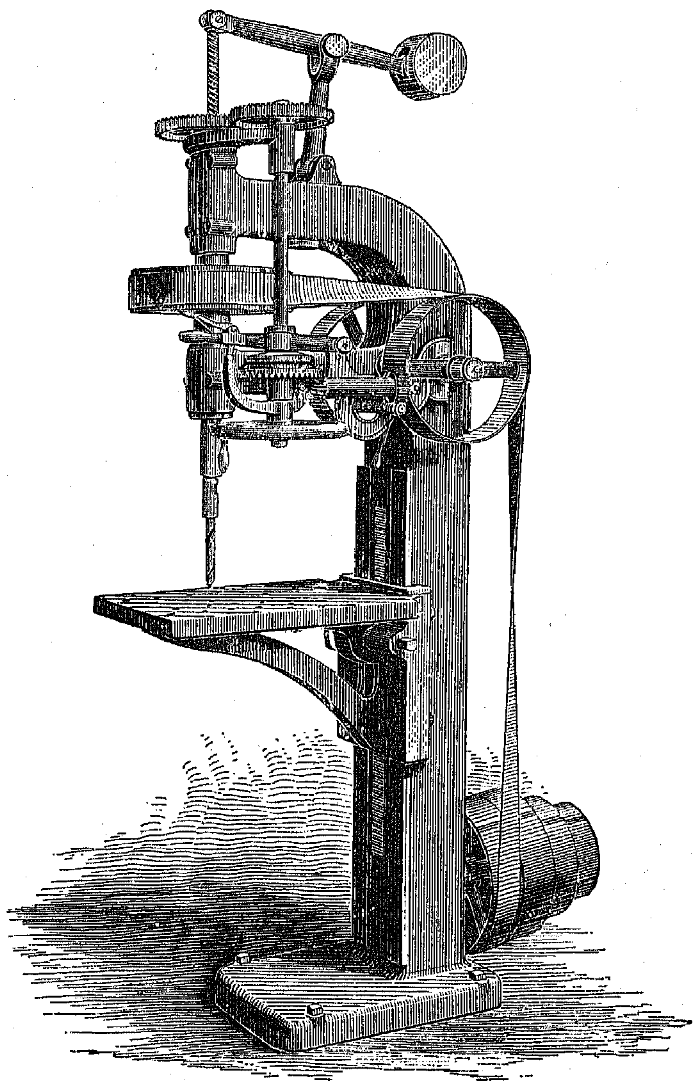
A bolt-cutter, much used in locomotive building for making bolts for accurate work, is designed to supersede the method of chasing them in a screw-cutting lathe. The bolts are placed upon centers exactly as they are secured in the screw-cutting lathe, but are threaded by running into dies. Where a skilled workman is required in chasing screws in a lathe, an ordinary hand is enabled by the use of this machine to thread from six to ten times as many bolts in the same time. The dies may be set to the required length of the thread, and will then open automatically at that point, while the bolt-carrier is thrown back to receive a new bolt. This feature, beside insuring a uniform length of cut and avoiding danger of breakage, enables one operative to tend two or more machines.

In drilling, besides the use of multiple drills, which are employed principally on boiler parts, an improvement is to be noted in the use of belted instead of the common form of geared drills. An illustration of such a belted drill is here given (No. 14). Gearing transmits power by a constant succession of shocks, which, however small, are the means of wearing out the drill. With belts the motion is smooth and without shock, so that the drills last longer and may be run at a higher speed.

The hydraulic wheel press is a machine characteristic of the manufacture, and as such is illustrated (No. 15). The primitive method of pressing wheels upon axles was by screwing up bolts upon rods. In car work, at Windsor, Vermont, in 1848, a power wheel press was built which was considered a novelty and an improvement on previous methods. It was powerful enough to double up a $3\frac{1}{2}$-inch axle.

From the foregoing examples a fair idea will be derived of the nature of a machine plant for locomotive work and of the improvements which are in process of introduction, the full benefits of many of which have not yet been made available.

Erecting and other work.—The work of erection, which has been diminished by the introduction of the



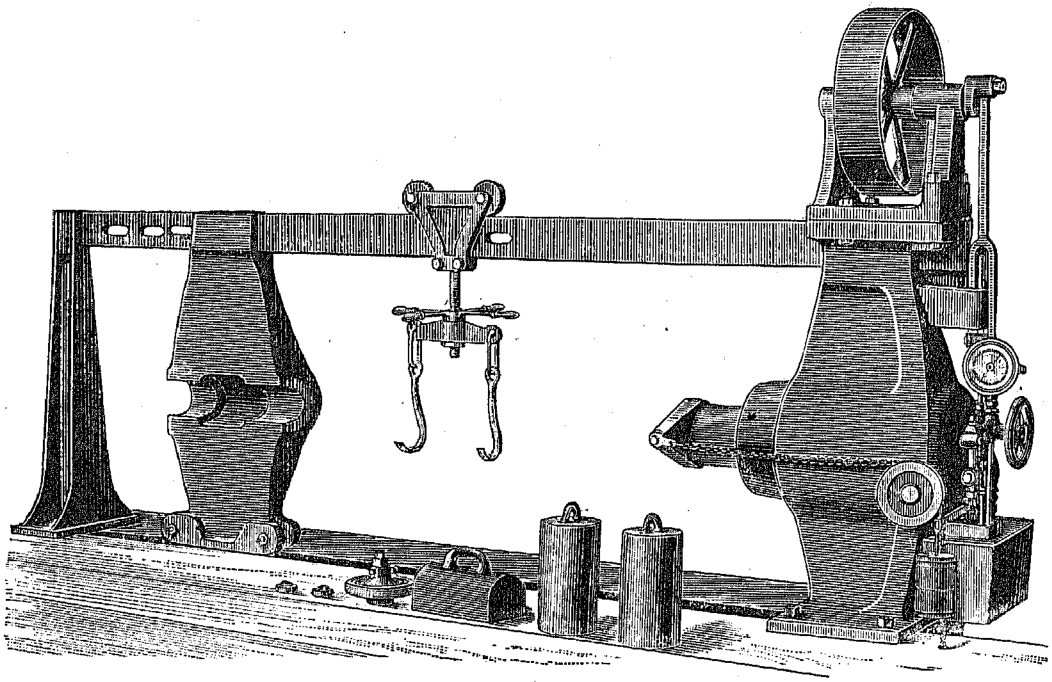
No. 14.

uniform system, still requires the equivalent of upward of a year's work by a single man. "Old Ironsides" was a year in building, but in 1873, at the Baldwin works, a small locomotive was made from the raw material in sixteen working days, and in 1878 forty heavy "Mogul" locomotives were built for Russian railways inside of eight weeks from the receipt of order, the first being turned out in three weeks.

From the annual product and the number of locomotives in course of erection at locomotive-works something may be judged of the usual time spent in erection and finishing. This may average four or five weeks for erection and a few weeks for the preliminary work, but the time is of course varied to suit the exigencies of the case.

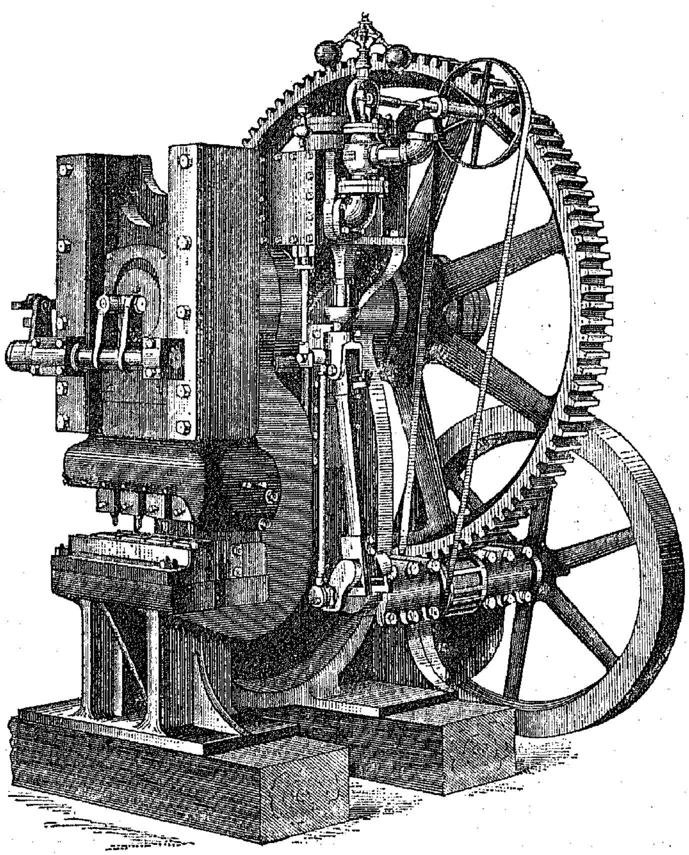
The manufacture of springs sometimes constitutes a small separate department in the locomotive-works, and the wood-working is also a small department, the small number of machines required in making the wood-work for several hundred locomotives in a year affording marked evidence of the rapidity of wood-working processes.

In general railroad repair work many labor-saving and convenient machines have been introduced, some of them, such as the special car-box drill, for removing broken bolts from car-boxes, indicating the vastness of an interest which demands special devices for convenience in such minor details.



No. 15.

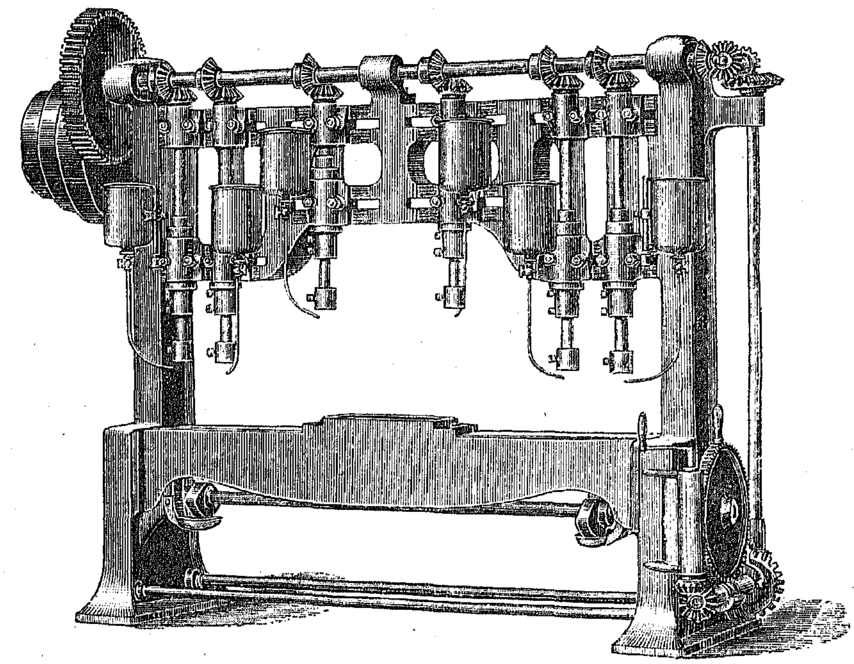
One of the most notable and prolific machines in use for any class of railroad work is the Bement fish-plate punching-machine (No. 16). The fish-plates are eleven-sixteenths of an inch thick, and the holes are oblong, fifteen-sixteenths by one inch and thirteen-sixteenths A 25 horse-power engine is required to drive the punch, which is capable of operating (four holes at a stroke) as rapidly as the plates can be supplied, and in actual usage does turn out 110 tons of fish-plates in ten hours, eleven car-loads in a day.



No. 16.

The last example of a labor-saving machine which will be here noted is the truck frame drilling-machine (No. 17) for railroad-car trucks, introduced nine years ago, and now in extensive use. This will drill one truck frame every minute continuously, the truck irons being usually 3 inches wide by 1 inch thick, and each requiring six holes to be drilled. There may be no exact comparison between the work of this machine and the same work by hand; the machine may do thirty times as much work as the average operative with a hand-drill, and it may do forty times as much or more, depending upon the diligence and activity of the average operative.

The introduction of labor-saving and automatic machinery is always slowest and most difficult in heavy work, because of the greater expense of innovations and the relative smallness of the numerical demand. In locomotive building the great growth of railroad facilities has supplied the condition of large demand, and the responsive enterprise of locomotive builders has pushed the work to its present high efficiency; but the conditions once admitting of the introduction of labor-saving machines, their application is seldom limited to the industry which has first called them into play; and as the conditions of fire-arms manufacture introduced the interchangeable system and improved machinery into a great range of small manufactures, the conditions of locomotive building are exercising a like influence in the introduction of uniform and labor-saving methods in the manufacture of marine engines and other heavy work.



No. 17.

In conclusion, acknowledgment should be made to the officers of the Rogers, Grant, Danforth, Brooks, and Schenectady locomotive works, and more especially to Messrs. Burnham, Parry, Williams & Co., of the Baldwin locomotive works, for the kindly extension of courtesies and the facilities of inquiry upon which the foregoing review of the manufacture has been based. Also to Messrs. William Sellers & Co. and William Bement & Son.

V.—THE MANUFACTURE OF WATCHES.

NOTE.—For statistical information regarding the manufacture of watches, see Table III, page 84.

The constituent material in watch-making comprises a small portion of the cost and a small cost also relative to that of the factory supplies and materials used, which are of great variety. The jewels, mostly garnets and rubies, with some sapphires, are of no great value when in the rough, most of their value in the works of a watch being due to the labor of making and setting. The brass, steel, and copper punchings are the most essential materials. These are largely furnished, even for remote sections, by the brass-works of Waterbury, Connecticut, being punched from dies furnished by the watch manufacturers and sold by weight. For hair-springs the best imported steel wire is used. The range of work in factories usually extends to every part except the largest punchings. In some cases also the mainsprings, and in others the jewels, are bought, since in the making of jewels the improvement in mechanical facilities has not been as marked as in some other portions of the work. In order to insure purity, the diamond dust is sometimes ground, and other material is prepared at the watch factory. The diamond dust is ground from the "bort", or outside cuttings of the stone, in hard steel mortars, and grinds about eight times its weight of steel dust from the mortars, being afterward separated from the steel. Of course the higher the grade of the watch the smaller out of all proportion is the relative cost of the material used, which, inclusive of mill supplies, may be commonly rated at about a third of the value of the product; but it must be said that the census returns of material relative to product or number of operatives are no indication of the grade of watches made, but indicate rather a discrepancy of views among manufacturers as to what constitutes material and may properly be reported as such.

The manufacture of watches is conducted under conditions which admit of the fullest development of systematic detail, but these conditions, in opposition to much prejudice, have themselves been developed by the ingenuity and the administrative talent of American enterprise. The manufacture of watches by machinery on the uniform system was first attempted by and at the instance of Aaron L. Dennison, of Boston, in 1848, and was first made a commercial success by the American Watch Company, of Waltham, Massachusetts. This company, as it was thus the pioneer, has also been the standard-bearer of the American system of watch-making in the competitive displays and trials at all the world's fairs since 1876, with such brilliant success as to stimulate the most strenuous efforts of foreign watch-makers to equal its results. The essential features of a system so successful and so widely published can scarcely fail of ultimate adoption in other countries.

In the American system the watches are made with parts practically interchangeable, except at a few points, upon which can be concentrated as great a nicety of adjustment as may be necessary to secure the highest accuracy; but by accurate machining the liabilities to error and the expense and necessity of skillful adjustment and rectification are eliminated from the greater part of the work. In the quality of a watch the American system, properly conducted, furnishes the most substantial foundation for accuracy.

The same mechanism which secures interchangeability increases the product, the interchangeability itself facilitating the work of assembling, finishing, and adjusting, and the division of labor resulting therefrom enables skill to be made perfect by practice upon a single kind of work. The establishment of standard forms and sizes of the component parts secures the closest attention to their best proportionment and the development of the most precise mechanical facilities for producing them. There has thus been a continuous improvement, the delicacy of the work and the rapidity with which the pieces are produced being advanced step by step.

The facility in repairs insured is also a great and obvious merit of this method of fabricating watches.

The manufacture of certain classes of large machinery may involve comparatively little system. There may be a foundery, a machine-shop, a blacksmith-shop, and an assembling-shop, but the work is only so rudely classified that attention is not concentrated upon details closely enough to stimulate their improvement. But in watch-making the system resolves the smallest items of the work into separate problems, and, as it were, puts them beneath a magnifying glass, so that under the eyes of skillful managers there is the closest pursuit of every advantage assured or promised in the existing knowledge of mechanical possibilities.

But comparison is suggested, not between two phases of the American system, the same now as ever in principle, though now with greater perfection of detail, but with a system of manufacture which has never existed to any appreciable extent in this country. This European system consisted in making watches by scattered labor, the manufacturing being technically only the assembling of the parts made by different artisans at different places. It was a system of farming-out work, which has no present analogy in American manufactures (except possibly in such work as the manufacture of gloves at Johnstown and Gloversville, New York). The number of skilled trades required for making a watch by this method is usually stated at about fifty, some of the work being done at the homes of the operatives, as gun components were once similarly made, a man having a bench or a foot-lathe, or even a little forge, under the roof of his cottage. To such methods the factory system comes like a clearing-house, saving trade by consolidating the interests of small buyers, relieving the manufacturer of onerous duties as a dealer in a vast variety of small and unreliable components, preventing wastage of material, diminishing the number of pieces rejected upon inspection, and bringing in the exact operations of machinery to swell the product for the same expenditure of labor, both by more rapid action and by the saving in fitting and finishing.

Leaving out of account the superiority of the product resulting from the precise machine methods of the American system, a comparison by number is afforded in the statement of M. Edouard Favre-Perret, that where 40,000 workmen in Switzerland make on an average each 40 watches per annum, in the United States the average is 150 watches. "Therefore," he adds, "the machine produces three and a half to four times more than the workman."

Under this uniform system the greater proportion of the operatives are paid by the piece. At the works of the American Watch Company, at Waltham, monthly cards are prepared by the superintendent for each foreman, stating the number and kind of watches to be made. Each foreman makes a daily report of work done and of the transfers of work between the several departments, and to facilitate this each foreman has a book-keeper, who is responsible to the superintendent.

The custom generally prevails of starting watches in large lots, say 1,000 of one kind or grade, 1,000 of another grade being started when these are out of the way, and so on. But the watches are not finished in the same order, the partly-finished portions being kept in store and given out in job lots of ten for assembling. In the process of assembling these parts are kept temporarily in trays with suitable compartments, but in stock they are kept in glass jars. Thus, while one lot of a thousand watches remains in the works, many subsequent lots may be completed. It is stated at some factories that the usual average time of completion is about five months, including the testing; it being obvious that no such time is required in the simple fabrication of the movement.

The watch parts to which interchangeability does not extend are the jewelry pivots, which are selected to fit the jewels, and the balances and hair-springs, which are adjusted or selected of weight and strength to correspond; but records of these parts are carefully preserved for every watch, so that they may still be replaced with accuracy.

The quality of interchangeability is specially utilized in some styles of stem-winding watches made by the Elgin National Watch Company, which, by the transfer of a single bevel gear, are made to wind either at the figure 3 or at the figure 12, so as to permit the movement to be conveniently fitted to an open-face or a hunting-case watch.

Owing to the more complex and detailed organism necessary in conducting the manufacture, the capital investment required in making watches upon a large scale is much greater relative to the product than in clock-making. The machinery is a very heavy item of expense, and the more so, as most of it is of private design, made in machine-shops of considerable size connected with the factories, and made as the finest job-work, without regard to the expense. The number of machinists in these shops is usually 6 or 7 per cent. of the whole number of operatives. As neatness and order are matters of the highest consideration, the factories themselves are handsomely laid out, built, and equipped, and require a heavier investment in real estate than is necessary for most other classes of manufacture.

We now come to the consideration of the labor, its division in the work, and its efficiency in all, and, so far as may be stated, in the several departments; but as these departments and the requirements put upon them differ somewhat in the various factories, they cannot in some cases be more than vaguely defined. Apart from the machine-shop work and the case-making, there is the press-work, from which the plates, bridges, and so on, go to the frame-making, and thence to the stoning, gilding, and engraving; the wheels and similar parts to the train-making or the pinion roughing and finishing, and then to the stoning and gilding; the dials to the enameling and painting, and the stem-winding, balance, and escapement parts to their special departments. The jewel-making and the jewel-setting, the flat steel work and the tempering, the nickel-finishing, the spring-making, and the springing and the screw-making are departments naturally separated by the character of the work. The assembling—both in the gray, that is, before gilding, and finally—and the finishing and adjustment complete the enumeration of all the usual departments. All these involve essentially different classes of work; and as each embraces work upon a variety of pieces, it is easy to see where more than 50 skilled trades might be required in the manufacture of a watch. The work of several of these enumerated departments may be executed under one foreman, or the work of one of them may be divided among two or more foremen, such divisions being termed "jobs" or "ends" of the work, the subdivision in this respect being, as might be expected, more minute in the larger factories.

The percentage of the numbers of persons occupied in the various duties of watch-making is here given roundly in an average of the practice at several factories, viz: The springing and finishing, including the train-finishing, 17½ per cent.; the pinion roughing and finishing, 15½ per cent.; the screw, flat steel, and escapement work, 12½ per cent.; the jewel-making, 7½ per cent.; the jeweling, 7½ per cent.; the plate work and engraving, 7½ per cent.; the balance-making, etc., 7 per cent.; the machine-shop work, 6½ per cent.; the dial work, 6 per cent.; the carpenter and blacksmith work, clerical work, watching, and time-keeping, 6 per cent.; the stoning and gilding, 3½ per cent.; the mainspring making, 1½ per cent.; the nickel-finishing, 1½ per cent.

The percentage of female operatives to the whole number ranges as follows in those parts of the work upon which females are employed: In pinion roughing and finishing, 70 to 80 per cent.; in screw-making and flat steel and escapement work, 30 to 64 per cent.; in gilding, 36 to 50 per cent.; in jewel-making, about 50 per cent.; in balance-making, 44 per cent.; in springing and finishing, 21 to 43 per cent.; in plate work, 20 to 39 per cent.; in dial-making, 17 to 37 per cent.; in jeweling, 30 to 35 per cent.; in nickel-finishing, etc., 10 to 33 per cent.; and for the whole work, from about 33 to over 40 per cent. Relative to the employment of female labor, we may quote from the report on horology by Professor James C. Watson, at the international exhibition of 1876, as to the practice of the American Watch Company:

> There are many important operations in the manufacture of watches by this method where the delicate manipulation of female hands is of the highest consequence, and it ought to be mentioned here that for this labor the amount of wages paid by the company is determined by the skill and experience required, not by the sex of the operative.

Upon much of the work either sex might be employed, but it may be of interest to note some of the items of work upon which women are usually engaged, viz, the cutting and setting of pillars, the drilling of pin- and screw-holes in plates, the cutting of the teeth of wheels and pinions, the leaf-polishing, the gilding, the making of hair-springs, the setting of springs, the making of pivot jewels and balance screws, the putting of movements together, and the fitting in of roller jewels and jewel pins. Beside the machine-shop and general work and superintendence, some items of work usually performed by men are the punching and press work, the brazing, enameling, firing, and lettering of dials, the plate-turning, fitting, and engraving, the fitting of wheels and pinions, the uprighting and end shaking, the stoning and oxidizing prior to gilding, the rosette-turning, cutting of scape wheels, milling of pallets, balance-making and handling, and the final work of finishing and adjusting.

From the minute division of the work it will be seen that it is almost entirely specialized, and that the labor required is skilled. In a few cases, such, for example, as the cutting of pinions, the machinery may be so far automatic or conveniently arranged that the operations of attendance are simple and easily performed; but even here the smallness and delicacy of the work and mechanism and the rapidity of action demand much more careful oversight than in a similar duty in the manufacture of coarser work. We can scarcely indicate one of the numerous departments mentioned where trained intelligence and skillful manipulation are not required in a high degree by the nature of the operations. The operatives are for the most part of American birth, and although some are young, none can be classed as boys or girls or unskilled laborers; and despite the many instances of manual skill which may be witnessed by a person in passing through a watch factory, he may, on the whole, be no more impressed by the dexterity of the fingers than by the high intelligence of the faces of the operatives.

The number of watches produced (correct time-keepers of a good medium grade) may be rated at over 150 per operative per annum for all hands employed, the number at some factories ranging higher for an average of all grades produced, all being fine full-jeweled watches. At some factories the productive capacity per operative has within the decade been more than doubled—an advantage attendant upon an increase of the gross capacity of the factories no less than upon the introduction of labor-saving methods.

The power required may be rated at about one-tenth horse-power per operative and one-fifth horse-power per power machine, and although watch-making machinery is in most cases very light, it is very rapid running, and rapid movement consumes great power at a small stress. In fabricating the movements from six to eight hundred processes are estimated to be employed, there being upward of 100 and sometimes more than 150 pieces in a watch, over a fourth of which are usually screws.

The manufacture of watch movements usually commences with the punching, but in case-making the material is first rolled into sheets. The old style of sets of rolls for rolling silver plate had the driving spurs of the same size as the rolls, so that large rolls had to be used to get pinions large enough to resist breakage. The spacing of the rollers was effected by a loose square coupling, involving knocking and lost motion. A form of rolls has been devised by Mr. Charles V. Woerd, in which the rolls carry large spurs, driven by smaller pinions and movable in a vertical slide, the pinions turning upon spindles in set positions. The space between the rolls can thus be considerably varied without sensibly affecting the engagement of the gears, which, nevertheless, have epicycloidal teeth.

The heaviest press used in this country in watch-making is at Waltham, and has a capacity of 2,700 tons. The frame weighs 9 tons, and is cast of gun-iron, which may be reckoned at double the strength of ordinary cast-iron. The uprights of the frame are two solid 12-by-12 inch pillars, and the moving die is forced up by an eccentric upon a shaft below. This press is used for silver cases, but for the heaviest plates, bridges, and the like, the metal is rolled and punched at Waterbury, Connecticut, the punchings being one of the products of brass and one of the materials of watch manufacture. The smaller punchings are pressed out at the watch factories by comparatively small presses. One man with a 20-ton punch will blank out 10,000 watch wheels a day.

In the die-presses used by the American Watch Company the blanks as they are formed are forced up into the upper member of the press, passing into a cavity opening outward and with a sloping top, so that in the process of the work there is a column of blanks being continuously pushed up and out.

In punching the dials one stroke cuts the blank from the copper strip, punches the holes for hour and second hands, turns up the edge of the plate so as to retain the coating of enamel afterward put on, and makes the impressions into which the dial feet are brazed. Three men will do the work of punching and brazing dials for 200 movements in a day.

The plate work may be considered to include the following principal operations: The turning or facing-off of the pillar plates (which is done in lathes, the plates being set in revolving heads and the tool being brought up on a slide-rest by a lever); the drilling of holes for screws and steady pins, which is done in jigs of hardened steel; the countersinking of the holes to remove the burrs left after drilling; the cutting of threads in a tapping lathe; sundry finishing operations on bridges, potences, and the like; the numbering of the parts by stamps; the screwing of steady pins into the plates; the finish-turning of steady pins; the milling of steady pins; the fitting of plate parts together; the turning of plates to fit cases; the uprighting of jewel holes, and the drilling of pivot holes. Over one-fourth of the labor is in the turning of the plates. The eight last-named operations are briefly executed, one man doing the work of each operation for from 100 to 200 movements a day. There are considered to be some 275 operations of turning, beside about 100 other operations upon the plate work. In drilling holes the plate is put into a jig. In one instance 26 holes are drilled by one operative, using five different sizes of drills before the removal of the plate. A variety of raised circles, part circles, rim cuts, and grooves have to be made on both sides of the plate. At the outset the bottom plate is a disk one-sixteenth of an inch thick, half the weight being afterward machined away. The largest hole drilled is usually one-sixteenth of an inch in diameter. The countersinking of the holes is done upon lathes by cutters running at a high speed. This lathe is the most essential piece of mechanism used in watch-making, and the vast majority of the whole number of machines are lathes more or less fitted with appliances for special work. In cutting and setting case pillars one operative, with the Elgin pillar cutter and setter, cuts 2,000 pillars a day; by hand-work one man would cut and set only 30 in a day. In cutting threads upon pins they are run into a little die which finishes the thread. The finest pitch cut is about 250 to the inch, and in drilling pivot holes the finest drills are near the size of a human hair. In one instance the pivot containing the drilled hole and the wire polishing the same are revolved at high speed in opposite directions, making an aggregate relative revolution of 14,000 turns a minute. After completion, the watch parts are distributed in trays of ten compartments each, ten watch plates to a tray. The device most commonly employed for holding the plate, case, and other work is a simple chuck with three jaws, so characteristic of the manufacture as to be sometimes called the first element in watch machinery. Machines in which cutters work to formers are used in cutting bridges of irregular outline. These are simply neat little profiling-machines. The power is communicated from a horizontal drum at the back of the machine to a pulley on the vertical cutter-spindle, which is carried by a frame with a transverse traverse and vertical adjustment by a handle in a universal pivot, while the bed carrying the former and the work holder (against which the guide-pin and the cutter respectively bear) has a horizontal traverse perpendicular to that of the frame.

In some factories there is a single department comprising the plate work, pinion roughing and finishing, and train work, under the style of train, plate, and motion department.

In the pinion room are usually made the balance and center staves, the center, minute, third and fourth wheels and pinions, the scape, cannon, and winding pinions, the barrel, the barrel-head, the barrel and pallet arbors, the intermediate and stem-winding wheels, the dial feet, and the hair-spring collets, beside the handling of other parts. The stem-wind work sometimes constitutes a separate department. In one factory thirty different parts are made in the pinion roughing room; and in general it may be said that pinion roughing comprises the cutting of teeth and some operations of threading and turning to size from brass and steel wires and brass blanks. The brass and steel wires are usually received in three-foot lengths. A cutting-off machine, operated by one person, is capable of cutting 6,000 pieces an hour. Turning to length and size is done upon lathes. In cutting teeth, one operative, with machine, will cut 60 piles of 20 eighty-leaf watch wheels (1,200 wheels, 96,000 teeth) a day. In pinion cutting, the finishing cuts, which give a fine epicycloidal shape to the finest leaves, are sometimes made by an index pinion cutter, the index regulating the turning of the blank so as to admit of cutting variable numbers of leaves, there being a three-mill rotary tool-stock, the pinion blanks reciprocating for the traverse and the pinion holder shifting for every leaf, and stopping the motion when all are cut with one mill. The tool-stock then turns, and a second cutter repeats the operation, the work being finished by a third. Another form of automatic pinion cutter has a horizontal chuck for holding the pinions, and a three-cutter horizontal tool-stock perpendicular to and above it, with a feed motion of the cutters and a pivoted lift to bring them clear of the work for the return movement. The term chucking is applied to the intermittent turning of the pinion blank so as to bring tooth after tooth under the cutter. Strictly speaking, chucking is the placing, centering, or adjusting of work in a chuck, although a chucking-machine is sometimes understood to signify a machine in which the tool remains stationary while the work revolves, being held in a chuck.

In cutting the wheels they are piled together and a large number are cut at once, the process being the same as in pinion cutting. Some machines for cutting wheels with long sleeve-bearings cut only one wheel at a time, a cutter with a horizontal axis moving vertically, while the wheel being cut chucks about a vertical axis. All of these machines are exceedingly prolific in output. Even with hand machines the output is large. The cutting mills usually make about 7,000 revolutions a minute. In the hand machines the mills are given a reciprocating motion from a lever operated by hand. The indexing or chucking is also done by a hand-click, the attendant operating the index wheel with the left and the reciprocating feed of the cutter with the right hand, the mills, of course, being driven by power.

The mechanical requirements for wheel and pinion cutting may be briefly recapitulated. The work, if wheels, must be carried on an arbor and held fast; if pinions on staves, they must be held fast in a centering chuck. The work must automatically or manually turn and stop as many times in a revolution as there are leaves to be cut. This is usually accomplished by a click and ratchet-wheel or some other arrangement of intermittent link work. If it is desired to make the machine adjustable for cutting different numbers of leaves, an index ratchet-wheel is used, with an arrangement for regulating the stop so as to pass a given number of teeth in the ratchet-wheel, either by varying the throw of the click or introducing change wheels in the train. In automatic machines, after the leaves have been cut all around, the machine must stop itself. This is effected by a disengagement in the train, sometimes by the pushing out of a catch, allowing a bearing to drop, or removing a half-nut from the screw thread in which it works. The cutter must of course be upon a power spindle; and if there are several of them, they must chuck or turn and stop to work successively upon the pinion, each in turn engaging with a driving spindle. Either the work or the cutter must move longitudinally to furnish the feed. If the work moves longitudinally, the return movement may be utilized to turn the work into position for a new cut. In case the cutter with its carriage moves longitudinally, its power motion has to be continued by means of a drum and belting, as in profiling machinery.

An automatic pinion cutter of fine design, used at the works of the Hampden Watch Company, is stated to have cost $4,000, and to be capable of cutting pinions for fully 100 watches a day.

In one instance the output of pieces from the pinion-roughing department was 160 per operative per day. The finest piece made is the pallet arbor, a pivotal bolt, which for a small size of watch has a thread of 260 to the inch, weighs $\frac{1}{130000}$ of a pound, and undergoes twenty-five operations, costing 2.27 cents for all. Measurements are gauged to $\frac{1}{25000}$ of an inch, sometimes called a degree.

Pinion finishing comprises leaf-polishing, which is done with fine crocus in reciprocating apparatus, sometimes called "wig-wags" (the pinion being turned and the polishing piece passing over each tooth space in succession); facing or polishing the ends of leaves; burring and turning under (sometimes done by hand with a graver), and staff polishing by reciprocating machinery.

The train work, in the practice of one factory, comprises the finishing of the brass barrel, the end-shaking, the truing and inspection of the wheels, and operations of fitting, such as fitting the cannon pinion to the hour wheel, the arbor to the barrel, and the staves to the wheels. In this case about a fourth of the operatives engaged in the train work are occupied in fitting staves to wheels, and nearly as many in end-shaking. End-shaking is usually gauged to $\frac{1}{10000}$ and side-shaking to $\frac{1}{25000}$ of an inch. These measurements are effected by dial gauges, with trains of gears for multiplying the discrepancy. These gauges are sometimes furnished with a screw adjustment of the height of the table, with a set screw, so as to take up wear and adjust the pointer to the zero of the dial. The end-shaking machinery is sometimes made to measure from each actual arbor to determine the depth of bearing to be drilled. The drill is driven by a belt, and is pushed down to the required depth by a handle with a pin, which arrests the motion by striking a stop upon a fixed frame. The rod of the handle is divided below the pin, the separate ends being held in place by a yoke. Between these ends the arbor is inserted, and by its length determines the height of the pin above the stop and the consequent depth of the hole drilled.

The manufacture of dials is in all its details a special and interesting process. At the works of the American Watch Company the muffle furnaces are of a specially ingenious construction, designed by Mr. Woerd, being built of interchangeable fire-brick blocks (which can be quickly replaced), and so arranged as to insure a vastly greater endurance of the muffles and a considerable saving of fuel.

The enamel is ground with pestles in Wedgewood mortars. In the form of paste it is spread upon the copper dials, being retained in place by the raised rim. The dials are then heated to about 1,100° F. in the muffles; are removed for surfacing, fired, reheated in the muffles, and then the figures and lettering are put on in black enamel, there being in all four operations of firing. The most expeditious method of putting on the hour figures is found to be by covering the figure ring with black and ruling out and scraping off all but the lines of the figures. But the fine lettering is done by skilled hand-work with brushes.

Dial sinking is the process of cutting out the seconds and other circles of the dial and cementing in circles at lower levels, to give an ornamental appearance to the face of the watch.

Stoning and gilding are usually done in the same room, stoning being the smoothing of the surfaces of the brass parts of the train and plate work preparatory to gilding. It consists in rubbing the pieces upon Ayr-water stone, the pieces being sometimes set in cork. After stoning, the pieces are strung upon wires, immersed in a hot alkali, and then in an acid bath, and are then "oxidized", which consists in brushing the pieces in brass-wire brushing-machines, the brushes revolving in a bath of beer. This gives them a frosted surface. Then follow, in succession, gilding with a galvanic battery, wire-brushing, regilding, drying (after an alcohol bath) in boxwood sawdust, and wrapping in tissue paper ready for the finishing department. In gilding, a cold solution is sometimes used with the best results, thus avoiding the poisonous fumes of the cyanide of potassium. Sixteen operatives will stone and double gild the work for about 240 watches in a day.

For the ordinary work of engraving, the impressions of names, lettering, and ornamentation are stamped, and afterward finished with a graver. Hand-stamps are commonly used, but elaborate presses are sometimes employed, in which the position of the work is nicely adjusted by verniers.

In jewel-making the jewels are first sawed into slabs one five-hundredths of an inch thick. These slabs are shellacked to plates, in which are concentric rings or grooves, so that the slab may be better trued to the plate. They are then surfaced upon one side with an ivory lap, and that side, being in turn shellacked to the plate, the other is similarly surfaced. From these slabs the separate jewels are obtained by sawing or by marking out and breaking. In making the pivot bearings the jewel is fastened by shellac to the end of a spindle, which during the working the operative heats at intervals by a small lamp. Thus held, it is in position to be worked on one side. The jewel is, in form, similar to a plano-convex lens with rounded edges. It is also drilled through the center, and there is a depression or cavity in the center of the convex side for an oil-cup. The cutters are diamond points carried by a holder, which first moves the cutter upon a long radius for surfacing the face of the lens, and is then unshipped and brought up on one side of the spindle to round the back edge. Diamond dust is also used for polishing, and sticks of pith for cleaning the jewels. The jewel, prepared for its bearing, will weigh about an eighty-thousandth of a pound troy. In turning the oil-cup side and edge of the jewel one operative does from 200 to 300 a day, the flat side not taking as long. On the average, one operative finishes over 150 a day.

The jewel is put into a setting, and the setting is then trued, so as to bring the jewel hole exactly in the center. The holes are opened to the required size with diamond dust. After washing, they are gauged on a needle gauge and distributed in boxes according to size. The pivot holes are also gauged, and records of these measurements are preserved. The jewels are then fitted into pivots of corresponding size, and all are fitted into the plates.

A machine has been devised by Mr. C. V. Woerd for the side-shaking of jewels, by which each pivot setting is bored to correspond with its jewel. In this the tool is carried upon a rocking-frame, and at double the distance from its center is the measuring device, an edge upon the rocking-frame approaching a fixed edge, so that the jewel or arbor placed between them will throw the boring tool half the diameter of the jewel off center, causing the tool to bore a hole to fit the diameter of the jewel.

The jewel bearings are polished by a wire with diamond dust, and afterward by a pointed splint of wood. In the straight gauge for measuring the holes in jewels the jewel is run upon a fine graduated wire point as far as it will go. The point is then pushed back against a spring, the jewel acting as a stop and determining the movement of a pointer along a scale, one of whose divisions is equivalent to the twenty-five thousandth of an inch in the diameter of the jewel hole.

Machines in which cutters work to formers are used in nickel-finishing, and also in cutting rosette work upon the watch-case. The rosette-cutting machines have a spindle for holding the work, pivoted below upon parallel bearings. The formers are escalloped or fluted wheels upon this swinging spindle. In its revolution these bear upon a guide which moves the spindle relatively to the cutting tool, causing these wavy lines to be reproduced upon the watch-case to a diminished scale. Very beautiful ornamentation is executed upon the nickel work of watch plates, a great variety of curious forms being produced by the movement of an ivory style or steel point over the nickel surface, the movement of the style being obtained by elliptic gearing, escalloped wheels acting as formers, or other aggregations of cam motions, to vary the position of the style as the rotation progresses. This is called nickel-finishing.

The stem-winding movement usually comprises some twenty-five or more additional pieces, the most characteristic being bevel gears, requiring bevel-gear cutters and angle grinders and polishers. The movement usually consists of a train with bevel gears for stem-winding, and another train for stem-setting, which engages upon pressing a button or pulling out the stem itself, so that the hands are also moved as the winding proceeds.

In the common screw-machine for watch screws the wire is first stopped and shouldered; the die is then carried over it, and the motion is reversed, running the die off, when the screw is run into a screw plate and the wire is cut off, leaving the head. A screw plate full of screws with plain heads is thus obtained, which is placed under a mill for slotting the heads. In this way one man can make 1,200 screws a day, not including the slotting. When more than one operation is performed on the wire blank before cutting off a pivoted tool-stock is used. Such tool-stocks for this and for other work in watch-making, instead of being like ordinary turret lathes, are often centered back of the work, so that the cutting tools converge toward instead of diverging from a center.

The unslotted screws are sometimes run into a cylindrical holder, so that they may all be slotted by one operation of turning. Automatic screw machinery, which is very prolific in output, is used by the American Watch Company, having been designed by Mr. Woerd in 1872. With the same attendance it will turn out fine watch screws about as rapidly as the most prolific automatic screw machines used in sewing-machine work will turn out the smallest sewing-machine screws. Most of the movements in these screw machines are derived from cams on a side shaft. Such a cam causes a chuck to feed the wire forward and gives it a rotation by means of fast and loose friction pulleys; another cam moves a toothed sector, which by a pinion actuates the chaser-screw spindle, which drives the die spindle by a pair of adjustable gears; another cam operates, after the wire has been threaded by the die, to throw over an arm pivoted upon another spindle, which arm carries a small griping chuck, or holder, and on coming into line with the die (which is drawn back by a cam) is allowed to spring forward and take the screw just as the head is formed by cutting off with a straight automatic tool. Finally, another cam operates to lift and lower upon a pivot the frame carrying the mill, which is driven by pulleys with round leather bands, and slots the screw head after it has been brought into position by the return of the pivoted arm, which successively transfers the pieces from the die spindle after they have been threaded and cut off. The smallest watch screws weigh only about $\frac{1}{122400}$ of a pound. In polishing the heads of screws they are inserted in a metal disk, and are then passed over a glass and emery surface, being given an eccentric rotary motion, moving from the center toward the circumference.

The scape-wheel has 15 teeth. They are cut in piles of ten or more by a machine with eight sapphire cutters. With this one man in a day can cut 3,000 wheels, and, delicate as is the work, with the wheels once set the operative might turn the handles with his eyes shut.

The hair-spring studs go through sixteen operations. In grinding and polishing these studs one man will do 250 a day. The watch pallet is first punched from sheet-steel in the press-room, and is then slotted and milled on lathes fitted with suitable chucks and holders. Slips of jewel are inserted to form the acting surfaces and to take the wear. The pallet is often made in curious forms merely for ornamentation. The pallet jewels are sawed in strips with diamond saws, are polished by fine diamond laps, and in ten hours one man will complete 300 of these jewels, one of them weighing $\frac{1}{150000}$ of a pound. Roller jewels are made from long bits of jewel, which are fastened in a revolving spindle ground and polished to size. One man will make 200 a day, and one will weigh $\frac{1}{256320}$ of a pound.

An apparatus called a horizontal bar and pole is sometimes used for surfacing steel work, the pieces, by means of it, being brushed over a stone—that is, held and imbedded in a brush, which is swept over the stone. The tempering of the steel work and the hair-springs requires experienced judgment, but is only a small item of labor.

In balance-making the steel blanks are first pressed out and brass rims are fused or brazed upon them. The blanks are then repunched, and the sections, leaving the single arm, are also punched out. This cross-piece, or arm, is sometimes formed by four milling cuts, and the rest of the steel disk is turned out, excepting a narrow rim of steel within the brass. Screws of gold or brass are placed in the rims. Two machines, one operative attending each, turn out 400 balance screws a day, 1 pound of brass being enough to make 2,000, and 1 pennyweight of gold 50 screws. One operative can drill upward of 2,200 screw holes for the balance-wheels in a day. There are 80 operations upon a balance-wheel, 66 of them being drilling, threading, and countersinking holes. The drills revolve at 4,800 turns a minute. The balance, which at first is a steel disk rimmed with brass, weighs 72 grains, but after machining weighs only 7 grains, and, fitted with 16 gold screws, 7.20 grains. The hands are punched in two operations, the finished weight being one-fifth of the original weight of the blank.

The final operation of assembling is called the gilt training, in distinction from the assembling before gilding or in the gray, and the finishing and adjustment of the balances is commonly called the balance handling. In the finishing one operative will in a day set 90 mainsprings and fit them into the movements. The mainsprings are cut from rolled sheet, the remaining operations being tempering, polishing, and winding. The temper is very neatly drawn by bench apparatus with burners. The polishing and working are usually done by hand, the tools being drawn to and fro over the springs, which are extended flat and fastened in vises at the ends.

The hair-springs are made from spools of fine wire. These wires are polished by drawing them between diamond points, and are cut to length, coiled, hardened, and tempered. The coiling of the hair-springs is a very simple operation. The ends of two or more, generally of three, springs are inserted in holes in a small arbor, which is placed in a small cylindrical box and turned until the springs wind themselves within the box, the thickness of one or two springs being the space thus determined between the coils of a single spring. These boxes, with tops wired on, are bunched together, and the springs, after tempering, retain their form. Hair-springs are sometimes made of gold, and this is the case in the movements for the Yale time-locks for vaults, as steel is specially subject to corrosion from the dampness and condensation of moisture.

In common watches the fast and slow regulation of the hair-spring is effected by moving a lever on which are pins, which clasp the spring and extend or shorten its vibrating length by a little, causing the vibration to be slower or quicker. The inner end of the hair-spring is fastened by running it through a hole in the collet of the balance pin, where it is clinched by pushing in a tiny brass pin, made long enough to be driven from outside the spring and then nipped off close to the collet. The point at which the outer end of the hair-spring is held, in respect to the position of insertion of the inner end in the collet, having been once properly fixed, cannot be greatly varied without impairing the isochronism of the movement of the balance. In watches of the finest time-keeping qualities the balance is therefore carefully selected to accord with the strength of the spring, so that the least possible adjustment may be necessary in shortening or lengthening the spring. The balances are weighed to the fourteen hundredth part of a grain, and the strength of the spring is gauged relatively by winding and unwinding against a given spring. The time-keeping of a watch is perfected by a trial, so as to adapt it to a wide range of circumstances, and is subjected to high and low temperatures, and made to run with 6 up, 12 up, 3 up, 9 up, face down, and so on. The adjustments resorted to in consequence of the results of these experiments are such as seem justified by a long course of experience, and are of a nature and nicety which cannot well be explained.

The foregoing illustrations of the processes of watch-making outline more or less superficially the character of the work. The examples cited have been drawn from observation of the practice at all of the larger factories, and acknowledgments are due to the officers of the American Watch Company, of Waltham, Massachusetts; the Elgin National Watch Company, of Elgin; the Illinois Watch Company, of Springfield, Illinois, and the Hampden Watch Company, of Springfield, Massachusetts, for courtesies kindly extended.

VI.—THE MANUFACTURE OF CLOCKS.

NOTE.—For statistical information regarding the manufacture of clocks, see Table III, page 28.

The manufacture of clocks exhibits a much more rapid growth during the past ten years than in any preceding decade, there having been, in 1850, 82 per cent. as many operatives as in 1860; in 1860, 73 per cent. as many as in 1870; and in 1870, 47 per cent. as many as in 1880. At the same time the reported value of material handled and of product per operative is less than in 1870; against 47 per cent. as many operatives in 1870 as in 1880, there being a return of about 77 per cent. as great a value in the product. There thus appears a change in the character as well as in the extent of the industry. The value of material formerly trebled is now little more than doubled in the process of manufacture. At the same time it may be said that a smaller proportion of the labor is now devoted to the clock movement, more being expended upon the manufacture of ornamental cases in great variety, bronzes, and the like.

It is obvious that much less labor is expended upon the same weight or even upon the same value of material in clock- than in watch-making. A greater value of material is therefore handled by the same number of operatives, and the relative value of constituent materials for movements is three or four times as great, and the aggregate value of all materials is for the same number of operatives greater in clock than in watch manufacture.

Clock materials are almost entirely domestic, except a small proportion of foreign woods used in casing. Copper and zinc, the chief constituents of sheet-brass, are obtained in this country in unsurpassed purity and excellence; the steel and iron wire are also commonly American, and native black walnut is the wood in most general use for cases.

Clock-making was one of the earliest outgrowths of Connecticut ingenuity, and clock parts being coarse as compared with watch parts, practical uniformity has followed more in consequence of wholesale manufacture and the necessity of correct gearing for uniform velocity ratios than as an end deliberately sought or utilized for the interchanging of parts. The work upon the common clock movement is for the most part of two kinds: plate work and wire work. Dies for punching the plate parts determine their uniformity, and the wire gauge determines that of the arbors, pillars, and trundles. Even the wires are not formed into complicated shapes, and in common clocks screws are not used, the plates being riveted like lock-plates.

But clock-making, having been so long practiced (and the primitive processes being susceptible of such great improvement), exhibits perhaps more forcibly than any other manufacture of mechanism the great strides that have been made. The successful manufacture and general use of many kinds of mechanism has been consequent upon the prior existence of manufacturing mechanism, but from the single-handed manufacture of wooden toys clock-making has gradually come to be conducted in large establishments, having all the advantages of labor-saving machinery. Some of these produce an average above two clocks per working minute.

The departments of the work are principally two, devoted respectively to the manufacture of movements and of cases, of which the latter often requires the greater space and the greater number of operatives, although the material for the movements usually costs more than that for the cases. Metallic cases also are made for many styles of clocks, involving both metal working and foundery facilities in their manufacture.

The capital required is notably smaller in clock than in watch manufacture. The returns for the United States in 1880 show an average of $1,236 per operative for watch and $756 per operative for clock manufacture, the total products in the two cases being nearly equal, the total capital being twice as great in watch as in clock manufacture, and the average number of hands being about four-fifths as great in the latter as in the former.

In the earliest work of wood clock-making in Connecticut it took a man upward of a week, sometimes several weeks, to make a clock; but by 1820 the average time was about three and a half days.

In 1820 thirty hands made 2,500 wooden clocks in four different styles in the course of a year, or 83 clocks per operative per annum. These clocks were made with cherry wheels and laurel pinions, the teeth being set in. But in 1880, though the number of different styles made in a single establishment is fifteen or twenty times more, and many of them are of an elaborate ornamental character, an average of over 520 brass clocks per operative per annum is attained, and for the cheaper styles the output would of course be considerably greater. It may be said roundly that one operative will upon an average in a given time perform the work upon four times as many ordinary clocks, including casing, as upon ordinary watch movements. Of large calendar clocks, more than 125 are turned out per operative per annum, and since 1870 an improvement of as much as three or four fold is stated in some instances, the advantage being due to improved machinery and to the practice of manufacturing clocks of the same kind in very much larger lots at a time than before.

A large proportion of the labor in clock-making is unskilled, about 10 per cent. of all the hands being children and youths, while practically no children or youths are employed in watch-making. In clock-making, about 12½ per cent. of the operatives are females, in contrast with 36 per cent. in watch-making. Of the operatives, we may consider roundly that about one-third of them are machine-tenders, and the remaining two-thirds bench-workers, varnishers, packers, and so on. The number of power machines ranges from as many to half as many as the number of operatives, but many of the machines are not in continuous operation.

In clock as compared with watch manufacture the machine processes are generally similar, but without the same degree of refinement. The large proportion of wood-case work is also peculiar to clock-making.

In 1807 Eli Terry, of Plymouth, Connecticut, commenced using machinery in making wooden clocks. Clock-gears were then marked out and sawed by hand, a much slower and more laborious work even than fret-sawing. Such movements were sold at $25 each, but by 1840 the cost of a wood movement had been reduced to $5, and at this time the manufacture was fairly revolutionized by Chauncey Jerome, who introduced the one-day brass clock, the movement for which can now be made for less than 50 cents, three men being able to level the sheets and punch out wheels for 500 such clocks in a day. Mr. Jerome sent his first consignment of clocks as a venture to England in 1842, and the export business thus commenced has grown to such an extent that some American manufacturers have their catalogues printed in French, German, Spanish, Italian, Swedish, and Portuguese. Not only is the civilized world supplied, but American clocks are found to have preceded the American traveler in semi-barbarous lands.

The labor on a handsome wood clock-case often costs a surprisingly small sum, and the common zinc faces are cut, painted, and lettered at 3 or 4 cents apiece. In the case-making the processes are of great variety. Knobs and ornaments are turned and carved; stencils are used in laying out patterns to be carved; and curved, round, and half-round cases are formed by deeply scoring the wood at intervals upon the inner side and bending it to shape. Some of the most elaborate ornamentation is executed by pressing compositions of glue and sawdust, which, when finished, appear like fine wood carvings. Ornaments in glass are etched by acids. Wheels covered with sand-paper are used in smoothing wood work, the wheels for finishing moldings being molded to correspond to the work. Planing, sawing out, drilling, mitering, gluing, varnishing, bronzing, painting, and polishing comprise the balance of the work on ordinary cases.

Most of the work upon ordinary clock movements is done by those machine methods well known to be of the greatest rapidity, viz: Press work, turning pins and arbors from wire, and cutting small gears in piles. The making of main-springs and the riveting and other kinds of bench work are also rapidly performed.

Index gear and pinion cutters are commonly used, these being sometimes automatic. Among other instances, automatic machines are used for placing pinion blanks upon arbors. The blanks and arbors are held in proper feed receptacles, the blanks being allowed to drop successively into grooves, when the arbors are thrust through them. The arbors with the pinion blanks exactly placed are then thrown out ready for the pinion cutter. The little staves in the lantern pinions are placed by girls. There is much work of turning, and the turning tools are commonly set upon arbors, which rest in sockets parallel with the lathe spindles, the tools being brought against the work by handles set in the arbors, which will accommodate a number of tools placed radially in various positions.

It is, however, obvious that between the fine and the heavy, the plain and the fanciful, a great range of work is involved in clock-making. No mechanism is too exact for the manufacture of fine astronomical clocks, and tower clocks are large and heavy machines, involving nice work, and being sometimes built by special contract. The other extreme is in the manufacture of small alarm and other cheap clocks, upon which, however, the exactness of machine methods in wholesale manufacture enables a very excellent quality of work to be done at a low cost.

The power required in clock manufacture may usually be rated at from two-fifths to one-half horse-power per operative, of which the greater part is commonly consumed in the case-making.

VII.—THE MANUFACTURE OF AGRICULTURAL IMPLEMENTS.

NOTE.—For statistical information regarding the manufacture of agricultural implements, see Table VII.

GEOGRAPHICAL DISTRIBUTION.

In agricultural implements we have a product whose manufacture has a widespread geographical distribution. Many manufactures of interchangeable mechanism, as fire-arms, sewing-machines, watches, clocks, and hardware, will often be found in groups of factories in places within easy access of large cities. For agricultural implements accessibility to city markets is a matter of minor importance, and so small a proportion of the product is consumed by export trade that location in or near seaports is, in the present condition of the industry, a matter of no consideration.

Yet the manufacture is more centralized than the population. We find in Maine an average of 448 operatives, nearly all in Kennebec county, the product being mainly scythes, shovels, hoes, hay-forks, etc. In New Hampshire, of 178 operatives, over half are in Grafton and Merrimack counties, and the product is mainly scythes, hand-rakes, and hay-cutters. In Vermont, of 464 operatives, 297 are in Rutland, Windsor, and Windham counties, and the product is mainly scythes, hand-rakes, hay-forks, separators, and sirup-evaporators. In Massachusetts, of 973 operatives, over half are engaged in the great shovel and plow factories of Bristol county, and the manufacture of hay-cutters, tedders, horse-rakes, etc., is largely pursued in Hampden county. In Connecticut, of 565 operatives, over half are in Middlesex and Litchfield counties, scythes, hoes, plows, lawn-mowers, and fodder-cutters being the chief products. In New England the factories are commonly located upon river-courses, the seaboard counties producing few manufactures of this class. Hand implements, involving wooden ware, are of the most general manufacture.

Plow manufacture does not require a large factory organization, but from the great demand for plows and similar products the manufacture is often conducted upon a large scale, as well as at small shops widely distributed through nearly all parts of the country. It is obvious that the manufacture of grain-cradles and scythe-snaths may be conducted on a small scale, but the manufacture of mowers, reapers, and thrashing-machines, and of similar composite products, necessitates a factory organization for their economical production. Such composite products are mainly manufactured in the great belt of states from New York to Illinois, inclusive, which in 1870 employed 69 per cent. and in 1880 66 per cent. of all the operatives engaged in the manufacture of agricultural implements. Through these states the mechanical facilities are of a high order, and the factories are widely distributed; but the centralization of the greater part of the work is strongly marked. In New York, of 6,462 operatives, over half are in five counties—Cayuga, Rensselaer, Monroe, Onondaga, and Saratoga; in Pennsylvania, of 2,617 operatives, over half are in four counties—York, Allegheny, Philadelphia, and Lancaster; in Ohio, of 7,536 operatives, over half are in three counties—Clarke, Stark, and Summit; in Indiana, of 2,471 operatives, over half are in two counties—Saint Joseph and Wayne; in Illinois, of 7,300 operatives, over half are in five counties—Rock Island, Cook, Winnebago, Warren, and De Kalb; also, in Michigan, of 2,004 operatives, over half are in four counties—Calhoun, Jackson, Kalamazoo, and Kent; in Wisconsin, of 2,067 operatives, over half are in two counties—Racine and Rock; and in Minnesota, of 1,197 operatives, over half are in Washington county.

But this predominance of a few localities is equally noticeable in states in which the manufacture is not as largely pursued. In New Jersey, of 206 operatives, nearly half are in three counties—Mercer, Warren, and Somerset; in Delaware, of 66 operatives, over half are in New Castle county; in Maryland, of 356 operatives, over half are in two counties—Baltimore and Washington; in Virginia, of 530 operatives, over half are in two counties—Henrico and Dinwiddie; while in West Virginia, of 63 operatives, 58 are in the little tenon of the state between Pennsylvania and Ohio, comprising Marshall, Ohio, and Brooke counties; in North Carolina, of 202 operatives, over half are in Mecklenburg, Davidson, Edgecombe, Chatham, and Randolph counties; and in South Carolina, of a total of 88 operatives, 75 are in a single establishment in Charleston; in Georgia, of 274 operatives, more than half are in Fulton and Coweta counties; in Alabama, of 36 operatives, over half are in Cherokee, Monroe, and Morgan counties; in Mississippi, of 61 operatives, over half are in Attala and Lauderdale counties; in Texas, of 139 operatives, over half are in Marion and Fannin counties; in Tennessee, of 178 operatives, over half are in Gibson, pulverizer; but the latter may cost five to ten times as much as the former. There is one man to a hoe, and one man to a riding cultivator; but the cultivator may cost fifty times as much as the hoe. There is one man to a hand-rake, and one man to a horse-rake or a hay-tedder; but the latter may cost twenty to fifty times as much as the former. There is one man to a scythe or a grain-cradle, and one man to a mower or a reaper; but the latter may cost seventy to one hundred times as much as the former. We find one man to a flail, and a few men to a separator and engine; but the latter may cost a thousand-fold more than the former. When, therefore, knowing that machinery of high cost has gradually superseded inexpensive hand tools, we still find that since 1850 the value of farm implements and machinery, instead of increasing, has fallen off, relative to the value of farms for the entire Union, and most notably so in the heavier farming sections, it would appear that an estimate of double the amount of labor for the hand tools upon the same acreage would be an inadequate estimate, despite the increased value of farm land and the inclusion of wagons, harness, etc., among farm implements in either case. But if only half the labor has been saved, it is easy to estimate how great a body of men is relieved of the work of farm labor *pro rata* by every man engaged in the manufacture of agricultural implements. It is, in fact, estimated by careful men, thoroughly conversant with the changes that have taken place, that in the improvement made in agricultural tools the average farmer can, with sufficient horse-power, do with three men the work of fifteen men forty years ago, and do it better.

It is as a condition in the manufacture of agricultural implements that this saving in farm-work is here treated, and it explains the growth of great factories, the wholesale demand for their products, and the cheapness with which those products may be furnished to the farmer. But a comprehensive exhibit of this saving can only be made by reference to farm work, which is more or less desultory, the seasons of plowing and seeding in spring and fall, of cultivating growing crops, of hay-making and harvesting, creating imperative demands for the prompt exercise of much labor, other less exacting duties being made to fill in the time between these working seasons.

The first of these classes of work is naturally the preparation of the soil. The labor of plowing may be more distributed than that of harvesting. For stony soils less saving seems feasible in this duty than in any other. Harrows and scarifiers have long been in use, but their extensive employment for saving replowing is a modern practice, the advance of which is shown by the immense relative increase in their manufacture. In preparing land for turnips after wheat two scarifyings (including seeding) and one plowing displace four plowings and seedings, and as the draft of a scarifier may be estimated at from one-half to one-fourth that of a plow for the same speed and width of land passed, the horse-labor saved is about in the ratio of four to one and two-thirds, and for six-horse gangs of cultivators or harrows—compared with single-plow furrows, the width of land being about as 5 feet to 5 inches—it will be seen that the saving in men's labor will be even greater. For ordinary plowing the amount plowed will not exceed that of thirty or forty years ago, but the comfort and the rapidity of working have been increased by sulky- or riding-plows. In the east many side-hill or reversible plows are made in place of ordinary land-side plows, which leave a dead furrow, that may later interfere with the convenient operation of horse-mowers, tedders, and rakes. The form of point, share, and mold for the best results obviously differs for every condition of tenacity of the soil and depth of furrow, and to meet these conditions a great variety of forms is made. Thus a prairie-breaker or a road-plow has a longer, sharper share than a stubble-, a deep-soil-, a sod-, or a trench-plow, and the heavy clay soils of Indiana and of Ohio, the sugar-lands of Louisiana, and other sections have each their series specially adapted to their crops and soil, each manufacturer making a specialty of a number of such established series. For alluvial or black, sticky soils a plow that will scour well is necessary. This is secured by making the shares of cast-steel or of chilled or patent hard metal. Of the whole number of plows made per year in this country, probably about half a million are cast-steel plows for the alluvial soil of the Mississippi valley.

Some degree of interchangeability was practiced in making plows at an early period. For the same size and series the shares are made interchangeable, and the slip-share points and other plow parts are often made removable and interchangeable, so that a single plow stock may serve for a variety of attachments, while the change of slip-share points saves shares and keeps the plow in running order at a comparatively small expense. But in the manufacture of plows the advantages of uniformity as an administrative feature of the work are not to be rated above other benefits resulting from the most easy and natural methods. The same is true in the manufacture of many other agricultural implements, where the forms are given by casting and finished by grinding, and it is only in such wrought-iron work or in such fine cast-iron work as requires cutting or paring by machine tools that uniformity of work exhibits distinctive advantages in the division of labor and the system of working.

The usage of different sections in the employment of farm machinery may occasionally throw some light upon items enumerated as units, but at the same time having great differences among themselves. Thus the term plow covers all kinds, from a small and cheap stirring-plow to an expensive sulky-plow. Handled plows are used everywhere, but the sulky-plows principally in the western farming states, being manufactured by a comparatively few large factories in that section. A single style of sulky-plow is estimated to be in use on 60,000 farms.

Two-horse and riding cultivators are largely used in the West, and the screw pulverizer, which does such peculiar and effective service, was employed on over 35,000 acres of land in 1880. In New England the cultivator is mainly used with one horse for cultivating between rows of corn or of root crops. It also takes the place of the harrow in covering grain. Handled cultivators have wheels or runners to gauge the depth of working. The simplest products. In Minnesota a large proportion of the operatives are engaged in making thrashers and separators, and in Kansas and Nebraska plows, harrows, cultivators, and stone-gatherers are the principal products.

The agricultural manufactures of California are mainly plows, separators, and horse-powers. The large ranches are necessarily supplied with jobbing shops of some sort, and these sometimes suffice for the erection of the large headers and separators forming a feature of farm practice in that country. Much of this machinery is brought from the East.

THE CHARACTER AND DIRECTION OF THE INDUSTRIAL GROWTH.

A machine for thrashing and separating is in the great majority of cases reported as one separator, but sometimes as one thrasher, and in a few instances, from the identity of numbers returned, there is a strong inference that the same machine has been returned as one thrasher and one separator.

So in the return of grain-drills the production does not seem to have kept pace with the increase of operative labor in the manufacture of agricultural implements, but a portion of the return is doubtless absorbed under the heads of grain-sowers and seed-sowers. A variety of machines (corn- and cotton-planters, grain-drills, pulverizers, and even harrows and hay-rakes) may be adapted for sowing seed and grain, and also guano, plaster, or other fertilizers. Such machines will usually be returned in accordance with the function considered most essential and important, but there is liability to duplication.

The third class of farm machinery liable to be reported ambiguously includes the following items: Harvesters, mowers, reapers and mowers, reapers. All of these are included under the title of harvesting machinery. The term harvester would not be applied to a mower, but might be applied to a reaper, or to a reaper and mower. Gavelers, droppers, hand-, chain-, self-, and sweep-rake reapers, as well as twine and wire self-binders, are liable to come under the caption of harvesters. The numbers of harvesters and reapers produced are given:

	1880.
Harvesters	25,537
Mowers	72,090
Reapers and mowers	54,884
Reapers	35,327

The movements in the manufacture of particular classes of farming machinery are of significance as exhibiting developments in methods of farming, no less than the mere transfer of the manufacture from one region to another, or its greater centralization or diffusion. The inadequacy of the returns as to the numbers of implements made in 1870 through enumerators prevents detailed comparison with that year, but the general relations of the two years are fairly evident. The manufacture of cane-mills in 1870 was confined to Kentucky and North Carolina, most of them being made in Kentucky. In 1880 their manufacture had become vastly increased, and was not only diffused through the sugar-cane growing states, but was also made an important item of manufacture in northern states. Thus, in round figures, about 27 per cent. of all the cane-mills were made in Missouri, 18 per cent. in Kentucky (but over four times as many as in 1870), 17 per cent. in New York, 11 per cent. in Indiana, 6 per cent. in Tennessee, 5 per cent. in Virginia, about 4 per cent. each in Georgia and Wisconsin, 3 per cent. in North Carolina, 2 per cent. in Arkansas, over 1 per cent. in Texas, and the residue in six other states.

In 1870 clover-hullers were manufactured in but three states, and nearly all in Pennsylvania. They are now manufactured in six states (38 per cent. being made in Indiana, 31 per cent. in Ohio, and 21 per cent. in Maryland), and the manufacture appears almost to have disappeared from Pennsylvania and to have diminished greatly, consequent upon changes in farm methods, much clover-hulling being now done by attachments to thrashers.

In 1870 corn-planters were made in seven states, chiefly in Illinois and in Missouri. They are now made in twenty-one states, 63 per cent. in Illinois, 21 per cent. in Ohio, and over 6 per cent. in Wisconsin.

In 1870 all of the cotton-planters were made in Georgia, but since that time the introduction of cotton-planting machinery has progressed greatly, and its manufacture is now increased nearly tenfold, and is pursued in fourteen states, but specially in Ohio, where two-thirds of all the cotton-planters are made, about 8 per cent. being made in Pennsylvania, and about 8 per cent. in Georgia.

In 1870 plows were made in thirty-three, harrows in twenty-three, and cultivators in twenty-four states and territories. In 1880 plows were made in thirty-six, harrows in thirty-four, and cultivators in thirty-three states and territories, the percentages of the entire numbers made in the states in which the manufacture was most largely pursued being, for plows: Illinois, 20 per cent.; Indiana, 13 per cent.; Kentucky, nearly 10 per cent.; New York, 7 per cent.; Pennsylvania, 6 per cent. For harrows, in 1880: Illinois, 29 per cent.; Michigan, 21 per cent.; Kentucky, 11 per cent.; New York, 8 per cent.; Wisconsin, 7 per cent. For cultivators, in 1880: Illinois, 42 per cent.; Georgia, 11 per cent.; Michigan, 9 per cent.; Kentucky, 7 per cent.; Ohio, 5 per cent.

The relative falling off in the number of plows manufactured indicates that their function is being performed to some extent by other implements. We may say that in 1870 one harrow appears to have been made to every ninety-four plows, and in 1880 one to every ten plows; and that in 1870 one cultivator was reported to every ten, and in 1880 one to every four plows. In the great agricultural state of Illinois the reduction of the ratios seems even more decided, viz: In 1870 one harrow to one hundred and twenty-five, and in 1880 one to seven plows; in 1870 one cultivator to five and a fraction, and in 1880 one to two plows.

The change has been going on during the decade in the use of cultivators, displacing plowing and hoeing, and of cultivators and harrows, saving much of the labor of plowing in the preparation of land for crops. In the English four-year rotation the cultivator has, it is estimated, saved half the labor of plowing; but upon prairie land in this country the use of harrows, cultivators, sulky-plows, and pulverizers has lessened labor to an extent variable with the conditions of crops and of seasons, but undoubtedly to a much greater extent than in England. As compared with approved methods of putting in and tending crops with plows, harrows, and cultivators, the screw pulverizer alone is claimed to save from one-third to one-half the labor of preparing land for corn and from one-third to one-half in the whole cost of cotton-raising up to the picking. A screw pulverizer is not adapted to a hilly or stony country, but on level, stoneless land will go over 20 acres a day, fitting land at the rate of 7 to 10 acres a day in thrice or twice going over. By it oats may sometimes be put in on stubble land after once going over, and it not only cuts stalks and seeds at the same time, but saves after-harrowing.

The manufacture, and, by inference, the use, of cultivators and harrows is also shown by the statistics to be more general in level states like Illinois than in states whose land is more hilly and stony.

The manufacture of fanning-mills was in 1870 conducted in eighteen states, 23 per cent. being made in New York, 15 per cent. in Iowa, and 12 per cent. in Michigan; and in 1880 in twenty-one states, 38 per cent. being made in Wisconsin, 27 per cent. in Michigan, and 6 per cent. in Ohio.

Grain-cradles were in 1870 made in twelve states; in 1880 in twenty-four states. Scythe-snaths were in 1870 made in three states; in 1880 in nineteen states. Of grain-cradles, in 1870, 38 per cent. were made in Indiana, 33 per cent. in New York, and 16 per cent. in Michigan; in 1880, 27 per cent. were made in Indiana, 23 per cent. in Michigan, and 22 per cent. in New York. Of scythe-snaths, in 1870, 74 per cent. were made in Vermont, 22 per cent. in Pennsylvania, and 4 per cent. in Maine; in 1880, 34 per cent. were made in Vermont, 14 per cent. in Iowa, and 13 per cent. in Michigan. Such manufactures are often predominant in well-wooded states, although it is obvious that with the transportation facilities for light freights this may easily become a secondary and obscured influence.

Hand-rakes were in 1870 made in fourteen states; in 1880 in twenty-five states. Hay-forks were in 1870 made in fourteen states; in 1880 in seventeen states. Of hand-rakes, in 1870, nearly 70 per cent. were made in Michigan alone; but in 1880 over 71 per cent. were made in New York alone, this including both hay- and garden-rakes. In 1870 hay-forks were most largely made in New York, Pennsylvania, Indiana, and Ohio; in 1880 most largely in Pennsylvania, Vermont, Ohio, and Michigan. Scythes and sickles were in 1870 made in nine states, most largely in Connecticut, New York, and Rhode Island; in 1880 they were made in thirteen states, scythes most largely in Maine, Connecticut, New Hampshire, and New York, and sickles principally in Ohio, Maine, and Connecticut.

Of grain-drills, seed-sowers, fertilizer distributers, and grain-sowers, in 1870 the manufacture was confined to fourteen states, and was most largely conducted in Ohio, Indiana, and New Hampshire. In 1880 these implements were manufactured in twenty-six states, and most largely in Ohio, Indiana, and Wisconsin.

In 1870 there were built, as reported, 24,062, and, in 1880, 19,527 thrashers and separators. This numerical decrease may be attributed to the greater use of combined thrashers and separators, so that while the aggregate number of both is decreased the function of the governing unit may in many cases be considered to be doubled. In 1870 the manufacture of these machines was conducted in twenty-two states, most largely in Missouri, Ohio, and Pennsylvania; and in 1880 they were manufactured in twenty-six states, most largely in New York, Ohio, and Wisconsin.

The great growth (eighteen-fold) in the manufacture of lawn-mowers simply bears evidence of the increasing custom of keeping lawns closely trimmed. In 1870 nearly all of them were made in New York, but they are now made in six states, notably in Pennsylvania, Ohio, New York, and Connecticut.

Hay- and fodder-cutters were in 1870 made in thirteen states, most largely in Massachusetts, Connecticut, and Ohio. They are now made in twenty-five states, and most largely in Massachusetts, New York, Kentucky, Michigan, Connecticut, Ohio, and Virginia.

Hoes in 1870 were made in twelve states, most largely in Massachusetts, Connecticut, and New York; and in 1880 in thirty states, most largely in Kentucky, New York, Ohio, Massachusetts, and Michigan.

Stump-pullers, whose manufacture is of course indicative of forest clearings, were in 1870 made only in Pennsylvania; but in 1880 the manufacture was extended into eleven states, most being made in Wisconsin, Michigan, and Indiana.

Of horse-powers in 1870 about 37 per cent. were made in Ohio, 19 per cent. in New York, and 12 per cent. in Michigan; in 1880, 17 per cent. were made in Ohio, 16 per cent. in Wisconsin, and 13 per cent. in Pennsylvania, the manufacture being more generally distributed.

Of sirup-evaporators 24 per cent. are made in Vermont, 21 per cent. in Missouri, and 16 per cent. in Kentucky.

The change in the numbers of operatives employed in the manufacture of agricultural implements in the several states is shown for the last four census years to be as follows, the states being grouped according to the tendencies in growth or decadence of the manufacture within their limits:

States.	1850.	1860.	1870.	1880.
Continuous increase.				
Ohio	765	2, 239	5, 124	7, 536
Illinois	646	1, 790	3, 935	7, 300
New York	923	2, 905	4, 953	6, 462
Pennsylvania	947	1, 465	2, 286	2, 617
Indiana	210	709	1, 268	2, 471
Wisconsin	178	666	1, 387	2, 067
Michigan	35	666	969	2, 004
Minnesota	....	42	167	1, 197
Kentucky	217	462	624	1, 033
Iowa	15	208	552	809
Missouri	89	221	537	726
California	....	12	68	295
Kansas	....	3	29	103
West Virginia	....	....	55	63
Nebraska	....	....	9	54
Oregon	....	7	10	18
Continuous decrease.				
Louisiana	29	28	15	5

States.	1850.	1860.	1870.	1880.
Increase after 1870.				
Virginia	374	418	267	530
Maryland	333	368	295	356
North Carolina	52	100	78	202
Tennessee	143	110	110	178
Texas	....	138	44	139
Delaware	20	116	56	66
Mississippi	113	127	34	61
Alabama	23	84	9	36
Massachusetts	786	630	477	973
South Carolina	53	30	....	88
Vermont	178	155	372	464
Maine	325	189	210	448
Georgia	205	37	59	274
Arkansas	14	10	16	24
Decrease after 1870.				
Connecticut	297	498	593	565
New Jersey	80	260	366	206
New Hampshire	147	96	184	178
Rhode Island	70	10	81	16

From the growth of the West, and also from the change in farm methods, the facts cited relative to the manufacture of specified implements show that the manufacture has been greatly diffused; but apart from this growth the tendency is toward concentration into fewer establishments. The following table shows the number of operatives per establishment in the United States and in the several states for 1850, 1860, 1870, and 1880 in that order, fractions being discarded:

States.	1850.	1860.	1870.	1880.
The United States	5	7	12	20
Ohio	4	12	23	48
Minnesota	....	3	6	37
Massachusetts	14	11	12	33
Illinois	7	8	13	33
Connecticut	8	10	15	26
Indiana	3	6	10	25
New York	6	8	14	24
Wisconsin	5	8	16	19
Maine	6	4	6	16
Michigan	2	6	5	14
California	....	2	6	14
Georgia	7	2	5	13
Vermont	5	4	8	13
Iowa	3	4	10	13
Kentucky	4	7	14	12
South Carolina	4	2	....	12
Pennsylvania	4	5	7	11

States.	1850.	1860.	1870.	1880.
New Hampshire	5	3	7	10
Texas	....	3	3	10
Virginia	3	7	7	10
Maryland	4	10	8	9
Missouri	4	5	14	9
Kansas	....	3	9	7
Tennessee	2	7	4	5
West Virginia	....	....	5	7
Delaware	5	6	5	5
Louisiana	2	2	15	5
Mississippi	3	3	3	5
North Carolina	3	4	3	5
New Jersey	3	7	12	5
Oregon	....	1	2	4
Rhode Island	23	3	16	4
Nebraska	....	....	4	4
Arkansas	3	1	16	2
Alabama	11	4	3	1

While in the entire Union the number of operatives has steadily increased, the number of establishments has now begun to fall off. In six great agricultural states the number of establishments culminated in 1870, viz:

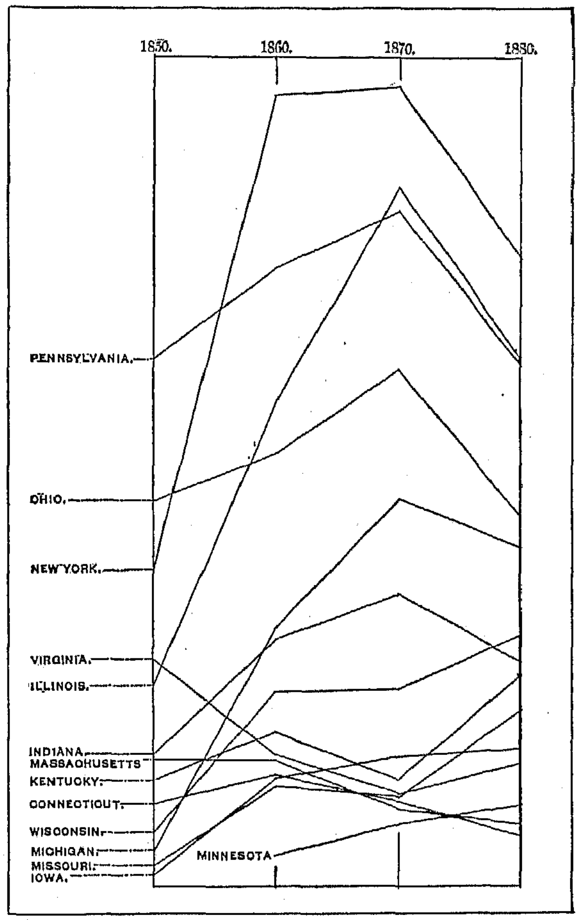
States.	1850.	1860.	1870.	1880.
New York	135	333	337	265
Illinois	84	201	294	220
Pennsylvania	222	260	286	220
Ohio	161	182	210	156
Michigan	13	108	164	143
Indiana	58	103	124	96

That is, in 1870, or later, the growth generally ceased to consist in the making of new establishments, and was concentrated in the enlarging of established factories, some small establishments being absorbed.

In two states, Connecticut and New Hampshire, the growth in the number of establishments culminated in 1860, and in two other New England states, Maine and Massachusetts, the number of establishments has decreased since 1850.

In only six rapidly-growing states has there been a continuous increase in the number of establishments, viz., Wisconsin, Iowa, Minnesota, California, Kansas, and Nebraska. In Kentucky, Missouri, New Jersey, Delaware, and Oregon, and in all of the southern states except West Virginia, there was a falling off in the number of establishments in 1870, generally followed by an increase in 1880.

The progress of growth and concentration in the states in which an average of over 500 operatives is employed is shown graphically in a diagram of the relative numbers of establishments:



While the manufacture of agricultural implements is, of course, dependent upon agriculture, it is mainly dependent upon an agriculture revolutionized by agricultural machinery itself—a manufacture which may be said to have made itself necessary, and which has created its own demand. Already the influence of this industry has had a significance of which but few are fully cognizant. In other arts curious developments have been made and great progress has been achieved, but this progress and these developments have been accomplished mainly by the labor freed from the necessary tillage of the soil by the manufacture of agricultural implements. This manufacture, now pursued by only thirty or forty thousand operatives, has been the simple means of taking hundreds of thousands from farm work, of feeding them, clothing them, educating them, and establishing them in every species of manufacture, art, and profession, and this is one of the prime causes of the rapid development of this country.

It is in the immense applicability of these improvements that their great power lies, as they lessen the labor of millions of men engaged in raising food products. Their economic influence is greater than any other in the whole range of labor-saving invention, because it applies to the greatest class of workers and to the most fundamental species of work.

The processes of fifty years ago, plowing and turning under the hand-sown seed, weeding and stirring the soil with hand-hoes, mowing and raking hay and cradling grain and binding it by hand, required implements which made a comparatively small demand upon the manufacturer; and the flail for thrashing, and the shell-shaped, wicker-work hand-fans for winnowing the grain on the barn-floor, unknown to this generation, were implements of slight cost. Over two-thirds of the value of farm implements now in use is estimated to be in the improved machinery which distinguishes modern from primitive American farming.

The increased cost of farm implements and machinery appears very great when we consider the numbers of men employed with machinery of a given cost. There is one man to a plow, and one man to a sulky-plow or a pulverizer; but the latter may cost five to ten times as much as the former. There is one man to a hoe, and one man to a riding cultivator; but the cultivator may cost fifty times as much as the hoe. There is one man to a hand-rake, and one man to a horse-rake or a hay-tedder; but the latter may cost twenty to fifty times as much as the former. There is one man to a scythe or a grain-cradle, and one man to a mower or a reaper; but the latter may cost seventy to one hundred times as much as the former. We find one man to a flail, and a few men to a separator and engine; but the latter may cost a thousand-fold more than the former. When, therefore, knowing that machinery of high cost has gradually superseded inexpensive hand tools, we still find that since 1850 the value of farm implements and machinery, instead of increasing, has fallen off, relative to the value of farms for the entire Union, and most notably so in the heavier farming sections, it would appear that an estimate of double the amount of labor for the hand tools upon the same acreage would be an inadequate estimate, despite the increased value of farm land and the inclusion of wagons, harness, etc., among farm implements in either case. But if only half the labor has been saved, it is easy to estimate how great a body of men is relieved of the work of farm labor *pro rata* by every man engaged in the manufacture of agricultural implements. It is, in fact, estimated by careful men, thoroughly conversant with the changes that have taken place, that in the improvement made in agricultural tools the average farmer can, with sufficient horse-power, do with three men the work of fifteen men forty years ago, and do it better.

It is as a condition in the manufacture of agricultural implements that this saving in farm-work is here treated, and it explains the growth of great factories, the wholesale demand for their products, and the cheapness with which those products may be furnished to the farmer. But a comprehensive exhibit of this saving can only be made by reference to farm work, which is more or less desultory, the seasons of plowing and seeding in spring and fall, of cultivating growing crops, of hay-making and harvesting, creating imperative demands for the prompt exercise of much labor, other less exacting duties being made to fill in the time between these working seasons.

The first of these classes of work is naturally the preparation of the soil. The labor of plowing may be more distributed than that of harvesting. For stony soils less saving seems feasible in this duty than in any other. Harrows and scarifiers have long been in use, but their extensive employment for saving replowing is a modern practice, the advance of which is shown by the immense relative increase in their manufacture. In preparing land for turnips after wheat two scarifyings (including seeding) and one plowing displace four plowings and seedings, and as the draft of a scarifier may be estimated at from one-half to one-fourth that of a plow for the same speed and width of land passed, the horse-labor saved is about in the ratio of four to one and two-thirds, and for six-horse gangs of cultivators or harrows—compared with single-plow furrows, the width of land being about as 5 feet to 5 inches—it will be seen that the saving in men's labor will be even greater. For ordinary plowing the amount plowed will not exceed that of thirty or forty years ago, but the comfort and the rapidity of working have been increased by sulky- or riding-plows. In the east many side-hill or reversible plows are made in place of ordinary land-side plows, which leave a dead furrow, that may later interfere with the convenient operation of horse-mowers, tedders, and rakes. The form of point, share, and mold for the best results obviously differs for every condition of tenacity of the soil and depth of furrow, and to meet these conditions a great variety of forms is made. Thus a prairie-breaker or a road-plow has a longer, sharper share than a stubble-, a deep-soil-, a sod-, or a trench-plow, and the heavy clay soils of Indiana and of Ohio, the sugar-lands of Louisiana, and other sections have each their series specially adapted to their crops and soil, each manufacturer making a specialty of a number of such established series. For alluvial or black, sticky soils a plow that will scour well is necessary. This is secured by making the shares of cast-steel or of chilled or patent hard metal. Of the whole number of plows made per year in this country, probably about half a million are cast-steel plows for the alluvial soil of the Mississippi valley.

Some degree of interchangeability was practiced in making plows at an early period. For the same size and series the shares are made interchangeable, and the slip-share points and other plow parts are often made removable and interchangeable, so that a single plow stock may serve for a variety of attachments, while the change of slip-share points saves shares and keeps the plow in running order at a comparatively small expense. But in the manufacture of plows the advantages of uniformity as an administrative feature of the work are not to be rated above other benefits resulting from the most easy and natural methods. The same is true in the manufacture of many other agricultural implements, where the forms are given by casting and finished by grinding, and it is only in such wrought-iron work or in such fine cast-iron work as requires cutting or paring by machine tools that uniformity of work exhibits distinctive advantages in the division of labor and the system of working.

The usage of different sections in the employment of farm machinery may occasionally throw some light upon items enumerated as units, but at the same time having great differences among themselves. Thus the term plow covers all kinds, from a small and cheap stirring-plow to an expensive sulky-plow. Handled plows are used everywhere, but the sulky-plows principally in the western farming states, being manufactured by a comparatively few large factories in that section. A single style of sulky-plow is estimated to be in use on 60,000 farms.

Two-horse and riding cultivators are largely used in the West, and the screw pulverizer, which does such peculiar and effective service, was employed on over 35,000 acres of land in 1880. In New England the cultivator is mainly used with one horse for cultivating between rows of corn or of root crops. It also takes the place of the harrow in covering grain. Handled cultivators have wheels or runners to gauge the depth of working. The simplest form of cultivator is a V- or an A-frame with cast-iron duck feet. The cultivator may have pulverizing point teeth, or these may be replaced by hoes, scooters, bull-tongues, colters, hilling wings, etc. Tobacco- and cotton-ridgers are sometimes provided with marking wheels for making equidistant holes for seed. In the horse hoeing-machine the hoes are of an inclination adjustable by handles, so that the weeds may be neatly removed and the soil stirred about hills or rows of plants. It is but a moderate estimate to say that in corn a horse-hoe will do the work of five men, beside keeping the weeds under better. It also enables the farmer to finish hoeing before the haying season begins.

Of harrows there is a great variety, the simplest form being an A-frame, with teeth. In order more fully to pulverize and go over the soil harrows are commonly made in sections, hinged so that they will vibrate. Spring teeth are also employed as well as ingenious contrivances which rotate the teeth as they are drawn through the soil. In fallowing (or cross-plowing) a well-known form of disk-harrow, which operates by cutting the soil into thin slices and breaking these by the oblique setting of the disks, is claimed to do more and better work than six plows.

Seed-drills and fertilizer distributers are commonly also cultivators. The walking-drills have tongues, shovels, hoes, or brake-pin teeth, and the riding-drills have points pressed down by springs, the seed being automatically fed through ducts or so-called shoes or boots, the quantity being adjustable. Seed-drills sow from one to eight or more rows at a time, the spacing of the rows being sometimes variable. Cottonseed, with the fiber, is sowed after being prepared with a solution, to prevent the seed from sticking together. The first two-rowed cotton-planter was made in 1879, one-rowed planters being previously used. The seed is pressed by following-wheels. With the two-rowed planter it is claimed that one man and a mule will do the work formerly requiring six men and four mules. Combining as they do cultivating and seeding, seed-drills effect their saving doubly as compared with hand seeding and hand cultivating. A one-horse check-row corn-planter plants 8 or 10 acres a day; a two-horse eight-shoe planter plants 16 or 17 acres of rice a day.

In hay-making a good tedder will do the work of ten or fifteen men in spreading and turning hay, and self-dump riding-rakes enable a farmer's boy to do the hand work of about five men.

Of hand-reaping nearly a third of the labor is in binding into sheaves. The performance of this hand work by machinery was begun during the past decade in the introduction of self-binding harvesters, working with twine or with wire, and these machines involve a high degree of mechanical ingenuity in their design, as well as of efficiency in operation. Under ordinary conditions, reapers will go over 15 or 20 acres a day. A self-binder will cut and bind 15 acres a day, and one of these machines has been known to work at the rate of 30 sheaves a minute. It is considered that with the average of mowers, reapers, and harvesters one man and a pair of horses will do the work of eight men. Manual delivery reapers are used by the smaller farmholders in the East or elsewhere.

In thrashing, the capacity of machines varies with the size and the speed of cylinders. The efficiency of the means of separation also varies. On headers in California one 25 horse-power thrasher has thrashed over 6,000 bushels of wheat in a day, requiring ten headers (reapers that cut off the heads of the grain) and thirty-six header-wagons, and keeping four men busy filling and four sewing sacks. With ordinary thrashers perhaps ten bushels of wheat per horse-power per hour is a good average, although better showings are often obtained. Oats shell easily and thrash twice as rapidly as wheat. In the great wheat states large thrashers or separators are used with steam-power. If horse-power is used, the lever-powers are more common; but in New England and the East the tread-powers are preferred, being commonly used with one, two, or three horses. The so-called ground-hog thrashers (not mounted upon wheels) are somewhat used in Kentucky and Tennessee, and similar fixed machines are used in New England, the power being the lever in the former and the tread in the latter case. With a simple hand-thrasher used in New England, one man turning and one feeding, 10 bushels of oats per hour may be thrashed. The efficiency of the simple work of thrashing by machine and by flails may be estimated in contrast at twelve or fifteen to one for the human labor employed, without regard to the separating done by the machine, which, compared with hand winnowing, would probably show an equal saving.

Horse-power is recommended for thrashers requiring six horse-power or less and steam-power for thrashers requiring 8 horse-power or more, and it is said that a steam-engine will pay for itself on a farm of upward of 200 acres. In the more settled sections steam is cheaper than horse-power, and horses are necessary for many classes of work to which steam-power has not been adapted; but for heavy work in thrashing, steam-power is notably cheaper and more rapid than horse-power, and in some sections the power applied in thrashing during the harvesting season is at other times used for wood-sawing, cotton-ginning, milling, or light manufacturing.

Much of the labor saved by improvement in agricultural tools is not to be found in any financial equivalent, but it exists in the greater ease of farm life, the shortening of the day's labor and of seasons of heavy work, and in other comforts of living. In the matter of household furnishing, persons brought up in the enjoyment of many luxuries do not comprehend that they are the result of saved labor, because they have no realizing sense of the bare floors, the unplastered walls, the thatched roofs, and unpainted exteriors common to the ordinary conditions of farm life half a century ago—conditions as luxurious as a man could earn with the ox-plow, the hoe, the spade, the scythe,

the cradle, the hand-rake, the hay-fork, the flail, and the hand-fan; and to gain an idea of how many fold in the intrinsic results of labor present conditions are superior to those of the past we must contrast their cost with that of the barest necessities of living.

In former times, moreover, agricultural produce was not subject to so much freighting and mercantile handling. The mercantile handling of some products (notably fruits and hay) has had an immense growth within the past few years; but in former times a much larger population lived in the country upon the immediate products of farms, and a relatively smaller number in the manufacturing and commercial centers. Smaller money values, therefore, were used in moving and handling food, and a person whose mind naturally reverts to the most plenteous harvests whose produce was given away or destroyed, but who has come from the farm to a city or town life, in which every article of food must be bought with money, may have no realizing sense of the fact that food is obtainable in greater quantity and variety for a less expenditure of labor now than ever before. These considerations are stated, not digressively, but simply to show that the remarkable statements of labor saved from the use of agricultural machinery are not inconsistent with the present prices of farm produce or the present conditions of farm life.

Since the majority of farmers are already farm proprietors, employing an average of less than a laborer each, and since many conditions combine to forbid the enlargement of farms, it may be considered that the available labor-saving efficiency has been nearly reached.

Almost every comparison of agricultural statistics illustrates the influences of improvement in agricultural machinery. The relatively larger employment of horses in place of working-oxen, as evidenced by statistics, is chiefly due to improved machinery. The ox is not swift enough for labor-saving riding implements; and harrows, riding cultivators, sulky-plows, screw pulverizers, and the whole range of haying and harvesting implements, are drawn by horses, the ox being only employed for carting and heavy plowing and harrowing. Taking three states for example, we form the following table:

MASSACHUSETTS.

Year.	Horses.	Work-cattle.	Ratio of horses to work-cattle.
1850	42,216	46,611	0.91
1860	47,786	38,221	1.25
1870	41,039	24,430	1.68

OHIO.

Year.	Horses.	Work-cattle.	Ratio of horses to work-cattle.
1850	463,397	65,381	7.09
1860	625,346	63,078	9.91
1870	609,722	23,606	25.82

ILLINOIS.

Year.	Horses.	Work-cattle.	Ratio of horses to work-cattle.
1850	267,653	76,156	3.51
1860	563,736	90,380	6.23
1870	853,738	19,766	43.19

These figures from former census years are very instructive in exhibiting the tendencies in the growth of the usage of improved agricultural tools. They also illustrate the difference in rapidity of working practicable on the prairies of the West, as compared with the stony and hilly land of New England, especially in the preparation of the soil.

While the value of agricultural implements manufactured per annum in the entire Union has increased nearly one-third since 1870, the production has generally fallen off in the New England and the middle states on account of the employment of the facilities for other manufacturing purposes. But in Maine, Massachusetts, and Vermont the development of large factories devoted to agricultural specialties has more than compensated for the general falling off, the production in Maine having nearly trebled, while in Vermont it has increased by over one-third and in Massachusetts by nearly two-thirds. In New York also, in which state the production has fallen off slightly, and in Pennsylvania, where it has barely held its own, the general falling off has been much greater, having been more or less compensated by the growth of a few centers of manufacture. The increased production in the southern states has been relatively considerable, but not great in itself, with the notable exception of Georgia, in which state the production has increased nearly eight-fold, a rate only exceeded in Minnesota. In Indiana the production has more than doubled, while in Michigan the rate of increase has been nearly in the same ratio, and in Illinois, Iowa, and Wisconsin it has increased by over one-half.

MATERIALS.

After a careful study of the statistics of the manufacture of agricultural implements, it can only be said that the variations in the implied ratios of product to material appear due to a confluence of causes, of which no assignable ones are sufficiently distinctive to establish very decided rules; but the high ratios of product to material will often be found in those sections where manufacturing is not pursued effectively, or in large factories, and the low ratios in the great centers of manufacture for agricultural implements. Where for a similar class of work the value of the material appears only doubled or less than doubled in large factories, in sections where the manufacture must be pursued on a small scale the value is sometimes increased four or five fold. The principal significance of this is that labor is applied with greater system and advantage in the large factory, and its value relative to the value of material is thereby diminished; but of course inefficient and desultory labor can only compete with highly-organized labor to an extent limited by local demand, transportation facilities, and other conditions of trade.

The influences due to organized system in manufacture in determining the ratio of product to material will be found more marked than the influences of the cost of materials in different sections of the country, or even than those due to the different kinds of implements manufactured. In the cost of the more essential materials the variation is more notable from time to time than from section to section. The sources of supply for pig-iron, wood, and coal are so widely diffused, and the means of transportation are so readily available, that the cost of wood and of iron at least will be found to vary only 12 or 15 per cent. for the more important manufacturing sections, while a few months may show a greater fluctuation in the market at New York. The cost of coal is not of sufficient importance to determine the location of factories in sections where it may be most cheaply obtained unless these sections are also great agricultural fields. In New York and in Illinois coal is higher than in West Virginia, Pennsylvania, Missouri, Kentucky, and Ohio; and in Wisconsin, Michigan, Minnesota, Iowa, Maine, Vermont, Massachusetts, Georgia, and other important manufacturing states it is very much higher, sometimes two or three times as high as in the five prominent coal states mentioned.

For the limited manufactures of less-settled sections a small quantity of material is often obtainable at a small cost, while the locality would be unable to continue the showing upon a larger scale. Thus, in a frontier state, where pig-iron rules high, an anomalous appearance might result from the purchase of a lot of scrap at lower than iron region prices. The statistics of manufactures are full of such special instances, which make exception to methodical ratios and caution us to rest our conclusions only upon a wide survey.

The more elaborate the product the less, of course, should be the relative value of materials, but the extremely variable conditions of labor and of demand in the different sections are sufficient to obscure the distinction.

More labor is also expended relative to the quantity and the value of material employed upon some hand tools than upon more complex constructions. Thus the same value of material put into shovels and into riding-harrows would acquire a considerably greater value in the former than in the latter case. Under similar conditions, and apart from occasional exceptions, the value of material relative to product is greatest in common drag-harrows, plows, and wood tools; next in horse-rakes, seed-drills, and cultivators; next in fanning-mills, thrashers, and separators; and least in mowers and reapers Plows, being made nearly everywhere, exhibit the widest range of ratios; but the manufacture of complex mechanism, such as that of harvesters and separators, is, with few exceptions, confined to those factories where the work is pursued effectively with a system of interchangeability and the division of labor which it entails, so that, despite the intrinsic work done, the value of the product is often less than double that of the material.

Given a well-organized system of manufacture, with a close division of labor, and complex products can be produced as cheaply as simple ones, and the added labor and expenses do not give a large increase to the value of the material. In sections whose facilities permit the manufacture of composite machines only in the old-time way, one man or a few men doing all the work upon a machine, the process is so slow as to be almost prohibitory when (by means of transportation) it is brought into competition with the results of modern and improved systems. But simple products, which involve little or no division of labor, can be made upon a small scale, perhaps not as advantageously as in large quantities, but still at a disadvantage so small as to be counterbalanced by nearness to a limited and local market.

Respecting the values of wood and of iron and steel used, the value of wood is usually the greater in fanning-mills, corn-shellers, grain-cradles, etc., and sometimes in thrashers and separators. In plows, cultivators, and harrows, and in mowers and reapers, the value of iron and steel is the greater, as it also commonly is in horse-powers, horse-rakes, and grain-drills. The classification in this respect is an obvious one, the wood tools and set machinery framed in wood being on one side, and the plows and riding machinery, largely composed of iron castings, on the other, the relative values of the materials being less distinctly emphasized in the lighter riding machinery. In every state plows and agricultural castings are manufactured so largely as to reduce the relative value of wood, which is usually less than 40 per cent., and in the majority of states less than 30 per cent. of the value of all materials. The manufacture of iron mowers and some forms of seed-drills requires a relatively smaller value of wood than for plows, and has its influence upon the aggregate ratios of such states as New York and Ohio, while in Vermont the manufacture of hay-rakes, etc., and in Minnesota and in California of thrashers and separators, may be instanced as producing a contrary effect. Of the values of metal and of wood used the following table gives the ratios by states:

States.	Percentage of wood.	Percentage of iron and steel.	States.	Percentage of wood.	Percentage of iron and steel.
Missouri	64	36	Illinois	28	72
California	52	48	Arkansas	29	71
Delaware	46	54	North Carolina	24	76
South Carolina	42	58	Virginia	25	75
Connecticut	38	62	Alabama	25	75
Vermont	38	62	Wisconsin	24	76
Oregon	38	62	Massachusetts	23	77
Minnesota	36	64	Mississippi	22	78
Rhode Island	33	67	New York	21	79
Nebraska	34	66	Indiana	21	79
Kansas	32	68	Louisiana	17	83
Michigan	30	70	Kentucky	16	84
Maryland	29	71	Georgia	16	84
New Jersey	29	71	New Hampshire	14	86
Pennsylvania	30	70	Ohio	14	86
Texas	28	72	West Virginia	14	86
Iowa	28	72	Utah	13	87
Tennessee	29	71	Maine	8	92

It happens that for the entire Union there is used in the manufacture of agricultural implements not far from a ton of iron and steel to every thousand feet of lumber. The percentage of value of unspecified material relative to all material ranges from 5 to 37 per cent., being commonly from one-fourth to one-fifth. A fuller return of mill supplies and material other than constituent may be expected from a large than from a small factory. That this is the fact is evidenced by the following table, showing the average number of operatives per establishment and the percentage (by value) of material returned as other than wood, iron, and steel for the several states:

States.	Operatives per establishment.	Per cent. of material unspecified to all material.	States.	Operatives per establishment.	Per cent. of material unspecified to all material.
Ohio	48	25	Texas	10	22
Minnesota	37	27	Virginia	10	14
Massachusetts	33	8	Maryland	9	13
Illinois	33	28	Missouri	9	6
Connecticut	26	17	Kansas	7	15
Indiana	25	25	Tennessee	5	19
New York	24	23	West Virginia	7	20
Wisconsin	19	27	Delaware	5	22
Maine	16	24	Louisiana	5	8
Michigan	14	37	Mississippi	5	14
California	14	21	North Carolina	5	22
Georgia	13	23	New Jersey	5	25
Vermont	13	30	Oregon	4	18
Iowa	13	22	Rhode Island	4	17
Kentucky	12	31	Nebraska	4	5
South Carolina	12	25	Arkansas	2	30
Pennsylvania	11	18	Alabama	1	22
New Hampshire	10	28			

Exceptions will, of course, be noted, but if we take the averages of over ten and under eleven operatives per establishment, as given by states, the value of material other than wood, iron, and steel will appear as 24 per cent. in the former against 17 per cent. in the latter case. Of the more notable exceptions, also, in Massachusetts and in Connecticut, the most important items of manufacture are shovels and hoes, which require but a small value in mill supplies, and in the case of Arkansas the peculiarity of the showing is due to one or two shops, whose product conveys no apparent justification for the disproportionate value of other material consumed.

For the three census years, 1860, 1870, and 1880, the values of material, product, and product less material per given number of operatives, compared with the showing of 1850 as a unit, appear as follows:

	1850.	1860.	1870.	1880.
Material	1	1.12	2.51	2.35
Product	1	1.24	2.17	1.83
Product less material	1	1.31	1.90	1.54

The ratio of product to material was, in 1850, 2.80; in 1860, 3.11; in 1870, 2.42; and in 1880, 2.18. In 1870 the prices of materials may be said to have been high, with a stubborn downward tendency; in 1880 much lower (we may say roundly one-sixth), but rising with great fluctuations. It is considered that 10 per cent. more material was actually handled per operative in the manufacture of agricultural implements in 1880 than in 1870. The falling off of the ratio of product to material, which has progressed since 1860, is doubtless due in part to the labor saved by more wholesale manufacture, but probably in some degree to the more direct influences of competition, and also to the fuller returns of mill supplies in the later census years.

There are required for 600 cast-iron plows of medium size, and having iron beams and wooden handles, $300 worth of ½-inch and ⅜-inch bolts, 600 pairs handles, worth $132; 600 cross-bars, worth $12; and about $30 worth of paint, beside 52½ tons of pig- or scrap-iron, at 3 cents per pound, amounting to $3,150; or we may say for a single plow, 50 cents' worth of bolts, a pair of handles at 22 cents, a cross-bar at 2 cents, 5 cents' worth of paint, and 175 pounds of pig-iron at 3 cents=$5 25, the material of the plow costing $6 04, of which about 86 per cent. is in cast- and 8 per cent. in wrought-iron. For a chilled plow of about the same value made in large lots we may reckon the value of iron and steel at $4, lumber at 26 cents, and other materials at 85 cents per plow. For another plow of similar weight, but with a wooden beam, the iron is rated at $4 25, wood at $1 75, and other materials at 15 cents per plow.

In making hoes there are used for a common size of garden-hoe 1⅓ pounds steel and iron, at about 5 cents per pound, amounting to about 7 cents; about 3 cents' worth of ash wood, about 2 cents' worth of grit (or grindstones), and for forge (anthracite) and power coal, about 1 cent's worth (four times as much for power as for forging). Thus for a hoe worth about 32 cents the constituent material costs about 10 and the other material about 3 cents. The total value given is therefore about two and one-half times that of the material. In like manner, for an ordinary shovel there may be required 4 or 5 pounds of iron or steel, a handle worth about 7 cents, and a few cents' worth of other material, the ratio of the value of product to that of the material being also about two and one-half.

The material in so complex an apparatus as a large separator is subject to great variation, in accordance with the different constructions of machines, in some of which two-thirds of the value of the material is in the wood work, in others not more than a half or a third. The wood employed is such as is used in wagon work and machine framing, mainly ash and hickory, beside elm, poplar, hard pine, and other woods. The iron work comprises the usual wheel-work fittings, the thrashing cylinder, axles and bearings for thrashers, beaters, fans, etc., the pulleys, coupling rods and riddles, beside nails, hinges, and many small fittings, aggregating considerable value. The cost of other materials—paint, varnish, belting, mill supplies, etc.—is also considerable. In fanning-mills, corn-shellers, fodder-cutters, etc., the structures are not subjected to the strain which comes upon a mounted machine, and not as much ash and fine wood is used in the framing, but the machines are stoutly framed in wood, the iron work being confined to a few working parts, so that the value of the wood work is often from 60 to 75 per cent. of the whole value of the constituent material.

In implements for drilling or planting seed or grain there is a wide range in character and cost of construction. Some of the simpler forms of cotton-planters are little more than wood barrows, fitted up with simple feed-wheels and smoothers; but of the more elaborate riding-drills, the chief cost of the material is in the metal work, of which the seeding rigs, with their steel springs, cultivator points, and seed boots, constitute no inconsiderable part. The value of material is increased two or three fold in the manufacture, and 80 or 90 per cent. of that value is in the metal work.

In building 1,500 mowing-machines of an ordinary type there are required about $2,000 worth of hard lumber, $27,000 worth of iron, and $6,000 worth of steel, every such mower having $18 worth of iron, $4 worth of steel, and $1 33 worth of hard lumber put into it. For 700 mowers and reapers there are required 140 tons of iron, 6 tons of steel, and 60 thousand feet of hard wood, or, for each mower and reaper:

400 pounds of iron, at 5 cents	$20 00
17 pounds of steel, at 10 cents	1 70
86 feet of wood, at $30 per thousand	2 58
	24 28

Iron and steel, 50 to 75 per cent.; wood, 20 to 10 per cent.; and other materials, 30 to 15 per cent., may be considered to cover the ordinary range in cost of material. Separate factories have been established for making mower and reaper knives, thus affording an opportunity to specify this part of the work separately. In making knives the value of constituent material is about 40 per cent. of that of the product. For every knife there are used 3⅓ pounds of sheet-steel and 3 pounds of malleable iron, each knife containing about seventeen sections. The coal used in the manufacture costs a little less than 3 cents per knife. In the manufacture of a style of lawn-mower, 75 per cent. of the cost of all material is in the iron and steel, 5 per cent. in the wood, and 20 per cent. in the auxiliary materials.

For 2,000 riding-harrows of the disk type there are required $4,000 worth of lumber, $7,000 worth of iron, and $14,000 worth of steel, or, per harrow, $2 worth of lumber, $3 50 worth of iron, and $7 worth of steel. The value of material in one such disk harrow is equal to that in nearly 150 hoes, but there would be in the hoes more steel, more wood, and much less iron.

CAPITAL.

The returns of capital employed in 1880 in the manufacture of agricultural implements are comparatively satisfactory. Capital is often invested with peculiar vagueness. Investments are maintained by continual and often ill-accounted expense, which may sometimes amount to more than the preservation of the former conditions, and thus become an additional investment. Most factories grow, not by one investment, nor even by a few well-defined investments, but by gradual accessions more or less merged with the necessary running expenses. But the returns in this instance are as definite as the conditions will admit, showing both diligence in the enumeration and integrity in making the returns.

The capital investment should include the value of land, buildings, and machinery, and the surplus funds necessary to provide for stock, wages, and other expenses. Some of these expenses, such as rental, might be consistently esteemed the interest of a larger principal really invested in the business. The capital investment returned seems full enough to cover the items which have been enumerated as essential to the manufacture, and to express what the manufacturers understand their investment to be. It is therefore consistent with itself.

The manufacture of agricultural implements may, as a whole, be classified into blacksmithing, foundery work, wood-working, machining, grinding, and fitting or assembling. These may be ranged in the order of the capital usually required:

1. Machining and assembling.
2. Wood-working and assembling.
3. Foundery work, machining, and assembling.
4. Foundery work and grinding.
5. Blacksmithing and grinding.

Under the first head we would naturally place the manufacture of the finer class of iron and steel machinery; for example, reapers and self-binders; but foundery work will, in connection, form an important item, and may bring the requirement below that of the second head, under which would come the manufacture of thrashers, separators, etc. Plows and agricultural castings would come mainly under the fourth, and shovels, hoes, and agricultural forgings under the fifth head. Any high degree of assembling requires considerable capital, as it implies an organized system of making interchangeable work and machinery for making tolerably exact cuts, and also requires large floor and storage space. Wood-working often requires large space, much power, and costly machinery, and foundery work requires a larger expense for real estate, fuel, flasks, etc., than is usually required for the blacksmith's forge, even when it is associated with a few trip-hammers and bending presses.

In this manufacture as a whole the capital per hundred operatives was, for the entire Union, in successive census years, as follows:

	Amount.	Ratio.
1850	$49,365	1.00
1860	77,476	1.57
1870	137,964	2.79
1880	156,921	3.17

being now about three times as great as in 1850 and twice as great as in 1860. These figures are believed to mark with great accuracy the progressive development of organized system in the manufacture.

LABOR.

For the principal fourteen counties the average of wages paid per operative per annum is $449; for the rest of the United States, $355; but if the labor is one-fourth more costly per man for the large factories, the value of material handled per man is as $1,055 to $657, or over 50 per cent. more, and the product per operative is as $2,178 to $1,494.

SYSTEM AND PROCESSES.

In the cases of locomotives, sewing-machines, guns, and other products the known conditions of manufacture are so far uniform that the numbers of a specified piece of mechanism that may be produced per operative per annum may be stated with some degree of approximation, showing progress in contrast with what it has been in the past. But the manufacture of agricultural implements, except in its cruder and simpler products, was not developed until after the era of improved machinery began, and at the same time the work is so largely pursued in all parts of the country that, while a great number of illustrations are readily obtainable, the conditions of manufacture, the character of the defined implement, and the efficiency of the labor are much more variable. Apart from other investigations, the statistical tables themselves afford scope for some curious comparisons, but not without a sufficiently definite understanding of the character of the products enumerated.

For some of the simpler implements the weight is a partial criterion of the expense of manufacture. By the pound, a plow costs about double the cost of a cultivator and about treble that of an ordinary harrow. A handled plow also costs more per pound than a riding-plow, the proper plow parts usually costing more for the same weight than the running-gear. The weight of a plow of a given style will increase very nearly in proportion to the width of cut, being about 50 pounds for an 8 and 100 pounds for a 16 inch cut; but foreign plows usually weigh vastly more for the same depth and width of furrow. A riding cultivator may weigh about 300 pounds, and a sulky-plow of the "Gilpin" type weighs 450 pounds, while large harrows, as commonly used, will weigh between 100 and 200 pounds each.

If we take an average plow of about 12 inches cut, weighing 75 pounds, we may estimate an average product per operative for large works at about 120 plows per annum; or, if we take a plow weighing as much as an ordinary family sewing-machine, it may cost the buyer about half as much as the sewing-machine, but the number made per annum per operative will be about the same as in making sewing-machines. In this comparison much must be allowed for the higher organization and effectiveness of sewing-machine manufacture, and in practice the productive efficiency in plow manufacture is often much less than stated. It is found that where 9 men make plows at the rate of 66 per annum each, 180 men make a similar plow at the rate of 110 per annum each, wholesale work nearly doubling the efficiency per man.

Whether we take the product in value or in numbers of implements, it will usually be, per operative, much smaller for small shops than for large factories; but occasionally in the statistical tables a large apparent product per man will be obtained in a very small shop, which is due to the fact that the labor of the proprietor assists, but is not reported with that of the one or two men employed.

In like manner we might estimate that, per operative per annum, the average thrasher and separator might be produced at the rate of 8 or 20, the average mower at the rate of 40 or 50, the average harvester at the rate of 15 or 20, the average horse-rake at 50 or 60, disk riding-harrows at about 125, shovels at the rate of 200 dozen, and hoes at the rate of 300 dozen—results accomplished by organized system and division of labor; but these figures are intended to convey an idea of average and not of the most effective production.

For this whole range of manufacture the foundery may be considered the most essential department. In this the principal source of improvement is in more convenient forms of flask, and, simple as the change may seem, if an improved hinged flask is capable of only slightly increasing the daily work of a molder the aggregate advantage for a large force is very great, often greater than may be derived from more pretentious labor-saving appliances. If we compare the practice in a large plow foundery with that in a large sewing-machine foundery, we find that per man less weight of metal is used and the castings for fewer plows than sewing-machines are made; but for the same floor space a greater weight of plow than of sewing-machine castings is made, and there are more men to the same floor space for the plow than for the sewing-machine parts. The difference in production may be in great measure attributed to the employment of molding machinery in the latter case. For large plow-castings molding machinery is not used, but it is employed to a limited extent in making the small agricultural machine castings to which bench molding is applicable.

Cast-steel plow parts are commonly forged from the cast-steel by hammers or rolls, but the cast steel is sometimes recast into plows. In plow-making, if the plows are chilled, hard metal, or recast steel plows, the foundery is the principal department, but if the plow parts are forged from cast-steel plates, the blacksmith-shop may be the largest department. In such a plow factory the percentages of total floor space are occupied as follows: Blacksmith-shop, 42 per cent.; grinding-shop, 21 per cent.; foundery, 16 per cent.; wood-shop, 13 per cent.; fitting-shop, 8 per cent.

In blacksmithing a great deal of hand work with forge and anvil has still to be done, but where the expense is warranted by the output the forms are given to the heated metal by the pressure of shapes actuated by power. Die-forging with drops is employed in making plows, and rolling dies are also used. In making hand-tools of steel, blacksmithing is the principal work, and the stock is drawn and shaped with rapidity and cheapness by the use of presses and rolls. Scythes, like axes, are of welded steel and iron. The steel is first welded to the iron under a hammer, after which follow rolling to length, shaping out with a hammer, back-turning or bending to a curve, and upsetting the back of the scythe, which is done in a press. The heel of the scythe is made uniform and interchangeable by the aid of gauges. The scythes are hammered to a point by hand, after which they are hardened and tempered, straightened, ground, and polished. In making shovels, presses are used for cutting up and trimming and for forming the blade and the socket, and the rolling out of the stock is also part of the process. Of the machinery used the dies constitute an expensive item, costing, for any considerable variety of blade, as much as or more than the drops and presses with which they are employed. Forks are made of steel by similar machinery, but do not necessitate so great an expense for dies. The first operation is cutting off stock; the second, forming the shank; the third, passing through a "splitting and turning out mill", which roughs out the fork, forming the tines. The splitting-mill saves half the hand labor for this part of the work. The tines are then drawn out by rolls or trip-hammers, and the forks are passed through bending and forming mills, the tines being pointed by rolls. The metal is, of course, worked hot, and tempering followed by polishing and fitting to handles completes the hay-fork. Hoes are forged under trip-hammers and cut out with presses, after which follow neck-bending in presses, grinding, and polishing. In making hoes in a small factory the labor is about evenly divided between the hammer work, the grinding, the polishing, and the press and other work. Two men are required to a trip-hammer. The hoe is forged down from the bar to a flat spread shape, and is then reheated and rehammered. It is then sometimes rolled to thickness, which saves labor in grinding and insures evenness of temper, and it is then cut out to size by a trimming press, and, after reheating, is shaped or concaved by drop-forging in dies, the burr at the shank is taken off by a rapidly-revolving iron wheel, and grinding, polishing, and fitting to handles complete the hoe. Socket-hoes have the sockets welded upon the shanks.

The metal-working machine plant constitutes a much less part of the capital in the manufacture of agricultural implements than in other manufactures of interchangeable mechanism. In general agricultural works it is often not more than one-fourth as much as the value of the real estate. In making a style of mower and reaper a machine plant for turning out about a thousand machines a year is composed as follows: For the metal-working tools, 5 lathes, 3 drill presses, 1 planer, and 1 bolt cutter; for the wood-working tools, 2 planers, 3 circular saws, 1 band- or jig-saw, 1 or 2 boring lathes and 1 shaper; for the abrasive work, 4 or 5 grindstones and emery frames. In a general agricultural implement manufactory, employing about 70 men, there are used 24 metal- and 24 wood-working machines and 6 or 8 grindstones and emery frames. In one shop there were, per operative, 25 pounds shafting and 3½ feet belting. In plow work metal tooling is included in the fitting department, but this is mainly bench and anvil work, chiseling, forging, and grinding. The use of emery has largely displaced filing. Holes are more commonly punched than drilled in fitting plows.

In making mower knives the machinery, inclusive of power machines, is of less than one-seventh the value of the whole capital required, the tools being mainly power shears, punches for sheet-steel, milling-machines, and grinding and polishing frames.

In a small factory making cast plows one grindstone pit is used per 200 plows per annum. One grinding-machine is used per 15,000 mower knives per annum, and one grindstone pit for 30,000 hoes per annum. Scythe backs are ground in a machine to secure uniformity; scythe blades are ground upon large stones (6 or 7 feet in diameter) running at about 200 revolutions per minute.

In wood working, cut-off and rip saws, shapers, planers, mortising-machines, boring-machines, tenoning-machines, and pattern-turning machines are the principal tools. All of these are applicable to a great range of work, and there are few special tools except in wheel working. The work, therefore, demands no extended specification. It is similar to that of car- and wagon-shops, although both lighter and less elaborate than the work in car-shops. The rough stock is first cut up by a cut-off saw, which has a traverse relative to the work, being mounted upon a swinging arm or upon a carriage, the arbor driven by a take-up pulley, or by pulleys on such parallel swinging frames as permit the traverse. The stock is more exactly cut to shape by rip-saws, which are table saws with fences and adjustments. The shaper is a table machine with cutters upon vertical spindles, and for many classes of work its importance is only second to that of the saw. Both traverse and cylinder planers are used. Vertical mortising- or slotting-machines are often mounted on the same frame with boring-machines for the convenient performance of two classes of work which have often to be done consecutively. Tenoning is done by cutters upon revolving heads. Bending machinery for fellies, plow-handles, etc., is more or less simple, the wood being bent upon formers. Tool-handles of irregular forms are turned as rapidly as a man can place and center them.

Wheel-and-axle work may be considered to constitute a distinct branch of the industry, as it is often conducted separately. A special felly-machine will, with unskilled attendance, cut 3,000 wagon fellies a day; an axle-tree lathe turning to pattern will turn 40 pairs of axle-trees in ten hours. There are also special machines for mortising hubs, driving and tenoning spokes, and a great variety of other operations, wheel-making, from its peculiar character and the large demands of the work, having perhaps more labor-saving machines of special application than any other wood-working process.

The consumption of power in agricultural implement works will usually range from three-fifths to one horse-power, unless much wood working is done, when more may be required, as the rapid action of wood-working machines requires much more power than ordinary metal-working machines. Grinding also consumes a great deal of power, sometimes one or two horse-power per hour to a grindstone pit. In one case the power required in manufacturing mowers was found to be at the rate of 60 horse-power per mower per hour; and in another case, for mowers and reapers, it was at the rate of 100 horse-power per reaper per hour. So, in making hoes, it was found to be at the rate of four-fifths horse-power per hoe per hour, and in making disk riding-harrows it was at the rate of 45 horse-power per harrow per hour, while in the manufacture of plows it was found to range in a number of examples from 20 to 50 horse-power per plow per hour.

The foregoing observations regarding processes in vogue may aid in forming correct ideas upon a subject in which there is not enough consistency to admit of exact treatment, and in which there is great variation in methods pursued, work covered, and system employed. In some factories the piece-work system has supplanted the day's-work system, with the result of greatly improved efficiency. In the large factories piece-work is the rule, but the two systems are usually more or less merged.

The system of interchangeability is of course involved in the extensive manufacture of agricultural as of other machines, and is a practical necessity for large works, securing an efficient division of labor, as well as facility in making repairs. Parts of machines are customarily kept in store to replace parts that may become broken or worn, and these fitting parts are usually made to gauges; but agricultural machines have, as a rule, comparatively few fitting points, partly because the action of these implements is not mainly between the parts of the implement itself, but upon the soil or crops, so that interchangeability is not as important a feature. This is really a prime distinction between agricultural implements and the other forms of interchangeable mechanism which have been previously treated. Watches, clocks, and fire-arms have practically no exterior action so far as the functions of the mechanical parts are concerned, such action in the locomotive being confined to a few rolling surfaces, and in the sewing-machine to the point of a needle. But in the plow, cultivator, seed-drill, mower, etc., the principal acting parts work against extraneous bodies, whether clods of soil or gavels of grain, with which fitting and interchangeability are out of the question. While interchangeability is so far limited, it has a wide scope in the parts to which it is applicable; but for the small shops the conditions of output may not permit any great development of the advantages of a uniform system; for, though the repairs may be made practically uniform, the administrative advantages of division of labor cannot exist without a sufficiency of labor to be properly divided.

The larger the factory, and the more fully it is devoted to the production of a single implement, the higher will be the results attained in productive efficiency. In many of the large factories there is much room for improvement, especially in concentrating facilities upon a single product or upon a few products, and so long as the main dependence is upon a local market, however considerable, the manufacture will to a great extent be of a miscellaneous character, but everything tending to enlarge the market and unify demand will also unify the manufacture. It is in this connection that the export trade has and will have a bearing upon the productive efficiency of factories of this class.

Most of the large works export their products, and, while the exported product is relatively small in contrast with that of home consumption, American mowers, reapers, grain-drills, horse-powers, etc., are sent to Spain, Egypt, Denmark, Turkey, New Zealand, and in fact to all parts of the civilized world. But this exportation is handicapped by commercial disadvantages, and manufacturers often report that they have made a few such shipments "without effort", the demand coming from parties personally familiar with the superiority of American machinery.

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