THE FIRST CENTURY OF THE REPUBLIC.

[Fourth Paper.]

MECHANICAL PROGRESS.—III.

OUR space will allow of scarcely more than a recapitulation of the remaining achievements which distinguish the present century. The subject of Printing, however, must be reserved for fuller treatment.

ELEVATORS.

The *elevator*, as an ordinary apparatus in a hotel, business house, or building devoted to offices, is an American institution. The man-engine and the hoisting platform or cage have been for nearly a century the ordinary means of ascending mining shafts; the cage has more lately been introduced into factories to save the operators the labor of climbing, and now the winding apparatus has been much improved, the car luxuriously furnished and lighted, and safety devices introduced to prevent overwinding and to arrest descent if the rope breaks.

There are three principal forms: 1. That in which the winding drum is driven by a steam-engine, the rope passing over a pulley above the shaft, and thence downward to the suspended cage. 2. The hydraulic elevator, in which the water from the city main acts upon a ram with great force, and *fleets*, as the sailor might say, the blocks of a compound tackle, drawing upon the rope which passes over the sheaves at a rate proportioned to the number of sheaves involved. 3. The direct hydraulic lift; in this the platform is supported by a piston working in a cylinder into which water is admitted from the city main. This requires a piston as long above the lowest floor as the height to be lifted, and a well or cylinder as great a length below it. As the water runs into the cylinder it acts against the lower end of the piston, and when the platform is to be lowered, a faucet is opened, which allows the water to escape. It is safe, and is probably a French invention—the *Ascenseur Edoux*.

Besides these, there is a peculiarly American system of hoisting and storing grain, forming a prominent feature in the views of our sea-board and lake cities. An elevator-leg, as it is termed, reaches into the bin or well into which the wagons or cars have been discharged, or into the hold of the vessel. This leg is the extension device round which passes an endless belt with cups, each of which runs up full of grain and discharges into a hopper above, where the grain is weighed, and from whence it passes by spouts to the various bins. From these it is drawn, when reshipped, into cars or vessels.

In the American practice the grain is discharged into the hopper of a weighing machine gauged exactly for one hundred bushels; by opening a valve the contents are sent by a spout to the bin, the valve closed, and the elevating process resumed. Seven thousand bushels an hour are thus weighed. An elevator at Milwaukee is 280 feet long and 80 feet wide. The total length of the great driving-belt, urged by a 200 horse-power engine, is 280 feet, that is, the half, extending from cellar to comb, is 140 feet, and the down half is of course equal to it. This belt is 36 inches wide and three-quarters of an inch thick, and is made of six plies or thicknesses of canvas, with sheets of India rubber laid between them. It drives nine receiving elevators, or belts set with buckets, each of which lifts the grain 140 feet. The buckets are made of thick tin bound with hoop-iron, and are well riveted to the belt at intervals of fourteen inches. They are 6 inches across the mouth, 18 inches long, and when full each contains a peck. They do not usually go up quite full, but, allowing for this, there are 100 pecks (25 bushels) loaded on one side of the belt whenever it is at work. If all nine are running at once, as is often the case, the quantity of wheat lifted on these swift-running belts is 225 bushels. The established weight of a bushel of No. 2 Milwaukee Spring is 55 pounds. This would make the total lift of the receiving elevators during the time they are at work over 12,000 pounds.

The bins into which this wheat is poured are of great size, being 60 feet deep, 20 wide, and 10 across, containing 12,000 cubic feet. The total receiving and storing capacity of this building is 1,500,000 bushels. Of the crop of 1869 it received 7,000,000 bushels.

In discharging into the lake grain vessels, as soon as a ship is moored beside an elevator the hatches are removed, and great spouts extended over them from the bottom of one of the bins described. The gate is raised, and a torrent of wheat pours down. The loading power of these spouts is 12,000 bushels an hour. A vessel with a capacity for 18,000 bushels may be loaded in an hour and a half. The Oswego and Ogdensburg schooners, and vessels destined for the Welland Canal, usually take from 12,000 to 20,000 bushels. The Buffalo vessels are larger, often receiving 30,000, and in a few cases 45,000 bushels.

No other mode of handling grain has ever been devised which affords such facilities for unloading, weighing, storing, loading, moving from one bin to another for examination or for ventilation. A hundred years ago the shovel, sack, and the hoisting chain, or else the wheelbarrow, were the usual facilities of the grain merchant.

DOMESTIC MACHINERY.

Domestic machinery is not the least important of the features which characterize the present age.

The *sewing-machine* is an American invention of the last forty years. As was previously remarked of *reapers*, the European attempts at making machines to supersede the hand method served to exhibit the difficulty of the problem, but in no important degree to solve it. The shoe-sewing machine of Thomas Saint, patented in England in 1790, had a single thread, which was driven by a forked needle through a hole previously punched by an awl, and was then caught by a looper which held the loop so that it was entered by the needle and thread in their next descent, making a crochet stitch. The feed and the stitch-tightening movements were automatic.

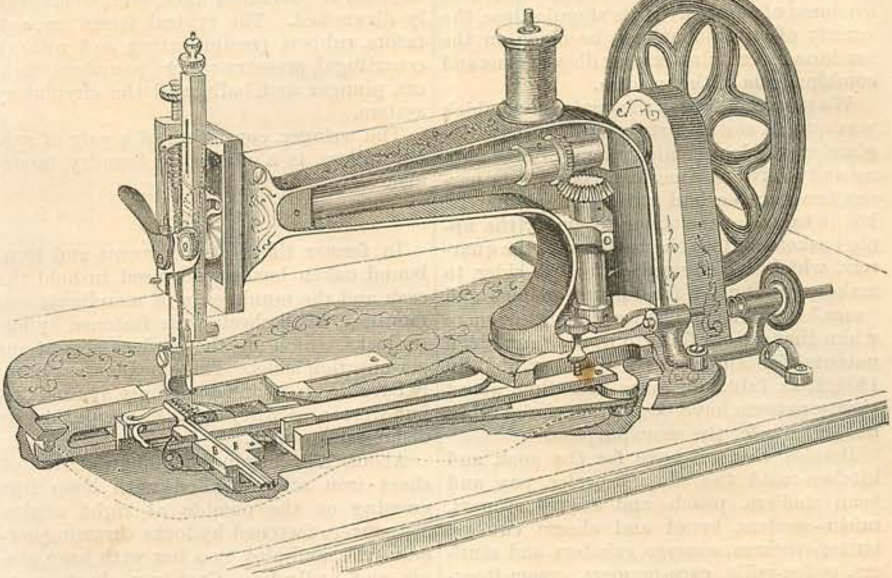
The sewing-machine of Thimonnier, of Paris, was used in 1830 for making army clothing. Eighty of these machines, made of wood, were destroyed by a mob, which regarded them as an "invention of the enemy." They were afterward made of metal. Adams and Dodge, of Monkton, Vermont, in 1818, and more especially J. J. Greenough, of New York, in 1842, added improvements. Walter Hunt, 1832–35, made and sold lock-stitch sewing-machines, but neglected to pursue the business, which consequently attracted but little attention at the time. His extreme versatility prevented success; his inventions absorbed his time, and he seemingly had none left for securing the pecuniary results of his genius. He just missed, and by mere inattention, one of the grandest opportunities of the century. Elias Howe, with inferior inventive abilities, but with an adaptedness to follow out a single object persistently, and with business ability, reaped the field. The world, as we have had occasion to remark previously, thanks the man who gives an improvement into its hands. The name of Elias Howe is indissolubly associated with the success of the sewing-machine. This machine is no exception to the ordinary rule that an invention is a growth rather than an inspiration, and the discussion on the relative merits of inventors has been both voluminous and acrimonious. Examiners, commissioners, judges, each in their turn have found it a very knotty question how to apportion the respective credits. It is no small matter to conceive the need and apply one's mind to the intricacies of the problem. Then come the details. The original machine had a simple needle, and made a *running* stitch; next we see a machine which made a succession of loops, forming a *crochet* stitch; here the machine paused a while. A score of years was passed in devising modes of feeding, continuous or intermitting, by various arrangements of parts. The greatest advance up to that time was the *lock* stitch, invented by Hunt, and made by passing a shuttle containing a lower thread through the loop of an upper thread carried down through the cloth by an eye-pointed needle. This was also the feature of the "Howe" machine. Following this were many improvements, variations, and nice adjustments, such as A. B. Wilson's four-motion feed and rotating looping-hook, the latter of which draws down the needle thread, and drops through it the spool containing the lower thread. There is no room here even to recite the prominent improvements. Finally, the machine is much indebted to the skill and enterprise of the mechanics and tradesmen in whose hands it has grown to the wonderful proportions it now exhibits. Without impugning the genius of the earlier inventors, it may still be said that the present proximate perfection of the machine is due to the men who took up the work where Howe left it.

The original Howe machine had a curved eye-pointed needle attached to the end of a vibrating lever, and carrying the upper thread. The shuttle, carrying the lower thread between the needle and the upper thread, was driven in its race by means of two strikers carried on the ends of vibrating arms worked by two cams. The cloth was attached by pins on the edge of a thin steel rib called a baster-plate, which had holes engaged by the teeth of a small intermittingly moving pinion. This was the feed, and clumsy enough.

Space permits but one illustration, and the Singer is given as a representative machine. The well-known table and treadle are omitted, and the principal working parts only are shown. The motion derived from the treadle is imparted to the horizontal shafts, and communicated in two directions to the *needle bar* and to the *shuttle driver*. Various subsidiary movements occur which are tolerably familiar to our readers, and need not be explained at length.

About 2000 patents have been granted in the United States for sewing-machines: one improvement after another, until there seems to be no end to the devices. Some have reference to special parts, others are adaptations of the machine to new uses and materials to which it had not before been accustomed.

If required to point out three mechanical contrivances upon which the most extraordinary versatility of invention has been expended, the writer would most unhesitatingly instance the *harvester*, the *breech-loading fire-arm*, and the *sewing-machine*; each of these has thousands of patents, and each of them is the growth of the last forty years.



SINGER SEWING-MACHINE.

Although each of these was on trial, and to some extent a success, previous to 1850, yet it may be said, in general terms, that their celebrity and usefulness date from about that time. The Hussey and M'Cormick reapers were largely introduced to our countrymen by their success at the London World's Fair in 1851; the breech-loaders were forced upon an unwilling Ordnance Bureau by the exigencies of the late war, the demand of the public, and the stern determination of some civilians who were in authority; the first valuable working sewing-machine was the "Singer," made in the fall of 1850. Last year (1873) about 600,000 sewing-machines were made and sold; 232,444 of these were of the "Singer."

The security of patents has encouraged men of talent, capital, and enterprise to engage in the sewing-machine business, and as much as $40,000,000 is now estimated to be employed in that manufacture. The retail prices of sewing-machines bear no proper relation to their cost, but the prices to the consumer result from the method of selling by means of a system of agencies and traveling canvassers, to the latter of whom so large a profit is allowed that they can afford to sell them on time, on trial, or on payment by installments. There are cheaper means, as with ordinary tools and articles of consumption and wear, of bringing the producer and consumer together; but in the sale of sewing-machines no substitute has been found for the personal solicitations of canvassers, who scour the country with their wagons, and receive for their pay one-half of the purchase price. The organization of the corps of agents by the general agent absorbs another fifteen per cent., so that the manufacturer receives only about thirty-five per cent. of the price. This system will not last longer than the necessity for personal effort at the homes of the people; and when it becomes an established *want* in every family, as it is now an actual *need*, the price may be expected to come down to what will afford but a usual profit upon the capital and skill employed. The principal patents have already expired, and the business will soon be open to competition, when the best devised and constructed machines will be sold merely on their own merits, without the adventitious aids of exclusive rights to sustain prices.

The business of boot and shoe making has received a fillip from the introduction of machinery, enriching the manufacturers and cheapening the product. Without occupying room by even naming the machines which furnish the shoe factory, it may be stated that the M'Kay sewing-machine was the result of three years' mental labor and hand-work, and involved an expenditure of $130,000 before a practical working machine was completed and put in operation in 1861. Since this time 225,000,000 pairs of boots and shoes have been made on these machines in the United States, besides many millions in England and on the continent of Europe. A very skillful operator has occasionally sewed as many as 900 pairs in a day of ten hours, and any good operator can easily sew from 500 to 600 pairs per day.

The *knitting-machine* is another form of iron-fingered curiosity, which will knit at an unexampled rate, and with admirable evenness of tension. It is singular, too, the variety of stitch that may be made on the machine by certain peculiar dispositions and combinations of the needles.

We must not forget the *apple-parer*, which was quoted some thirty years since in England as the last comical vagary of the funny and awkward American cousin. A paring bee may be had without apple-parers, but it takes much longer to empty the apple baskets and fill the kettle with the quarters, which are stewed in boiled cider to make apple-butter for the winter pies and "sass." It was no chance thought or mere whim that set our folks to work. American patents for apple-parers were granted in 1803, 1809, 1810, and since that time about eighty patents have been granted for other implements for the same purpose.

Besides this we have for the cook and kitchen-maid the almond-peeler, pea and bean shellers, peach and cherry stoners, raisin-seeders, bread and cheese cutters, butter-workers, sausage grinders and stuffers, coffee-mills, corn-poppers, cream-freezers, dish-washers, egg-boilers, flour-sifters, flat-irons, knife-sharpeners, and lemon-squeezers. Then we have for the dairy-maid the milking-machines, milk-coolers, churns, cheese-presses, and a number of other aids to leisure.

We have, moreover, the baby-jumper and baby-walker for the nursery, and a wonderful variety of brooms, mops, carpet stretchers and fasteners, for the footman and housemaid.

Nor must the *washing-machine*, another strictly American notion, be disregarded. There are hundreds of patents. The typical forms are few; the variations on these forms are most amusingly numerous. The ins and the outs of invention have been wonderfully diversified. The typical forms are, agitators, rubbers (reciprocating and rotary), centrifugal, pressure-rollers, pounders, dashers, plunger and balls, and the circulatory system.

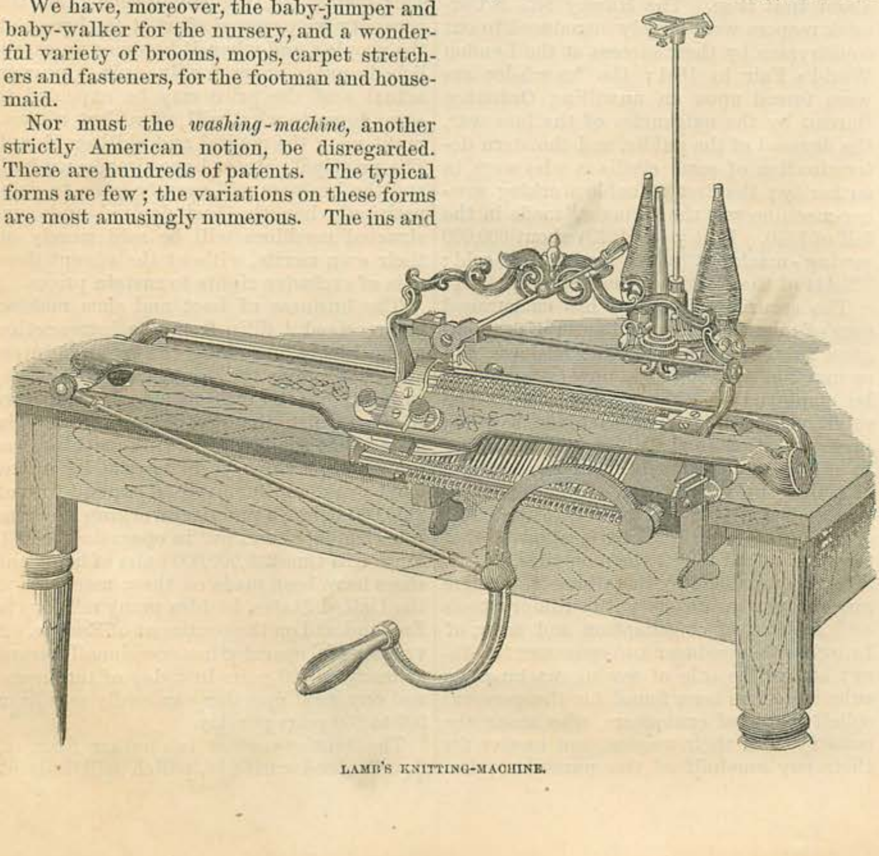
The wringer, consisting of a pair of rubber rollers, is a necessary laundry implemen

SAFES.

In former times strong rooms and iron-bound oaken boxes were used to hold the cash and the muniments of merchants and families. Such chests were fastened by letter locks, which are the predecessors of our permutation locks. These boxes were hardly burglar-proof, and no defense against fire, but were a security against peculation by dishonest servants.

About 1776 began the manufacture of sheet-iron safes, banded with hoop iron crossing on the outside at right angles. These were fastened by locks throwing several bolts, and also by a bar with hasp, staple, and padlocks. Cast-iron chests were used in 1800.

Attempts were previously made to render strong rooms fire-proof by building the walls double and pouring in gypsum; but the first attempts at fire-proof portable safes were early in the nineteenth century, and con-



LAMB'S KNITTING-MACHINE.

sisted of wooden boxes covered with sheet iron and riveted bands, and an intervening thickness of gypsum.

After various experiments, in which the wooden box was saturated with potash lye or alum to render it incombustible, and was coated inside the sheet-iron casing with clay, lime, graphite, or mica, the boxes were made of iron inside and outside, with intervening non-combustible material, and known as "double chests." Such was the fire-proof safe patented in England in 1801. Asbestus was used in 1834. Chubb in 1835 attempted to make the safe burglar-proof by lining it with steel or case-hardened iron plates.

In 1843 Wilder made a safe of heavy plates of iron, with a filling of hydrated gypsum. Hydraulic cement, steatite, alum, and the neutralized and dried residuum of the so-called soda-water manufacture, were successively used.

Another idea was to connect the intervening space of the safe with the water main, to prevent a charring heat from reaching the contents when the outside became exposed to fire.

Lillie used slabs of chilled cast iron, and flowed cast iron over wrought-iron ribs. Herring made safes with boiler-iron exterior, hardened steel inner safe, and the interspace filled with a casting of franklinite over rods of soft steel.

The American safe of the best quality is really a first-class production, and is not equaled elsewhere. The locks are also wonderful specimens of ingenuity, worthy of an extended notice.

Safe-deposit companies in our principal cities have ranks of safes with curious unpickable locks inclosed in a chamber with grated doors, lighted by gas, and watched by attendants. These are rented to private parties.

Various plans have also been devised to give notice of tampering with the safe—electro-magnetic alarms, whistles sounded by setting free a body of compressed air imprisoned between the air-tight walls, generating asphyxiating gas in the chamber to choke the burglars. It is a race between the skilled mechanic and the equally skillful professional thief.

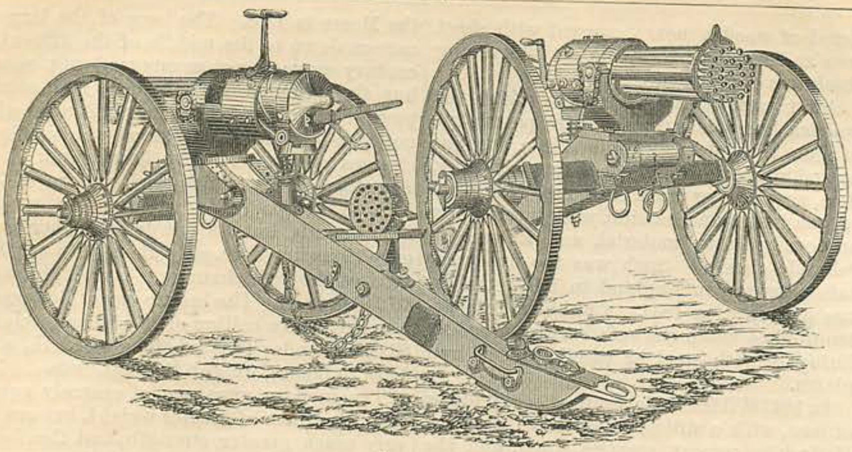
FIRE-ARMS AND ORDNANCE.

From the old wall piece or arquebuse with which the Swiss defeated Charles the Bold in 1476, to the Sharps, Remington, Winchester, or Maynard rifle, or the Parker shot-gun, is a great step. So of the pieces used by the cavalry of 1554, and named from Pistoja, to the Colt or the Smith and Wesson revolver of our day. Equally great is the advance in ordnance from the cannon used at the siege of Cordova, 1280, and those with which Ferdinand captured Gibraltar from the Moors in 1308. The bore of the larger cannon down to the middle of the fifteenth century was as great as any modern pieces; but they carried large stones, had small powder chambers like a mortar, and could not possibly have withstood the modern charges of powder. The bronze gun *Tzar Pooschka*, cast A.D. 1586, had a bore of 36 inches; its projectile was said to weigh 2000 pounds, but its powder chamber had only 19 inches bore, only about 1 to 3.6 the area of the ball chamber. Its weight was 86,248 pounds. The bronze gun of Bejapoor, A.D. 1548, had a calibre of 28.5 inches, weight 89,600 pounds; that of Mohammed II., A.D. 1464, 25 inches, weight 41,888 pounds.

The modern guns are of scarcely equal calibre, seldom of greater weight, but are of very much greater strength, and the force of the projectile, due to its velocity, may be said to be out of comparison greater than that of those pieces of antiquity.

The Woolwich (England) 35-ton gun weighs 79,084 pounds; the large Armstrong (Big Will), 50,400; Krupp's 14-inch, 100,000; Rodman's smooth-bore 20-inch, 116,497. Every body is casting heavier and heavier guns, and these figures will not long represent the condition of things. The latest advance is in the guns for the British armor-clad *Inflexible*, which has armor 24 inches thick, and is to be furnished with four guns of 81 tons weight each (181,440 pounds). The total length of this gun, including the plug-screw at the breech end, is 27 feet; length of bore, 24 feet; calibre not determined, but either 14 or 16 inches. The ball of the piece, reckoned at 14 inches calibre, will be from 1000 to 1200 pounds, the charge of powder one-sixth of the weight of the ball. The 1000-pound shot, at an initial velocity of 1300 feet per second, will have a punching force of 11,715 foot-tons, the ball of 1200 pounds a penetrative force of 14,058 foot-tons. Eight years ago the English 7-ton gun was considered the limit of production. Entirely new sets of tools and plants have succeeded each other, as the 35-ton and 81-ton guns have been produced.

In getting gracefully back again from the great guns of the world to the military and sporting arms, we may pause a moment to regard a class of weapons which partake of the characteristics of each, known as machine guns, having a plurality of barrels, and mounted upon a carriage. The first hint of these was a piece upon a tripod, having a chambered breech revolving behind a single barrel. This was patented in England in 1718. The clumsy contrivance which Fieschi used in firing on Louis Philippe had a row of barrels fired simultaneously, and anticipated in the horizontal arrangement of its barrels the Requa battery in this country and the Abbertini mitrailleur of the continent of Europe. The mitrailleur of the French has



TAYLOR'S MACHINE GUN.*

a cluster of barrels, in whose rear is placed a chambered plate, each of whose chambers corresponds to one of the cluster of barrels, against whose rear it is locked before firing.

The most efficient weapons, all things considered, are the Gatling battery gun and the Taylor machine gun.

The Gatling gun, invented by Mr. J. R. Gatling, of Indianapolis, has now a regular place in the military equipment of the United States and of England. It has a revolving cluster of parallel barrels, in the rear of each of which, and rotating therewith, is its own loading, firing, and spent capsule retracting mechanism. The usual American ammunition with metallic capsule and the fulminate in the flange is used. The barrels and the mechanisms for loading and firing are rigidly secured upon an axial shaft, which is revolved by means of bevel gearing and a crank. The ammunition is fed in at a hopper. Each barrel receives its charge as it comes to the top in the course of its revolutions, and fires as it comes to its lowest position, the firing being thus consecutive, and with a rapidity depending upon the rate of rotation of the crank. The complement of the hopper, 400 cartridges, may be fired in one minute if desired. The gun is manufactured at the Colt Works, Hartford.

The Taylor gun is the invention of Mr. Taylor, of Knoxville, Tennessee, and has a cluster of stationary barrels, in the rear of which is a chamber to receive the cartridges; these are secured in a charging block, and forced into the barrels by a lateral movement of the vertical handle seen in the engraving. This handle is attached to an oscillating sleeve having internal studs, which work in spiral grooves in a sliding breech cylinder. The latter carries plungers, one for each barrel, containing central firing pins, retracted by rotation of a crank shaft carrying suitable tappets, so that the barrels may be discharged in rapid succession. The piece is built at the Remington Works, Ilion, New York.

The military and sporting rifles and shotguns of our country have no superiors. The late trial at Creedmoor between the American and Irish teams has not proved the superiority of the breech-loader over the muzzle-loader, nor conversely; nor is there any difference worth mentioning between a string of 931 (Irish) and of 934 (American) in a possible 1080. It proves, however, the excellent character of the guns and the steadiness, sight, and skill of the men on both sides. The value of the breech-loading gun has been determined by other considerations than the actual shooting force, as rapidity of loading, the avoidance of shifting the gun end for end in loading, and also of assuming positions in handling which expose the marksman. The American style of fixed ammunition, carrying its fulminate in the base of the cartridge, has also a great convenience, and has riveted the former conclusion of the greater value of the breech-loader.

The cartridge was introduced by Gustavus Adolphus, who was killed at Lutzen in 1632. It at first only contained the powder, the bullets being carried in a bag. The idea of using sheet metal for cartridge cases originated with the French. In 1826 Cazalat patented a metallic cartridge case, drawn from a single piece of copper, and having an opening in the centre of the base for the communication of fire from the fulminate, which was covered with water-proof paper. Lefaucheux and Flobert, of Paris, improved and introduced the metallic cartridge, but it has received its final improvements in this country, being, in fact, a prominent feature in what is known as the *American system*.

* All but two or three of the illustrations for this paper are borrowed from *Knight's Mechanical Dictionary*, published by J. B. Ford and Co., New York.

The systems of breech-loading are three: the "movement of barrel," the "movement of breech block," and the "revolver." Of these genera there are thirteen species and twenty-six varieties. Of the different modes there are about 1050 patents in the United States Patent-office, beginning with the patent of J. H. Hall, of North Carolina, in 1811, for a rising breech block, which slipped from behind the borè to allow the cartridge to be inserted at the breech. Ten thousand of these arms were made for the United States government between 1811 and 1839, and some of them were captured at the taking of Fort Donelson.

While it is true that the use of breech-loaders dates back to the sixteenth century, that form of arm being almost as old as the muzzle-loader, the actual use of breech-loaders on a large scale in military service, or the habitual use of them by sportsmen, is quite modern. The Hall gun of 1811, mentioned above, was manufactured on a small scale, and appears to have been locked up in arsenals, where it was forgotten. The *needle-gun* was introduced into the Prussian service to a limited extent in 1846, and into the Danish and Norwegian soon afterward. The Schleswig-Holstein war was fought with needle-guns. The French Chassepôt is reputed to have been first used in the Italian struggle in the Garibaldi times.

Previous to our own war of 1861–65 our principal breech-loading arms were Sharps's, Burnside's, Maynard's, Merrill's, and Spencer's. The number of breech-loaders purchased by the United States government between January 1, 1861, and January 30, 1866, is stated to have been as follows, arms of which the purchases were below 10,000 being omitted:

Burnside	55,567	Remington	20,000
Gallagher	22,728	Sharps	80,512
Joslyn	11,261	Henry	30,062
Merrill	14,295	Spencer	94,156
Maynard	20,002	Starr	25,603

Some of the above have fallen out of public notice; the Sharps, Maynard, and Remington and Winchester (known during the war as the Henry), Ward-Burton, Colt, and Springfield have taken front rank as military and sporting rifles, while the Parker, Maynard, and Remington are the prominent shot-guns. Reference has been made to the American system of assembling the parts, which are made interchangeable, and also to the development of the system by Colonel Colt, in the manufacture of his revolving-chambered pistol. The Smith and Wesson arm is made by the same process.

In 1866 Prussia with breech-loaders defeated Austria with muzzle-loaders. A few years afterward the Prussian *Zündnadelgewehr* and the French *Chassepôt* struggled for pre-eminence on the soil of France.

It may be added that, with a single exception, the main features of all the prominent military rifles originated in the United States. The exception is the European needle-gun, which is never likely to be used here. The English "Martini-Henry" gun is but a modification of the American "Peabody," which was the first military rifle to use the metallic cartridge. Six hundred thousand of the Martini-Henry gun are now being made by the Providence Tool Company, Rhode Island, for the Turkish government.

The "Winchester Repeating Arms Company," of New Haven, Connecticut, is making the ammunition for these guns. Four thousand tons of lead have been cast into bullets for the cartridges, and the boxing costs $100,000. These cartridges will freight eight vessels of 500 tons each.

TELEGRAPH.

When the men of 1776 threw down the gage of battle, there were no means of signaling news other than by such semaphores as had existed in one form or another for 2500 years past, and are yet used by the Indians of the plains. Visible signals by swinging arms mounted on the tops of masts or of elevated buildings signaled the events even of Trafalgar and Waterloo along the Falmouth and Dover roads to London. In a less pretentious way, concerted fires and smokes by night or by day were made by the nations of antiquity, as recorded by Homer and Jeremiah; by the Highlanders, as recounted by Scott; and by the Indians of our Western plains, as lately described by General Custer.

The semaphoric system of Polybius was adapted to spell out messages letter by letter. Signaling by flags and lanterns is employed in military and railway practice.

The electric telegraph preceded the electro-magnetic by many decades. Gray, in 1729, noticed the conductivity of certain bodies; Nollet soon after passed a shock through 180 men of the French guards, and a line 100 toises in length; Watson observed that the transmission of the shock through 12,000 feet of wire was practically instantaneous, and signaled an observer by this means. Then came a number of experimenters, each of whom added something to the stock of knowledge on the subject. Le Sage, of Geneva (1774), had a wire for each letter, and pith-ball electroscopes for the excited agents. Lamond (1787) had a single wire and concerted movements of the pith ball. Cavallo, in 1795, proposed to transmit letters by combinations of dots and spaces. The next year Betancourt constructed a telegraph between Madrid and Aranjuez, a distance of twenty-seven miles. The messages were read by the divergence of pith balls.

Then came the discoveries of Volta, Galvani, Oersted, Ampère, Faraday, and Henry. The experiments of the first two mentioned are at the bottom of the discoveries in dynamic electricity. Oersted, in 1820, observed that the magnetic needle had a tendency to assume a direction at right angles to that of the excited wire. The farther experiments of Oersted and Ampère, and the discovery of Faraday that magnetism was induced in a bar of soft iron under the influence of a voltaic circuit, and that of Sturgeon, in 1825, that a soft iron bar surrounded by a helix of wire through which a voltaic current is passed is magnetized during the time such current continues, gave rise to the first really convenient and practical system of electro-telegraphy. One difficulty remained—the resistance of the transmitting wire to the comparatively feeble current engendered by the voltaic battery. This was overcome by Professor Henry, who, in 1831, invented the form of magnet now in use, and discovered the principle of *combination of circuits* constituting the *receiving magnet* and *relay*, or *local battery*, as they are familiarly known in connection with the Morse apparatus. The effect of a combination of circuits is to enable a weak or exhausted circuit to bring into action and substitute for itself a fresh and powerful one. This is an essential condition to obtaining useful mechanical results from electricity where a long circuit of conductors is used.

In 1832 Professor Morse began to devote his attention to the subject of telegraphy, and in that year, while on his passage home from Europe, he invented the form of telegraph since so well known as "Morse's."

A short line worked on his plan was set up in 1835, though it was not until June 20, 1840, that he obtained his first patent, and nearly four years elapsed before means could be procured, which were finally granted by the government of the United States, to test its practical working over a line of any length, though he had as early as 1837 endeavored to induce Congress to appropriate a sum of money sufficient to construct a line between Washington and Baltimore.

Morse's first idea was to employ chemical agencies for recording the signals, but he subsequently abandoned this for an apparatus which simply marked on strips of paper the dots and dashes composing his alphabet. The paper itself is now generally dispensed with, at least in this country, and the signals read by sound—a circumstance which conduces to accuracy in transmission, as the ear is found less liable to mistake the duration and succession of sounds than the eye to read a series of marks on paper.

Professor Morse deserves high honor for the ingenious manner in which he availed himself of scientific discoveries previously made by others, for many important discoveries of his own, and for the courage and perseverance which he manifested in endeavoring to render his system of practical utility to mankind by bringing it prominently to the notice of the public, and he lived to see it adopted in its essential features throughout the civilized world.

The attention of Wheatstone in England appears to have been drawn to the subject of telegraphy in 1834. His first telegraph comprised five pointing needles and as many line wires, requiring the deflection of two of the needles to indicate each letter. His first dial instrument was patented in 1840. Modifications were, however, subsequently made in it. The transmission of messages was effected by a wheel having fifteen teeth and as many interspaces, each representing a letter of the alphabet or a numeral, and thirty spokes corresponding to this, and forming part of the line. The circuit was closed by two diametrically opposite springs so arranged that when one was in contact with a tooth the other was opposite a space, when the transmitter was turned until opposite a particular letter and held there, a continuous current being produced, causing an index on the indicating dial at the other end of the line, which had thirty divisions corresponding to those of the transmitter, to turn until it arrived opposite the letter to be indicated. The revolution of the index was effected by clock-work, the escapement of which was actuated by an electro-magnet at either end of a pivoted beam, the ends of which carried two soft iron armatures. One of the line wires, as well as one of the contact springs of the transmitter, and one of the electro magnets of the indicator, were afterward dispensed with.

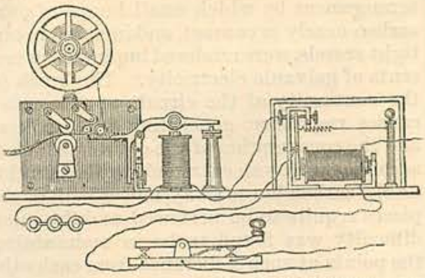
A magneto-electric apparatus was subsequently substituted for the voltaic battery.

The single-needle telegraph of Cooke and Wheatstone is caused to indicate the letters and figures by means of the deflections to the right or left of a vertical pointer; for instance, the letter A is indicated by two deflections to the left, N by two deflections to the right, I by three consecutive deflections to the right and then one to the left, and so on. This is extensively employed in Great Britain and India.

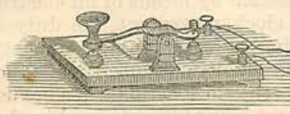
Bain, in 1846, patented the electro-chemical telegraph, which dispensed with the relay magnet at intermediate stations, and subsequently Gintl, in Austria, and Bonelli constructed telegraphs of this class varying in details from that of Bain.

The diagram on the next page shows the system of indicator, relay, local battery, lines, and key.

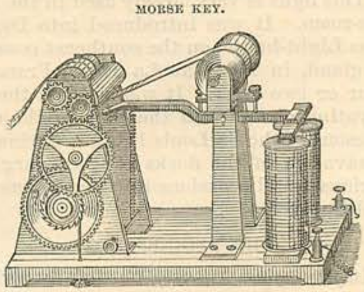
The middle figure shows the *key*, which is worked by the sender of the message, and the lower figure the *register*, by which motions of the stylus under the excitement which renders it temporarily magnetic are recorded on the paper in dots or dashes,



MORSE APPARATUS, CIRCUIT AND BATTERY.



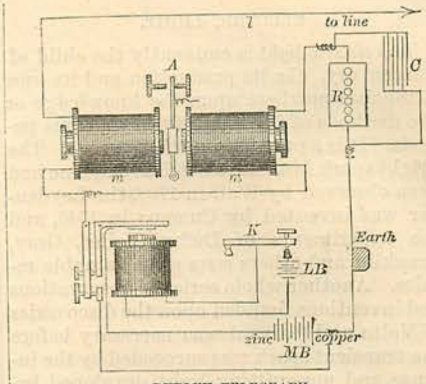
MORSE KEY.



MORSE REGISTER.

according to the length of time during which the circuit is maintained. This is the principal instrument in America and on the continent of Europe. Room fails to tell of the autographic systems of Caselli and Bonelli; the printing telegraphs of House and Hughes; the automatic telegraphs of Edison and others.

The *duplex telegraph*, by which messages are sent over the same wire in contrary directions at the same time, is so strange that a diagram and short description will be given. Several plans of duplex telegraph have been proposed. The device selected for illustration is that of Stearns, of Boston, which is based upon the plan of Gintl, of Austria, 1853. The relay, or receiving instrument, is composed of two pairs of electro-magnets (*m m*) acting in opposite directions upon a common armature lever (*A*). The key is the armature of an electro-magnet which is in a local circuit controlled by a Morse key (*K*). *LB* is the local battery. The main battery (*MB*) current is equally divided between the relay magnets (*m m*), one-half passing through one set of magnets to the line *l*, and the other half passing through the other magnets and a rheostat (*R*), equal to the resistance of the main line, to earth. The relay magnets are thus equally excited, and their influence upon the armature neutralized, so that the outgoing current gives no signal at the sending sta-

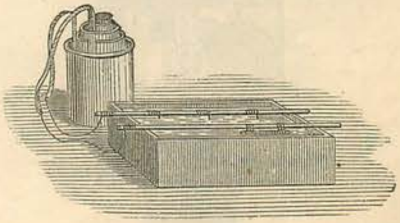


DUPLEX TELEGRAPH.

tion. A current received, however, traverses only one set of the electro-magnets, destroying the equilibrium, and causing a signal. The key is so constructed that it closes one circuit to the earth before breaking another, thus always preserving the continuity of the circuit, a condition essential in systems of this kind. A condenser (*C*) is placed in a shunt circuit to the magnets in the short or home circuit, in order to neutralize the effect of the extra current on the line magnets of the relay.

ELECTROPLATING.

Electroplating is an invention of the century. Volta himself experimented about 1800. Cruikshank noticed the corrosion in one wire and the precipitation of metallic silver on the other when passing the "galvanic influence" through the wires in a bath

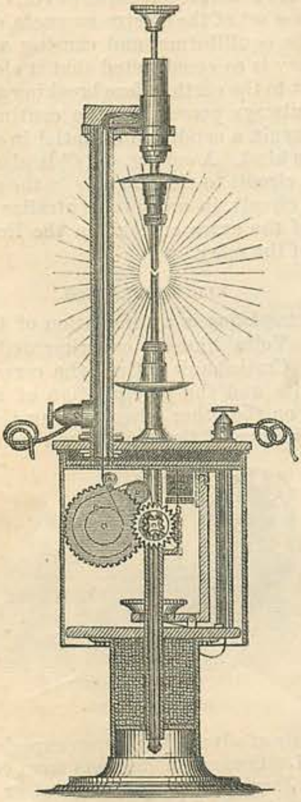


ELECTROPLATING.

of nitrate of silver. Wollaston experimented in 1801. Spencer made casts from coins in 1838. Jacobi, of Dorpat, soon after gilded the iron dome of the Cathedral of St. Isaac, at St. Petersburg, with 274 pounds of ducat gold, deposited by battery. The art has grown into use, and now baser metals, in the shape of articles for household service, are cased with silver; electrotyped forms are used as printing surfaces; nickel is deposited on numerous articles which are exposed to damp, and on others to add to their beauty, as with movements of watches. It is impossible to enumerate the uses and applications, and not easy to exaggerate the value of the art.

ELECTRIC LIGHT.

The *electric light* is eminently the child of the century. In its production and its uses it touches nowhere upon the knowledge or the methods of the men of the previous periods. It is a pure gain of the present. The bright spark from the electrical machine had been observed by Wall in 1708, the Leyden-jar was invented by Cunœus in 1746, and the experiments of Dufay, Nollet, Gray, Franklin, and others soon gave valuable results. Another whole series of observations and inventions founded upon the discoveries of Volta and Galvani was necessary before the transient spark was succeeded by the intense and unremitting light developed between two pieces of carbon placed at the positive and negative ends of a voltaic circuit. The electricity may be developed either by a battery, or from magnets in connection with a series of helices arranged on a rotating wheel, the latter source being preferred for light-houses and in other situations where permanency is intended. The battery is the usual source for lectures in theatres having no regular laboratory.



ELECTRIC LIGHT.

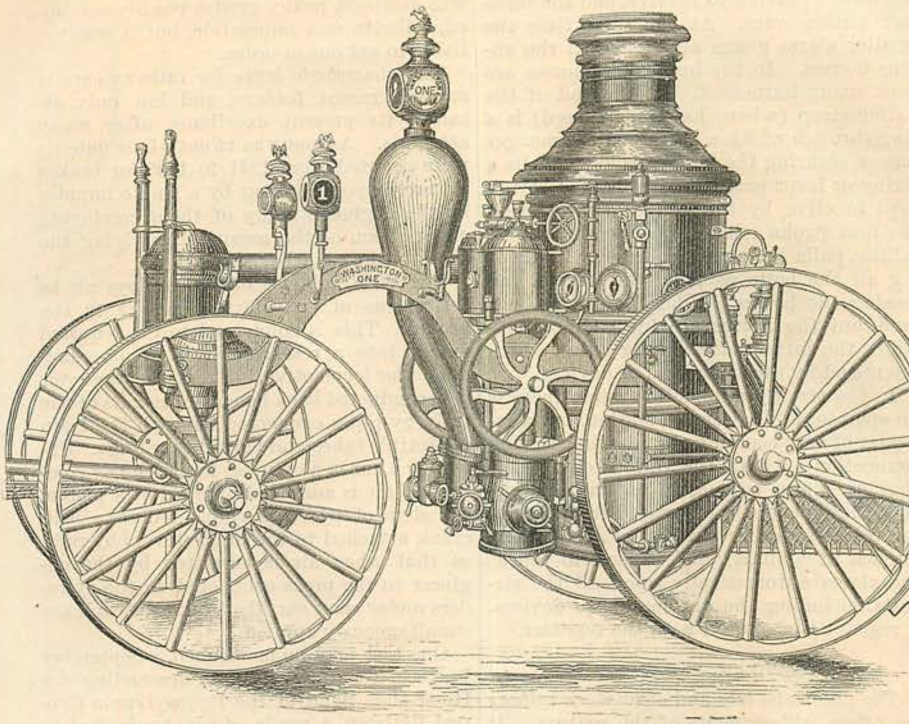
The electric light was first brought into notice by Greener and Staite in 1846, in an arrangement by which small lumps of pure carbon nearly in contact, and inclosed in air-tight vessels, were rendered luminous by currents of galvanic electricity. The break in the continuity of the circuit at this point causes resistance, generating intense heat and the consumption of the carbon, which is accompanied by an extremely brilliant light. As the carbon burns away, one or both of the pieces require to be advanced, and the chief difficulty was found to be in maintaining the points at such a distance from each other as to render the light continuous. This is now effected by means of an electro-magnet and clock movement, the duty of the latter being to bring the points together as they are gradually consumed, while the magnet checks the clock action when not desired.

This light is very largely used in the lecture-room. It was introduced into Dungeness Light-house, on the southeast coast of England, in 1862; at La Hève, France, a year or two later. It was used in the excavating chamber in the base of the deep caissons of the St. Louis Bridge; during the excavation of the docks at Cherbourg; on various festal occasions in cities of America and Europe.

FIRE-ENGINES, ETC.

In *fire-engines* America has hardly a rival. When our century commenced a clumsy hand-engine was employed, a gradual improvement upon the mere syringe which was used from the time of Trajan down to the sixteenth century. At Augsburg, about 1518, force-pumps were mounted on wheels and worked by levers. At Nuremberg, in 1657, the town engine had a cistern and pump mounted on a sled; the brakes were worked by twenty-eight men, and threw a stream through an inch nozzle to a height of eighty feet. The Van der Heyden brothers about this time much improved the device. Newsham's engine, about the end of the seventeenth century, had the double-acting force-pump with air chamber. This was not superseded till about 1832, when our personal recollections commenced, and about that time improvements were rapidly made which culminated in the gorgeous hand-engines with which we ran, of which we boasted, and, lamentable to say, about which we fought.

Steam-power forcing-pumps for extinguishing fires were in use long before portable steam fire-engines. The first steam fire-engines were perhaps those mounted on barges on the river Thames, and which were moved or towed to fires occurring on the river front. Next was undoubtedly the portable steam-engine of Captain Ericsson. This was made in Manchester, England, about 1830, a little after he constructed the "Novelty" locomotive, which contended for the prize on that famous day in 1829 on the



STEAM FIRE-ENGINE "WASHINGTON, NO. 1," BROOKLYN, NEW YORK.

Liverpool and Manchester Railway. He also made a steam fire-engine in New York in 1842–43.

But, after all, the steam fire-engine as a fixed and valuable fact dates from Cincinnati, Ohio, where the talents of the brothers Latta and Mr. Shawk, inventors and builders, were seconded by the enterprise of Miles Greenwood. The "Citizens' Gift," one of the first successful engines, was built in 1853, and in 1866 was still among the most useful of her class. Since that time the principal cities of North America have been supplied with steam fire-engines; also many of the largest cities of England, and some few on the continent of Europe.

The American system of *fire-alarms* is likely to work its way gradually into the cities of Europe. It is one of those things which are difficult to introduce, and impossible to dispense with when once tried. We can *not* imagine such an impertinent and absurd proposition as to go back to the old times when the flames of a burning house were the signal to the watchman in the tower of the engine-house.

The fire-alarm telegraph first in use was merely a connection by Morse telegraph between fire-alarm stations. This was in use in New York and Berlin in 1851. The present system is founded upon the patented invention of Farmer and Channing, 1857. Mr. Channing wrote upon the subject in 1845, and in 1848 Mr. Farmer devised a means of ringing bells by electricity, and in an experimental trial that year the bell in the tower of Boston City Hall was rung by an operator in New York. The fire-alarm telegraph was first put up in the year 1852, in Boston.

The primary requisites of a fire-alarm telegraph system are a telegraph line, a central receiving station, and a number of signal boxes suitably distributed for transmitting an alarm.

When there are a number of such boxes, as in most cities, they are not arranged upon the same circuit, but upon several circuits connected to some central station. The signal boxes generally used contain a spring or weight and gearing, rotating a circuit-breaking wheel and a fly for regulating the speed. The circuit wheel in one form is provided with projections, upon which a spring presses and closes the circuit, which is broken as the spring passes over the intervals between the cogs; in another form the surface of the wheel is smooth, an insulating material being let into the wheel so as to break the circuit. A train of gearing, upon one shaft of which is a cam or lug, operates the pivoted hammer. This gear is held in rest by the armature of a magnet acting as a detent; so every time a current passes, the armature allows the gearing to revolve, and the hammer strikes once. At the same time the smaller alarm gongs are struck in the engine-houses. In the houses the horses are kept ready harnessed. At the end of the halter strap (where halters are used) is a ring through which a bolt upon the manger passes, securing the horse; from the bolts a string or lever passes to a weight or spring kept inactive by the gong-hammer lever; the first stroke releases the weight, which, falling, pulls the string or lever, withdrawing all the bolts securing the halters, and loosing the horses. When halters are not used, but the horses are turned into box-stalls, the latter have sliding gates, which are raised by the same kind of devices.

In the strictly automatic system there is no operator at the central station, but a repeater of very complex organization, having connection with all the various circuits, so that, an alarm coming in on any one circuit, the repeater is prevented from receiving from any other circuit (to avoid interference of signals), and caused to repeat the alarm automatically upon all the circuits, including the various alarm devices. A register is also used with the repeater.

ATMOSPHERIC RAILWAY, ETC.

The *pneumatic tube* and *atmospheric railway* are other achievements of the century. It can not be said that they have come into extensive use for passengers, but for small parcels and letters they have been in successful use for fifteen years in London.

Dr. Papin, of Blois, in France, suggested the idea about the end of the seventeenth century, but, like some other children of his fertile brain, it never grew up. Medhurst in 1810 patented the idea of forcing a carriage on a pair of tracks along an air-tight tube by means of compression of air behind it.

Vallance in 1824 patented the other mode, exhausting the air in front of it. The idea was carried out at the Sydenham Palace, near London, where an ordinary railway carriage with a somewhat elastic piston traveled in an elliptical tunnel eight by nine feet in its minor and major diameters. The same idea is carried out in Beach's short tunnel under Broadway, New York, which has been visited by many of our readers.

Out of this grew the atmospheric railway, in which a piston traveling in a tube is connected to a carriage running upon rails outside, a long valve filling a slot in the top of the tube being displaced by a bar depending from the carriage, and falling into place again behind. This plan had many modifications, and was actually employed on two railways, but afterward abandoned—from 1844 to 1855 on the Kingstown and Dalkey, Ireland, 1¾ miles; from London to Croydon, England, 10 miles. Good speed was attained, heavy grades readily ascended, collision was impossible, but it was too liable to get out of order.

The *atmospheric brake* for railway cars is another recent feature, and has only attained its present excellence after many attempts. As many as twenty-four patents were granted from 1841 to 1865 for brakes actuated upon each car by a single impulse by the engineer, many of them employing air or steam as the means of applying the shoes to the car wheels.

The Westinghouse brake employs air as the means of transmitting power to the brakes. This is condensed to the required extent into a reservoir by a steam-pump upon the locomotive. From the reservoir it is conducted back beneath the cars of the train by pipes connected beneath the train by flexible tubes and valved couplings. Under each car is a cylinder to which the compressed air is admitted forward of a piston, the stem of which is connected to a bell-crank attached to the brake levers by rods, so that when air is admitted by the engineer to the pipes connected to the cylinders under each car, the brakes of each are simultaneously applied.

One test may be mentioned. September 18, 1869, a train of six cars descending the Horse-shoe Bend of the Pennsylvania Central Railway, a grade of ninety-six feet to the mile, at the rate of thirty miles per hour, was brought to a stand-still in 420 feet—seven car lengths.

Blowers and *blowing engines* are but forms of air-compressing or air-exhausting pumps, but it is hard to overvalue them. They increase the draught in metallurgic furnaces; furnish vital air to close and fetid places, such as mines, cisterns, holds of ships; supply warmed, cooled, moistened, or medicated air to public buildings, schools, hospitals, etc.; furnish a drying atmosphere to lumber and grain kilns and powder mills; assist in evaporating liquids and removing the steam from the vicinity of the boiling solution; raise liquids on the principle of the Giffard injector, as in oil wells and subaqueous caissons; assist in the dispersion of liquids, as in atomizers and some forms of ice machines; remove dust and chips from saw-mills and planers, the fatal dust from the stones and glazers of cutlers; supply breath to organs.

The blower of three centuries since consisted of one open-ended box slipping into another; it was used in that very remarkable city, Nuremberg, for furnaces, and was an improvement over the ordinary bellows. Later, about 1621, a bellows was used consisting of a valve oscillating in a sector chamber. The fan-blower dates from 1729. The water-bellows was invented by Hornblower.

The first powerful blast machines were

probably those erected by Smeaton at the Carron Iron-works, 1760. The furnaces grew larger in size, and more powerful blowers were needed. Watt's engine came just in time to crown the whole affair with success and revolutionize the iron trade. Neilson invented the hot blast in 1828.

Power blowers are now used. The forms are piston; fan; vertical open-ended cylinder plunging in water; pair of wheels, with alternate vanes and packing surfaces, and rotating in concert.

BALLOONS.

Aerostation is almost all within the century. Since Icarus fell into the Ægean Sea very little advance has been made in flying machines, the flight of Dædalus from Crete to Sicily being altogether the most successful on record. Some presume to doubt *this*. *Ballooning* was rendered possible upon the discovery of hydrogen gas by Cavendish in 1766. It is true it had been produced before, but was not understood or used. Dr. Black the next year suggested its use for aerostation. The brothers Montgolfier ascended by a fire balloon in 1783; the ascensive power was obtained by heated air rising from a fire made in the open mouth of the balloon. Pilatre de Rozière and the Marquis d'Arlandes repeated the experiment the same year. MM. Charles and Robert inflated their balloon with hydrogen gas, and ascended 9700 feet and reached a distance of twenty-five miles in one hour and three-quarters. Ascensions after this became frequent. Pilatre and Romain tried to combine a hydrogen balloon with a fire balloon; the expanding gas reached the fire, the whole was consumed, and the aeronauts perished. Balloons of observation were used by the French army at Liege and Fleurus in 1794. This was repeated at Solferino in 1859, and with our Army of the Potomac. The most remarkable ascent for a long time was that of Gay-Lussac, in 1804, who reached the height of 23,040 feet. Glaisher, it is said, afterward ascended to a height of seven miles. Green, in 1820, introduced the plan of inflating with the ordinary illuminating gas of the streets.

The history of the balloon since this time embraces many names—Wise, King, Lowe, and Donaldson in this country; Gifford, Godard, and De Lorne in France. M. Godard conducted the balloon postal administration during the siege of Paris. Wise's trip from St. Louis is the longest on record, nearly 1200 miles.

WEIGHING MACHINES.

Probably no invention, if we except that of the locomotive, has to so great a degree expedited the transactions of commerce as the platform balance, invented by the Fairbanks Brothers about 1830. The business of making these weighing machines has grown to enormous proportions. From the Fairbanks manufactory at St. Johnsbury, Vermont, 50,000 scales are sent out annually to all parts of the world.

GAS.

Illuminating gas was unknown, except as a surface emanation or a laboratory production, in the year 1776. In China from time immemorial the natural flow of carbureted hydrogen has been used for lighting, and for boiling the brine yielded by salt wells. Similar convenient applications have been made at Fredonia, New York, Portland, on Lake Erie, Wigan, Scotland, in lighting, and at Kanawha, West Virginia, in evaporating brine. Gas emanating from a well 1200 feet deep is used at the "Siberian Works," Pittsburg, under the boilers and in the puddling furnaces. The fire-worshipers of Persia have regarded such emanations with high respect, and the holy fires of Baku, on the Caspian, have a great local fame, and are thus maintained.

Gas was first obtained by the distillation of coal in 1688 by Dr. Clayton; Boyle refers to it in that year. Watson, Bishop of Llandaff, 1756, Lord Dundonald, 1786, distilled coal and tar and burned the issuing gas. Murdock was the first to light a building with it. He thus lighted his house and offices at Redruth, Cornwall, in 1792. In 1798 he lighted with gas the works of Boulton and Watt at Soho. He illuminated these buildings in 1803 in the rejoicings for peace: Trafalgar, Austerlitz, and Jena, within four years afterward, are a curious commentary. Murdock's name stands at the head of the list as the man who reduced the idea to practice. In 1804–05 he lighted the cotton factory of Phillips and Lee, Manchester, with a brilliancy estimated to be equal to 3000 candles. This was a grand success.

In 1803 Winsor lighted the Lyceum Theatre, in London, and obtained a patent for lighting streets by gas. He established the first gas company. The first street lighted was one side of Pall Mall, in 1807; Westminster Bridge and the Houses of Parliament, in 1813; London streets commonly were lighted in 1815; Paris, the same year; Baltimore, 1816; Boston, 1822; New York, 1825.

This is all very recent, and yet how far into the past the dim period of street oil-lamps seems to have retreated! The mode of making illuminating gas is pretty generally understood. The coal is baked in retorts, and the gas flows therefrom in company with other vapors, which are removed by successive operations. It is conducted first to the convoluted pipes of the condenser, by which it is cooled and the tar precipitated. Thence it passes to the washer, where the ammonia is seized by the water, allowing the gas to pass on to the puri-

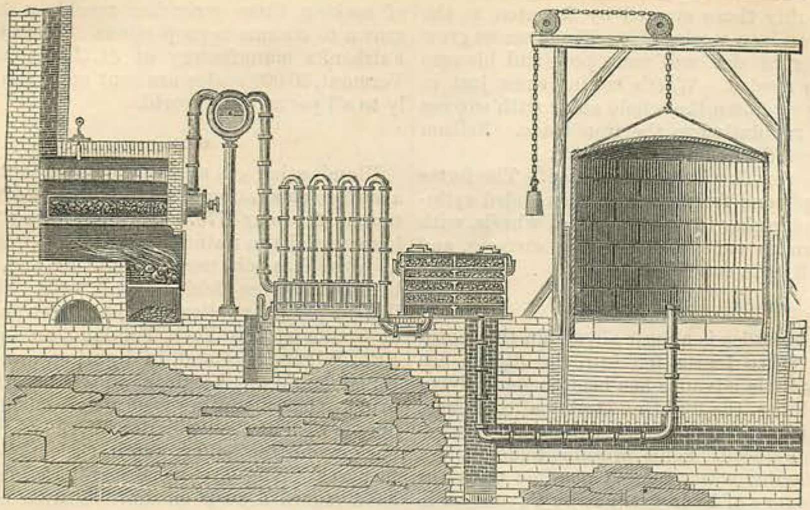


DIAGRAM OF GAS-WORKS.

fier, where it is deprived of its sulphur and carbonic acid by dry lime, or latterly by the hydrated sesquioxide of iron. Clegg invented the purifier and wet meter in 1807; Malam the dry meter in 1820.

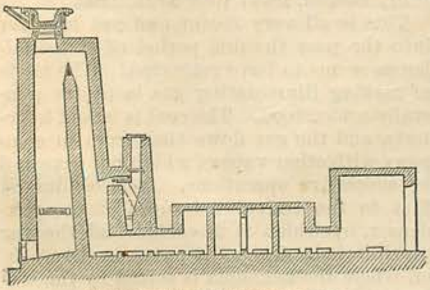
SILVER.

The *silver processes* now adopted in our Western Territories are the result of long care and observation, with chemical analyses—the union of experimental test and scientific deduction.

Amalgamating pans and barrels are made in great variety; roasting furnaces and processes have been adapted to the varying characters of ore and the means at command for treating. One of the most satisfactory of the latter must stand as a representative of the whole family, as it is not possible to treat the matter either at length or in detail.

The Stetefeldt roasting furnace for silver ores containing sulphur is what is technically known as a *shaft furnace;* the ground and stamped ore is dusted in a shower into a vertical shaft, up which the flame of a furnace is directed.

The ground ore is mixed with salt, and pulverized at the stamp battery. The pulp is carried by a conveyer to the feeder at the top of the shaft, and shaken through the sieve so as to fall in a shower through the flame of the gas entering at the side apertures low down in the shaft. The principal portion falls to the bottom, but the finer matter passing over is exposed to a flame arising from the mingled air and the carbonic oxide of a charcoal fire discharging into the downcast shaft leading to the series of chambers in which fine metallic dust is eventually deposited, and from which it is removed from time to time.

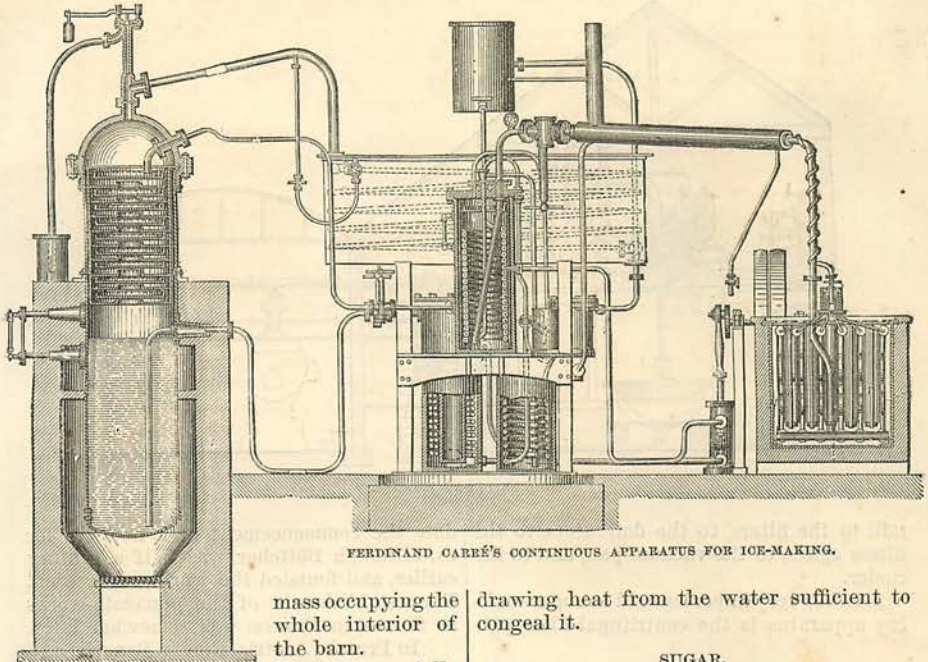


STETEFELDT'S ROASTING FURNACE.

In the furnace shaft a double decomposition takes place, which converts the sulphide of silver into the chloride, in which latter condition it is brought, as one may say, within the grasp of the mercury. In the presence of sulphurous gases from the sulphide of silver the chloride of sodium is decomposed, and yields its chlorine to the silver, forming the chloride of silver, while the sulphurous gases uniting with the soda form sulphate of soda, which is washed out with the tailings. The material from the furnace is ready for the amalgamating pan.

ICE.

Ice is one thing in which Americans revel in the summer-time. No other nation lays in such a stock, or so peremptorily demands an abundant supply. American ice is sold in London, Calcutta, and a hundred places between the two. Usually the ice is "harvested" on ponds or rivers in the North, and the business has created a whole set of peculiar contrivances for scraping off the surface and removing snow; sawing the sheet into blocks without quite detaching; splitting them off; floating them to the hoist; elevating them by endless chains; delivering them to the men who stow them in a solid



FERDINAND CARRÉ'S CONTINUOUS APPARATUS FOR ICE-MAKING.

mass occupying the whole interior of the barn.

More specially noticeable, however, are the machines for congealing water into ice, and which are commencing to work at a price below that at which the ice can be gathered and transported.

Speaking in short terms, there are four modes of making ice—vaporization, radiation, liquefaction, and sudden reduction of pressure.

Vaporization in a partial vacuum formed the basis of Dr. Cullen's attempts in 1755; in 1777 Nairne used sulphuric acid to absorb the vapor rising from water in an exhausted receiver. Edmond Carré's apparatus is on this principle, and is used to produce the *carafes frappées* so common in Parisian restaurants. In the continuous operation of Ferdinand Carré ammonia is employed as being more volatile than water, and under ordinary atmospheric pressure permanently gaseous. The apparatus is somewhat complicated, but effective. The water is in cans in a bath of uncongealable liquid, cooled by zigzag tubes, into which the liquid ammonia is conducted to expand, and thereby convert the sensible heat of the surrounding bath into latent, due to its assumption of the gaseous condition. There are many modifications of the vaporization principle, but no room to tell of them.

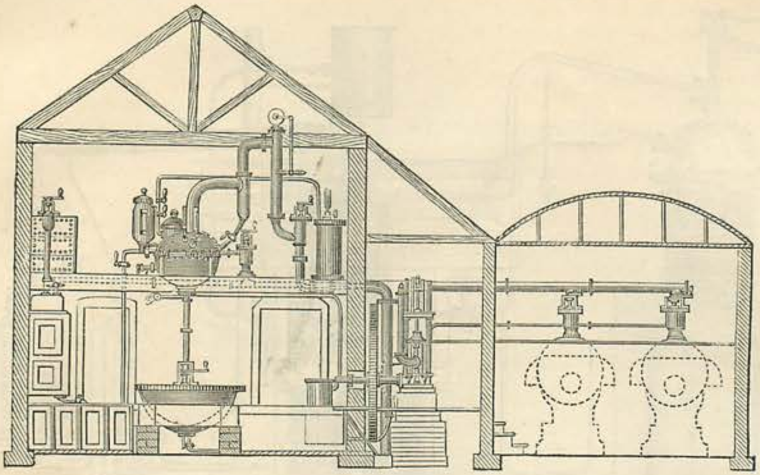
Liquefaction is another mode, and snow and ice are used in connection with salts. Combinations of salts are also used. Machines are also used in which air is exhausted by a steam-engine from a receiver, the expansion of liquid into a gaseous condition drawing heat from the water sufficient to congeal it.

SUGAR.

Sugar is mentioned by Dioscorides and Pliny as a kind of honey obtained from cane, and was introduced into Europe by the Arabs. The first mention of it in European annals is in the account of Nearchus, who commanded the fleet of Alexander. The Crusades added to the European knowledge of it, and in the twelfth century it was grown in Sicily. Thence it was taken to Madeira in 1420, and thence to the Canaries, to Brazil, and to San Domingo in 1506; to Barbadoes from Brazil in 1641. It is a native of the East Indies, and its name is from the Sanskrit, *sarkara;* Persian, *schakar;* Hindostanee, *schukur;* Arabic, *sukkar. Kanda* (candy) is also Sanskrit.

It was used for many centuries as a vehicle in medicine before it became an article of food. For the refining processes we are indebted to the Venetians of the sixteenth century. As time passed, the clarification, defecation, and crystallization proceeded on a gradually improving scale, boiling, settling, filtering, white of egg, skimming, bone-black, etc., being used. Loaf-sugar was first made in Venice.

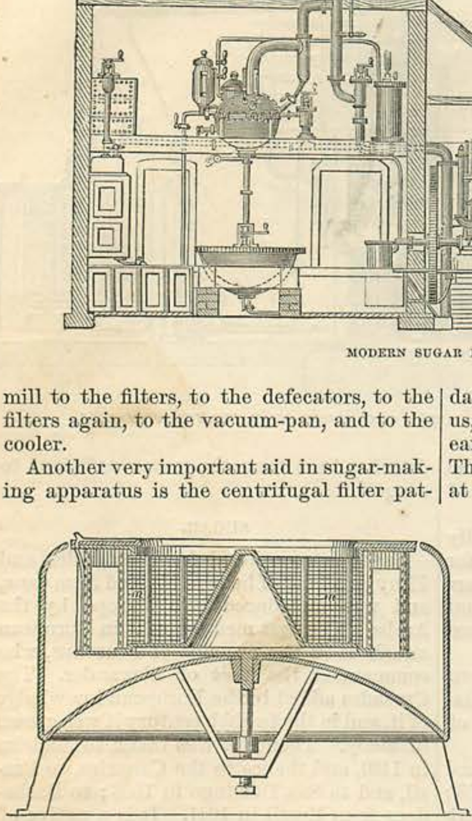
The vacuum-pan is the invention of Charles E. Howard, an English refiner, about 1813. In this a partial vacuum is obtained over the sirup, so that it will boil at a much lower temperature. This not merely saves fuel, but prevents charring and discoloration of the sugar. The modes of handling the sirup, so to speak, are also much simplified and assisted, the cane juice, by means of pumps or by gravity, flowing from the



MODERN SUGAR PROCESS.

mill to the filters, to the defecators, to the filters again, to the vacuum-pan, and to the cooler.

Another very important aid in sugar-making apparatus is the centrifugal filter pat-



CENTRIFUGAL FILTER.

ented by Hurd, of Massachusetts, 1844. In this the magma is placed in a foraminous cylinder, and rotated with great rapidity, so that the liquid portion—the water and the uncrystallizable sugar—is expelled by centrifugal force, leaving the granulated sugar in the cylinder.

This really beautiful contrivance has since been adapted for many purposes as a drainer filter, and as a substitute for the clothes-wringer.

PORCELAIN.

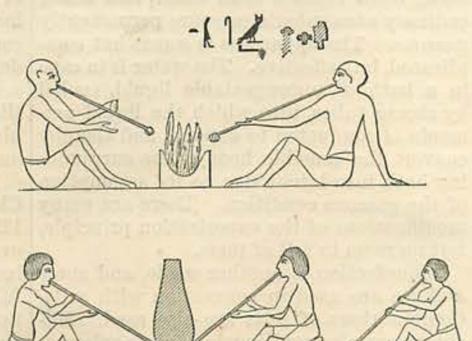
Porcelain, although not finer in texture than the Chinese article of many ages back, nor of more graceful and agreeable shapes than the vases of Etruria and Greece, has, as far as we are concerned in the art, made almost all its progress within the century just passing away.

Wedgwood's improvements, 1759–70, date the commencement of a new era for us, although Böttcher was half a century earlier, and founded the works of Dresden. The establishment of the porcelain-works at Sèvres, in France, was somewhat later. In Prussia, Austria, Russia, Bavaria, and France the works are governmental. Staffordshire, the old home of Wedgwood, is the centre of the English works, which are all private ventures.

GLASS.

Glass was known in ancient Nineveh, and was skillfully worked by the ancient Egyptians, though it was mostly ornamental, and did not probably enter much into the common uses of life. Pliny describes the mode of making it, and it was used all down through the ages to our own time. It is only within the last three centuries that its use has become common. The manufacture of blown glass was introduced into England in 1559; plate-glass in 1673.

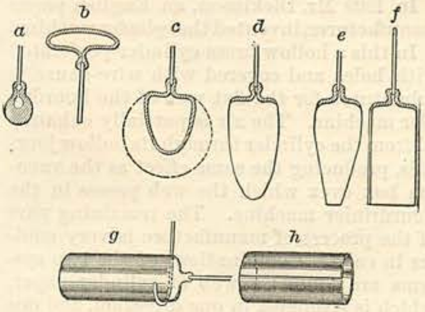
Cylinder glass was made for some scores

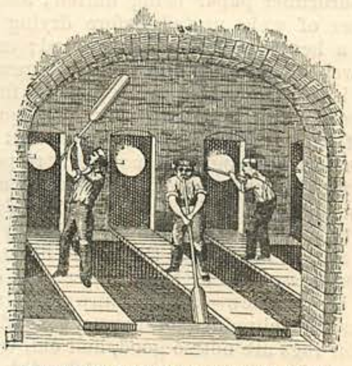


GLASS-MAKING IN EGYPT, 1500 B.C.

of years before it was introduced into England in 1846, just in time for the great Exhibition building of 1851, which was designed by Sir Joseph Paxton, and roofed with cylinder glass made by Chance and Co., of Birmingham.

The process is as follows: The workman collects a mass of glass (*a*) around the end of his blowing tube, and then distends and rounds it by blowing and rolling it on the *marver*, or flat cast-iron table. The subsequent operations consist in reheating, blowing, and swinging, until the diameter and then the length of the cylinder required are attained, the glass successively assuming the forms *b c* represented in the figure. In the fourth stage, where it has assumed a





SUCCESSIVE STAGES OF CYLINDER GLASS.

conoidal form (*d*), the point is very thin, and the blower, having filled the shell with air at a pressure, places it in the furnace, when the expansion of the air by heat causes the conoid to burst at the apex (*e*). The edge of the hole is then trimmed with shears, and enlarged by the *pucellas*, a peculiar hand tool, which resembles a pair of spring sugar-tongs with flat jaws. The cylindrical form (*f*) being then perfected, the cylinder is ready to be removed from the blowing tube, a circular piece of glass coming away with the tube, so as to make an opening in the other end of the cylinder. This separation is effected by a red-hot bent iron, in which the cylinder is turned round a few times, so as to expand the glass at that point (*g*). A drop of water on the heated line makes an instant fracture. The cylinder is then split by a diamond, or by means similar to that which removed the disk from the end (*h*). *Flatting* and *annealing* finish the process. These are accomplished in separate furnaces, or apartments heated by the same furnace. In the combined form the *flatting furnace* consists of consecutive chambers heated by a furnace beneath. The cylinder is placed on the heated floor of the flatting furnace, with the cracked side uppermost. The heat of the furnace causes it to soften and spread out, when all the curves and lumps are removed by a straight piece of wood fastened crosswise at the end of an iron handle, and wetted before applying. The flatting stone is made very smooth, as any inequalities are transferred to the glass. The sheet of glass is then pushed into the annealing chamber, where it is set upon edge, and left to cool gradually.

The operations of making crown and cylinder glass are exceedingly interesting, and have some marked peculiarities. Wonderful is the command attained by skill over the plastic stuff, and in no other art except pottery is there such a growth beneath the hand of the operator.

The lower illustration shows the men, each one on his platform, one swinging his prolonged bulb above his head, another blowing and swinging it beneath his feet, while a third is observing the operation of heating the glass, which he keeps constantly turning round by means of the rod to which it is attached.

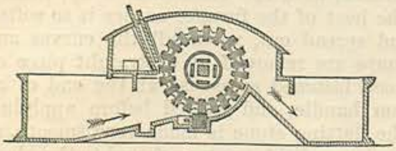
In articles of *bijouterie* and *virtu*, we have nothing to claim of elegance or beauty over the Venetians of centuries back. In glass-cutting the most interesting of modern inventions is Tilghman's sand blast, by which a stream of sharp sand or emery is directed upon glass to drill it, as may be required, or to sink a pattern into it, or sink a panel around a raised pattern. It is also used for drilling stone, and even the hardest varieties, such as agate and porphyry.

PAPER.

As Pliny remarked in the first century of our era, "All the usages of civilized life depend in a remarkable degree upon the employment of paper; at all events, the remembrance of past events." This he said of the material obtained by splitting apart the successive folds of the papyrus stalk, a reed growing plentifully then in the marshy grounds of Egypt, but which is now somewhat rare.

Paper, as we understand it, was not then known to the Mediterranean nations, and perhaps not out of China. Paper made by the maceration of rags was introduced into Europe by the Spanish Saracens during the eighth century. It was, of course, made by hand, as it is in Asia at present.

All paper-making machinery is included within our century. By the hand process the rags, being sorted, washed, and bleached, are cut in pieces, and then ground or beaten to a pulp. This was done in mortars till the invention of the rag engine in Holland, about the middle of the seventeenth century. As now practiced, the beater or pulping engine grinds the rags into pulp, which is transferred to a vat.



PULPING ENGINE.

By the hand process, which is extinct in Europe and America, except for some grades of drawing and writing papers, the paper-maker dips into the vat a shallow triangular frame, known as the *mould*, having a closely woven wire-cloth, a sort of flat sieve with wire meshes. Lying upon this is an open rectangular frame like a slate frame, and known as a *deckle*, which forms a margin for the sheet of paper to be made. He dips the two into the pulp, and withdraws them in horizontal position, the mould being full. The water drips away as the man shakes the mould to felt the fibres, and he transfers the soft sheet to a sheet of felt, over which he lays another sheet of felt, on this a second sheet of moulded pulp, and so on, until the pile is high enough to be pressed. It is a second time piled, without the felt sheets, and again pressed, then sized, calendered, and made into reams.

Ten centuries passed and saw the civilized nations of the world making paper thus.

A few years after the commencement of our century, Robert, a Frenchman, devised a machine for making a web of paper from pulp. Before 1800 he had made it succeed in a degree, but it took a number of years and the brains of many co-workers before valuable results were attained. The scene of the effort was shifted from the paper mill of François Didot, of Essones, France, to the works of the wealthy brothers Fourdrinier, in England, who were assisted by Donkin in bringing the machine to perfection.

In the Fourdrinier or *flat web* machine the previously prepared pulp is introduced into a vat, where it is thinned with water previously expressed from the sheet during its formation, and agitated by means of a rotary stirrer. Passing through a peculiarly formed strainer, the invention of Ibbotson, by which it is freed from knots, the pulp, in a stream the thickness of which is regulated according to that of the paper to be made, falls upon an apron, which conducts it a short distance to an endless wire-gauze flat web, by which it is carried forward and over a box partially exhausted of air; this flattens the web of paper, and partially extracts the water. ' The width of the sheet is governed by traveling deckles or side straps, which prevent any portion of the pulp from passing away at the sides of the wire-gauze. The web is then conducted upon endless blankets between two sets of rollers, which express most of the remaining water, and partially obliterate the marks of the wire-gauze, and dried by passing between several pairs of hollow steam-heated rollers, being finally wound upon a roller at the farther end of the machine, or delivered on to another machine by which it is cut into lengths.

In 1809 Mr. Dickinson, an English paper manufacturer, invented the *cylinder* machine. In this a hollow brass cylinder perforated with holes and covered with wire-gauze is substituted for the flat web of the Fourdrinier machine. The air is partially exhausted from the cylinder through its hollow journals, producing the same effect as the vacuum box over which the web passes in the Fourdrinier machine. The remaining part of the process of manufacture is very similar in each. Combinations of the two systems are found: a web of cylinder paper, which is strongest in one direction, and one of Fourdrinier paper being united; also a number of webs united before drying to form a heavy paper or card-board; or a fine web of pulp has fibres of silk strewed upon it to be imbedded in the paper to form a paper for fractional currency. The quality of paper depends mainly upon that of the material, though the making is responsible for the evenness of its thickness and the smoothness of its surface. The best quality made in this country is hardly so good as that made from the longer fibres of silk or *broussonetia* by the Chinese; but our best is from new—that is, unworn—linen stocks, the clippings of garment making. Cotton rags are not so good, and old, worn rags, partly rotten, are worse. After this we reach still commoner material for stout brown paper, such as hemp and old rope, and the cheapest of all is straw, for wrapping paper.

INDIA RUBBER.

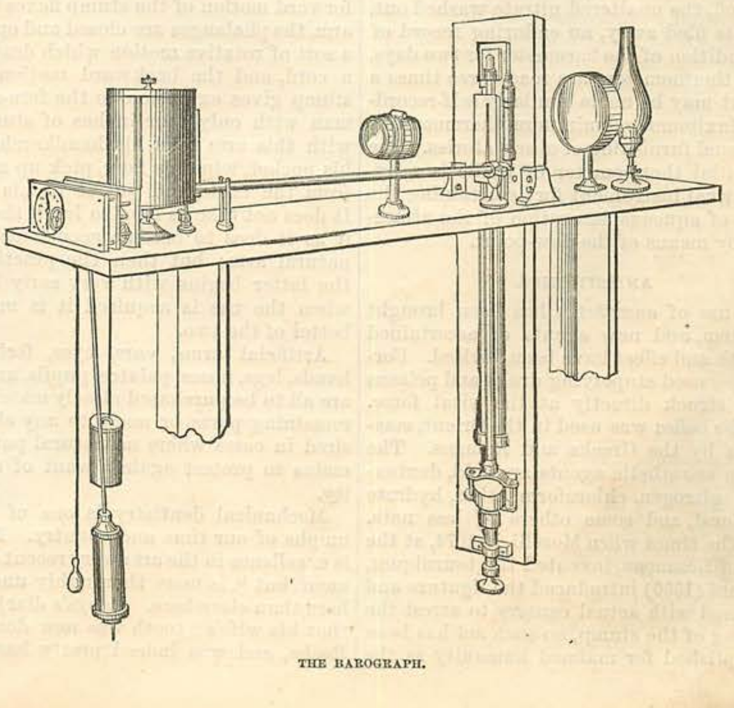
What would the men before '76 have said to the India rubber manufacture? The substance was first brought to England from Brazil as a curiosity early in the eighteenth century, and about 1776 it seems that Priestley suggested that it was "excellently adapted for removing pencil marks from paper." It was dissolved in turpentine, and used by Peal in 1791 as water-proofing composition for fabrics. Hancock and Mackintosh, about 1823, were the first to apply the gum to the uses of water-proof clothing. The gum was placed between two thicknesses of fabric, and was a sticky affair at the best. The business never really prospered until the discovery of the *vulcanizing* process by Goodyear, the subject of his patent of June 15, 1844. He preferred the proportions of twenty-five caoutchouc, five sulphur, seven white lead; but these quantities and the nature of the substances employed were varied by Goodyear himself and by his successors. The same may be said of the heat employed in combining the substances, this being generally proportionate to the degree of hardness required in the vulcanite.

The history of invention does not furnish an instance of greater persistence under discouragement than is afforded by the struggles of Charles Goodyear. It was a purely tentative process. He first mixed the gum with half its weight of magnesia to dry it and remove the stickiness; but the compound softened. He then tried India rubber sap with magnesia, with better results. Next he tried surface treatment with nitric acid. This scheme, which seemed promising, was overthrown by the financial crisis of 1837. After a number of attempts, Goodyear shifted on to the line previously traveled by Hayward—the use of sulphur. Hayward had mixed and covered the rubber with sulphur, and exposed it to the sun's rays, producing a superficial hardening. While experimenting with some goods which had been thus made and returned as rotten, a piece of it was charred by contact with the stove, and the result was sufficient to indicate to the alert mind of Goodyear that what was needed was the baking of the rubber and sulphur together. He then devoted himself to details, the proper proportions for given qualities of goods, the materials to be added to give color and solidity, the uses to which this admirable compound may be put. The results of his genius, care, and persistence are all around us.

METEOROLOGICAL INSTRUMENTS.

The *meteorological instruments* of the present day derive much of their public interest from the tri-daily report of the numerous stations to the Signal-office in Washington, where the generalizations are made, and from whence conjectures for the following twenty-four hours are transmitted. The principal instruments are the *anemometer*, for direction and rate of the wind; the *barometer*, for the atmospheric pressure; the *thermometer*, for atmospheric temperature.

Weather-cocks for indicating the direction of the wind are as old as the sailing of boats, but an instrument for measuring its force can be hardly said to have existed before 1776, when Lind invented an anemometer, which has been long since superseded by those of Whewell, Ostler, Robinson, and others. The present anemometers are self-recording. The *barograph*, or registering barometer, used at the Chief Signal-office, War Department, Washington, is shown in the figure. The barometer is in a dark case, with the mercury column exposed at a slit



THE BAROGRAPH.

through which the light of a lamp passes. At the farther end of the machine, shown at the left in the cut, is a cylinder wrapped with sensitized paper so as to blacken with light. This cylinder and its paper cover are moved by clock-work so as to rotate once in forty-eight hours. The image of that part of the slit above the mercurial column is thus caused to form a continuous dark band of irregular width on the paper, becoming narrower as the mercury rises and widening as it descends in the tube, the width of the band indicating not only the relative changes, but also the absolute height of the barometer. A shutter operated by the clock-work cuts off the light for four minutes at the end of each second hour, leaving a vertical white line on the paper.

By the expansion of a zinc rod on each side of the barometer tube, in connection with a glass rod and lever, the thermometric changes are made, and the true barometric indications, with corrections for temperature, are photographically recorded. The strip after remaining forty-eight hours is taken off, the unaltered nitrate washed out, and it is filed away, an enduring record of the condition of the barometer for two days.

The thermometers are read three times a day, but may be made similarly self-recording. Maximum and minimum thermometers are a usual furnishing of observatories. The differential thermometer of Leslie is a hygrometrical instrument for ascertaining the degree of aqueous saturation of the atmosphere by means of the dew-point.

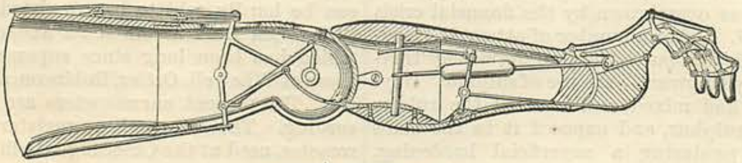
ANÆSTHETICS.

The use of *anæsthetics* has been brought to system, and new agents of ascertained strength and effect have been devised. Former ages used stupefying drugs and poisons which struck directly at the vital force. *Cannabis indica* was used in the Orient, *mandragora* by the Greeks and Romans. The modern anæsthetic agents are cold, deutoxide of nitrogen, chloroform, ether, hydrate of chloral, and some others of less note. From the times when Morelli, in 1674, at the siege of Besançon, invented the tourniquet, and Peré (1550) introduced the ligature and dispensed with actual cautery to arrest the bleeding of the stump, no such act has been accomplished for maimed humanity as the introduction of a safe anæsthetic. As Charles IX. said when he hid the Huguenot surgeon in his royal chamber to guard him from the assassins on the night of St. Bartholomew, "there is only one Peré." Palissy, another Huguenot, was similarly shielded by Catherine de Medicis, the queen-dowager, as there was "only one potter." Palissy died in prison eventually. Ether was known for many centuries before Drs. Morton and Jackson, of Boston, brought it into notice as an anæsthetic in 1846. Chloroform was discovered in 1831; first used as an anæsthetic by Dr. Simpson, of Edinburgh, in 1847.

ARTIFICIAL LIMBS.

Artificial limbs and other *prosthetic appliances* have advanced with the line—artificial hands and legs whose simulation of the natural is so close that a casual observer will not notice the difference.

The artificial arm illustrated has three motions derived from the stump, the arm being secured by bands to the body. The forward motion of the stump flexes the fore-arm, the phalanges are closed and opened by a sort of rotative motion which draws upon a cord, and the backward motion of the stump gives extension to the fore-arm. A man with only four inches of stump may with this arm take his handkerchief from his pocket, wipe his nose, pick up a marble from the table, and put it in his pocket. It does not take as long to learn the use of it as it does to become accustomed to the natural arm; but then the practice with the latter begins with very early life, and when the use is acquired it is much the better of the two.



CONDELL'S ARTIFICIAL ARM.
(Longitudinal section of left arm.)

Artificial arms, ears, eyes, feet, gums, hands, legs, noses, palates, pupils, and teeth are all to be purchased closely matching the remaining parts, or made to any shape desired in cases where no natural portion remains to protest against want of uniformity.

Mechanical dentistry is one of the triumphs of our time and country. Not only is excellence in the art a very recent achievement, but it is more thoroughly understood here than elsewhere. Pepys's diary records that his wife's "tooth was new done by La Roche, and was indeed pretty handsome," but it was probably a piece of ivory or walrus tooth.

AQUARIA.

Aquaria have been constructed on a scale sufficient to show aquatic animals and plants in their natural condition, and with a reasonable degree of freedom. The mode of aerating the water by a jet of air introduced into and ascending in bubbles through the water has much simplified that part of the matter. The proper understanding of the reciprocal duties and effects of the animal and vegetable tenants lies at the bottom of the success with an aquarium. The office of the flora is to abstract the excess of carbonic acid gas due to the breathing of the fauna, and restore the oxygen, as with the terrestrial flora. Then certain animals which feed on decaying vegetable matter are put in the minature pond to act as scavengers to the community. The demonstration of these conditions is due to R. Warrington, 1850. N. B. Ward is also not to be forgotten. An aquarium 36 by 150 feet was constructed in 1860 in the Jardin d'Acclimatation in Paris by Lloyd. The same person erected a large one at Hamburg. An aquarium at Manchester, England, has 750 feet frontage. The aquarium of the Paris Exposition was a large and effective one. That of Brighton is on a grander scale than any other. It occupies ground 100 by 715 feet, the general structure being a quadrangular series of tanks with plate-glass sides, and a central roofed apartment lighted through the tank sides so as to give the idea of being under water. The tanks have fresh or salt water to suit the tenants, and vary in size from 11 by 20 to 30 by 55 feet.

An aquarium car lately went from New England to San Francisco with young fish for stocking the Pacific rivers.

MATCHES.

The old-fashioned match was simply a wooden splint dipped in brimstone, and kindled from a piece of tinder set on fire by a spark from the flint and steel.

The tinder was sometimes ignited by an air-compressing pump. In other cases the matches were tipped with chlorate of potash, and set on fire by plunging in a vial containing asbestus saturated with sulphuric acid. Dobereiner's lamp, in which a hydrogen jet is brought in contact with platinum sponge, and a coil of platinum wire kept red-hot by alcohol, were also sometimes employed, rather, however, as curiosities than devices of general practical use.

Lucifer-matches have now superseded all other appliances for producing an instantaneous light, throughout the civilized world at least, and have become an article of manufacture employing an enormous capital. They are made by sawing or splitting blocks of soft wood into splints, which are dipped into a composition containing either phosphorus or chlorate of potash as a basis, and dried.

Round matches are made by forcing the splints through plates having circular apertures, which at once cut out and compress them; the machinery employed cuts as many as 30,000 splints per minute. These are sold by the hogshead to those who make a special business of applying the composition, which is also effected by machinery.

MUSICAL INSTRUMENTS.

Musical instruments should not be overlooked. They have advanced within the century equally with the other subjects stated.

The organ is as old as Ctesibus of Alexandria, who lived in the Ptolemaic period. The pressure of air was obtained by a sort of water-bellows, the pipes were but very few, and the compass of course quite limited. Down through the ages we find that it had a precarious existence. Haroun-al-Raschid and the excellent Gerbert of Rheims are two of the great names associated with its possession and use. The missals of the Middle Ages show a variety of clumsy contrivances for evoking sounds from pipes by machinery, but excellence was not attained much before the time of Father Smith (referred to by Pepys), who crossed the Channel to repair the damages occasioned in the English churches by the Parliamentary soldiers. Since this time the instrument has been much enlarged, its power, compass, and capacity increased, perhaps without increasing its sweetness. The great organ of Haarlem has sixty stops and 8000 pipes; one at Seville 5300 pipes. The organ of the "Albert Hall of Arts and Sciences," London, has 111 stops, 14 couplers, 32 combinations, and about 9000 pipes. The organs of the Boston Music-Hall, Baltimore Cathedral, and Plymouth Church, Brooklyn, are among the largest in this country.

The parlor organ is an outgrowth of the accordeon, which was introduced in Europe in 1821. The first metallic-reed musical instrument was the *Eolodicon*, by Eschenberg, of Bohemia, 1810. The rocking melodeon was a large accordeon on a stand. Carhart, in this country, has done more than any one else in the improvement of this instrument. He introduced the exhaust plan in 1846. Previous to this the air had been forced through the reed slits, and is still so in Europe. His first instrument had four octaves, but they were afterward increased. Mason and Hamlin in 1855 had instruments with seven octaves, four sets of reeds, and two manuals.

The piano is the successor of a whole series of stringed instruments, dating from the harp. It is a *prostrate harp*, whose strings are beaten by hammers actuated by keys. The citole, clavicymbalum, virginal, spinet, and harpsichord occupy the period from the fourteenth to the eighteenth century. The piano-forte was really invented by Christofori, of Florence, 1711, but it was near the end of the century before it had attained excellence enough to supersede the spinet and harpsichord, the strings of which were twanged by plectra. The grand point to be attained in the piano, or as it was early called, the *hammer harpsichord*, was for the hammer to fall back immediately after striking the string, so as to allow the latter free vibration.

The improvements in this instrument are marvelous, and our country is in the front rank of ingenuity and excellence. The names of Broadwood, Collard, Erard, Steinway, Chickering, Knabe, with many others we can not find space to name, go to an admiring posterity in company.

WASHINGTON, D. C. EDWARD H. KNIGHT.

CHRISTIAN MISSIONS.

WHEN Agassiz wished to trace the progress of the glacier, he found it impossible to do so except by a method which enabled him to compare its condition in successive seasons. For this purpose he placed a row of stakes in the glacier extending in a straight line from stakes firmly fixed among the rocks on either bank. Then, by returning from year to year and comparing the relative position of his stakes, he could determine the rate and the nature of the progress which had been meantime made. It is by an analogous method that we must trace the progress which has been made in the world by and through the instrumentality of Christian missions. He who looks upon the stream can hardly persuade himself that any thing is in process of accomplishment. But he who is content to compare the state of the world where Christian missions have been at work with its condition where the Gospel is still unknown, or the present resources and activity of Christian missions with their condition a century ago, will readily perceive that the glacier is moving with a real and very vigorous progress, none the less that it is almost imperceptible to the casual and careless observer.

In this article we do not propose to enter upon a consideration of the theological aspects of Christian missions, but merely and briefly to indicate in outline what they have accomplished of visible and temporal good in ameliorating the horrors of war, promoting the arts of peace, and enfranchising and developing the mind of the individual.

The condition of the world at the advent of Christ is one which our imagination can not easily and rarely does correctly picture. A certain civilization certainly existed in Greece, Rome, Egypt, Phœnicia, Carthage. But those features of modern civilization which enure to the benefit of all mankind were absolutely unknown. Natural science had no existence, and could have none, so long as men were taught to believe that nature itself was deity. No Franklin could be guilty of the impiety of sending a kite into the heavens to catch the lightning so long as the lightning was believed to be Jove's thunder-bolts. No mariner was likely to be sufficiently audacious to conceive even a system of navigation which should carry him far out to sea so long as the sea was the exclusive domain of Neptune. The common conveniences of our modern life were unknown to heathen Rome even in the period of its greatest luxury. There was no postal system. If a Roman wished to send a letter to a friend in Corinth, he must do it by private messenger. There were private bankers, but no banking system. If one wished to transmit money, he must carry it in person at the risk of robbery, or send it by a herald at the greater risk of embezzlement. There were magnificent palaces, but no houses. It is doubtful whether under the Cæsars there was a chimney or a glass window in all Rome. If either existed, it was only in the privileged houses of the wealthy few. Nor is it to be regarded strange that inconvenience and semi-barbarism thus accompanied wealth and luxury. The intimate relations of friendships, which are directly traceable to the genial influence of Christianity, and the intricate relations of a universal trade and commerce, which are indirectly traceable to the stimulating influence of Christianity, never existed to any considerable extent in pagan lands, and without them the post-office would have been an unused convenience, and banking at once impracticable and incomprehensible. The very word *home* has no equivalent in either the Greek or the Latin languages; and where the institution was comparatively unknown, the outward comforts and conveniences which it has created for itself, as the silk-worm weaves its own cocoon, were also naturally, if not necessarily, unknown. So long as the wife was only an upper servant whom the husband might dismiss at his pleasure, as he could under both Grecian and Roman law, so long it was not strange that her kitchen was usually a portable stove in the open yard, and her boudoir an attic chamber, where she lived apart from her lord, except when he was pleased to command her presence.

How far the progress which has been made since the first century is due to general laws of development, how far to the influence of race, and how far to the direct or indirect influence of Christianity, is a question which we shall not here attempt to dis-