A POPULAR HISTORY OF AMERICAN INVENTION

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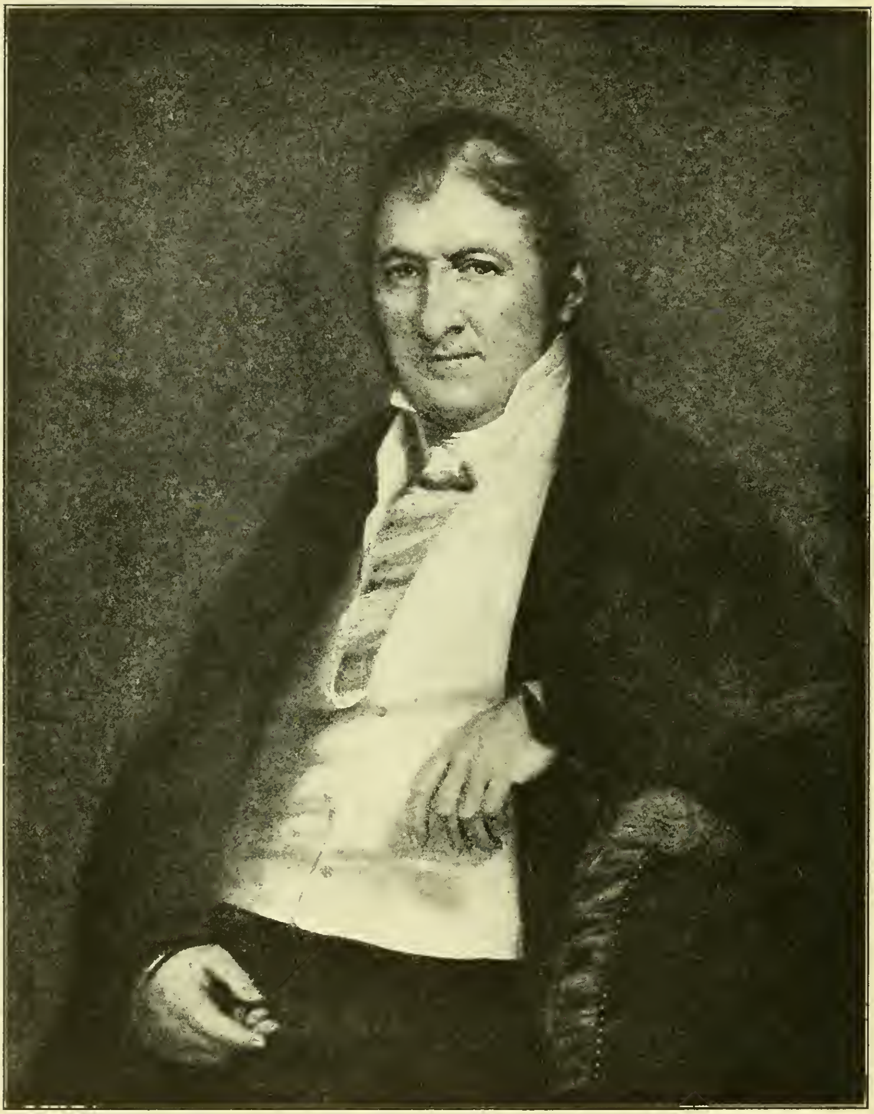

From a painting by King.

ELI WHITNEY.

Inventor of the cotton-gin and also of the modern system of interchangeable parts applied throughout the American machine industry.

A POPULAR HISTORY OF AMERICAN INVENTION

EDITED BY
WALDEMAR Bernhard KAEMPFFERT

WITH OVER FIVE HUNDRED ILLUSTRATIONS

VOLUME II

MATERIAL RESOURCES AND LABOR-SAVING
MACHINES

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CONTENTS

VOLUME II

PART IV. EXPLOITING MATERIAL RESOURCES

PART V. AUTOMATIC LABOR-SAVING DEVICES

LIST OF ILLUSTRATIONS

PART IV

EXPLOITING MATERIAL RESOURCES

CHAPTER I

THE STORY OF IRON AND STEEL

NEXT in importance to the air we breathe and the water we drink, comes iron, most indispensable of metals. Nothing can take the place of iron. Luckily, it is the most abundant and cheapest of the heavy metals, as well as the strongest and most magnetic of known substances. Iron and steel are the very foundation of the greatness of the United States of America, and the history of our country's development to commercial ascendancy is linked with the history of these two metals. More iron and steel is produced and used by the United States than by any other country of the world.

There is a story that Sir Walter Raleigh, the great English explorer, brought the news of huge iron deposits in Virginia to England about the year 1685. True or not, certain it is that rich deposits of iron ore lay in the Alleghanies, and that iron mining was begun in Virginia about the year 1608, the first, by the way, in the New World. A quantity of it was shipped to England by the Virginia Company. Virginia colonists, iron-makers to the number of 150 from Warwickshire, Staffordshire, and Sussex, in England, established a colony and tried to smelt iron near Jamestown, on Falling Creek, a tributary of the James River, in 1619. Lack of money retarded their efforts, and in 1622 they were massacred to a man by the Indians. Twenty-five years later, the Massachusetts colonists tried smelting iron and were more successful.

In fact, iron ore was discovered in every one of the thirteen colonies by the middle of the eighteenth century, and iron furnaces were blazing in all directions. America even supplied a little iron to England. In those days, the metal was smelted with charcoal, which gave to the colonies an early advantage over the mother country because of their unlimited timber. In England, many people considered iron smelting almost a curse, since the demand for charcoal was rapidly destroying her forests.

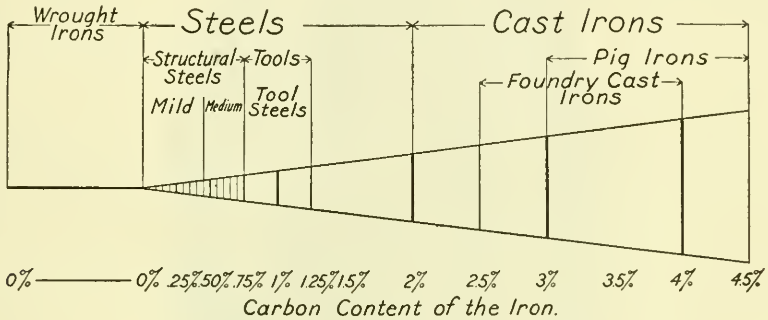
After a hundred years of iron-making in the colonies, Parliament, in 1750, passed a law forbidding them to build any mill for rolling and splitting iron, or any furnace for making steel. This confined the colonists to pig and bar iron. They could not lawfully cast anchors and kettles, or make horseshoes, hammers, crowbars, and iron parts for farming tools, wagons, ships, and the like. Articles of steel, such as knives and scissors, and implements of rolled sheet-iron must all be imported from England. This was a costly proceeding; the colonists could have made them more cheaply themselves.

Early Uses for Iron

For centuries man had used charcoal to make iron, as do savages in many parts of the world even now. But charcoal was expensive. Only two or three hundred pounds of iron could be made at a time, and the crude forges failed to melt the substance so that it might be poured to make castings.

It is supposed that man first learned to smelt iron with charcoal when he built a big fire upon red soil. The red soil contained iron, and the fire, fanned by a strong wind, burned fiercely, melting out little drops of a dark-colored metal, which were found to be extremely useful for the making of spear-heads and hatchets. The dark metal was iron, and an iron spear-point or hatchet, hammered into shape, was more useful than one of stone.

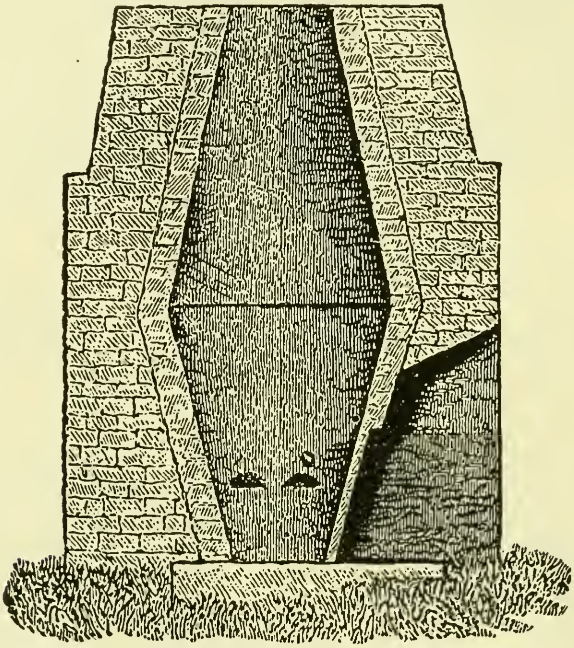
Exactly when this early discovery was made is not known. The possibly oldest piece of iron known was found under the great Egyptian pyramid of Gizeh, and is at least 6,000 years old. Most of the primitive weapons that have come down to us are made either of copper or bronze. Although it is generally thought that copper and bronze were used before iron, authorities are by no means agreed on the point. Most of them are inclined to the belief that the use of iron was discovered later. This would follow from the fact that iron is much more difficult to melt than copper, and it is reasonable to assume that man first used the more easily meltable metal. Bronze, being an alloy of copper and tin, it might be argued that its production is evidence of considerable technical ability. It must not be forgotten that copper is often found mixed with other metals, among them tin. It is probable that bronze implements found in very ancient ruins were made from some natural alloy of copper and tin. On the whole a metallurgist would be inclined to argue that copper and natural mixtures of copper and tin were used before iron. The early Egyptians, Assyrians, Chaldeans, Babylonians, and Hebrews most probably made iron, and ruins of large iron works have been found on the Sinai peninsula, in Egypt. During the heyday of Rome, the ancient Britons and Scandinavians also practiced iron-making.



THE IRON AND STEEL FAMILY-TREE.

For centuries, iron was expensive because it could be made only in small quantities. Furnaces were little more than charcoal fires heaped up on hard stone. One kind of primitive furnace is still used in remote parts, even in our own South. It is called the "Catalan" furnace, because it was used in Catalonia, Spain. The Catalan furnace, similar to a country blacksmith's forge, had a wall of stone or burnt clay in which a charcoal fire was built, more charcoal piled in gradually, and pieces of iron ore smelted. A blast of air was blown into the burning mass with the aid of a bellows, and when the furnace cooled, a few pounds of iron would be found at the bottom. The heat secured in this way was not enough actually to melt iron, but the lump of metal could be heated again and hammered out until it became of fine quality. Some few improvements were made in furnaces, but present-day engineers have calculated that if modern smelting were conducted by the methods of the Romans, iron would cost about $1,000 a ton.

The Germans, in the Middle Ages, greatly improved iron-making. They raised the walls of the Catalan furnace, which had been about three or four feet high, and made it a chimney of ten to fifteen feet. That gave greater heat, and when the chimney was built still higher, iron was easily melted. The Belgians improved it a little more, and with a large bellows, worked by a water-wheel, to blow in greater quantities of air, they made the first blast furnace. The French imitated them, and, as already told, the English were soon making such a quantity of iron in their blast furnaces that, even before the death of Elizabeth, her forests were being razed to supply char-



From Spring's "Non-Technical Chats on Iron and Steel." Courtesy of Frederick A. Stokes Company.

THE GERMAN STUCKOFEN.

The German Stuckofen was an improvement on the Catalan furnace. To obtain greater heat the walls of the Catalan, which had been three or four feet high, were raised to form a chimney ten to fifteen feet in height.

coal. In 1619 an Englishman, named Dud Dudley (1599–1684), was the first man to melt iron in a blast furnace with charred coal (coke) instead of charcoal (charred wood.) His efforts were not commercially successful, and charcoal burners destroyed his furnace. But it was the beginning of the use of coke, which fuel is now indispensable in the making of steel and iron. Dud Dudley was the earliest of many British inventors who discovered better ways of making iron and steel, and his idea was made more practical by Abraham Darby, another Englishman, about 1713, nearly a century later.

Henry Cort Invents the "Puddling" Furnace

Then came Henry Cort (1740–1800), who devised the "puddling" furnace and the rolling-mill. Cort built the first reverberatory furnace in 1784. This differed from the blast furnace. In the latter, charcoal and iron were mixed together. Cort's furnace had two compartments; one contained the coal to be burned, the other the iron to be melted. Coal and iron should not be burned together, for coal contains sulphur, which makes iron and steel brittle. Cort saw to it that the coal and iron were not in contact. A long flame passed from the coal burning on a grate, over a fire-wall, and melted the pig iron which was piled on a furnace bed or hearth. Upon stirring the melted mass it soon became stiff and pasty from loss of carbon, and was then taken out and hammered. This method of melting iron, known as "puddling," is still in use.

Cort's iron, made in this way, was cheap for those times, but after giving the world a better and speedier process for making wrought iron, he became impatient with the old slow method of hammering his iron into bars. The new process could supply iron much faster than it could be worked into bars, rods, and other shapes, ready for the blacksmith. Cort went a step further and made the first iron rollers through which red-hot bars or balls of iron could be passed. For this he used two iron rolls, one underneath the other, in which were cut a series of grooves of different sizes. The rolls turned in opposite directions, like the rollers of a clothes-wringer. When a piece of red-hot iron was inserted in the largest groove, it was drawn in, squeezed down to the exact size of the groove, and thus shaped into a bar. Put through the next smaller groove, and so on, it was ultimately reduced to the thickness and width desired. Of course, as it was passed through the rolls, it grew longer and thinner. Rolling improved the quality of iron in about the same way that hammering improved the crude iron melted in the Catalan furnace. Cort did not originate the idea of a rolling-mill, but he was the first to build one successfully.

It was an extremely important invention, much the more important of the new methods Cort gave the iron industry, and rolling-mills of the same kind, though greatly improved, are now used the world over. Iron made by Cort's process was so good that the English navy soon required it in place of imported Swedish and Russian iron. Given large contracts, Cort and his partner decided to enlarge their ironworks. To do this, they borrowed money from a former government official, assigning Cort's patent rights as security for the money advanced. It was found later that the official who loaned them the money had embezzled it from funds entrusted to him by the government for the payment of sailors' wages. The direct result of this was a cruel blow to Cort. Although his patents were earning enough to repay every cent that had been stolen, the government refused to listen to his pleas to allow him to make good the loss. Both the ironworks and his patent rights were seized without an effort to collect the royalties due him from those who were using his processes. As Cort had spent a great amount of money in experimental work, he and his family of twelve children were soon destitute. The government later granted him a small pension, but he died soon afterward, broken in health and spirit, in comparative poverty. In 1811, forty-one British iron-making firms raised a sum of money for his widow and children.

Thanks to Dudley and Cort, iron, once made by the pound, could now be made by the ton. During the next century inventors were to produce iron cheaply and in such quantity that it could be used by millions of tons. It was also to be as cheaply turned into steel, and iron and steel industries began to spring up in places that once had been wildernesses. To understand what these different inventors did, a little knowledge of the chemistry of iron and steel will be helpful.

Chemistry Aids Steel-Making

Early iron-makers found that charcoal had a mysterious property that enabled it miraculously to change red stone or iron ore into iron. But they knew nothing about chemistry, and not until chemistry became a science was it possible to make iron and steel in almost unlimited quantities, and build with it railroads, bridges, skyscrapers, and all the machinery of modern life.

Iron is a metal, a chemical element, not quite so soft as copper, but when pure rather easily worked. It is the basis of all the irons and steels; for while we ordinarily speak merely of "iron" or "steel" there are, in reality, many irons and steels, just as there are many woods.

Now, there are two other chemical elements that iron particularly likes. One is oxygen, a gas contained in the air we breathe; the other is carbon, which we know best as charcoal, coal, coke, and the graphite in pencils. Iron and oxygen seize every opportunity to get at each other, for the liking is mutual. Unless the iron is constantly protected, the result is an iron-oxygen marriage, known as iron oxide, or rust. This union occurs under our very eyes, for all about us we see iron and steel rusting, and rusting particularly fast if the air is moist.

But, whatever has been done can usually be undone by some means or other. Iron and oxygen, after they are married, may be divorced. The divorce is effected by heat with the aid of the element carbon. It appears that carbon likes oxygen even better than iron does, so that when the iron-oxide combination (rust or iron ore) is mixed with carbon, and the mass heated, the carbon steals away the oxygen from the iron, and iron alone is left. It is this form of iron, somewhat modified, that we use in building machines and tall buildings and bridges. So that, when we make iron out of iron ore, we merely take vast quantities of rust from the earth and remove the oxygen. The process carried out is the second of iron's two stages:

1. Iron rusts in oxygen to iron oxide, a red, yellow, or black powder. Iron ore is iron oxide, a form of rust.
2. Iron oxide or ore heated with charcoal or coke (carbon)

gives up its oxygen and sets the iron in the ore free again.

It is, then, by the latter process that we get all our iron in the first place, for iron, as such, is not found free in nature, but in a state of rust. Man has had to "free" all the iron which we now have. The iron-ore rust comes from our mines, mostly by lake boats to Chicago, Gary, or Lake Erie ports, and from some of the latter to Pittsburgh, Youngstown, and so forth. It is put into big blast furnaces with coke, which burns and takes away the oxygen, whereupon the freed molten iron trickles to the bottom of the furnace and is drawn off—"tapped" as the iron-makers call it.

The other half of the chemical story is just as simple. Iron also likes carbon. But unless it is heated red hot, or hotter, or is in a molten condition, it has no appetite at all for the carbon. Iron is a comparatively slow "feeder," but when molten it devours carbon with the voracity of a dragon.

Both "cast iron" and "pig iron" are iron which has wolfed a full meal of carbon, or the maximum. This is about four per cent.—four pounds of carbon per hundred pounds of iron. Because of this carbon, cast iron and pig iron, after having cooled, melt more easily when heated again than does iron with less carbon, or iron with no carbon at all. So fluid do they become when molten that they will run into moulds like water. Such forms of iron are very brittle when cold, however. It is easy to break cast iron with a hammer.

Iron which has absorbed less than two per cent. of its own weight of carbon, when molten, does not "cast" into moulds so well, because it is less fluid. On the other hand, it does not become quite so brittle when cold; indeed, if it contains only a little carbon, the metal is very pliable. For this reason, it is the kind which is made into wire or other products which must bend easily if desired. Such low-carbon, pliable irons are called "mild" steels. The high-carbon irons, *i. e.*, those with from three-quarters to one and one-half per cent of carbon, are the harder steels from which most of our tools are made. Those with over two per cent. of carbon are not called steels, being altogether too brittle either to bend or forge. For the most part, iron without any carbon at all is called "wrought iron," which we will describe later.

The sketch of the iron and steel family tree on page 5 shows very plainly the various combinations of iron and carbon.

The difference between pig iron and cast iron is this: Pig iron is the iron-carbon alloy, a combination, as it first comes from the blast or smelting furnace. Up to a few years ago the molten metal was run into long, narrow troughs of sand, which covered the floor of the furnace house. Here it was allowed to solidify and cool. The blocks of iron, called "pigs," were then broken from the longer blocks, called "sows." To save heat, much of the molten iron as it comes from the furnace is now taken directly to the steel works as "hot metal" and used without being allowed to solidify. It does not get solid until after it has been converted, or made, into steel by the removal of most of its carbon.

Cast iron, on the other hand, is usually only a remelt of pigs of iron, in a particular kind of furnace. While a few castings are made from iron taken directly from the blast furnace, practically all of our cast-iron articles are made from re-melted and blended iron, which, because of the re-melting, has a little less carbon, and is therefore a stronger, more uniform and refined metal.

This process of absorbing or taking up carbon can be reversed, so that the carbon, which was taken up by the iron in its change into pig iron, can also be taken away from it. As we have seen, carbon and oxygen have a great liking for each other; therefore oxygen can be made to take away the carbon which the iron has absorbed. We now have two more very important facts:

3. Iron heated to a red or white heat in powdered charcoal (carbon) for a considerable time, or melted iron plus carbon, gives what is called "mild" steel, harder steel, or cast iron, depending on how much carbon is taken up by the iron.
4. This iron-carbon combination can be broken up by heating with oxygen to steal the carbon away from the iron.

We now know more about the chemistry of iron, and about the reasons why there are different irons and steels, than was known up to the year 1855. In that year, Henry Bessemer made a great discovery, of which we shall have much to say later. Although the alchemists of the Middle Ages had searched for the "Philosopher's Stone" that would, so they thought, turn everything it touched into gold, real progress was not made in chemistry. Consequently the making of iron and steel was a crude performance until the few simple facts which have been explained became known. While the world at that time was several thousand years along in its knowledge of iron, in reality it had not yet begun to understand its most useful metal.

For many centuries men made small balls of soft iron in the Catalan kind of furnace. Only the chemical reaction No. 2 was possible, for their fires were never very big or hot, and their iron was fed little charcoal. All they got were little balls of soft iron without carbon. In time they progressed to reheating their swords, hammered from such iron, in powdered charcoal. In some places they seem to have made little pots of clay into which they put small pieces of iron, together with a few leaves or pieces of wood—carbon. In this manner, they made a steel which could be hardened, like our modern tool steels, by heating it red hot and plunging it in water to cool it suddenly. This gave them their keen, hard-edge swords and other implements of war.

In time, another and strange iron product arrived. Some unknown genius had used a large furnace, something like the one shown on page 6. In this, with more intimate mixing of charcoal and ore, and higher heat, the iron absorbed a great deal more carbon; instead of being the usual stiff, pasty mass while hot, it melted and became so liquid that it could run like water. The iron thus made could be melted at a much lower temperature than any other sort of iron then known, and was first made about the middle of the fifteenth century. It had always been free-running when molten, but so brittle when cold that it could not be hammered into swords. It was that important product, "pig iron." In 1918, the United States alone made about 40,000,000 tons of pig iron; probably more, in that one year, than the whole world had produced in all of the hundreds of thousands of years before 1800.

Since pig iron was a material readily produced in the larger furnaces, and since it could be melted easily for reworking, it came to be used as a sort of raw material or starting point from which all the other iron products were made.

Wrought iron was discovered by melting such pig iron in a charcoal fire, stirring and blowing air over it. Shortly after melting, the mass would become pasty and less fluid, even when white-hot. It was taken out as a white-hot pasty ball and hammered into bars. This was good wrought iron, similar to the celebrated Swedish or Norway iron of to-day, but it could be made only in small quantities, until Henry Cort invented the "puddling" process.

How Crucible Steel Is Made

Even as late as the year 1800, the world probably knew only the hard steels of which swords and tools were made. Up to the eighteenth century, the finest steel used in England came from India, at an estimated cost of $50,000 a ton! Such steel is still made in India, in native furnaces. About one pound of metal is placed in a small clay crucible with finely chopped wood. The crucible is covered with leaves and damp clay, dried in the sun, and heated in a small furnace. The melted steel is found in the bottom of the clay pot. In Europe, steel was produced slowly and tediously by packing pieces of carbonless iron, that is, wrought iron, with powdered charcoal in stone boxes, and keeping the boxes red hot in furnaces for upward of six weeks. When the bars were cold they were broken and sorted according to the hardness of the pieces, the hardness varying with the amount of carbon that had penetrated. This irregular steel, for such it was, was reheated, forged and hammered into swords, knives, etc., or made more uniform by melting it in a crucible. Such steel is called "crucible" steel, because it is melted in clay or graphite pots, called crucibles.

Before crucible steel came to be generally known, manufacturers guarded their methods with the utmost secrecy. One, a successful steel-maker named Benjamin Huntsman (1704–1776), of Sheffield, England, permitted nobody to enter his forge which, about 1740, he had erected in a forest. Huntsman, a skilful clockmaker, found the steel used in watch-springs of such poor quality that he experimented in the hope of finding a better steel. Succeeding, he kept his method to himself. His competitors tried in every way to imitate his steel, and eventually they employed the services of a spy. During a severe storm the spy pretended he was lost in the forest and begged the shelter of Huntsman's workshop. Moved by his wretched plight, the inventor unlocked his door and asked him in. Entering, the spy beheld a very simple apparatus: merely the melting of broken pieces of carbonized iron in a pot or crucible, a process which made steel more uniform. The secret was out! Since then most of our finest tool steels have been, and still are, produced in crucibles.

PULLING A POT IN A CRUCIBLE STEEL PLANT.

The crucible is a small pot formerly made of clay but now usually of graphite. This pot is filled with small pieces of steel and put in a furnace where it is entirely surrounded by coke or coal.

The Crimean War of 1854–1856 made English army generals wish they had larger and better cannon. A young man named Henry Bessemer (1813–1898), determined to make them. He had invented a process for stamping deeds, records, and other important documents, and this the English Government found so good that it appropriated it for its own use without paying him a farthing, even though he protested.

Bessemer, the son of an inventor and owner of a type-foundry, had a considerable knowledge of metals. Through this knowledge he was able to invent an improved and marketable method of making bronze powder for gold paint. He kept the details of his discovery secret, and faring better than he had with his stamping invention, his bronze powder factory soon brought him in a steady profit.

Bessemer then set about studying the science of cannon and projectiles. He first devised a projectile which was not round, like the usual cannon-ball of his time, but long and pointed. He also caused it to spin as it left the gun. Instead of rifling the barrel of the cannon, as we now do, Bessemer put a rifling on the projectile. In either case, rifling makes the projectile spin so that it flies through the air without tumbling over and over, as does a stone. But he soon found that little real progress could be made unless he could get a stronger metal for the gun-barrel, because heavier projectiles required much heavier and stronger guns to discharge them. It was first necessary to discover a method of producing iron in larger quantities.

Bessemer was a hard worker who never asked favors. Nevertheless, he was not bashful whenever opportunity came for making himself known, and the acquaintanceship his clever inventions had enabled him to make he later turned to good account. Among others, Napoleon III was impressed by the young man. He introduced Bessemer to his army officers in charge of the manufacture of artillery, and directed that they assist and encourage him whenever possible. The young inventor soon produced a better cast iron; but while this helped, the metal problem was still unsolved. Bessemer was not easily discouraged, however, and using the money which came from his bronze powder business, he devised, then experimented with a "hotter" furnace for the making of wrought iron. By blowing extra air into the flame he obtained more heat.

Bessemer's Great Discovery

One day, in the year 1856, he noticed that a pig of iron lying on the edge of the molten pool of metal in the furnace—the "bath" as it is called—did not melt as expected. He tried to push it in with a bar, but found that it was a mere shell of decarbonized iron; that is, iron with its carbon burned out, the inside metal having melted and drained away. Most people would pay slight attention to such a curious happening. Not so with Bessemer. It was a mystery he must solve.

"Why does the inner metal of the pig melt more easily than the outer?" he reasoned. "How can this be? I know that pig iron melts easily, while the wrought iron with little or no carbon does not. But this was not wrought iron. It was pig iron, and must have contained high carbon when I started. Yes, the inner portion melted as it should. If that happened because of lack of carbon in the outer part of the pig, when and where was the carbon in it lost? I must look into this!"

The more Bessemer thought about it, the more convinced he became that the outer part did not melt because it contained less carbon, and that the air and flame in his furnace must have burned some or all of the carbon from the outside of the pig. If carbon could be removed in that way it was surely possible that it could be done on a larger scale, and wrought iron made in vast quantities by blowing air into melted pig iron.

Bessemer could scarcely rest until he had fixed a crucible in a fire and tried blowing air into the bottom of the molten pig iron through a pipe made of clay. To his delight the iron was not made colder, and the carbon seemed to burn. The iron with which he had started to experiment could not be forged because it was too brittle. But now he found he had a material that was malleable! It could be easily shaped by hammering!

The iron in the crucible did not "freeze" when he blew air into it. This was fine. Now for the next step. Could it be possible that no outside heat at all was necessary, that is no fire around the crucible while he was blowing air into the inside metal? Bessemer hastened to find out.

He built a big steel pot, lined it with firebricks and clay, and left six openings near the bottom through which air could be blown up and into the molten metal. At last all was ready, and he started the air-blowing engine. The air bubbled very fast through the metal, a few sparks flew out from the top of the vessel. A little later a flame appeared. Bessemer was almost prostrated with joy! All that was needed to make iron into molten steel was a steady application of oxygen, the cheapest fuel in the world! Infinite quantities of it for nothing!

Suddenly, the molten metal began to dance and jump about as though alive, and drop after drop spurted out and fell with a splash upon the roof. This was exceedingly dangerous, for molten steel is white-hot. Bessemer feared that he would set fire to his own and the neighboring buildings. Fortunately he did not stop his air-blowing engine. Soon the dangerous

BESSEMER CONVERTER BLOWING OFF.

Bessemer steel is made by blowing air through molten unmalleable cast iron in a pear-shaped "converter." First comes a brilliant shower of sparks, which finally subsides. When the metal is drawn off it is steel.

splashing was over, and the forced air bubbled quietly through the molten metal in the crucible. Upon removing the clay plug from the tap hole in the bottom, out flowed steel! It was a metal which, when cold, could be flattened under the hammer without cracking. Bessemer, in happy excitement, hacked with an axe the corner of a square block of it. Without doubt, it was a soft, malleable metal.

Here was an epoch-making discovery. Not only had he found a process by which he could make a malleable metal from unmalleable molten cast iron, but he could do it without the use of any further fuel whatsoever; something never dreamed of before. The metal contained its own fuel: twenty-five pounds of silicon, fifteen pounds of manganese, and seventy pounds of carbon, a total of over one hundred pounds of fuel in every ton. These substances burned as fiercely as the wood and coal in our stoves, and being so intimately mixed, when air was blown upon or through the molten metal, their burning made the metal extremely hot. The steel, when finished, was at least 600 or 800 degrees Fahrenheit higher in temperature than the molten cast iron with which he started.

Satisfying himself by repeated trials that his results were similar, he called in an engineer acquaintance, George Rennie, in order to get his opinion on the matter. Bessemer had now become so enthusiastic about it and saw in it such great possibilities that he was afraid he might have made some miscalculation. A discovery of this momentous nature would, he realised, revolutionize the whole iron and steel industry.

After listening to his explanation and witnessing the making of steel in Bessemer's furnace, Rennie exclaimed: "This is such an important discovery that you ought not to keep the secret another day. I am president of the Mechanical Section of the British Association, which meets next week. Why not present a paper describing your process at that meeting?"

Bessemer had never written a paper for an engineering society, and he suggested that his report might not be worth a hearing. Rennie replied: "Do not fear that. If you will only put on your paper just as clear and simple an account of your process as you have given to me, you will have nothing to fear. Though all the papers are now arranged for, your process is so important that I will take upon myself the responsibility of putting yours first on the list."

With considerable misgiving, Bessemer wrote a simple account of his process, and in a few days he left London for Cheltenham, where the meeting was to be held. On the following morning, while finishing his breakfast at the hotel, he was talking to Mr. Clay, a Liverpool iron manufacturer, when a well-known Welsh iron-maker, Mr. Budd, came up and sat down opposite. Knowing Clay, but not Bessemer, Budd said:

"Clay, I want you to come with me into one of the sections this morning, for we shall have some fun. You *must* come, Clay! Do you know, there is actually a fellow come down from London to read a paper on the manufacture of malleable iron without fuel? Ha, ha, ha!"

"Oh," said Mr. Clay, "that is just where this gentleman and I are going."

"Come along, then," said Mr. Budd.

The three arose from the table and went to the meeting. Imagine Mr. Budd's feelings when Bessemer appeared on the platform, to be greeted by the president and introduced as the inventor of the new and very important process of iron-making. Bessemer then read his paper and showed samples of his steel.

Those present listened attentively. The very first person to rise after the reading of the paper was James Nasmyth, the famous inventor of the steam-hammer, that marvellous machine which is so delicately adjusted that at the will of the operator the blow can be terrific or so light that the hammer will actually touch the crystal of a watch lying on the anvil without breaking it. Nasmyth held up in his fingers a small piece of the metal which Bessemer had exhibited, and said: "Gentlemen, this is a true British nugget. A while ago I took out a patent for making malleable metal in a manner somewhat like this, but Mr. Bessemer's method goes so far beyond mine that I shall go home from this meeting and tear up my patent."

Budd was the next to rise. He said he had listened with deep interest to the important details of the invention, and if Mr. Bessemer desired an opportunity of commercially testing it, he would be most happy to afford him every possible facility. His ironworks were entirely at Mr. Bessemer's disposal, and if he wished to avail himself of the offer it should not cost him a penny.

A number of firms wished to use the new process, and to many of them Bessemer sold rights for which he received a great deal of money. It had taken hard work and much experimenting merely to discover the process, and he realised that much more work and experimentation would be necessary before the manufacture of his steel reached the stage of commercial perfection. Like the majority of inventors, Bessemer was threatened with failure. Disappointment and trouble soon made their appearance. The firms that had begun making steel under his patents did not succeed at all. The metal they produced was brittle! This amazing contradiction caused such dissatisfaction, and such was the amount of criticism and ridicule hurled at his head for his apparent failure to make good his promises, that Bessemer actually bought back all the rights he had sold.

Lucky it was for England that the young inventor, whom she was later to honor with a knighthood, did not lose heart. Bessemer knew he was right; he had made and always could make a wonderful steel. Something was amiss with either the methods or the materials used by the manufacturers, and whatever it was could be remedied. He was satisfied with his process.

He employed chemists to make a careful analysis of all the materials used before and after they had been subjected to his process. Week after week ran by without any report or analysis helping him to discover the error, but instead of being disheartened, Bessemer kept up his investigations, convinced that his process was perfectly correct.

Finally, after about two years of hard work, costly experimenting, and repeated disappointment, he found out that cast iron which had only a small amount of phosphorus—and this happened to be the kind he had used in his London experiments—made good steel, while iron which contained more than this small amount did not make satisfactory steel. Now he knew what was wrong. His licensees had used high phosphorus iron—and failed.

Supplying this valuable information, he offered his licenses to the manufacturers. But no one would buy. Once bitten, twice shy, was their attitude. Bessemer had to build a plant of his own and go into the steel-making business simply to prove that he was right. A considerable time passed before the iron-makers would try again, but eventually the process came to be used extensively, not only in England, but also in this country. Here was the very steel for the heavier guns for England's army and navy, and it furnished the material for plates for her ships, and tools for her machines.

Bessemer was richly rewarded. The royalties he received from licensees were so large that at the expiration of his patent, in 1890, he and his partners had received a total of £1,000,000 sterling (about $5,000,000), a return in fourteen years of eighty-one times their invested capital, or practically their entire money back every two months.

Bessemer was the father of the steel age. Without him there might be no transcontinental railroads, no skyscrapers, no great bridges, ocean liners, or Panama Canals. In the development of the industrial world as we know it to-day, he stands next to Watt, the inventor of the steam-engine.

It is not commonly known, but right here in America this same process was worked out independently by an iron-maker named William Kelly. In his plant near Eddyville, Kentucky, about 1846, he invented a process for making large sugar-boiling kettles for the Southern planters, and in seeking to make better and cheaper wrought iron for his kettles, he discovered the same process as Bessemer—that a steady blast of air alone would refine iron and convert it into steel. Iron-makers laughed at the idea, Kelly's father-in-law threatened to withdraw money from his ironworks, and his customers, hearing that he had a "new-fangled way of refining iron," insisted that they wanted iron in the regular way or not at all. Then the ore supplies near his ironworks gave out. Despite these difficulties, he worked on his process in secret, built a converter in 1851 at the Cambria Iron Works, in Johnstown, Pennsylvania, and hearing of Bessemer's process, patented his converter in 1857. Some authorities give Kelly credit for being the first inventor in this field.

Meanwhile Alexander Lyman Holley, an American engineer, had obtained a license to make steel in this country under Bessemer's patents. Kelly, practically ruined in the panic of 1857, had sold his patent to his father for a thousand dollars. His father died, willing the patent rights to his daughters, and they in turn transferred them to Kelly's children. For while their brother was clever at inventions, they had a poor opinion of his business ability. This brought him to a standstill, so he accepted an offer to merge his interests with those of Holley.

Alexander Holley and the American Steel Industry

Holley became an important figure in American steel-making. Being a man of intelligence and great personal magnetism, he quickly won the confidence of inventors and steel-makers. Taking discoveries like those of Bessemer and Kelly, he applied them on a large scale, and persuaded others to adopt them. With him began what has been called the "American plan of steel-making," which is to make steel on an enormous scale. Less than twenty-five years after Bessemer's invention, the converter, backed by Holley's ability, enthusiasm, and his belief that America must be first, had enabled the United States to rival England in steel production. For fifteen years, Holley was the leading steel plant engineer in this country, designing nearly all of the big works then building in the United States.

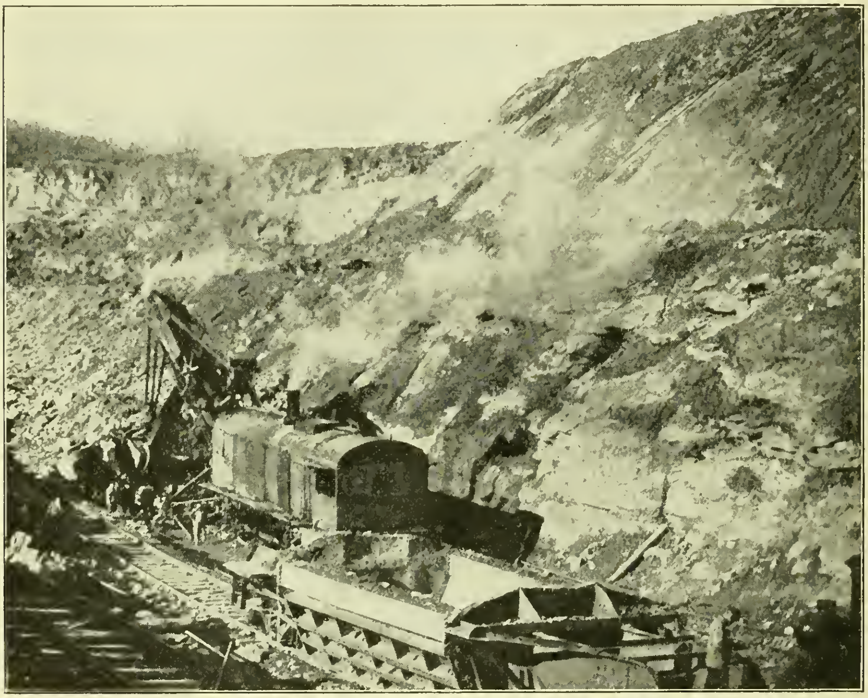
And now began what may be termed a great industrial procession. Up to this time there were only a few short railroad lines in this country. Following the great gold rush to California, in 1849, and the building up of the West, during the next thirty years the transcontinental railway lines were built which opened the entire western territory to immigration and trade. The earlier short railroad lines were largely absorbed and used as feeders to bring freight to the "through" lines. With the rapid settling and growth of population of the Western States, the demand for iron, steel, and other goods increased by leaps and bounds.

The first railroads did not have the sort of rails we have to-day. As told in the chapter, "From Stephenson to the Twentieth Century Limited," the early rails were only strips of wood. These were soon followed by strips of wrought iron, and then wrought-iron rails. But while wrought iron was good enough for the first engines, which were small and of light weight, they were too soft for service under the heavier engines and the denser railroad traffic which developed. It almost seems as if the Bessemer process of steel-making had been devised at the right moment to furnish a proper material for rails, so that this wonderful railroad expansion might not be hindered. Wrought iron would not do. Steel was highly satisfactory. Bessemer steel could be readily made in large quantities and of any hardness desired. The old wrought-iron rails were torn up, and in their place were laid rails of Bessemer steel.

Where did the iron ore come from? The States of New York and Pennsylvania had considerable iron ore, and this was first smelted with charcoal and, later, with anthracite coal, which was mined locally. There were also iron ore deposits in Virginia, Tennessee, and Alabama. But the greatest source of iron ore was discovered on September 19, 1844, by William A. Burt, United States deputy surveyor, who was working with his men near what is now Negaunee, Michigan. They found that the needle of a compass was behaving curiously. Burt, the inventor of the instrument, became worried. He knew that his compass was not at fault, so he cast about to find out the cause of the disturbance. One of his party discovered a deposit of iron ore just underneath the sod. That explained everything. Burt apparently was concerned only in devising a means of preventing a like interruption in the future. He paid no attention to the ore except to note in his book that it had been found there. Neither he nor any of his party ever profited, or attempted to profit, by their discovery.

The Mesaba Iron Ores and Their Exploitation

A few years before the Civil War there were rumors of gold in this northern wilderness, and among others who sought it was a woodsman, Lewis H. Merritt, who moved from New York State to Duluth, Minnesota, with a wife and four sons. It was only "fool's gold," glittering iron pyrites, but Merritt found some red iron ore. A few years later, when his boys had become lumbermen, they remembered the iron and explored the wilderness to locate it. Three nephews of the same name joined them, and they became known as the "seven Merritt brothers," and also as fools, if not tricksters. For they insisted that there was boundless wealth in iron on the Mesaba range, first discovered by Surveyor Burt, and they wanted to raise capital to build a railroad and bring it out. "Absurd!" said wise folks, and warned their neighbors against buying the Merritts' railroad shares. When they located their first iron mine, in 1885, and got money to start their railroad by pinching and borrowing, the people of Duluth would not permit them to use their city as a terminal. But they made connections with a railroad entering Duluth, and hauled their first train load of ore in 1892. Just as they had prospects of a rich reward for their long years of work and faith, they were ruined by the panic of 1893, and their railroad and mines passed into other hands.



HOW ORE IS MINED BY STEAM-SHOVELS IN THE MESABA DISTRICT OF LAKE SUPERIOR.

This district has turned out to be the greatest ore producer in the world. At first a little iron was smelted near by, but it was soon found advisable to carry the ore to the coke and the market, which was in the East. The first shipments were carried from the mine by mule. Later a plank railroad was built, with rails of strap iron, and grades so steep that the loaded cars sometimes ran over and killed the mules which drew them. Marquette, Michigan, was the shipping port, from there the ore coming around by water through the Sault Sainte Marie Canal. When Congress was debating the question of building the Sault Sainte Marie Canal, Henry Clay spoke against it, saying that spending money in that distant, uncertain place was like investing in the moon. As against the $1,000,000 yearly value of the fisheries given as a chief reason for the building of the canal, over $100,000,000 worth of ore now passes through the canal each year. Other commodities have long been of secondary importance.

The hard or lump ores of northern Michigan and the soft or "Mesabi" ores of Minnesota are now shipped from the Lake Superior ports in specially built ore-carrying steamers. So rapidly did this enormous trade develop that, over a number of years, the tonnage of these boats was continually found to be inadequate. Ore-carrying steamers had to be either scrapped or sold, and new and larger ones built with greater carrying capacity. The locks of the Sault Sainte Marie Canal had to be built and rebuilt four different times, to pass larger and larger ore steamers.

To get into the iron-ore mines in northern Michigan the miners go down an elevator into a deep shaft. Here the ore is found in hard form, like rock. The miners drill holes into it, fill the holes with dynamite, and then scurry away so that flying particles of the ore, broken down by the explosion, shall not hit them. In Minnesota, where even larger deposits of iron ore exist, big steam-shovels are at work, shovelling off the shallow top soil to get at the ore; others are on terraces, shovelling the soft, red dirt (ore) into railroad cars. The filling of freight-cars by these remarkably efficient steam-shovels requires very little time.

Soon the train load of ore is hurrying to Two Harbors, Minnesota, or other ports. Here the bottoms of the "hopper" cars are dropped and the ore falls through the elevated tracks of a high trestle into large hoppers or ore bins underneath, which are themselves built high up above the surface of the lake.

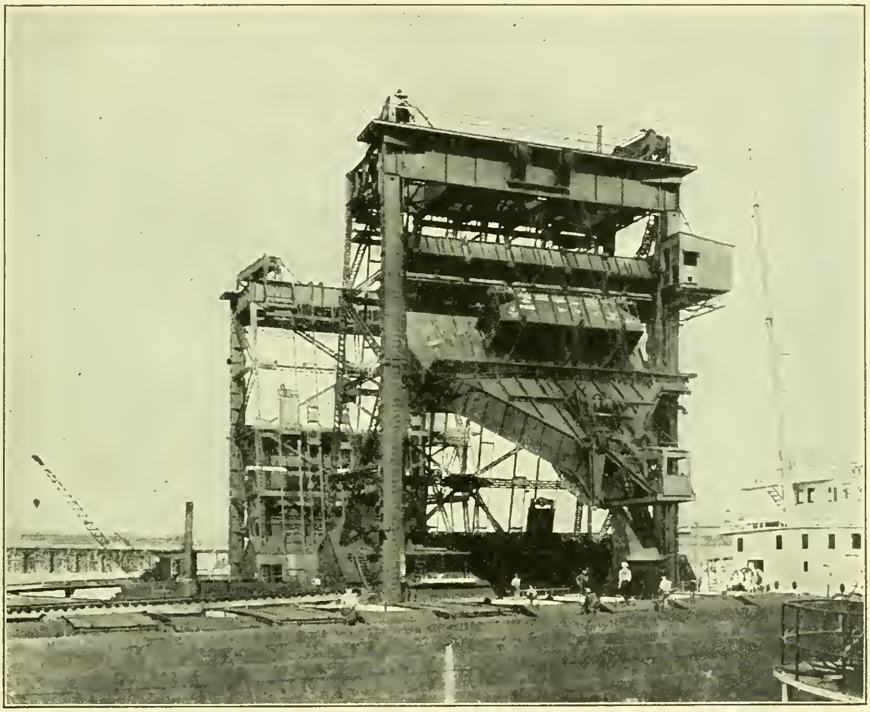
The hopper car is an American railroad device, developed for quickly dumping coal, gravel, and other bulky stuff by opening trap-doors in its bottom. At first it was made of wood, but about 1897 improved hopper cars were made of steel and used for hauling ore from the mine to the ship, and from the ship to the steel mill. A later American invention, that of George H. Hulett, first built at Ashtabula, Ohio, in 1893, was the car-dumper, a device which picks up a whole car of ore or coal, tilts it, and dumps thirty, fifty, and sometimes a hundred or more tons as easily as though it were a pound box of candy.

Mammoth ore-carrying boats anchor alongside the huge ore bins, the hinged metal chutes lower, and the ore slides from the bin through them down into the boats. Loading requires but fifteen or twenty minutes. The top of an ore boat is built almost flat, with steel hatch covers, which are quickly slid into place, thus covering the ore inside. The boat now sinks low in the water because of its heavy load. It pulls away from the dock and steams down the lakes, bound for the port at which it is to deliver its cargo. During the shipping season it often occurs that the ore boats follow one another so closely that no boat of the string, from Two Harbors, Minnesota, to Buffalo, is out of sight of another.

Our ore boats contribute to the maintenance of American supremacy in steel. English steel manufacturers bring iron ore from Spanish mines by an ocean route of 750 miles, and about 20 miles at each end from mine to ship and ship to smelter. Fortunately for them, this Spanish route is in a mild climate, and can be travelled all year round. On our Great Lakes route, ore is hauled eighty miles from mine to ship, then 1,000 miles by water, and often 150 miles more to the smelter. And the Great Lakes are frozen over four months each year. But British ore ships make only ten or twelve trips a year between Spain and England, while our Great Lakes ore-carriers make just twice as many. The value of time is shown in the story of one ore boat which still had a thousand tons of ore in her hold when a holiday interrupted the unloading. Instead of waiting over the holiday, she steamed back for another cargo, carrying that thousand tons which had not been unloaded.

Unloading the Ore

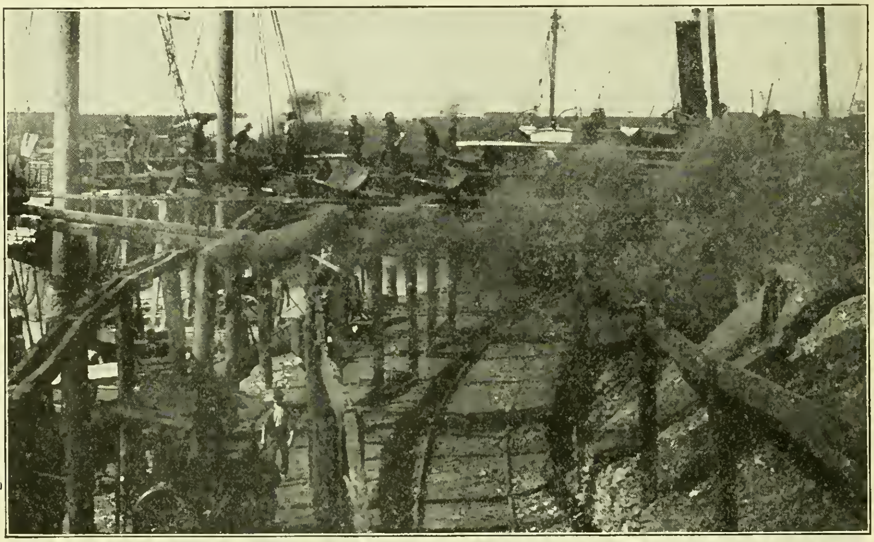
Unloading the ore is a harder job than loading. The ore simply falls into the boat when it is loaded; but it cannot fall out, it must be lifted. No sooner does the American boat touch the unloading dock than huge machines roll down to it, and the mammoth steel arm of each, with its huge bucket, swings around and down into the hold of the boat, the covers of which have been removed. The bucket opens on the way down, dropping into the ore with a thud, and there burying it-



DUMPING A WHOLE CAR-LOAD OF ORE OR COAL.

The car is pushed upon the machine by a "ground-hog" which operates in the centre of the track. When the car is empty and lowered to car level again, it is run off on the other side, whereupon the machine is ready for another car. Car-dumpers of this type were invented by George H. Hulett in 1893.

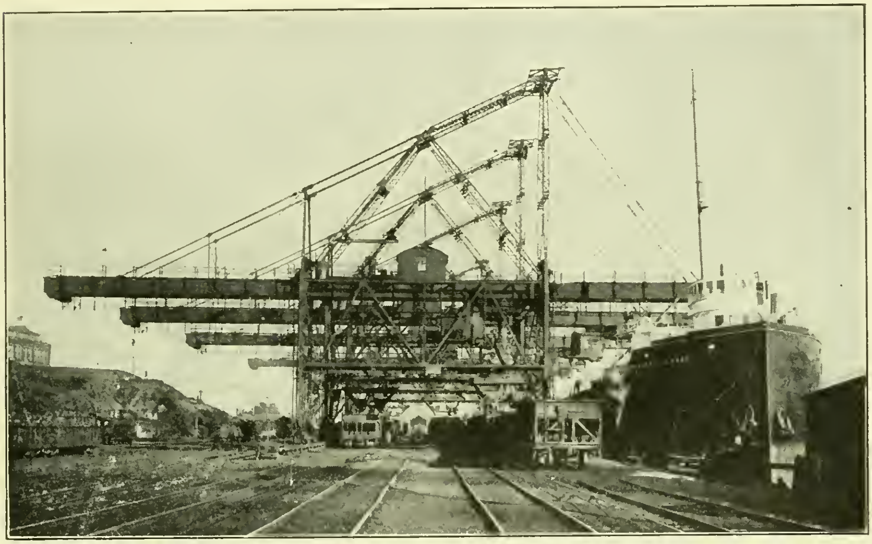
self. As it starts upward, its jaws close. Rising, it swings away from the boat, carrying not less than five tons of ore. It is as though a huge giant dipped his hand into a pile of dirt, closed his steel fingers, lifted his arm, and deposited the material in whichever place he desired. All along the wharf these machines work in the same way. The ore which was put into the boat so quickly by means of the ore chutes, now goes out almost as quickly, as these steel grab buckets continue their work. Not so many years ago, such unloading required days. Now an ore boat may be unloaded in about four hours.



BEFORE THE MECHANICAL ORE UNLOADER WAS INVENTED.

How ore was unloaded from boats before Alexander E. Brown invented his hoisting apparatus. The ore was loaded by hand into wheelbarrows, which were then hoisted to the ship's deck by horse or steam windlasses and then wheeled on gang-planks to the docks.

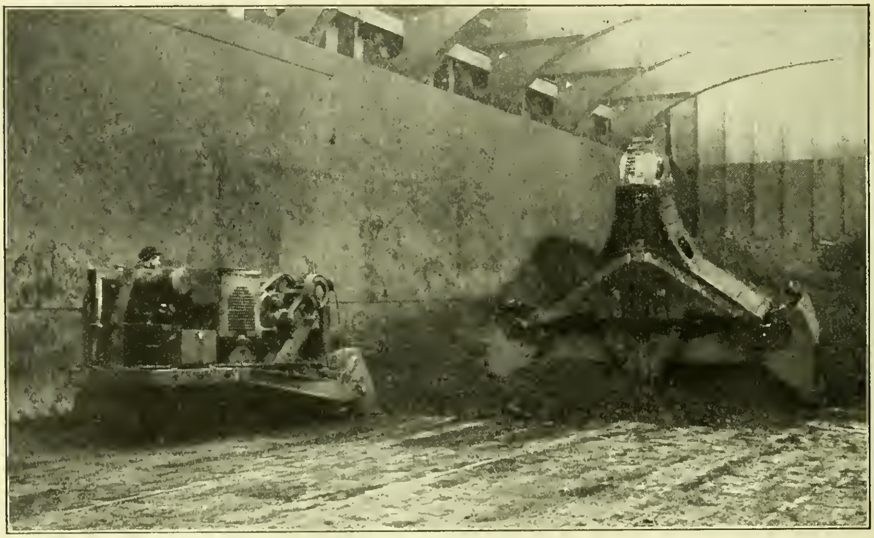
The first iron ore shipped from the Lake Superior ranges was in barrels. It had to be unloaded and hauled around rapids in wagons. In 1855, the opening up of the Sault Sainte Marie Canal made it possible to load ore loose for the whole voyage. But for the next ten years the work of unloading was all done by muscle and wheelbarrow. Then somebody ran a rope through a pulley on the ship's rigging, hoisting ore out of the ship with a tub raised by a horse, and in 1867 Robert Wallace used a steam-engine to hoist several tubs. A boat could be unloaded in a single day, and that was thought wonderful. But men had to shovel the ore into the tubs, and this cost forty or fifty cents a ton. It was an expense which inventors tried to do away with, and the result was the development of the huge unloading devices used to-day. A young man named Alexander E. Brown, was first. In 1880, he invented and built a mechanical ore unloader with two towers supporting a cableway. One tower was placed at the edge of the dock where the ore ships were moored, the other some distance from it. A trolley travelled over this cable carrying buckets of ore to the second tower, where it was dumped in a pile. This was the Brownhoist.



UNLOADING ORE SHIPS WITH BROWN MACHINES.

Each machine is equipped with a man-riding trolley from which is suspended a round bucket. The trolley with bucket travels from the extreme end of the front cantilever to the extreme end of the rear cantilever. Each machine is a separate operating unit that travels along the face of the dock. The operator on the trolley controls the trolley travel, operation of the bucket, and the movement of the machine along the docks.

Several years later, another young man, George H. Hulett, saw ore being unloaded with buckets, and decided the method was too slow. Although born a farm boy, he had become interested in machinery, and in 1884, turning his attention to ore unloading, he made some improvements in an unloading derrick used at South Chicago. In 1891, he built an unloading device in Cleveland, calling it the "Little Giant," but could not get people interested. In 1896, he invented and patented something entirely new. Iron ore was loaded into cars at the mine with steam-shovels. Hulett saw no reason why steam-shovel buckets should not lift it out of the ships, and he made drawings and models to illustrate his invention. It was so big and costly a machine that even the largest shippers were afraid to build one. Eventually, in 1898, he found a company willing to pay $48,000 for a Hulett unloader—provided it would work; otherwise he was to get nothing for his machine and tear it down at his own expense. The following year, 1899, after many trials and mechanical changes had been made, Hulett's unloading

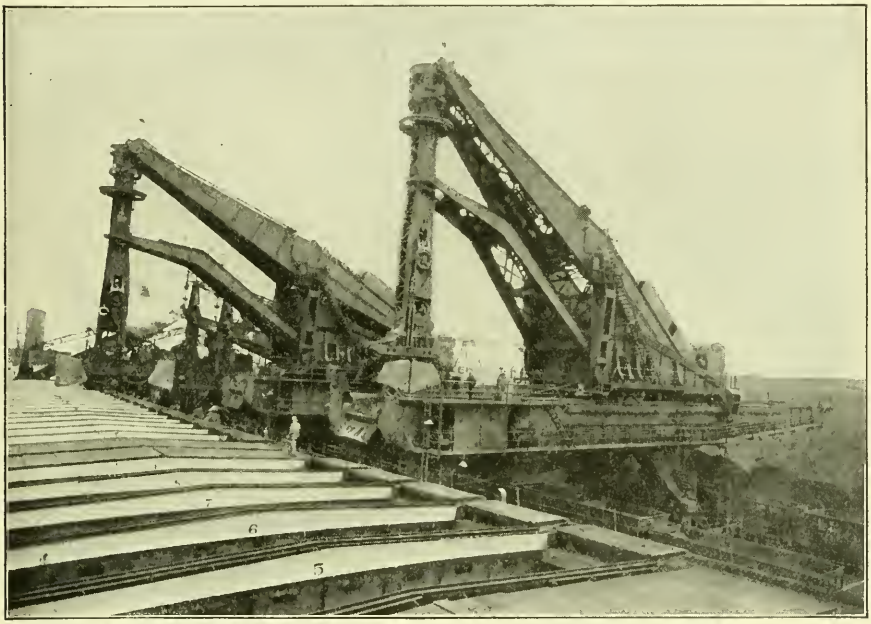


BROWN POWER SCRAPER AT WORK IN A HOLD.

In unloading boats of ore there is always a certain amount of material that lies between the hatches and cannot be reached by the unloading grasps. In this picture a Brown power scraper-shovel is shown placing this material beneath the hatch openings, thereby doing away with hand-shovelling. This power scraper-shovel has reduced the time of unloading boats of ore or coal five to twenty-five per cent.

machine proved successful. It was received with opposition by the workmen, who thought it would rob them of their employment. In reality, it helped them; for the machine unloader did away with the hardest drudgery in the whole process of manufacturing and delivering steel.

The iron and steel industry has largely centred around Pittsburgh, because near by are the coal-fields of the Connelsville district, from which come exceedingly good coking coals. As the ore must go through the blast furnace before it comes into the pig-iron form, coke and limestone will probably always be used for fuel and flux. The coke is made by "baking" certain grades of soft coal; the gas which the coal contains is driven off, and coke is the part which remains. Much ore also goes to Chicago, Milwaukee, Gary, Cleveland, Youngstown, Buffalo, and other well-known iron and steel-making cities. At

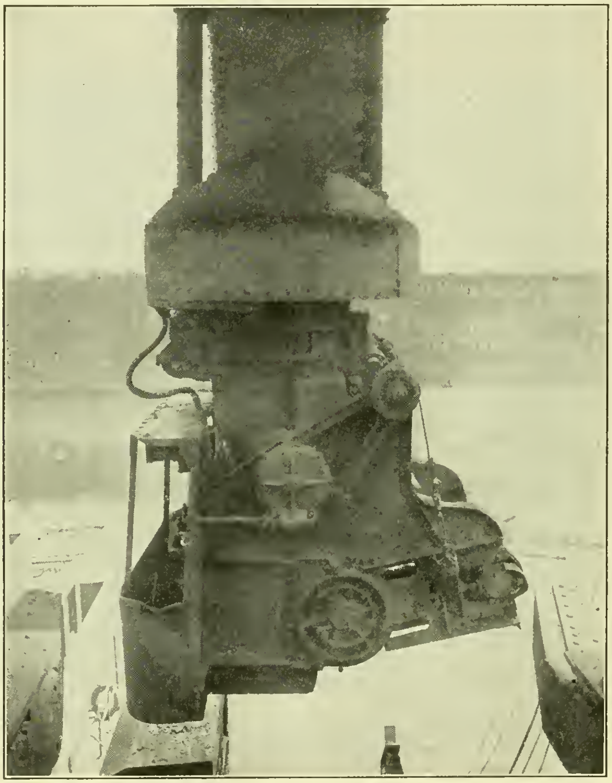


Courtesy of Wellman-Seaver-Morgan Company.

THE HULETT ORE UNLOADER.

In 1896 George H. Hulett devised a machine for unloading ore from ships by means of grab-buckets which were dipped into the hold and lifted by a huge working-beam. The machine was successfully introduced before 1900.

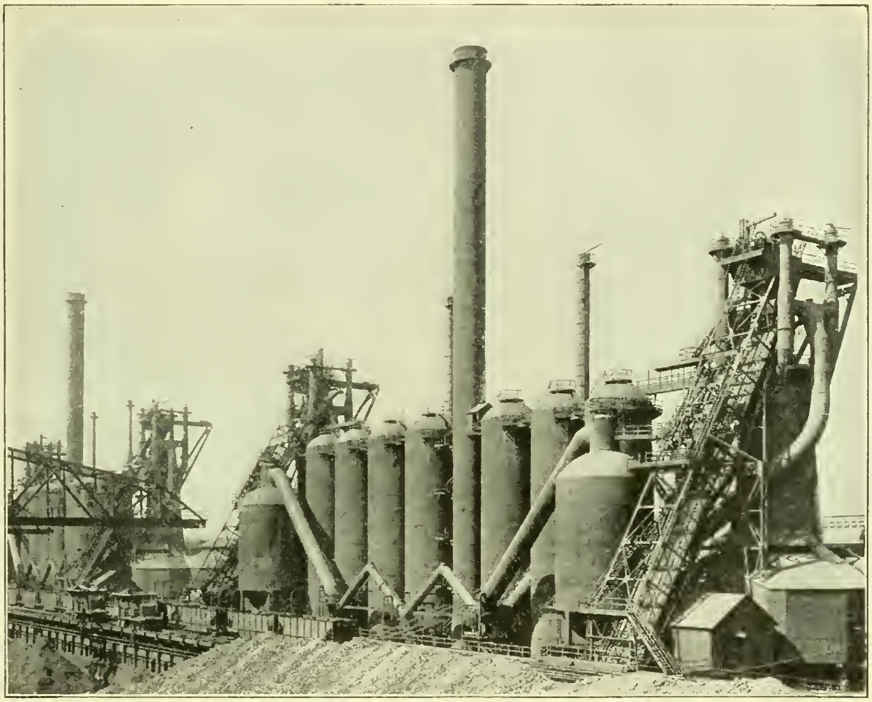
the furnaces, the ore and coke meet. These materials are weighed into proper "charges," hoisted by machinery to the tops of the furnaces and dumped in with some limestone. This gives alternate layers of fuel, iron ore, and limestone. The fuel burns, part of the carbon of the coke takes away the oxygen of the ore as has been described, and the melted pig iron, containing between four and five per cent of carbon, is "tapped" or drawn out at the bottom of the blast-furnace as often as sufficient metal collects there.



DETAIL OF ORE-UNLOADING GRAB-BUCKET WHICH DIPS INTO THE HOLD OF A SHIP AND LIFTS TONS OF ORE AT A TIME.

Inside of a Steel Plant

In the old days there was nothing more fascinating than the sight of molten, smoking-hot metal gurgling out of the tap-hole, running down the centre channel of the sand floor of the "cast house" until, at the farthest end, it ran into side channels cut in the sand, thence into the smaller channels where it lay until it solidified into "pigs." These were shortly broken off by men with sledge hammers, and eventually carried into the yard to be shipped. American efficiency did not like to lose the heat which evaporated when the metal was allowed to cool, so steel-making plants were built close to the blast furnace. In this way, without having cooled off much the molten metal arrived at the Bessemer converters, which "converted" it into steel. Now only the excess metal and that produced on Sunday morning—for steel plants work continuously night and day, from Monday morning until the next Sunday morning, when

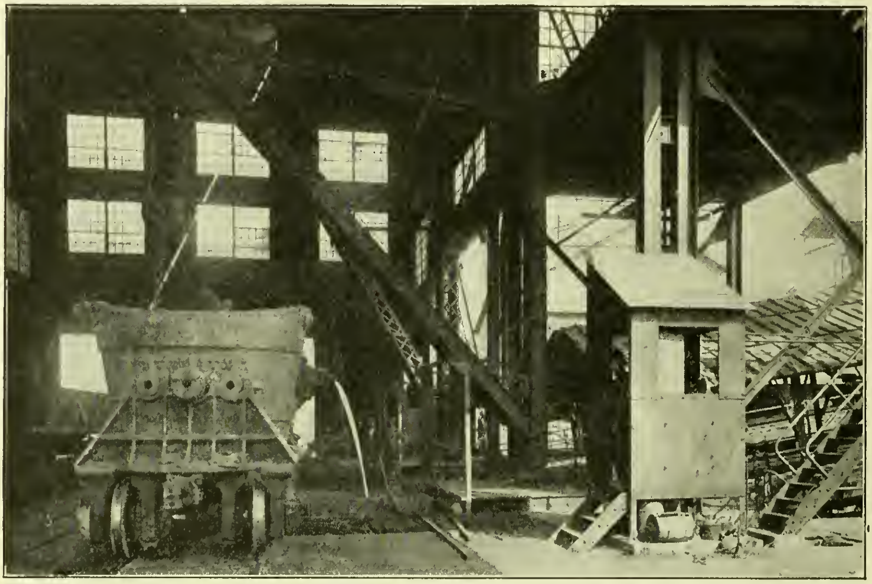


EXTERIOR OF BLAST-FURNACES.

Coke, ore, and limestone are weighed into proper "charges" and hoisted to the top of a furnace and dumped in the coke-burner; part of the carbon of the coke takes away the oxygen of the ore; and molten pig iron is tapped from the bottom of the furnace.

the Bessemer plant shuts down—goes into the old-time pig form.

Bessemer steel, which in this country is usually "blown" fifteen tons at a time in brick-lined, egg-shaped, steel vessels or converters, goes into tall, square, iron moulds, which stand on little cars on a narrow railroad track. The steel soon solidifies, the moulds are pulled off, and reveal "ingots," or red-hot blocks of steel, standing on the cars. In order to lose no more of the heat than is necessary, these ingots are rushed by small screechy engines, called "dinky" or donkey-engines, into the rail or blooming-mill. Huge travelling cranes lift them from the cars and lower them into furnaces, or "soaking pits," built in the floor, to reheat them. When the ingots are again at white heat, they are one by one pulled out and taken to the rolling-mill, through which they are passed backward and forward,



PIG-CASTING MACHINE IN ONE OF THE BETHLEHEM STEEL COMPANY'S FOUNDRIES.

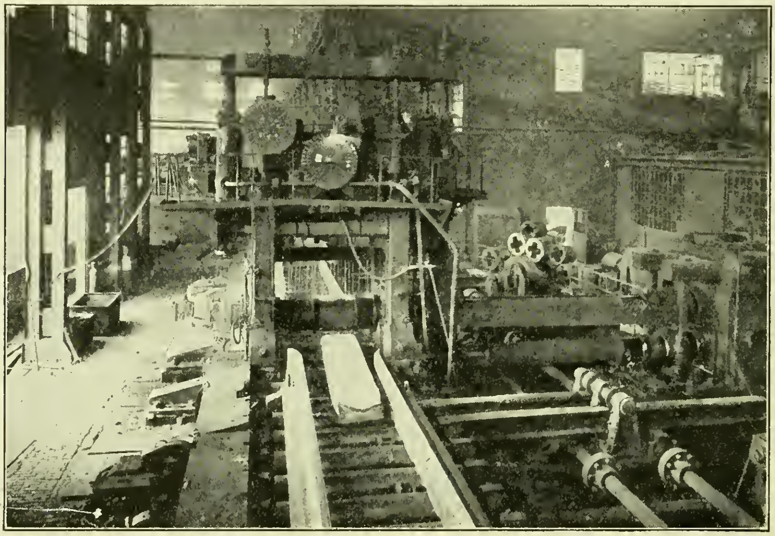
The moulds travel on an endless chain up an incline, and the metal is cast at the lower end. By the time the metal reaches the upper end of the incline the pigs are solid and fall into the car.

and squeezed smaller and smaller, and longer and longer, until they have been reduced to the required size. They are then cut into lengths, "blooms," which go to the rail-mill or to the rod and wire mill, as the case may be, where the rail or rod rolls quickly reduce them in size. For instance, in the rail-mill, after being rolled back and forth many times, each "bloom" becomes a rail, accurately shaped to size, and is then cut into proper lengths. If intended for rods and wire, the ingots are cast smaller, and the blooms cut are smaller than are those for rails. These are usually called "billets." Being small, they lose their heat faster than the larger ones, and must be reheated before going to the rolls.

POURING A HEAT OF SPECIAL STEEL INTO INGOT MOULDS.

The ingots are taken by the cars to the rail or blooming-mill.

The men engaged in this exciting work go about their duty with matter-of-fact unconcern. Practice has not only made them perfect, but also indifferent to ever-present dangers. The "roller" operator, standing in front of the many-grooved "three-high," or three-roll mill, catches the on-coming end of the fast travelling white-hot steel rod as it darts at him from the first groove in the rolls. Coolly and unerringly, he seizes it with his tongs, whirls it around, and inserts the end of it in the next smaller groove of the rolls turning in the opposite direction. The white-hot snake keeps on coming out of the larger groove, runs around him in a loop on the steel floor, and speeds into the next smaller groove into which he has just thrust it. This work the "roller" continues hour after hour. In the midst of such danger his only weapon is a hatchet, with which he can defend himself by cutting the fiery rod should it fail to go as intended and start on a rampage, as occasionally occurs. Not only one loop, but two or three he has almost constantly circling around him; for the rolls run very fast, and with two or three loops running at once, he gets greater "tonnage," and consequently more pay, than if he should roll only one at a time.



ROLLING AN INGOT IN A BLOOMING-MILL.

All of the steel is rolled in a continuous operation so that it does not cool very much from the time it is measured until it is in the shape of blooms, of which one is shown in the foreground emerging from the rolls.

Undoubtedly Bessemer steel made possible the great railroad expansion of the years 1870 to 1905, and started the great industrial growth. But Bessemer steel did not accomplish it all. Within ten years after the discovery of the Bessemer process, William and Frederick Siemens invented a system of chambers lined with brick-work, which treasured up the heat by taking it from the flame and hot gases as they passed through on their way to the chimney.

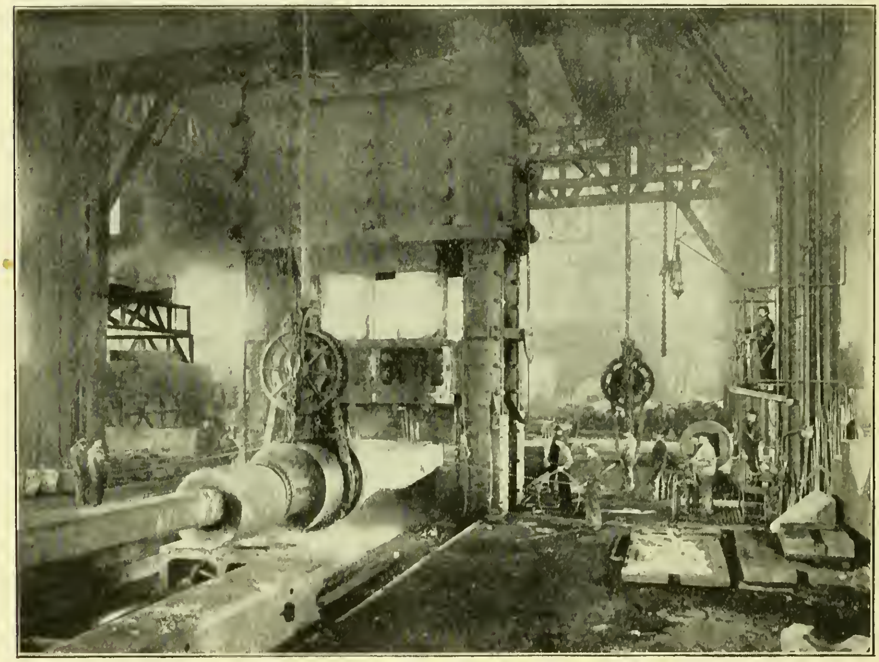
RAIL-MILL, FINISHING END.

The Development of the Siemens-Martin Furnace

This "regenerative" furnace was chiefly the invention of William Siemens, a German, who was born in 1823, and was five years younger than his brother. He was a scientist as well as an inventor, developing the process for electroplating, helping in the construction of telegraphs, designing a cable-laying ship, and he lived to promote the electric light and trolley-car.

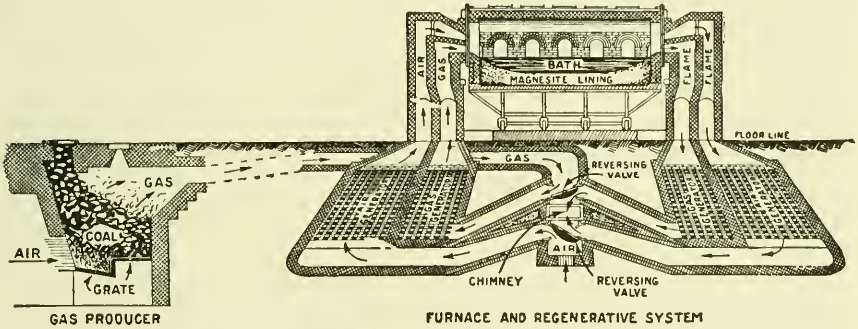
The Siemens furnace grew out of scientific studies made by William Siemens to prevent the waste of heat in steam-engines, and he invented a "regenerative engine" which was not commercially successful. But this same idea of saving heat, when applied to steel-making, brought about far-reaching changes.

His furnace, proposed in 1861, had two chambers, one for air and one for gas, oil or other volatile fuel. These connected with the furnace and chimney—by means of a reversing valve. The gas and flame is shot through the furnace in one direction, and then alternately through the other by directing the flow of incoming gas and air through the hottest chambers. In burning this preheated gas in the furnace, intense heat is produced sufficient to melt even the carbonless wrought iron, which, as we have read, was an unmeltable, pasty, white-hot ball in Cort's puddling process. The valve is reversed every little while, thus alternately utilizing the hottest chambers for heating the gas and air, and reheating the other ones after they have become somewhat cool from like service.



1,400-TON HYDRAULIC FORGING-PRESS.

This furnace is often called the Siemens-Martin furnace, because two Frenchmen, the brothers Pierre and Emil Martin, licensed by the Siemens under their patent, were active in developing the invention commercially, near Paris, in 1864. In connection with this there is a dispute, as often happens with great inventions. Some maintain that the Martin brothers deserve credit for improving the Siemens brothers' idea, while others credit the latter, saying that the Frenchmen were the first to carry out the idea in a practical way. Be this as it may, the regenerative furnace quickly transformed the steel industry, making possible what is known as the open-hearth process. In the long brick-lined shallow furnace above described, either cold pig iron or pig iron and scraps of steel are melted and made into new steel by expert furnacemen. The making of steel by this process is considerably slower than is steel-making in the Bessemer converter, and the process is far less spectacular. But the steel is generally considered to be somewhat better in quality.



From Spring's "Non-Technical Chats on Iron and Steel." Courtesy of Frederick A. Stokes Company.

THE OPEN-HEARTH METHOD OF STEEL-MAKING.

Early type of gas-producer, regenerators, and open-hearth furnace, showing the course taken by air, gas, and products of combustion, and also the valves that change the direction of flow.

In 1868, the first small furnace was erected at Trenton, New Jersey, by Cooper, Hewitt & Company, after their engineer, Fred J. Slade, had visited France to study the Martins' furnaces. It was not successful, because steel workers had to be taught new methods. An American engineer, Samuel T. Wellman, has been called the "father of the open hearth in America," because he spent many years installing and improving furnaces of this kind.

With the first appreciation of the high quality of open-hearth steel, fifty years ago, the prophecy was made many times that the Bessemer process must soon be a thing of the past. However, much Bessemer steel is still made. An enormous tonnage of open-hearth steel now goes into rails, plate, wire and structural steel for buildings, bridges, and so forth. Steel is measured by the "long ton" of 2,240 pounds, and a few figures of production may be interesting.

In 1869 the making of open-hearth steel first recorded in the United States was 893 tons; against this there was manufactured 10,714 tons of Bessemer. By 1880 the figures were 1,074,000 tons of Bessemer, and 110,850 of open-hearth. In 1900 it was 6,685,000 tons of Bessemer, and 3,398,000 tons of open-hearth; in 1910, 10,328,000 Bessemer, 20,780,000 open-hearth. In 1920 the open-hearth steel had increased to 32, 672,000 tons, while the Bessemer had decreased to 8,883,000 tons.

Perhaps we may be able to realise the immensity of the iron and steel industry in the United States, by noting that the 1920 production of over 40,000,000 tons is nearly one-half ton per year for every man, woman and child in the country, or over two pounds per day.

Making Steel in the Electric Furnace

But ever finer grades of steel than that produced in the open-hearth are needed for automobiles, machines, and many other purposes. These steels are made in electric furnaces, the most modern method, and one that is apparently very near perfection.

It was this same William Siemens, afterward Sir William, who, about 1870, designed many small experimental furnaces for melting iron and steel by aid of the electric arc. The electric arc is produced by forcing electric current to jump a gap like that between two carbons of the arc lamps used to light our streets. In jumping, the current is bent, forming an "arc," and it also develops a terrific heat—the greatest heat that man has yet been able to produce, upwards of 5,000 degrees Fahrenheit. The gap in an arc light is only the fraction of an inch, but in electric furnaces it may be several feet. Siemens succeeded in melting iron and steel in his electric furnaces, but as electric current was then very costly, he was unable to make the process pay. It was not until 1895 that an Italian army officer, Major Ernesto Stassano, designed a furnace that profitably melted steel. By that time electric current was cheaper. Stassano overcame many difficulties. Having no skilled helpers, he had to be his own machinist, electrician, chemist, laborer, and furnace-tender. More than $200,000 was sunk in his experiments before he succeeded in making steel on a large scale.

TAPPING AN OPEN-HEARTH FURNACE.

The large ladle contains steel and the small one slag.

The electric furnace had already been applied to melting and making things of greater value than steel. An American, Robert Hare, a Philadelphia chemist, born in 1781, is given credit for constructing the first electric furnace. With only a battery current he converted charcoal into graphite, and performed other scientific feats. In 1886, another American, Charles M. Hall, invented a process for making aluminum, passing an electric current through a heated mass of aluminum oxide and a Greenland mineral known as cryolite, which fused the metal. Up to that time, aluminum had been as costly as silver, but Halls's process made it cheap enough for everyday use. Hall was a clergyman's son, and developed his process at Oberlin College in Ohio, to which institution he left his large fortune. It is said that, as a boy, he took a fancy to chemistry through happening upon an old text-book in his father's library. The cover and title-page of this book had been torn off, so he never knew who was the author. Two brothers, Alfred and Eugene Cowles, who had worked with Hall, applied the process of the electric furnace to the making of aluminum bronze. In 1891, Edward G. Acheson, an American who had been in the employ of Edison, used the electric furnace to convert coke, sawdust, sand, and salt into a new substance, carborundum, now in everyday use for grinding. Acheson also made by far the purest graphite obtainable, in the electric furnace.*

In 1886, the year Hall took out his patent, a French inventor, Paul T. L. Héroult, patented a similar process for making aluminum in an electric furnace, and established the first aluminum works in Europe, at Neuhausen, Germany. Three years later, he turned his attention to making ferro-chrome, ferro-silicon, ferro-tungsten, and other iron alloys. The alloy steels are ordinary steel containing other metals, such as chromium, silicon, tungsten, manganese, vanadium, molybdenum, and the like, metals that make steel harder, tougher, and stronger. Realising that such steels sold for higher prices than ordinary steel, Héroult found that it was possible to make a handsome profit by means of the electric-furnace process. He, Stassano and others also used the high temperature of the electric furnace to purify steel, taking out of it the two dreaded impurities, sulphur and phosphorus.

Héroult's furnace was a brick-lined pot heated by the electric arc passed to and from the metal being melted by means of long rods of carbon or graphite, called electrodes. It is because of the great quantity of air blown through the metal in the Bessemer process that Bessemer steel suffers in quality. Air, though in a lesser amount, is used in the open-hearth process to make the gas, or fuel, burn. In both these processes

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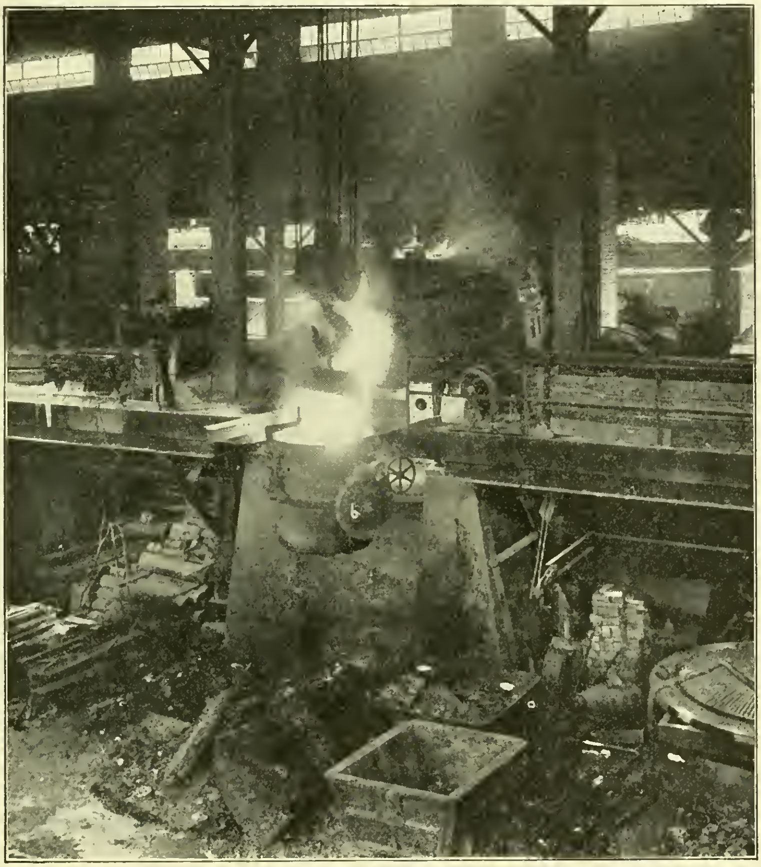
*See the chapter the Rise of Electricity.

the presence of air in the furnace is unavoidable. In the electric furnace no air is necessary. This, with a closer control of composition of the metal and various other advantages, gives to electric steel a quality that is near absolute perfection.



ELECTRIC STEEL-FURNACE.

In this form it is the development of Paul Héroult, a French engineer. His original furnace was a brick-lined pot heated by an electric arc.

In 1900, a Swedish engineer, F. A. Kjellin, patented another electric furnace along different lines. Up to that time inventors had used the arc, melting steel in its intense heat, or taking steel already melted in an ordinary furnace and refining it in the higher heat of the electric arc. Kjellin's furnace utilized the principle of "induction." Instead of an arc in which electricity jumped a gap, he ran his current through the steel itself, and the resistance of the steel to electric current melted it. As the arc type of electric furnace works like the arc lamp, so the induction furnace works like an incandescent lamp, with its filament heated white hot because it resists the current.

The electric furnace makes better steel than either the Bessemer or open-hearth processes, and makes it cheaper than the crucible process. Crucible steel began with Huntsman, in 1740, and is made by pretty much the same process to-day. The crucible is a small pot, formerly made of clay but now usually of graphite. This pot is filled with small pieces of steel and put into a furnace where it is entirely surrounded by coke or coal, the fire being so regulated that the steel is not too quickly melted. Fresh coal or coke must be put around the crucibles two or even three times, and they must be tended by an expert workman, called the "melter." This attention, together with the cost of crucibles and the small quantities of steel melted in that way, compared with the large charges of the Bessemer and open-hearth processes, make crucible steel expensive.

Our automobiles have frames of vanadium steel, forgings of nickel or chrome nickel steel, roller and ball-bearings of chrome steel, all made in the electric furnace. Even the tools which so swiftly and accurately shape the automobile parts are now, to a considerable extent, made from steel produced in the electric furnace, though many tool steel manufacturers still hold to the crucible process.

When our railroads demand still better rails than even the open-hearth can produce, the electric furnace must make them. Steel containing fourteen per cent. of manganese is known as manganese steel. This cannot be drilled or cut by ordinary machine tools, and its hardness makes it a wonderful material for "frogs" and rails which are to resist wear as on track curves, etc. Manganese steel is used for burglar-proof safes, crusher-rolls, gears, etc., which must resist excessive wear, although chrome steel is used for some such parts.

There is a wonderful future for these alloy steels. Some are so strong that they will not break under a pull of 350,000 pounds per square inch; some are hardened and used for armor plates for battleships; some, because they do not change much in length upon heating and cooling, as do most other metals, are used for parts of scientific instruments; and some are rustless, and therefore are used for cutlery, surgeons' instruments, and the like.

Another most important series of steels are the "high-speed steels." They are tool steels which will keep their hardness even when working red-hot. The old carbon tool steels, though apparently just as hard, very soon lose their hardness and cutting power when worked hot. The heat-withstanding properties of the high-speed steels are imparted by tungsten, chromium, and carbon. When the first of these steels appeared, their valuable properties could not be fully utilized because our lathes, shapers, and other machines, though strong enough for the old carbon steel tools, were neither strong nor powerful enough to push the tool for the deeper and faster cut which the high-speed steel tool was capable of taking. With the powerful machines and tools of to-day, so much metal can be cut away by one tool that it is sometimes difficult to carry away the chips as fast as the machine cuts them.

This is the Age of Steel. Why? Firstly, because more and more steel was required. America's output, in the eighteen-sixties, was less than 15,000 long tons a year, that is, under ten pounds a year per capita. We are now approaching the day when every man, woman, and child in this broad nation of ours will need a ton of steel every year. The yearly gain since 1900 has averaged 1,500,000 tons, as much increase each year as our total annual output in 1880. This means that the man of the eighteen-sixties who had only a few tools, who had to walk to his work, and who took an occasional railroad trip, has, to-day, an automobile, uses the trolley and railroad regularly, works in a steel-frame building, and is able to perform his tasks not by hand but with steel machines. Such was the answer to the demand for more steel.

Secondly, the cry was for cheaper steel. When Bessemer and Kelly patented their converter process, English manufacturers were selling steel at $300 a ton. During the past twenty years the price of steel "billets" has averaged only twenty-five to thirty-five dollars a ton.

Thirdly, there was the desire for better steel, new steel, with which it would be possible to do more work and make things stronger and lighter while they were also being made cheaper. The electric-furnace steel, and the wonderful alloy steels were the answer. With the latter steel, it is possible to take a thousand pounds weight out of a high-powered automobile.

This, then, is the meaning of the Age of Steel. Those who make iron and steel, from the workers in the mine to the experts in the finishing laboratories, serve us every moment of our lives. Steel, each year, becomes more and more indispensable to us.

CHAPTER II

MINING COPPER AND THE NOBLER METALS

WHAT metal did Man first find and use? It may have been silver or copper; some say iron, others lead, tin, zinc, even steel or brass, which latter are not natural metals. Most probably, gold was the earliest discovered metal.

A miner knows that ancient man was most likely to have used gold first, because, more than any other metal, it is found pure in nature. The archæologist finds gold ornaments in ancient man's graves, with stone weapons and tools. Gold was bright and attractive. Ancient man learned to trim and hammer it into ornaments, and later to melt it. In the same way, it is thought, he soon found silver: but that, too, was used chiefly for ornament.

Man's first working metal was copper. Combining it with tin and melting them together to make bronze, he had a metal with which he built great kingdoms and cities, and through long centuries he fought bloody wars without ever using iron. The wonderful civilizations of Mexico and Peru knew only these three or four metals, and many of their weapons and tools were of stone.

The Greeks and the people of Crete and other Mediterranean islands began to use copper about 3000 B. C. It was not known in western or northern Europe until nearly one thousand years later, when Phœnician traders brought marvellous copper ornaments and weapons to the stone-age people. The Phœnicians got tin from Cornwall, in England, and mixed it with copper to make bronze, which they found harder and better for their purpose. The Greeks began to use iron in the thirteenth century B. C., but bronze was still popular. Five hundred years after the appearance of iron amongst them, the Greek poet Æschylus spoke of it as "the stranger from across the sea." It became common in Greece about 1000 B. C., after a bronze age lasting two thousand years.

To-day, we have about fifty metals, some of which are seldom used. Most of us probably have a dozen different metals in our pockets, contained in articles such as money, knives, watches, keys, fountain pens, and so forth. In fact we carry gold, silver, copper, tin, iron, zinc, nickel, lead, aluminum, with a bit of rarer metal like iridium here and there, on the nibs of fountain pens, or in things made of alloy steels. In a bicycle, motor-cycle or automobile, a dozen more of these rarer metals may be found.

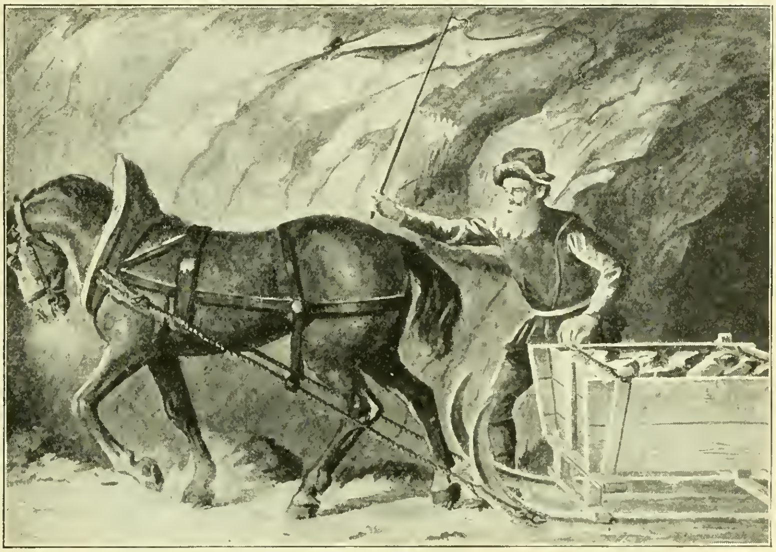
From drawings in the Deutsches Museum, Munich.

(Left) PRIMITIVE METHOD OF TRANSPORTING ORE.

(Right) EARLY METHOD OF TRANSPORTING ORE BY A WHEELBARROW. ACCORDING TO AGRICOLA, 1550.

Except in the case of iron, mining is a needle-in-the-haystack affair. The haystack is a mountain, and the needle a very small quantity of metal. Sometimes this metal is a vein of gold, silver, or copper, deep in the mountain. Again it may be a very small quantity of metal scattered in streaks through the whole mountain. The miner's job is to find the vein and get the metal out, or tear the mountain down and grind it up to get the metal.

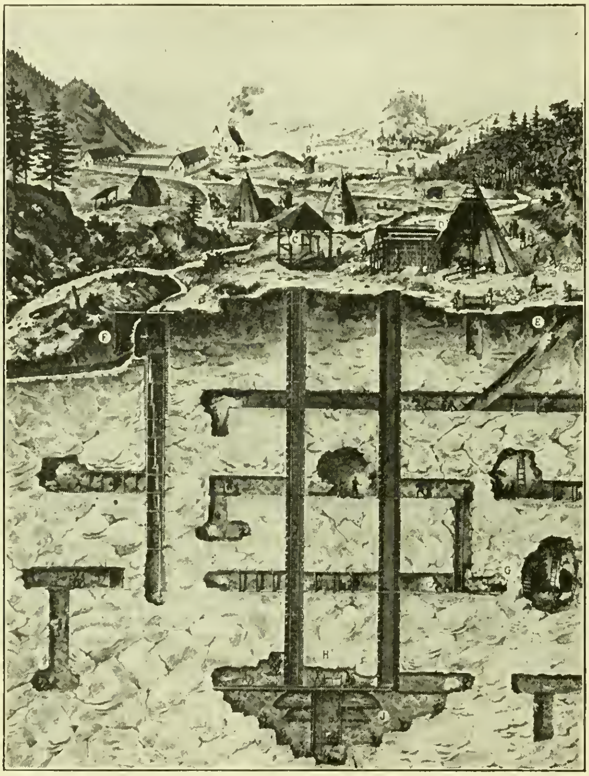
Scientists have worked out a theory of the origin of metals, the process which they now believe was followed by nature. They know that most of the rocks on our globe, especially the very hard ones like granite, were once molten and liquid. As they cooled, cracks would form in the granite of a mountain. Water, escaping from the hardening rock, would rise through these cracks in the form of vapors, which carried atoms of metals. These metals would be deposited along the cracks, and thus ore veins would be created in the mountain.



From a drawing in the Deutsches Museum, Munich.

TRANSPORTING ORE ON A SLED. ACCORDING TO AGRICOLA, 1550.

Nature no sooner raises a mountain than she begins tearing it down. The rains fall upon it and sweep into its crevices and cracks, forming underground streams. These streams may run along a vein which has a very small deposit of metal, but they will wash it loose and carry it down to some deeper crack, and there collect it in a much more valuable form which, some day, miners will find. Wind, ice, heat, the roots of plants, even animals, help in this work of tearing down the mountain. Its rock is reduced to sand, and this is washed away into streams and rivers miles distant. Metal is also dislodged and carried along by streams, sometimes in particles finer than sand, sometimes in large lumps. The metal sinks into the river beds, and it is in such places that man first found gold and silver in fair-sized lumps.



Courtesy of Deutsches Museum, Munich.

MINING IN THE SIXTEENTH CENTURY. ACCORDING TO AGRICOLA AND LOHNEYSS.

A. Smelting-furnace. *B.* Windmill for ventilation. *C.* Drawing out the air by bellows. *D.* Horse-windlass for raising ore. *E.* Incline. *F.* Water-wheel driven by a stream and serving to pump up water in several stages. *G.* Local fire for heating and thus loosening the ore. *H.* Windlass for raising the ore. *J.* Bottom ore bed.

Copper is not so easily found. Sometimes it can be picked up in lumps of "native" copper, but usually it is mixed with rock. Scientists reason that early Man, probably an Egyptian, banked his camp fire with pieces of copper ore in some place like the Sinai peninsula, at the head of the Red Sea, where copper existed, and the next morning discovered glittering hard drops of the metal that had been melted out.

"Without knowing, this man stood at the dawn of a new era, the Age of Metal," says Professor James Henry Breasted in his *Ancient Times*, from which some of these facts about man's earliest uses of metal have been taken. "The little bead of shining copper which he drew from the ashes, if this Egyptian could have seen it, might have reflected to him a vision of steel buildings, Brooklyn bridges, huge factories roaring with the noises of thousands of machines of metal, and vast stretches of steel roads along which thunder hosts of rushing locomotives. Since the discovery of fire over 50,000 years earlier, man had made no conquest of the things of the earth which could compare with this discovery of metal."

These drops were first used for beads until people learned that enough of this new metal could be melted out of rocks to make knives, spear-heads, arrow-heads, axes and working tools. Copper weapons were so much better than those made out of stone that men armed with them soon gained mastery over their less inventive enemies, just as centuries later men who invented iron and steel weapons vanquished enemies who had only weapons of bronze. With copper, too, men had better chances in hunting and fighting wild beasts.

Mining really began when people needed more metal than they could pick up from the ground. For hundreds of years a family might go through life with only a few ounces of copper: a knife, an axe, a spear, a chisel. But when armies needed weapons, the need for this metal became more urgent. Man could not wait for nature to wash the needle out of the haystack. He had to go to the mountain, find the vein, and dig the metal out.

How the Prospector Discovers the Ore

The first step in mining to-day is prospecting. When ancient man decided to go and find the metal in the mountain, he was no longer satisfied to sit down in a river bed and look for nuggets of gold, or silver, or lumps of copper ore, but walked up the river, keeping his eyes open, tracing metal to the deposits from which it had come. Every mine, great or small, whether it yields gold, or copper, or zinc, or diamonds, was first found by a prospector in the same way.

The prospector is the most romantic fellow in the mining business. He leads a rugged outdoor life, tramps hundreds of miles into the wilderness, lives partly by hunting and fishing, carries the fewest tools and supplies, and sleeps in a tent or under the stars. To be a successful prospector, he must know a great deal about technical matters, such as geology, ores, metals, and even natural history. He sees things that would not be noticed by other people, puts two and two together, and makes deductions as subtle as a detective; a Sherlock Holmes, pitting his wits against nature to find the wealth she has hidden in the mountain. The fascination of the work is so great that many men remain prospectors all their lives, by choice, though settling down and working a mine would usually be much more profitable. It is the independence and change and freedom from routine work, the exciting chance of making a wonderful discovery to-morrow that keeps prospectors roaming the hills, seeking mineral wealth that the engineer and miner may later develop into rich mineral industries.

With his donkey, or "mountain canary," following along behind with supplies and tools, the prospector walks up a valley, watching for "float," the name given to pieces of rock containing metal. These "floats" may be found either in a stream, washed down by water, or on the valley floor, having dropped from the mountains above. He may go for days before anything promising turns up. The prospector of antiquity looked for just a few metals: gold, silver, copper, tin, lead. To-day he may find riches, not in gold, but in some metal like tungsten, for which the world had little use twenty-five years ago. In a certain Western silver mine which had proved rich about fifty years ago, when the silver was taken out the miners were bothered by some queer black stuff which they hauled to the surface, sorted out, and threw on the waste heap. It was tungsten, now used to make filaments for electric lamps. It has since been gathered up and sold for more than the silver in that mine was worth.

A time comes when the prospector finds ore-bearing rock, not one or two pieces, but a trail of it leading up the mountain. It may take him days to clear away bushes and plants, working from one spot to another. He may have to clamber back and forth on steep slopes, examining every place from which rock has fallen off. Finally, if he is lucky, he discovers the place from which this "float" has dropped, and it is an exciting moment when he chops and digs to see if there is more than one outcropping of mineral, and whether it looks like a big vein running into the mountain, and how much metal there is in the ore.

But not once in a hundred such times does he discover a rich mine. His vein may hold a real fortune in metal, but the mining engineer must decide whether it can be taken out at a profit. The vein may be a hundred miles from a railroad, and the cost of removing the ore may be in excess of its actual value. Some day the railroad will come there, and the ore can be sent to the mills and smelters. Ore must be crushed to powder and run through separating machinery, and for that a steady supply of water is needed. A discovered vein may be miles from water, in the desert. Separating machinery requires steam or other power, and it would not be profitable to haul coal so far. Men will be needed to work the mine, and they may be scarce in that region.

There are many other things to be reckoned with besides simply finding a good vein of ore. One "strike" in a hundred may be worth working as a mine, and even then perhaps only one in a hundred mines prove profitable. Indeed, there are so many chances against success in mining, and so many failures, that experts have said the world puts more money into gold mines than it ever takes out—meaning that though some gold mines pay, the money sunk in those that fail is greater than the value of the gold. This is rather a gloomy way of looking at mining, but it has a basis of truth. Much of the silver now mined in this country, being mixed with zinc, or lead, or other bulkier metals, can be mined only as a by-product. That is, the cost of getting out the silver alone might be more than it is worth, but the other metals pay expenses. There are many such combination mines in our West, where the lead or zinc brings good prices one year, and the next lead or zinc may be too cheap to mine, the silver paying expenses.

Occasionally, the prospector finds a small deposit of ore so rich that he can take it out himself and haul it to a mill. Some gold miners search for rich "pockets," and wash the metal out of the gravel or earth by hand. Mark Twain was once a "pocket miner." He and his partners one day discovered what seemed to be a promising pocket. Mark Twain was carrying water to wash the gravel, which was getting richer and richer. The day was cold, and being chilled, the great humorist refused to carry any more. "Just one more bucket!" pleaded the man who was washing. But the water-carrier struck work then and there, and something took them away from that place. Two other miners came along later, found a rich pocket, and took out $20,000.

It is of gold and the days of "forty-nine," when a famous discovery lead us to the great wealth of metals locked up in our country, that most Americans think when they hear the magic word "mining." In colonial times there was little mining, because, apart from iron and coal, and some zinc in New Jersey, our Atlantic seaboard is poor in metals. Some gold had been found in the Southern States, and it is a little-known fact that one of the first stamp mills in California for breaking gold ore, was set up by a gold miner from Georgia, and still produces small amounts of this metal. We now produce twenty per cent. of the world's gold, forty per cent. of its silver and lead, fifty per cent. of its zinc, and sixty per cent. of its copper and aluminum. Except the last metal, which is not mined, but reduced from clay, these metals are mined West of the thirteen original States. Copper is found in Michigan, and lead and zinc in Missouri. But the far Western States produce the bulk of all our nobler metals.

It was the discovery of gold in California that opened up these treasures, and set our inventors at work developing wonderful mining machinery, for it is the natural resources of the country that stimulate inventors. Other countries have perhaps outstripped us in gold production, but through our inventions we lead in metals like copper. It is not generally known that the value of the copper we mine every year is greater than that of our iron.

"The Days of Old, the Days of Gold, the Days of Forty-nine"

On January 24, 1848, nine days before California was added to our territory under the treaty with Mexico, a carpenter, named James Marshall, was repairing a mill-race on a branch of the American River in the valley of the Sacramento River, in California. It had been dug to carry water for a saw-mill, but was not deep enough. The night before he had turned a great volume of water into it and had allowed it to run all night. That eventful morning he saw some bits of bright yellow stuff in the gravel that was left behind. Picking up one of these yellow fragments, he hammered it and found it was a soft metal. He then put it into a boiling kettle, only to discover that it did not dissolve, but came out as bright as ever. Thinking it might be gold, he took it to his employer, an enterprising Swiss, named John A. Sutter, who owned several thousand acres of land in that neighborhood, with many thousands of horses, cattle, and sheep. Several hundred men worked for him, and they had a fort for protection against the Indians. Sutter had some nitric acid among his chemicals, an acid that will tarnish nearly all the metals, with the exception of gold. Marshall's bright yellow stuff remained untarnished. Then Sutter weighed it, compared it with a gold coin, and declared it was gold.

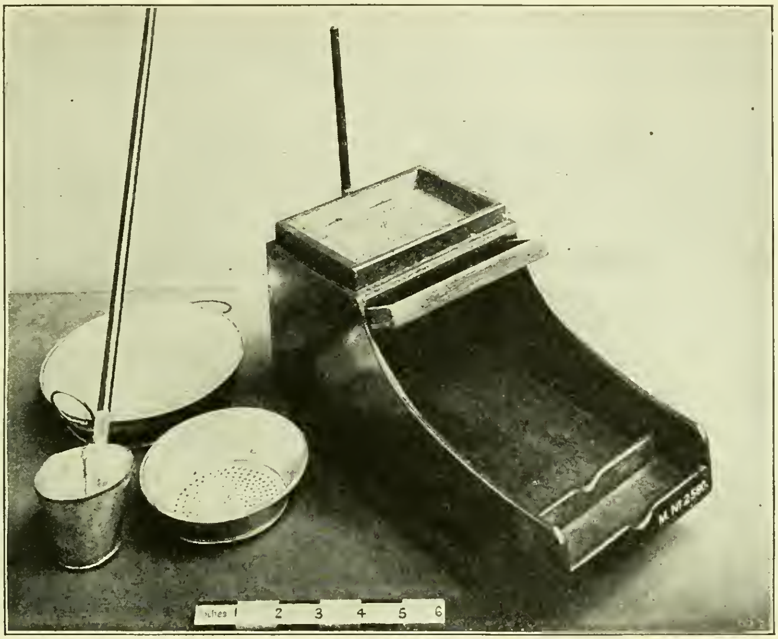
The news spread. Not only did Sutter's ranch hands leave him to become gold-seekers, but they also ran away with his horses. The Indians refused to harvest his crops. He was beggared, and neither Sutter nor Marshall ever profited by their discovery, both dying poor, some years later.

Two years afterward, in 1851, more than $80,000,000 worth of gold was mined in California. Men flocked in from everywhere. They left places like San Francisco, then little more than a village, rushing to the region where gold had been found. Sailors deserted ships, the neighboring Mormons came from Utah, people from the Eastern States crossed the prairies and mountains to reach California, and also went in ships by way of Panama, where they rode across the isthmus, taking another ship on the Pacific side. The rush was so great that a railroad was built across the isthmus to connect profitable steamship lines, opening in 1855. Other gold-seekers came from South America, and even from Australia, where gold was found in 1851 by Edward Hargreaves, an Australian who had been in California and learned where to look for the rare metal, and how to detect it.

With such a rush of adventurous men into a wild country, that to all intents and purposes possessed no government, there was some lawlessness, of course. It is a mistake, however, to think that all "forty-niners" were desperadoes, though this belief has come down as a sort of tradition. The greater number were young, healthy, vigorous, intelligent and enterprising men; only a few were outcasts, gamblers, and criminals. Though rough in dress and language, they were yet sober and trustworthy, and were not only law-abiding but able to establish government, make laws, and keep order. Had they been otherwise, they would never have founded a great new State, nor the vigorous industry that mining has since become, with its wonderful machinery for handling millions of tons of ore. Keeping the world supplied with metals, even gold, by the hand methods of 1849, would be no better than going back to prairie schooners to haul freight across our vast continent.

The first gold-seekers in California had only such tools as they could carry with them as they roamed from place to place looking for gold near the surface. First, they had pick, shovel, and "pan"; the latter a wide, shallow dish of metal like a flattened bread bowl. A shovelful of gold-bearing dirt was put into this, and the miner rocked it in his hands, working out over the edge, first the larger stones, then smaller and smaller ones, until a little sand was left at the bottom, from which he skilfully separated the gold. An early California miner, named Buffam, who washed gold in 1848, the year of the Californian discovery, has written about it:

"I shall never forget the delight with which I first struck and worked out a crevice. It was the second day after our installation in our little log hut—the first having been employed in what is called 'prospecting,' or searching for the most favorable place at which to commence operations. I had slung pick, shovel, and bar upon my shoulder, and trudged merrily away to a ravine about a mile from our house.. Pick, shovel, and bar did their duty, and I soon had a large rock in view. Getting down into the excavation I had made, and seating myself upon the rock, I commenced a careful search for a crevice, and at last found one extending longitudinally along the rock. It appeared to be filled with a hard, bluish clay and gravel, which I took out with my knife; and there at the bottom, strewn along the whole length of this rock, was bright, yellow gold in little pieces about the size and shape of a grain of barley. Eureka! Oh, how my heart beat! I sat still and looked at it some minutes before I touched it, greedily drinking in the pleasure of gazing upon gold that was in my very grasp, and feeling a sort



CRADLE AND UTENSILS FOR GOLD-WASHING USED BETWEEN 1849 AND 1856 AND PRESERVED IN SOUTH KENSINGTON MUSEUM, LONDON.

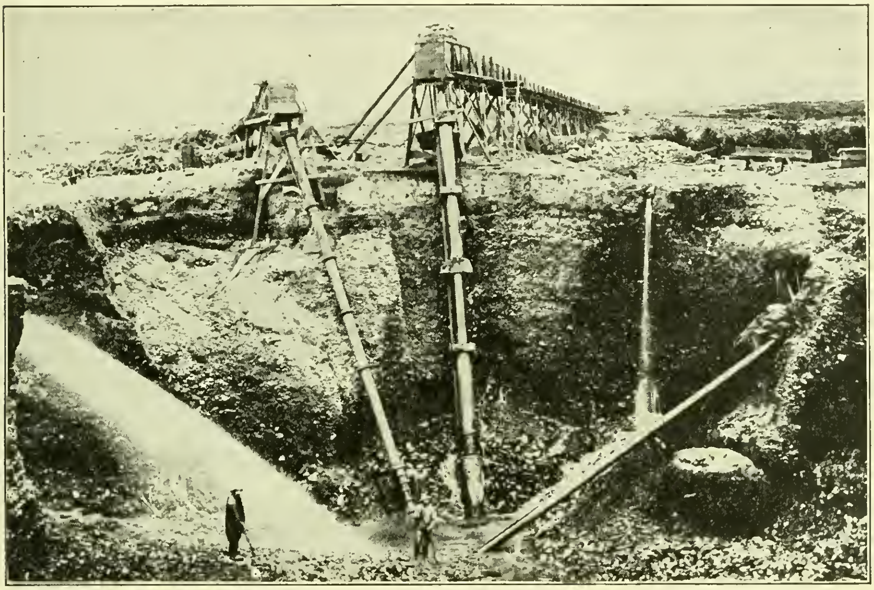
The cradle is a rough wooden box on rockers; in the head is a sieve into which is shovelled "pay dirt," while water is poured over it by the tin dipper, and the cradle is rocked by a handle. The gold, sand, and fine particles carried by the water through the sieve are guided by an inclined frame below the latter to the head of the box, and flow down the sloping bottom. A blanket stretched over the frame retains very fine particles, while coarse gold is caught by transverse ledges or "riffles" on the bottom. The pebbles left in the sieve are picked over by hand, in case a nugget be present, before being thrown aside.

of independent bravado in allowing it to remain there. When my eyes were sufficiently feasted, I scooped it out with the point of my knife and an iron spoon, and, placing it in my pan, ran home with it much delighted. I weighed it and found that my first day's labor in the mines had made me thirty-one dollars richer than I was in the morning."

But not all gravel is as rich as that, and very often the gold in a river bed has worked down to bed rock, making it necessary to dig to some depth. For washing the poorer gravel, a "cradle" or "rocker," a box mounted on rockers, with a perforated sheet-iron bottom, was used. This held several shovelsful of dirt, and when water was poured on it and the mixture rocked, the finer particles of dirt, with the gold, fell through the bottom upon a canvas screen. Then it ran over "riffles," or transverse bars of wood, holding mercury, and the gold formed an alloy with the mercury and was saved. Another variation of this method was the "Long Tom," a wooden trough into which ran a stream of water. Into it the miners shovelling earth and "riffles," with quicksilver, caught the gold at the other end. But among people as inventive as Americans these crude tools were sure to be improved. Gold-seekers stopped roving and settled down in camps; for as time went on gold was not so easily won. What little there was on the surface had been found; prospectors now had to dig down to bed rock or tunnel into a hill for it. From the first, this work was very hard. Forced to stand up to their waists in water, as they washed gold in a pan, or compelled to pry and lift up stones so that pay dirt could be shovelled into a rocker, these men were sure to find better methods.

In the past, gold-bearing dirt found far from water had to be carried to streams for washing. Then miners began to carry water to such places in sluices—wooden troughs often miles in length, bringing water from the mountains. This led to hydraulic mining. Water coming from the mountains was used with great force to wash down whole hills, being spouted through nozzles in powerful streams, the gold caught with quicksilver. There was one rich hill of gravel into which hundreds of miners had dug holes, the dirt from which they had hauled some distance and washed in a stream. When water was brought to that section in a sluice, the whole hill was soon washed down by the hydraulic method.

Hydraulic mining in California was begun in 1852 by a Frenchman named Chabot. He had a gold-bearing gravel bank near a stream on higher ground, and brought the water down in a hose, where he intended to wash the gravel after shovelling it into a sluice. His hose was four or five inches in diameter, and about forty feet long. After a while, instead of shovelling the dirt, he turned the water directly upon it and swept it into the sluice. It was the first use of a powerful stream to wash dirt instead of shovelling it. In 1853, another California miner, E. E. Matteson, rigged up a hose with a metal nozzle and directed the stream against a gravel bank. By this method he found he could do as much work as a hundred men. Out of his nozzle was developed the "monitor," a tapering nozzle that concentrated the water and increased its force. With the monitor, and a good supply of water, large streams of



Courtesy United States Bureau of Mines.

HYDRAULIC ELEVATOR USED IN DRIFT MINING, NOME, ALASKA.

The sand and gravel are pumped up with water and the ore separated by the riffle method.

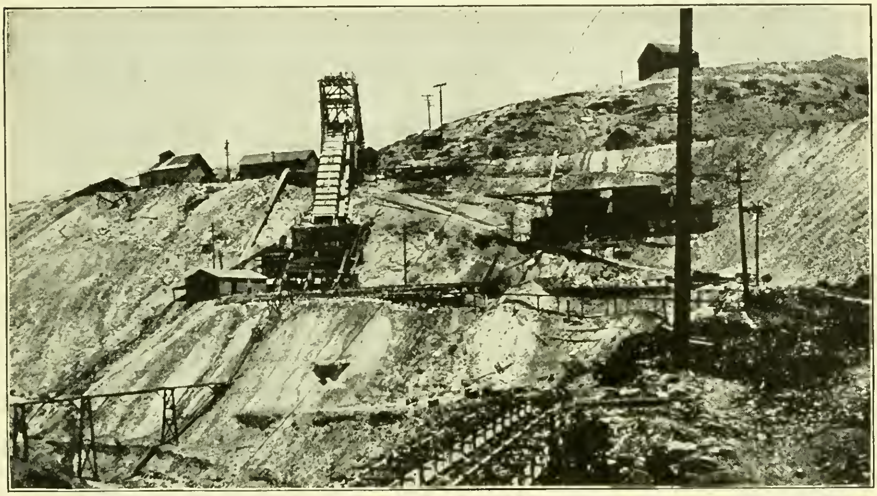
terrific force could be thrown hundreds of feet. In a short time hydraulic mining came into general use wherever there were gravel banks to which water could be brought in sufficient force. In a single season, whole acres of ground would be undermined as much as 200 feet below the surface, washed away and run through sluice boxes, leaving their gold. These monitors moved dirt so fast and cheaply that they were later used to cut through gravel hills in railroad building.

The Quartz Miner Attacks the Mountains

But already gold was being found imbedded in quartz—one such discovery had been made in 1850—and thereby a wonderful new field was to be opened up to the American inventor. Quartz mining is so different from the simple "placer" mining of early California days that placer miners did not always know wealth when they saw it in quartz. In 1849, a party of Mormons bound for California stopped to pan gold in a little creek in Nevada. Disappointed, they passed on. Yet that little creek was the door to one of the treasure vaults of the world, for the Comstock lode, on the border of Nevada and California, was an ore-body 125 miles long. Mexicans came two years later and, washing gold up the creek, found the great vein from which most of the gold came, but did nothing with it. In 1856, two brothers named Grosh found that a metal there, about which gold miners complained, thinking it was lead, was really silver, But they died before they could take advantage of their discovery. Finally, in June, 1859, two miners, Patrick McLaughlin and Peter O'Riley, washing gold in that region, found it in astonishing abundance, on some unworked ground. Just then a trapper, Henry Comstock, happened along, saw the gold, and insisted that they were trespassing on his ranch of 160 acres. It was pure bluff, but he argued with them until they gave him an equal share in their discovery, and thus the name of a keen-witted rover was given to that ore-body which men had been on the verge of discovering for ten years.

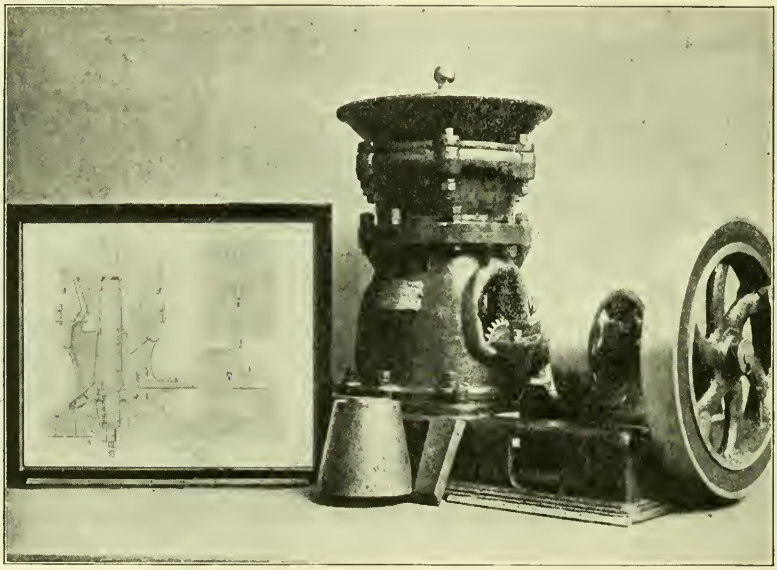
These miners knew nothing about quartz mining. Indeed, the mining of silver in this country was unknown before the Comstock lode was found. They sold their claim for a few thousand dollars, and all died poor, Comstock a suicide. That brought the inventor, the engineer, and the financier to the aid of the miner. Up to that time the latter had been little more than a wandering prospector, taking only such loose gold as he could find, and separating it from dirt and gravel with the simplest tools.

The prospector of to-day seeks veins of metal rich enough for quartz mining. Carrying his samples of ore back to civilization, he has them "assayed," or analyzed, to find out whether they contain enough metal to be worth mining. If they do, and he can interest men of money, a trained mining engineer is sent to the place from which the samples were taken, where he studies the vein, estimates its probable size, location, and richness, and whether the ore can be mined and its metal taken out at a profit. He brings pack animals carrying many tools the prospector has probably never heard about, instruments to survey the ground, and with him go helpers to dig and tunnel in different spots for the vein. A surprisingly correct estimate can often be made, because mineral veins generally have certain ways of running, and the mining engineer has learned much about them from study and experience. His helpers go to



Photograph by Kadel and Herbert.

HEAD-FRAME, BINS, AND LEACHING-TROUGHS, HOME-STAKE MINING COMPANY work upon the outcroppings with drills and dynamite, and if their findings show it to be a mine really worth working, then the property is sold to a mining company, or more often a new company is formed to work that particular mine. More machinery is brought in. Air-drills to bore holes rapidly, with air-compressors and engines to furnish power; hoists for cars to get the ore out of the mine; machinery to crush it, and separate the metal from the worthless rock dust.



Courtesy South Kensington Museum.

GATES ORE-CRUSHER.

This is a crusher in which the reciprocating jaw of the ordinary machine is supplanted by a gyratory crusher moving in a vertical conical shell; it was patented in 1881 by P. W. Gates. The machine is capable of breaking two to four tons of compact gold quartz an hour.

Very soon a village grows up around the spot where a few months before the lone prospector had chipped and dug in solitude. Miners hurry to the scene with their families. In that out-of-the-way place they will find a store where they can buy their various wants, often a school for their children, and perhaps a moving-picture show for entertainment. The mail-carrier soon makes his appearance. Soon there springs up a stage line from the nearest railroad station, or nowadays an automobile stage running on a road built for hauling out ore with motor trucks. If it is a great mine, requiring years of work to extract all its metals, the railroad will come, and the mining village will grow into a permanent town. Many years of work may be ahead of miners, as is shown by the deepest mine in the world, the No. 3 shaft of the Tamarack copper mine in Houghton County, Michigan, which has reached a depth of 5,200 feet, or practically one mile. Such very deep mines are warm, for the deeper men go the warmer it gets. Rock temperatures of 158 Fahrenheit have been faced by miners with good ventilating apparatus, without which they would have to stop from sheer exhaustion, even though great wealth lay beneath them.

It may be that, instead of a rich vein and single mine, the prospector and engineer have discovered a great new ore-body like the Comstock lode; or the gold deposits at Cripple Creek, Colorado, and Coolgardie, Australia, which two mines were discovered and opened up on opposite sides of the world at almost the same time, about 1890. Then there is excitement! Prospectors, miners, and adventurers join in a "rush," ranging over the new district, exploring, finding new outcrops and veins, staking out claims, and sometimes fighting over disputed discoveries, or getting possession of rich claims by theft and murder. That was more common thirty or forty years ago when, in districts like Cripple Creek, prospectors suddenly found gold in very hard rock, left by an extinct volcano. The West was then a new country, and lacking means of preserving order in out-of-the-way places. But times have changed since then. In one of the newer mining regions developed in recent years in a flat desert country, instead of the red-shirted gold-seeker of old days, prospecting is often done by men who work in the mines week-days, and run out into the country roundabout with an old automobile on Sundays and holidays.

In April, 1919, two prospectors in a worn-out "flivver" were bumping over a California road. They were John Kelly and Hamp Williams, the latter a half-breed Piute Indian. Kelly's hat blew off. Williams got out and found it in a small hole which some prospector had dug years before. Picking up some loose rock, he said: "This looks like silver ore to me," and he filled Kelly's hat with the stuff.

"That's the best hat I've got," objected Kelly. "I wish you would use something else for an ore-sample bag—but we'll have it assayed." Thus was discovered California's largest silver mine, the California-Rand, at Randsburg. In its first year it yielded more than $1,000,000 worth of silver.

What One Sees in a Modern Metal Mine

Visiting a modern metal mine, and noting its complicated machinery below and above ground, one finds it similar to a modern factory. Many inventors have helped to bring this mining system to a state bordering on perfection, although there is yet room for the more ingenious inventor. But neither machinery nor engineering science have destroyed the thrill of mining.

As the veins of metal-bearing rock are followed into the mountain, they may grow thicker and richer, or else may taper off and become poor. They may widen out again, or they may stop dead. In many cases where they do stop dead, mining engineers make surveys of the direction in which the veins have been running, and figure that so many hundred feet further on, through solid rock, they may be found again. So they start new tunnels to reach them by the shortest distance. Sometimes the calculations are correct within a few feet, sometimes it is work for nothing. On the other hand they may run into an entirely new vein. In this and other ways men still find thrills a-plenty in mining, and there will be thrills as long as we are willing to pit our technical knowledge and fortitude against the secrets held by Mother Earth.

Let us investigate what engineers call the "non-ferrous" mining industry, the mining of metals other than iron, that is, gold, silver, zinc, copper, lead, tin, and the like. Iron mines are described in the chapter written by L. W. Spring, and the great coal-mining industry in the chapter by Floyd L. Darrow. To start with we must put on "digging clothes"—hobnail boots and khaki—because we are going to walk maybe miles through dark tunnels, climb ladders, pick our way through great boulder-floored caverns, and ride up and down from one level to another in "cages"or "skips," as the mine elevators for raising ore are called. Once we would have carried candles or lanterns, but to-day the mine superintendent gives each of us a dazzling little acetylene lamp, or an electric torch. We follow him into the mine. It is dark in a moment, and we are lost in the mazes burrowed through the mountain. Great timbers support the enormous weight above our heads. As miners tunnel through, the rock and earth above must be supported by timbers, for which reason the lumberman finds the miner one of his best customers. In time, deserted tunnels cave in, and are thus closed by nature. When all the ore has been taken from a particular tunnel, the miners fill it with the rock blasted out in tunnelling or getting ore, from immediate parts of the mine, and this saves hauling such unprofitable material to the surface.

We dodge cars of ore hauled by mules or electricity, follow pipes carrying the compressed air for the drills, and presently come to a place where the miners are drilling into the ore itself. There are great piles of broken ore behind them, waiting to be carried out. Climbing over this broken ore, we come right up to the "face" of the vein itself. It may be like ordinary rock, or it may glisten and shine.

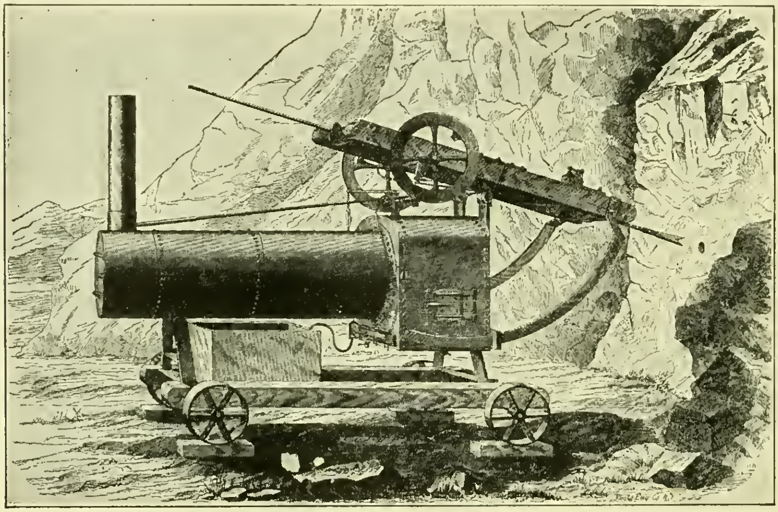
"Just look at that ore!" exclaims the superintendent, "Go right up to it—why, that's good enough to eat!"

But for all we know they might be building a subway or driving a railroad tunnel, and it is difficult to see where the vein ends and the rock begins. Metal mining is just subway and tunnel-building, with a little difference. When the subway or tunnel is bored, the work is practically done; but in mining it is never done until all the ore has been taken out. If all the miles of mine-tunnelling could be used for subways, there would be enough constructed every year to give subways to most of our cities.

It was for driving railroad tunnels that inventors devised much of the machinery used in metal mining to-day. If you are driving a tunnel through a mountain to carry railroad passengers for many years, the quicker you can get the job done and begin earning money, the better; in this case, cost is less important than speed, and for that reason expensive new machinery was first tried on railroad tunnels. But if you are driving a tunnel into a mountain merely to take out metal, cost is the big thing, not speed.

THE INVENTION OF POWER DRILLS AND HOW THEY EAT THROUGH MOUNTAINS

The tunnel job that did most for mining was the building of the Hoosac tunnel, in Massachusetts. It was not a fast job, because work began in 1850, and twenty-five years passed before the first train ran through. In the first fifteen years, much of the work was done by hand, holes being drilled in the rock with tools held and turned by one man while another struck them with a sledge. Later, the rock was blasted out with black powder.



THE FIRST POWER ROCK-DRILL.

J. J. Couch, of Philadelphia, in 1849 patented the first power rock-drill ever made in this country. With the aid of J. W. Fowle it was developed so that it played a conspicuous part in driving the famous Hoosac tunnel in 1867. The drill was operated by steam, and it struck a blow every second.

The year before work on this tunnel was commenced, in 1849, J. J. Couch, of Philadelphia, had invented a power rock-drill, operated by steam. Evidently he did not make it work at the outset, but with the help of J. W. Fowle, a Boston inventor, it was brought to the point where the Hoosac tunnel builders began to use it in 1867. It struck a blow every second, five to ten times as fast as by hand. Couch and Fowle built their drill in the railroad shops at Fitchburg, Massachusetts, where a machinist, Charles Burleigh, helped them. Burleigh made several improvements, and he finally bought it from the inventors, began to manufacture it, and called it the Burleigh drill.

Other inventors then started experimenting, among them Simon Ingersoll, who invented a power rock-drill in 1871. He was known as a mechanical genius. One day a contractor commented on the ruinous delay of much rock cutting:

"Ingersoll, you have done a good deal of inventing. I wonder whether you could invent a machine to take the place of hand labor in drilling rocks?"

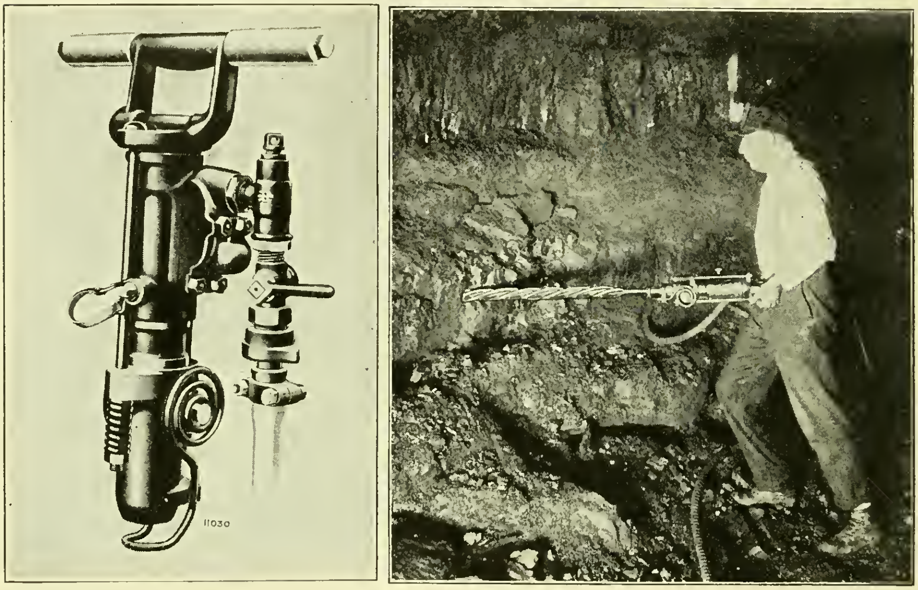
Ingersoll thought a moment, then replied: "I think I see a way by which I can make exactly what you want—a machine driven by power which will drill holes rapidly in rocks."

"That's it!" said the contractor. "And if you show me a model that successfully works, I'll give you $100."

In two or three weeks, Ingersoll had built not only a model but a drill ready for work which met every test. A few improvements were made, but the fundamental idea of Ingersoll's drill is still used to-day.

Even before the Hoosac tunnel was finished, miners began using the steam drill in Colorado. Gold had been found there in the fifties, and had been mined with pick, shovel, and hand-drill. In 1879, the discovery of silver-lead ore at Leadville started the great Colorado silver-mining industry. Power drills were needed to mine this kind of ore profitably, and inventors turned to the mines for their customers. Men like Ingersoll, A. C. Rand, George Githens, Henry C. Sergeant and others made mine drills that were operated with compressed air instead of steam. They also made them small enough for one man to operate, and made the drill turn while running. Rand's drill, invented in combination with George Githens, was used in the copper and iron mines of Michigan, in 1875, and it drilled the Hell Gate obstruction in the East River, opposite New York City for the great blast that cleared it away in October, 1885. Sergeant invented a drill between 1873 and 1878, which was used in driving many Western railroad tunnels, as well as in mining.

One of the leading inventors was J. George Leyner, a Colorado machinist, born and raised in mining towns. He began by repairing miners' drills, and then proceeded to improve them. Eventually, about 1897, he made the first "hammer drill," in which the piston moved up and down, striking the drilling tool, instead of being attached to it. The drilling tool was hollowed, so that water or air could be pumped through while it was working and the rock dust cleaned out of the hole that was being drilled. From this, inventors have gone on to smaller and smaller drills, until to-day tools of that kind are used for rivetting, hammering, chipping, and many other odd jobs. There are also drills operated by electricity.



LEYNER JACK-HAMMER

(Left) The modern jack-hammer was invented by J. George Leyner, a Colorado machinist, in 1897. In the jack-hammer the piston acts as a hammer. It is not attached to the drill but strikes it. The drill is hollow, so that water or air can be pumped through it to clear away the rock dust.

(Right) The jack-hammer equipped with an auger for drilling horizontal holes.

Working with hand tools, a miner could drill from one to two feet an hour, striking fifteen to twenty blows a minute. One of the latest power drills, striking 1,750 blows a minute, and operated by one man, will bore holes in granite at the rate of eighty feet an hour. Mining journals constantly report broken records. In a British Columbian mine not long ago, 932 feet of tunnel, measuring seven by nine feet, was bored through in a month. A crack crew of miners will bore their way through rock, driving a round hole, eight or ten feet across, at the rate of a foot an hour, including all the blasting and hauling out of broken rock—the "cycle," as miners call it.

Power drills have proved so effective that much now depends upon the machinery by which their cutting tools are sharpened. A rock-drill is a rod of very hard alloy steel, with a "bit" formed on its cutting end. These bits differ in shape according to the work to be done, but a common one is that of a cross. The cutting tool strikes the rock hundreds of times a minute, and is constantly turned to strike a new place, beating rock to powder, which is blown or washed out so that the bit may always strike clean rock. The drills are not sharpened by grinding, but heated white hot and new cutting edges formed by hammering. When bits were sharpened by hand, it was hard to make them true, so that in fast work they cut a crooked hole, and sometimes stuck. Also, if a miner wanted a deep hole one inch in diameter to hold his blast, he might have to start a three-inch hole, then work farther down with a two and a half inch drill, and finally finish with one inch. Much of the force of his explosive was lost in such a hole. With more accurate drills, not nearly so large a hole is needed at the top. Machines for sharpening drills make cutting edges of great accuracy, forming them with dies, and the blows of a power hammer, thereby doing the work much faster than is possible by hand, and more cheaply. Thus a better supply of drills can be kept ready for the miner.

Inventors are now intent upon tunnelling machines which, with many drills, will cut either holes in a circle for blasting, or hammer the whole face of the tunnel, eating their way bodily into rock. The first recorded machine of this kind was made for the Hoosac tunnel, in Boston, in 1851, to cut a circular groove in the face of the tunnel thirteen feet in diameter, and twenty-four inches in depth by revolving cutters. The machine was abandoned after cutting only ten feet. Other tunnelling machines have been built for penetrating earth and soft rock. The Beaumont, an English invention, patented in 1864, has a record of more than fifty feet per day. The Brunton tunnelling machine, patented in 1868, and used in the chalk formation under the English Channel, had a system of cutting disks which bored a seventeen-foot tunnel at the rate of two and a half feet an hour, but its inventor died before he could develop and place the machine on the market. In recent years inventors have been unusually active in this field, but have as yet given the miner no practical tunnelling machine, that is, one that will cut its way through hard rock.

Dynamite, the Miner's Cheap Hired Man, and Its Inventor

At the time Burleigh's drill was used in the Hoosac tunnel, a more powerful explosive supplanted black powder. It was known as nitroglycerine, discovered in 1847, by A. Sobrero. But it was an oily liquid, and very dangerous to handle. In 1867, a Swedish chemist, Alfred Nobel, whose father was a nitroglycerine manufacturer, learned how to make it safe to handle. He soaked the explosive in earth or wood pulp, forming a cartridge and thus giving dynamite to the tunnel builder, and soon after to the miner. Dynamite is the strong, cheap hired man of the miner, the engineer, the contractor, and even the farmer. Nobel also invented blasting gelatine by mixing nitroglycerine with collodion. After making millions of dollars out of explosives for peaceful work, Nobel, of pacifist tendencies, feared that the products of his genius would be used in war. So upon his death, in 1896, he left a fortune of over $10,000,000, the interest of which is distributed in prizes every year to men who have contributed most to the benefit of mankind during the previous year.

What did man do without explosives? He used his head more than people suppose. He learned to build a hot fire against an ore vein, and then douse it with water, a procedure that usually cracked off a lot of ore. If he mined in a cold climate, he poured water into cracks in the rock; the water froze, expanded, and broke off ore-bearing rock. Another of his methods was to drive soft wooden wedges into cracks, and on soaking these wedges with water the rock was broken off as they swelled. With one blast of powerful explosive to-day, the metal miner breaks up ten to twenty-five tons of ore, an amount which would have taken several days to smelt before the dawn of dynamite. In the silver and copper mines of South America there were hundreds of Indian ore-carriers, who, carrying the ore on their backs, climbed notched poles out of the mine long before Columbus discovered America. This they do to the present day in many of their mines. But in modern metal mines of to-day, there is wonderful hauling and hoisting machinery to do all this back-breaking work.

How the Ore is Separated

What miners call "separation" is getting the metal out of the rock after it is mined. The first method was to build a fire and achieve "separation" by melting, but the ore had to be rich for that. Modern methods permit metal to be taken out of ores that are very "lean." Fire would never melt it out cheaply enough; instead, water does the extraction on the same principle as did the old California gold miner's pan. On an enormous scale, machinery washes out the lighter dirt and rock. The ore, if in solid rock form, must first be ground to dust, so that the particles of metal may be separated by water. This system yet remains a great field for inventors.

The Egyptians and Romans had crude ways of pounding gold-bearing rock, keeping thousands of slaves at that work. They invented the first stamp mill; a stone mortar with an iron pestle, to break the rock. Somewhat better stamp mills were used in Germany in the fifteenth century, and in the famous mines of Potosí, Peru, in the sixteenth century, where the first stamp milling in the western hemisphere was done.

But the discovery of gold in California marked the real beginning of "separation." A crude stamp mill had been used at Tellurium, Virginia, in 1865, and later others appeared in Georgia. With labor costly in California, machinery was clearly needed for crushing. One of the first mills there was built by William S. Moses, who brought his knowledge of ironwork from Georgia. These early stamp mills were run by water power. California, with its huge mining industry, stimulated inventors, and men like C. P. Stanford, J. Fish, J. Wheeler, and H. B. Angel mechanically improved the stamp mill during the fifties and sixties, developing a machine which has come to be known as the "California mill," the stamp mill of to-day. Emulating the Egyptian slave, it picks up a weight and drops it, crushing the ore. The modern mill has many stamps, often of great weight, which are lifted and dropped by ingenious cam mechanism, designed to reduce wear and to increase the crushing effect, and run by water-power, steam, or electricity.

Different kinds of ore have to be powdered in different ways, and as ores get leaner and leaner, they must be ground finer. Men have built almost every kind of machine to do this work: pounding, crushing, and rolling-machines, also great steel cylinders in which ore is placed with a lot of flint pebbles or steel balls, or bundles of steel rods that roll over and over, finally pounding it into dust. Usually, this grinding is done with a series of machines, one kind breaking the ore into small bits, another reducing it to sand, and the last one making it so fine that, ground to powder, it can be sucked out of the mill by vacuum, like dust out of a carpet.

For many years California gold ores were rather crudely ground in stamp mills, and washed over tables where mercury caught the gold particles and held them in an alloy. Mercury, among man's oldest metals, is also called "quicksilver," because it is liquid until brought down to nearly 38 degrees below zero, Fahrenheit. It is really a metal in molten condition at ordinary temperatures. The ancients were familiar with mercury at least 700 years before Christ, and they learned that it had the peculiar quality of mixing with many other metals without their having to melt them. Mercury dissolves gold, silver, copper, tin, lead, and other metals when it touches them. The ancients used it to catch gold in much the same way as the California miners did, later. They also dissolved gold in mercury for gilding. Putting mercury that had caught gold into a bag of chamois or canvas, they twisted and squeezed the bag, forcing the liquid mercury out through the fabric, leaving the gold inside. The California miner used this method, too. The use of mercury to catch gold is called "amalgamation," and for centuries it was the only gold-recovering process known, with the exception of simple washing. Then, inventors developed ways of doing the work better with chemicals. Where the ancients were satisfied with an extraction of forty to forty-five per cent. of gold and silver, the chemist got ninety per cent.

CHEMISTRY AIDS SEPARATION

Chlorination, by which the power of chlorine gas was utilized to turn metallic gold into a chloride, after which it was dissolved out of that chemical by water, was applied by a German, C. F. Plattner, in 1848. An Englishman named Percy made the same discovery in 1849. The process consisted in grinding the ore to dust and then roasting it in a furnace, a procedure that turned all metals other than the gold or silver into oxide. The chloride failed to affect either the gold or silver, which rare metals were then washed out by water.

A better system is the cyanide process, developed in South Africa to extract gold from stubborn ore that could not be profitably treated either with mercury or chlorine gas. In the Middle Ages it was known that cyanide of potassium would dissolve gold in water. No way was found to use the discovery commercially until 1890, when MacArthur and Forrest, in South Africa, took out a patent for a cyanide process, which is now employed in gold and silver mining. Ore for cyanide treatment must be ground very fine. It is then put into tanks containing cyanide dissolved in water. The chemical takes up the gold and silver; the rock dust and liquor are separated; and electricity is utilized to make the liquor give up its precious metal. A cyanide plant is a place of enormous tanks, filters, and other contrivances for dissolving gold and silver. The slime of rock dust is easily separated, and tons upon tons of material are daily handled with as little hand work as possible, everything flowing through the different machines like water running down hill.

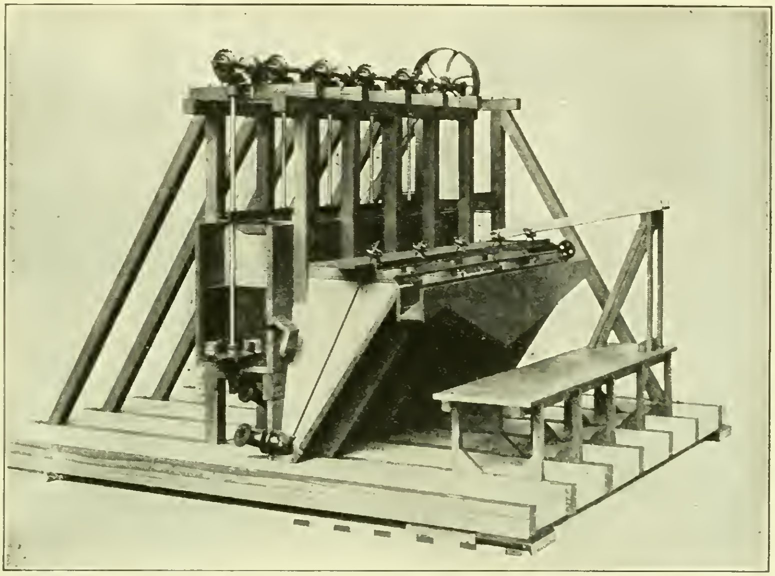
But this would not do for metals like copper, zinc, lead, tin. For years, they had to be separated by gravity—as most of them are to-day. The fine particles of metal are heavier than the particles of rock, with which they are mixed after grinding. This dust falls into a stream of water, and is carried along over separating tables of so many different kinds that one can hardly remember them all after visiting a milling plant. The water with its ore flows from table to table. Each table is jogged up and down or sideways, and its motion causes the heavier metal particles to sink a little lower than the rock dust, which flows one way, while the metal is caught against ridges and flows another. Each table catches some of the metal, and what particles get away are partly caught by the next table, and so on, until, water separation having done its best, the residue flows away to the dump.

Miners, however, knew that there was still wealth in the dump, if they could only get it out. There it lay, after all the work of mining the ore and grinding it up. If some new process could be found, the stuff was ready for the mill, with no more expense for mining or grinding.

Then came the latest marvel of metal mining, a process called "oil flotation"; also the "frothing" or "bubble" process. A great costly dispute has grown up about its invention, and scientists also disagree in trying to explain how it works. By this process, copper, zinc, lead, gold, silver, molybdenum, graphite, and other minerals are extracted or separated from 60,000,000 tons of ore a year in this country alone. In water separation, the fine particles of metal sink because they are heavier. In oil separation they float! Powdered ore is churned with oil and water until a froth is made, and in some miraculous way, the fine particles of metal cling to the oil bubbles by what scientists call "surface tension," and are lifted and floated away as though they were clinging to a life-buoy. The particles of powdered rock do not cling to the bubbles. Surface tension is the force that enables insects to run on water, and a needle to float on water. It is a kind of skin; an intangible skin of force.

Many kinds of oil are used. The process was first developed on a large scale in Australia, and oil from the eucalyptus trees of that country did the work. The United States is a petroleum country, and when oil flotation was introduced here, mineral oils and some vegetable oils, such as are obtained from the pine-tree, in making turpentine, were found satisfactory. Different oils work best with different metals and different ores. Naturally, the cheapness of the oil is an important point; for although a pint of oil, by its wonderful bubbles, treats many tons of ore dust, the quantity required to treat millions of tons may run into a great deal of money.

A woman had a hand in this invention. She was Carrie J. Everson, of Denver, Colorado, a doctor's wife, and she took out a patent in 1886. While washing some oily ore sacks, according to one story, she noticed that oil would stick to metal particles and float them. Another account says that she made this discovery by laboratory experiments. Herodotus, the Greek historian, knew that oil would float particles of metal, and, like him, Mrs. Everson neglected to make a working process out of the discovery. Before she washed those ore sacks, and since that time, other people had noticed this action of oil upon metal particles—so many of them, in fact, that great lawsuits have been fought over the matter. Oil flotation



Courtesy South Kensington Museum, London.

SECTIONAL MODEL OF A FROTH FLOTATION PLANT.

This is a method of ore concentration of rapidly increasing importance, whereby metallic sulphides in an ore pulp are separated by flotation. The method is based on the property that certain sulphides have of selectively attracting oils and greases, hence the mineral particle becomes surrounded by an envelope which lowers the specific gravity on the whole sufficiently to render it capable of floating on water.

really went to work for the metal miner when it was found that the bubbles were even more important than the oil, and some people think "froth flotation" a better name than "oil flotation." Oil flotation was first actually used on a working scale at a mine in Wales, by Francis E. Elmore, in 1899, and he patented his process in 1901. Its first use on a large scale was in Australia, in the famous Broken Hill mines, where three English inventors, H. L. Sulman, H. P. Picard, and J. Ballot used a process which they had patented in 1905, by which they extracted eighteen per cent. of zinc and seven per cent. of lead from 12,000,000 tons of mine waste. About 1910, it was introduced into the United States. Used in the same way, it recovers from mine dumps the metal thrown away in days of cruder methods, and extracts as high as ninety-eight per cent., from freshly mined ore.

Finding Wealth in Other Generations' Leavings

A fascinating trend in modern mining is to get wealth out of other generations' leavings. Inventors are constantly studying its accomplishment. Ancient miners rejoiced if they got even half the metal out of ore or gravel, but a few generations after they were dead and gone, other men, better miners, would work over their heaps of "tailings," and get more metal. The Romans mined silver on the island of Sardinia, leaving great piles of waste behind. Balzac, the French novelist, was told about these mine dumps by an Italian merchant, and dreamed of getting rich by extracting the silver the Romans had left. But before he could go to Sardinia, the merchant, taking the hint, got the right to work over this mine refuse. It yielded ten per cent. of lead, and there was ten per cent. pure silver in the lead. To-day, oil separation might make it profitable to work over that refuse again.

In brief, this is the story of mining everywhere. First, the loose metal lying on the ground is picked up, then the richest veins are found and worked, then those not so rich, until a time comes when man must use all his wits, inventing ways to work leaner and leaner ores. This happened in our own Western country. Finer and finer grinding, better and better separation were needed every year until, toward the close of the nineteenth century, methods had been brought to a point where an American mining genius stepped in and did a startling thing. Daniel C. Jackling, whom mining engineers declare to be more of a manufacturer than a miner, decided that, instead of digging into a mountain and following a vein of metal, he would pull a whole mountain down and grind it up. Out in Utah there was a whole mountain of porphyry rock which contained a very small proportion of copper, two per cent. and even less. There was a lot of it in the mountain, however. Jackling proposed to clear away or "strip" the thirty or forty feet of earth off the top of the mountain, drill down into the rock and blast it to break it up into sizeable lumps, shovel it onto railroad

Courtesy United States Bureau of Mines.

GENERAL VIEW OF UTAH COPPER COMPANY'S MINE.

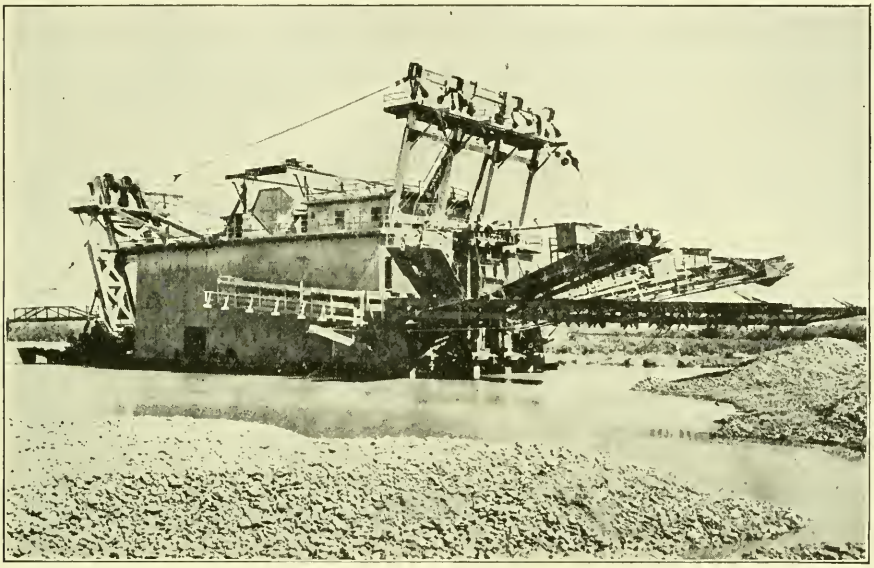
This is one of the large porphyry mines of the United States. The mine owes its existence to the daring and energy of Daniel C. Jackling. The mountain in the picture is composed of porphyry rock containing two per cent. and less of copper. Jackling conceived the idea of tearing down this mountain and grinding it up into powder from which this almost infinitesimal percentage of metal is recovered.

cars with steam shovels, and then grind and separate the copper on an enormous scale. It took several million dollars to build a railroad and an ore mill, but it paid in the end. Mining began in 1904, and Utah Copper has been so successful that other great porphyry copper mines are being similarly worked in this country and South America, as also is gold ore in Alaska, so lean that profit means the difference of ten and fifteen cents a ton in the gold recovered as it passes through the mill. Jackling was once asked what had given him the most satisfaction in his career, and he answered in figures, saying that when he began pulling down his first mountain, all the copper mines in the United States produced 900,000,000 pounds of copper a year, while to-day the low-grade mines alone, if those in South America are counted too, produce more than that.

One would think the limit had been reached in this sort of mining. Yet, still more wonderful is the gold-dredging method of placer mining, where a ton of rock and dirt is sorted over to get less than ten cents' worth of the precious metal. Placer mining is limited mainly to gold and platinum. Most metal mining is done by piercing mountains or tearing them down. Placer mining deals with mountains that were torn down by nature herself ages ago, carried away by rivers, and heaped up in gravel beds. Sometimes these beds have rich deposits of gold on top of them that men can wash out by hand. But the rich top soil is soon worked, and it takes mighty machinery to go through the many feet of gravel beneath, gravel that bears only a trace of gold to the ton. Gold may be found all the way down to depths of fifty or a hundred feet, and even more. It is possible to build dredges that will bring it up from such depths, but below sixty or seventy feet these machines must be so big and costly that it would probably not pay.

This kind of mining has its prospector. He is not like the prospector who seeks mineral veins in the mountains. In this case, prospecting is done by a crew of men and horses with a well-drilling machine. They go to an old river bed, where gold has already been found, and begin drilling holes about six inches across, and examining the gold found in each foot of ground as they go down to depths of twenty-five or fifty feet. They are thus able to find where there is gold enough to pay for dredging, and also to reject ground where rocks and boulders would make dredging too expensive, if not impossible.

The gold dredge is then built in. It is a great barge or scow, sometimes of wood, but more often steel, upon which is erected machinery for turning an endless belt of massive steel buckets. Through the West where there is plenty of water-power, electricity—generated by a waterfall—is used to run the machinery.



Courtesy United States Bureau of Mines.

THE YUBA GOLD DREDGE.

Huge dredges, such as this, make it profitable to dig up the soil of ranches and orchards in California in order to recover a few grains of gold in a ton of dirt. The gold dredge is a great barge or scow upon which is erected machinery for driving an endless belt of steel buckets by which a steady stream of material is dumped on separating screens. A complex system of riffles and sluices then separates the gold. Such a dredge may cost $600,000. Profit means the difference of ten or fifteen cents a ton in the gold recovered as it passes through.

Gold dredges were first tried, with success, in New Zealand as early as 1865, and steam-shovel dredging was attempted in California as early as 1888. The first successful gold dredge in this country was used on Grasshopper Creek, Montana, in 1894. At first, "spoon" dredges were used, iron spoons weighing a thousand pounds, at the end of a long pole, being dragged along the river bottom with rope and windlass. The dirt they brought up was washed by hand in rockers. Modern dredges have huge steel buckets in an endless belt, an idea first used by an inventor named Scott, in New Zealand, in 1882. The first successful dredge in this country, a bucket-lift dredge, was used in Montana. California quickly developed gold dredges. The first California Yuba dredge—so called after the place where it was first tried—cost $25,000. The biggest and latest dredge to-day costs $600,000.

The dredge is a boat, but it does not need a river to float in at the beginning. Almost any creek will do. It is brought to the spot in pieces, and set up on dry land. When ready, it reaches out and down to the ground, and begins digging a hole with its line of manganese steel buckets, each weighing two to three tons. The dirt and stones are piled up to make a dam behind it, and before long the water from the creek has filled the hole, and the dredge is afloat. After that, it can go anywhere through dirt or gravel by simply digging its own channel.

These dredges handle dirt and gravel at a cost as low as two cents a ton. Their buckets bring in a steady stream of material and dump it upon screens. The big stones are fished out, then the smaller ones, until finally nothing but the gold-bearing sand is left. That goes to a complex system of riffles and sluices, where quicksilver catches the almost invisible particles of the rare metal. With electricity for power, a big dredge can be operated by only four or five men, and in a region large enough for profitable gold-dredging, may have twenty or thirty years' work ahead of it. Very often it strikes a place where trees had grown over the ground, and then men are sent ahead to cut them down.

Placer mining, both by giant streams of water and dredges, at first left the ground so tossed and tumbled with stone piles and boulders that, although the soil was fertile enough in the beginning, it was useless to the farmer who might come later. This led to so many complaints against placer mining that now the latest gold dredges have "stackers" similar to the stacker of a threshing machine, that carry off the gravel and dirt, and spread them evenly behind as it slowly moves along. In this way the incoming farmer finds the soil ready made for him.

Gold is the chief metal secured by dredging, but machines also bring up small quantities of platinum and other scarce metals, and have even been used in tin mining. A gold dredge in Brazil was found to be on diamond-bearing ground, which set the dredgers excitedly watching for precious stones amongst the pebbles sorted out. Diamonds were first found in river beds, then traced back to the "pipes" of earth and stone where they had come from, and these "pipes" are developed as diamond mines. For several centuries diamonds had been found in the streams of Brazil, but no prospector ever followed them up. Not long ago an American geologist showed that Brazil has diamond pipes just like the famous ones in South Africa.

The Scientist Aids the Miner

The geologist believes that his science will be most important in the mining of to-morrow. Already, this is being proved correct. The inventor gave the miner marvellous machinery for getting ore out of the ground and extracting its metal. The engineer brought steam-shovels and railroads on the job, making it possible to mine on an enormous scale. The chemist has helped with his cyanide and other processes, among which is the interesting "tin can" process, used to take copper out of mine water. It was learned that water pumped from the great copper mines in Butte, Montana, contained copper which would be valuable if there were any way of getting it out. Chemists knew that water liked iron better than copper, and that when iron was put into water carrying copper, it would drop the copper and take away the iron. So the water from these mines is pumped into great troughs in which old scrap iron—anything from a battered tin can to a discarded steel rail—is dumped. Little by little this old iron changes into a soft, rusty-looking substance, which is later turned to copper metal by heat, at the copper smelting plants. The water drops copper worth fifteen to twenty-five cents a pound, and takes away old iron worth perhaps a cent.

Much of the metal won from ore must finally be smelted and refined, for it is usually mixed with impurities or other metals. This is done at smelting plants, far from the mine as a rule, because the metal dust, or "concentrate," washed out of rock dust, can be hauled long distances. Some metals, such as lead, silver and zinc, though mixed together, are separated by heat, for they have different melting points: lead, 621 degrees Fahrenheit; zinc, 787 degrees; silver, 1,761 degrees. There may be very small amounts of other metals mixed in copper, such as gold, silver, or platinum. These are too small to melt out, so they are extracted by electrical refining, in which the crude copper pig from the smelter is used as an anode in an electric battery, and, gathering on the cathode as pure copper, drops its gold, silver, platinum or other metals in the battery solution from which they are afterward recovered.

The geologist feels that his science will take out of mining many of the failures, losses, and false moves. Studying the rocks as nature has placed them around the world, he believes that he has learned how some of the valuable metals are put away in her storehouse; in other words, he knows where to look for the needle in the haystack. Investigations are constantly being made by government scientists connected with the United States Geological Survey and Bureau of Mines, as well as government scientists in other countries, to discover general principles for mining engineers to follow.

Geology is a new science, hardly a hundred years old. Mining geology is even younger. Thirty or forty years ago miners paid little attention to geology, and geologists could tell them almost nothing about mining. But by studying the arrangement of different kinds of rocks, and observing how nature places metals in them in the same way in different parts of the world, gathering a great many facts, and putting two and two together, the geologist is already able to aid the miner with truly scientific knowledge. He cannot yet say positively that one mountain contains copper, and that it will be a waste of time and money to look for copper in another. But he can say with probable accuracy, that a certain mountain contains copper, that it is likely to be found in a certain kind of rock running through the mountain, and that it runs in such and such directions because the mountain was built in such and such a way. Already he has learned enough to know that mining can be made a science instead of a gamble, and its development on scientific lines depends upon gathering still more facts, and learning the lessons that facts always teach when they are studied intelligently.

CHAPTER III

STRIKING OIL

CUT off the petroleum supply of the United States to-day and what would happen? Automobiles would stop running; airplanes would cease to fly; thousands of motor-boats would lie idle; many hundred thousand stationary engines on farms and in factories would stop; whole industries dependent on fuel-oil would collapse; almost half our homes would be in utter darkness; freight and passenger trains and great ocean steamers, all lubricated with oil, would turn neither wheel nor screw. No revolution could possibly prove so calamitous as the stoppage of the world's petroleum supply, yet only a little over a generation ago there was no such thing in the world as an oil well.

In India crude petroleum has been burnt for 2,000 years, smoky and foul-smelling. Even with a natural supply at hand the natives preferred to burn fish oil in their lamps until they obtained refined petroleum from the United States. Both ancient Greece and Rome knew something of petroleum, but utilized it only in its solidified form, asphaltum, as a cement or mortar for bricks. Indeed, nearly all the ancient people had stumbled on petroleum. It was left for keen, inquiring Americans of the past generation to develop its possibilities. Before the coming of petroleum the United States burnt candles or whale oil. Whaling ships, fitted out in New Bedford and other New England ports for voyages of one, two, or three years' duration, killed thousands of whales and brought back many thousands of barrels of whale oil and fine sperm oil. Sperm oil was the best lamp oil, and sperm candles were found in every home. A time soon came when whales ceased to be plentiful. A substitute for whale oil was demanded, and scientists and inventors produced, among other compounds, a mixture of turpentine distilled from pine sap and alcohol and called camphine.

How Kerosene Received Its Name

With such a scarcity of whale oil it was but natural that in 1847 James Young, of Glasgow, Scotland, began his successful experiments in utilizing distilled oil from coal. But oil was not enough. Where was the lamp that would burn the oil? In the United States Doctor Abram Gessner, a skilled chemist, had manufactured oil from coal even a year before Young. In 1854 he patented an improved illuminating oil, which he styled "kerosene," a name for which he secured trade-mark rights. "Coal oil" was the name by which illuminating oil was long sold, but later Gessner's name, "kerosene," was applied to refined petroleum used for lighting. Gessner's kerosene was a fine product for its time. It could not be sold nowadays; for it smelled to heaven.

How The Indians Obtained Petroleum

Who discovered petroleum in the United States? Tradition has it that centuries ago a Seneca Indian squaw dipped her blanket in the Pennsylvanian stream now known by the suggestive name of Oil Creek, in the vain endeavor to transfer to it the brilliant, iridescent hues of the floating petroleum. Although the blanket did not assume the desired color, it did absorb the oil from the surface of the water, and this the red woman squeezed out and found useful for other purposes. Pits were dug by the Indians and timbered with rough-hewn beams and posts. In these pits the oil was stored—the first practical storage of petroleum in America. Some of these old Indian pits are still in existence. Nor was it long before the palefaces copied the Indians, dug pits and soaked up the oil by the same crude blanket method. Two men working together, gathering the oil and wringing it out of a blanket, would harvest perhaps a barrel of oil a day. For many years this product, duly bottled and labelled "Seneca Oil," "Indian Oil," or "Snake Oil," was sold by druggists for both internal and external use as a cure for all ailments. The real value of the oil was curiously overlooked. Perhaps George Washington had a clearer vision of petroleum's possibilities than his contemporaries. The "oil spring" which he found in western Virginia was commended by his last will to the special consideration of his trustees.

As early as 1790 great numbers of salt wells were sunk in the United States, especially along the western slopes of the Allegheny Mountains. The brine was pumped up and then evaporated into salt. Many of these wells had to be abandoned because they produced not only salt water but petroleum, then considered a mere nuisance. To-day the exact opposite is true; many oil wells are invaded by brine and ruined. At Little Renox Creek, near Burkesville, Kentucky, in 1829, the attempt to sink a well and secure what was expected to be an inexhaustible supply of brine resulted in the striking of a genuine oil gusher. Consternation and disappointment reigned among the owners of the well. They saw vast quantities of oil pouring into the Cumberland River. This was America's first "gusher," but not the slightest practical use was made of its oil.

Ferris, the Oil Pioneer

The eyes of America were opened to the possibilities of petroleum by Colonel A. C. Ferris, a man of some wealth and of enormous energy. He did as much as any pioneer to introduce and popularize petroleum, to perfect a process of refining it, to rid it partially of its vile odor, and to perfect lamps in which it could be burned.

When Ferris was a fourteen-year-old apprentice in a New York store streets were lighted by whale-oil lamps. In the store in which he worked camphine was burned. Colonel Ferris went to California when gold was discovered there in 1849, but 1850 found him back in the city of New York. One day in 1857, when he happened to be in Pittsburgh, he saw a tin lamp in the wholesale drugstore of Nevin and MacKeown; it burned petroleum obtained as a by-product from the salt wells at Tarentum on the Allegheny River. The lamp was primitive; the stench that rose from it was well-nigh unendurable; but the oil immediately engaged Colonel Ferris's attention. Then and there he decided that a way must be found of refining the oil, of ridding it of its foul odor. A fire which destroyed his first experimental plant also showed him the need of an oil which would not explode easily. He employed a competent chemist and carried on extensive experiments in his laboratory, finally producing an almost odorless as well as a "high-test" oil, which means an oil that will not ignite too easily.

His faith in the new illuminant was always unbounded. By 1858 he was devoting himself entirely to the work of perfecting the oil on a commercial scale and introducing it. But before accomplishing all this he had to overcome many obstacles. He first established himself at 184 Water Street, New York, but the smell of the oil caused such complaint that he was obliged to remove to 191 Pearl Street. He had his troubles in selling the new oil. With a lamp in one hand and a can of oil in the other, his canvassers entered the shops of dealers and exhibited the light, counting themselves fortunate if they were allowed to send a few gallons of the oil and a half-dozen lamps, to be paid for when sold. There was much blundering in handling the new lamps, and often Colonel Ferris was called upon to pay for oil-stained furniture and carpets. Persistent canvassing and advertising spread his fame abroad. He was so beset with visitors that he had to employ an assistant to receive callers and answer questions. Constant improvement of both lamps and refining process finally won for the oil some popularity, so that before long the problem presented itself of obtaining enough crude oil to meet the demand.

Ferris bought his oil in regions where the blanket-wringing method was still employed. He heard of J. M. Williams, of Hamilton, Ontario, one of the first oil producers in America, a man who had dug oil wells with pick and shovel on the Eniskellan oil tract in the wilds of Canada as early as 1856. At once, Colonel Ferris posted off to Canada. He bought from Williams oil valued at $2,117 and had it shipped to New York by wagon and rail. Such was the Colonel's faith in the future of petroleum that he returned to Canada later and made arrangements to purchase the whole tract for $26,500. A number of wealthy New York business men promised their financial aid in the transaction. After Colonel Ferris had left, these faint-hearts concluded that he was a mere dreamer, and that it was impracticable to market the petroleum of far-off Canada, whereupon they left him in the lurch with the usual excuses. Instead of giving up hope, Ferris ordered oil from Europe, California, and even the East Indies, although the ships in which it was carried had to double Cape Horn and sail half-way around the world. He met with heartbreaking misfortunes time and time again. Only his conviction that the world would eventually buy and burn petroleum buoyed him up. He bought land at Tarentum, Pennsylvania, on which were oil-yielding salt wells. There a shaft twelve feet square was sunk at a cost of $20,000, but no oil was struck. Undiscouraged he started to sink a well at the bottom of the shaft, hoping to reach oil-bearing rock. Instead of oil he struck a huge vein of water. Work stopped then and there. Had Colonel Ferris happened to dig and drill at Oil Creek instead of Tarentum, he might have been known as the first great oil-well driver in history. As it was, Ferris did succeed in amassing a fortune in oil and died a rich man.

During this same period S. M. Kier sold great quantities of partially refined petroleum for medicinal purposes, bottling, advertising and disposing of it as a wonderful cure for most of the ills to which flesh is heir. His advertisements and his distributing wagons went everywhere. He soon found that the supply of oil was greater than the demand for it as a medicine, and he too reached the conclusion that it would make a good illuminant. Like Colonel Ferris he tried to find a suitable lamp, even offering to pay $1,000 for one which would burn the new oil acceptably.

THE INVENTION OF THE OIL-DRILLING PROCESS

While Ferris and Kier were doing their best to popularize oil, George A. Bissell and Jonathan G. Eveleth, New York lawyers, became interested in petroleum, and in 1854 formed a company to prospect for oil in Pennsylvania. They leased the property on which the famous oil spring of Oil Creek was located, and on which operations had been carried on in a crude way by digging trenches in which oil accumulated. In 1856 a new day dawned—a day which marked the birth of a great idea, the idea of obtaining petroleum by means of wells drilled just as water wells are drilled. It was an obvious idea, and yet it was an accident that made it flash in a man's brain. The man was Bissell. Driven under the awning of a Broadway drug store by the scorching heat of a summer day, in 1856, his eye fell upon a remarkable show-bill in the window lying beside a bottle of Kier's "Medicinal Petroleum." The bill appeared to be a $400 banknote, but when Bissell looked at it closely he saw that it was only an advertisement of the medicine. He stepped in and asked to see the bill. He studied the derricks pictured, and commented on the depth of the salt wells from which the oil was procured. Wells! That was the way to obtain petroleum. Drill wells! If wells could produce salt water with a little oil as a side issue, they could be drilled down into the oil rocks and produce mostly oil. The idea of drilling salt wells was an old one; that of drilling wells for oil was a brand new one, and as later events proved, there were but few people who had any faith in it.

400 A. D. 1848 DISCOVERED IN BORING FOR SALT WATER near THE Bank of the Allegheny River, IN ALLEGHENY COUNTY, PENNS'A. about FOUR HUNDRED FEET below the Earth's surface, is pumped up with the Salt Water, flows into the Cystern, floats on top, when a quantity accumulates, is drawn off into Barrels, is bottled in its natural state without any preparation or admixture. For particulars, get a Circular.

A. D. 1849 Wonderful MEDICAL VIRTUES DISCOVERED.

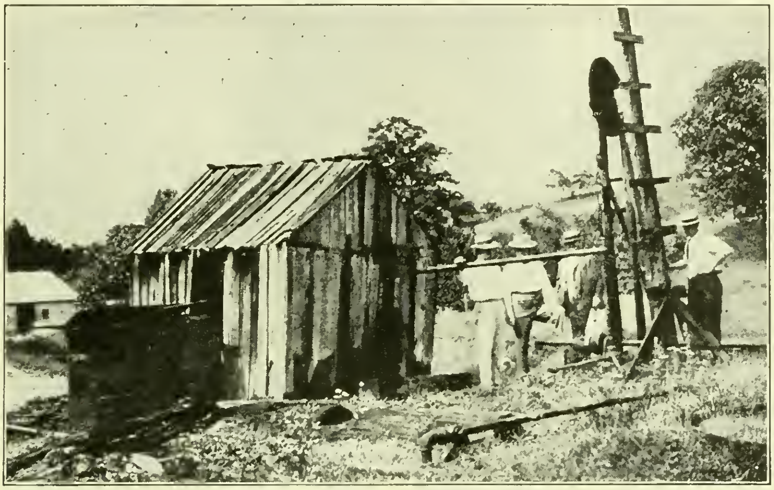
Pittsburgh. Jan. 1st, 1852. 400 S. M. Kier.

THE ADVERTISEMENT THAT FIRST SUGGESTED TO BISSELL THE POSSIBILITY OF SINKING A WELL TO OBTAIN OIL.

Bissell talked to his partner Eveleth about his great idea, and that gentleman saw the light at once. On March 23, 1858, the partners formed the Seneca Oil Company. Its superintendent was Colonel E. L. Drake, who, too, believed that oil was to be found in great underground pools. He arrived in the little town of Titusville on Oil Creek, early in May, 1858, started up the abandoned works of the oil company, and cast about for some one to drill a well. His first step was to dig an open well as deep as he could before beginning to drill, as Colonel Ferris was doing about this time. This was the usual way—to dig an open well to bed rock, and then begin with the drill.

But, like Ferris, Drake struck not only oil but water—such a volume of it that his workers had to clamber out and save themselves. What was to be done? Must the well be abandoned? It was here that Drake's genius asserted itself. He determined to try the scheme of driving an iron pipe through the water and the quicksands and the clay down to rock, and it worked!

This was a real invention—one that might have been patented and that might have made Drake rich. Drake now built a drill-house, ordered an engine, and engaged a driller, expecting to begin boring in September. But the engine was not ready on time, money failed to arrive, and the work had to be postponed for the winter. He encountered other difficulties, among them the lack of transportation facilities, of workmen who knew how to drill wells, and of proper tools.



AN OLD-TIME OIL RIG OF THE TYPE THAT DID SERVICE BEFORE THE DAYS OF COLONEL DRAKE.

In February, 1859, Colonel Drake went to Tarentum and tried to engage drillers. One after another failed him. They had no faith in a man who wanted to get oil out of a well like water. Kier recommended Uncle Billy Smith, who had drilled deep salt wells for him, a man who had been sinking wells since 1828, and who had never broken his word. With his two sons

Uncle Billy began work on May 20, 1859. They drove forty-nine feet of pipe down to bed-rock, cleaned this out, and then drilled down to a depth of sixty-nine and one-half feet on August 28. As Uncle Billy and his boys were about to leave for the night he noticed oil rising in the drive-pipe.

THE ORIGINAL DRAKE WELL.

It was the first artesian well drilled in the Pennsylvania oil region. It was located upon the Watson Flats, below Titusville, and was sixty-nine feet six inches in depth—struck August 28, 1859—and produced twelve barrels of oil per day.

"Look at this," he said to Colonel Drake.

"What does it mean?" asked Colonel Drake.

"That's your fortune coming," replied Uncle Billy.

Then he plugged one end of a rain-spout, attached it to a thin strip of lumber, lowered it into the well and drew it up filled with petroleum.

The news quickly reached the little village of Titusville. When Colonel Drake appeared the next morning, bright and early, he found the old man and his boys proudly guarding several barrels of petroleum which they had drawn up with their improvised dipper. Colonel Drake at once installed a pump—the first petroleum pump—and Uncle Billy and his boys pumped eight barrels of oil that day. To store the petroleum they used an old fish-oil can, which held five or six barrels, and all the barrels and receptacles on which they could lay their hands. No preparations had been made to handle the oil. Even Colonel Drake hardly expected that the well would yield more than a barrel or two a day. Indeed he was more astonished than any one at striking oil so quickly. He and Bissell had fully expected to have to drill down 1,000 feet. He now ordered a carpenter to build a twenty-five barrel wooden tank, and later larger tanks. In the meantime the oil was hauled away and shipped as rapidly as possible. The pump was worked harder, and by October it was yielding twenty barrels a day. But good luck was mixed with bad. On October 7, the tanks and derrick burned to the ground.

"The fire caught from a lamp in my hand," said Uncle Billy Smith. "We were so bothered with people coming to look at the well that we had to put up a big tank-house, and that night I thought the tank was not filling fast enough, and went in to see. I raised the lamp near the tank, and in an instant the whole thing was ablaze. Everything burned up."

But Colonel Drake was not discouraged. "The oil is still there in the well," he said. He immediately built a new derrick, and started pumping again, this time at the rate of thirty barrels a day, a rate maintained for several years.

The First Oil Boom

The news of the "strike" spread like wildfire. Titusville was aflame with excitement, and the country people for miles around flocked in to see the wonderful Drake well. Jonathan Watson, one of the stockholders in Drake's company, jumped on a horse and dashed off to secure a lease on the McClintock farm farther down Oil Creek. Bissell leased farm after farm along Oil Creek and the Allegheny River. Drake took the view that he had tapped the mother oil pool, and complacently kept on pumping oil while others secured leases. Most of the first leases were secured without payment of any money, the lessees agreeing to give the owners of the farms one-eighth or one-fourth of the oil produced. Drake, who was looked upon as the biggest man in the community, could have leased farms on the same easy terms. When several other wells had struck oil his eyes were opened, but too late.

Drake's first well "broke" the oil market—a little stream of oil which would hardly supply a country village to-day. Colonel Ferris now had plenty of crude oil, and he redoubled his efforts to find a market for the refined product. He and others managed to keep pace with the increased production. The old price of $2.00 a gallon could not be maintained, but for some time oil did bring about $1.00 a gallon, or $40.00 a barrel. Two more wells were drilled on the Drake tract, one of which was started on the very day that the Drake well struck oil. Other wells were soon drilled on near-by tracts. The excitement was intense. There was a great scarcity of barrels. Old whiskey barrels, vinegar barrels, barrels of any kind which would hold oil were used. Big pits were dug in the ground and lined with planks to store the oil. One was four acres in extent.

Two years later the first flowing well was struck. It was named the "Fountain Well," and, to the astonishment of all the oil men in the neighborhood, flowed steadily at the rate of 300 barrels a day. Before the wonder of this had subsided the Phillips well on Oil Creek burst forth with a stream of 3,000 barrels a day—a flood of petroleum for that time.

Having amassed about $20,000 Drake left the oil-fields in 1863, went to New York and became a partner of a Wall Street broker in oil stocks, an unfortunate venture that ruined him. His health broke down and he was reduced to abject poverty. When they heard of his plight the oil men raised $5,000 and gave it to Mrs. Drake. In 1873 the State of Pennsylvania, responding to a popular demand, passed a pension act which gave Colonel Drake or his widow a life income of $1,500 a year.

The Early Days of Oil Transportation

As the valleys of Oil Creek and other tributaries of the Allegheny River produced more and more oil, a region which had once been a wilderness was transformed into a scene of extraordinary activity. Thousands of teamsters were employed to haul tens of thousands of barrels of oil to the nearest railroad shipping points, and other thousands of barrels were shipped by water in every conceivable sort of craft. The inventive ability of the pioneer American asserted itself on every hand. Old lumber pilots, long retired for lack of something to do, were routed out to guide rafts of oil on the river. Even abandoned lumber dams found a new use. Oil Creek carried little water, and was navigable only in a flood. The old lumber dams were pressed into a service of which no one had ever dreamed. By their means the water was collected and retained to produce artificial floods once or twice a week. At the appointed time, the dams were opened, one after another, until the little stream had increased to a river. At each landing the stream received its tribute of oil-laden boats, until, after a journey of fifteen miles, the fleet often numbered 500 or 600 boats carrying 20,000 to 25,000, and possibly 40,000 barrels of oil. There was much manœuvring and many a collision as this oil flotilla swept out into the Allegheny from Oil Creek. Later, railroads were built into the oil regions, but for years it was a question whether the oil wells would not dry up and leave the railroads with nothing to transport. At first oil was shipped in barrels, but later tank-cars came into use, and then pipe lines.

There are to-day some 138,000 oil tank-cars, enough to store all the oil which was produced in the United States in 1880. The first tank-car was crude enough. About five years after Drake's well had struck oil Charles P. Hatch proceeded to Oil Creek in order to secure oil for his employers, the Empire Transportation Company. Oil was then shipped over the railroads in barrels. Hatch either conceived the idea of a tank-car, or else saw some kind of a tank-car in use. At his request the company sent him a box-car within which had been built three wooden tanks, according to his plans. He was instructed to use the car with care; for the company was sceptical, and expected to use the car again for ordinary freight. The tanks leaked frightfully. In order to caulk and make them oil-tight, Hatch had to tear off the sides of the car. "Return the car to the merchandise trade indeed!" he exclaimed, as the car was finally filled with oil and sent forward on its trip East. The car looked as if it had been subjected to a cannonading. It was ruined except for use as an oil car. And an oil car it remained, as many of its brothers and fellows have since. Within a few years long lines of tank-cars had taken the place of the barrels formerly seen along the railroad sidings. Indeed, there is now no such thing as an oil barrel, a "barrel" being now simply a measure of oil. The wooden tank-car was subjected to such strain and leaked so badly that within a few years iron tubular tank-cars, not greatly different from the present-day steel car, took its place.

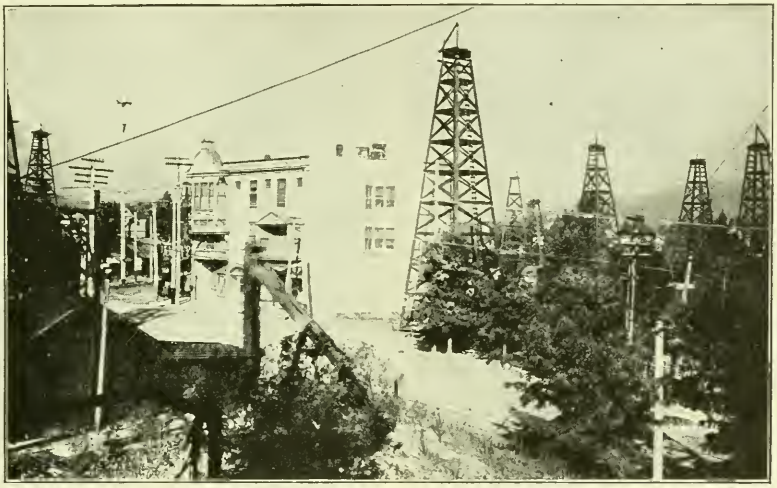
Developing the Oil-Fields of the United States

Up to 1876 oil was prospected for chiefly in what is known as the Appalachian field, embracing the States of Pennsylvania, New York, Ohio, West Virginia, Kentucky, and Tennessee. In that year California became an oil State, with a production of 12,000 barrels, and progressed so rapidly that in 1914 she led all the other States with a production of 99,775,000 barrels of oil. In 1923 her output was 262,876,000 barrels. All told California has produced nearly two billion barrels.

In 1886 Indiana struck oil in quantity, and by 1896 she had reached her maximum annual production of 25,000,000 barrels. In 1887 the Rocky Mountain field, including Colorado, Wyoming, Utah, and Montana, was opened with a yield of 75,000 barrels. The field has not been a very great producer, the figures for 1920 being 17,000,000 barrels. In 1889 a few hundred barrels of oil were produced in Illinois, but not until 1905 was oil really "struck," when 180,000 barrels were produced, followed by a rush that resulted in an output of 24,000,000 barrels in 1907.

The great mid-continent field, embracing Oklahoma, Kansas, and parts of Texas and Louisiana caused perhaps the most intense excitement of all. In 1889 a well or two was drilled, and a year later the field produced 1,200 barrels. For twelve or thirteen years the output was small, but in 1905 new discoveries brought forth 12,000,000 barrels. Oil men flocked to the region. By 1916 the production was 136,000,000 barrels. In 1922 it was 249,000,000 barrels, Oklahoma alone producing over 100,000,000 barrels.

The Gulf field, comprising coastal Texas and lower Louisiana, was another late discovery. In 1899 the output was only 530 barrels, but in 1900 nothing. In 1901 it amounted to 3,500,000 barrels, and 1902 to 18,000,000.

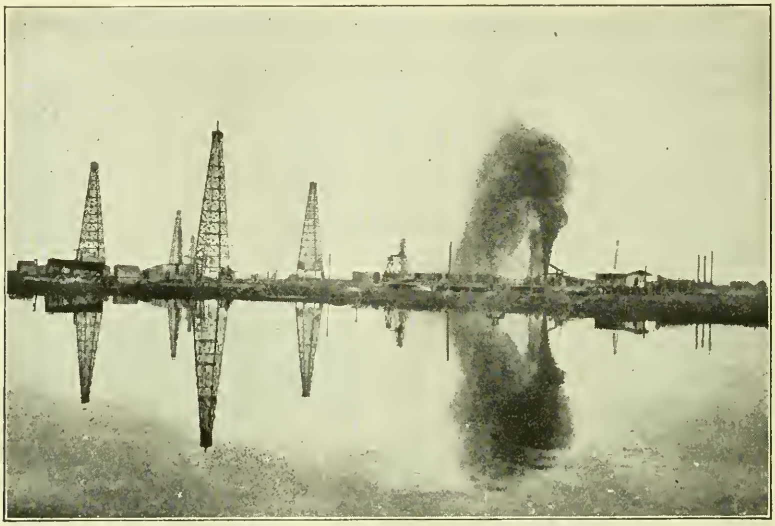


IN LOS ANGELES, CALIF., OIL-DERRICKS RISE OUT OF MANY YARDS.

Since the Drake well was drilled the United States has pumped up more than seven billion barrels of oil.

Hardly had one field been partially developed when sturdy oil pioneers pushed their "wildcat" ventures into new territory and discovered new pools. A "wildcat" is the first trial well in unknown territory—a gamble with nature, for there is no certain means of discovering oil except by drilling. Drake was a "wildcatter." Nearly all the great oil-fields have been discovered by wildcatters like him—tenacious gamblers, all.

When the "wildcat" drillers strike oil there follows a rush of investors and speculators, eager to buy up oil leases on a percentage of the oil produced, the leases sometimes changing hands over night at profits of 100, perhaps 500 per cent. If the strike is genuine many producing wells are drilled; railroad feeder lines are built; pipe lines are constructed; towns spring up where a few months before not a house was to be seen; banks are established, and corner lots, once worth $30 or $40 an acre, bring $5,000 or $10,000. The oil gushes out or is pumped up and money rolls in. Everybody is rich, and the thrifty habits of a lifetime are swept away. Speculation prompted by a mad desire to make a fortune in a day sways even the miserly. Individual fortunes are made and also lost. The farmer who leases his land to the driller is often enriched without turning a hand. Farm land, front yards in city blocks, orchards or orange groves, nothing is spared in the mad scramble to drill down to the hidden pools. In a thickly populated part of Los Angeles, oil derricks to-day rise out of many front and back yards.

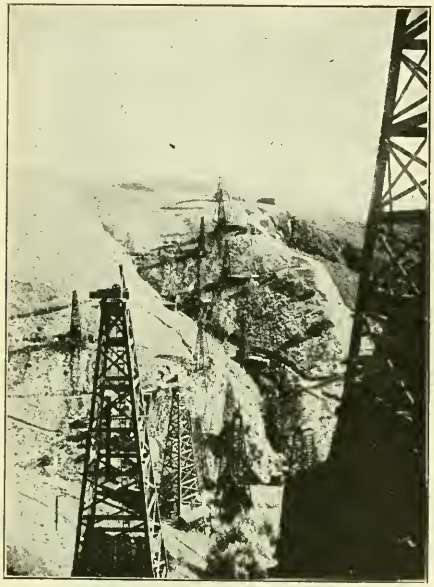


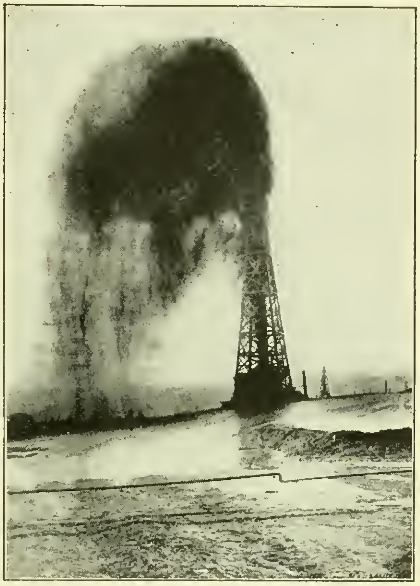
LAKE OF OIL, SUNSET FIELD, CALIFORNIA.

Most of this oil came from the gusher shown in activity.

The fierce energy of the wildcatters, their boundless optimism, their unquenchable courage, have never been equalled, not even in the gold rushes. Gold miners may succeed with little or no capital, but the drilling of a single well involves the expenditure of money, $10,000, $20,000, perhaps $50,000, and when the well is drilled it may be a "dry hole." There is as much truth as humor in this description of an oil well by George Fitch:

"An oil well is a hole in the ground about a quarter of a mile deep, into which a man may put a small fortune or out of which he may take a big one. And he never knows until the hole is finished. It takes a number of thousand dollars, several months, and a couple of non-committal men in mud-plastered overalls to dig an oil well. They begin by going up about 100 feet. When they have finished their derrick, they hang a drill on it weighing half a ton. Then the men hitch the drill to an engine and punch a 42-centimeter hole in the earth's crust. Sometimes, after they have been punching away for several weeks, the hole blows the derrick into the sky utterly ruining it. Then the owner shrieks with glee and employs 500 men to





(Left) DRILLING IN MOUNTAIN RAVINE.

No matter what the character of the territory may be the oil-driller shrinks from nothing. Here we see some of his derrick-building exploits in Los Angeles County, California.

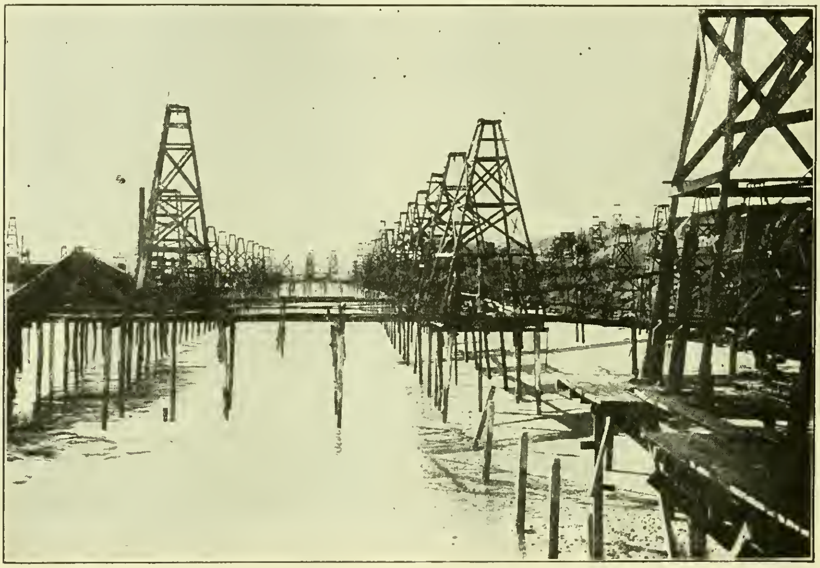
(Right) LAKEVIEW GUSHER ON MARCH 18, 1910.

A few days later the derrick was completely swept away. This well produced 55,000 barrels a day for a long period. Its total production is estimated at 6,000,000 barrels.

catch the spouting oil in barrels. But sometimes the derrick is as good as new when the hole is finished. Then the owner curses and takes the derrick away to some other place which smells oily."

Derricks and Deep Wells

The derrick is the visible mark of most oil wells—a tall wooden framework from 64 to 120 feet high. There are dozens, sometimes hundreds, and even thousands of these lofty derricks, each the counterpart of its neighbor in a huge oil-field, each working with clocklike regularity.

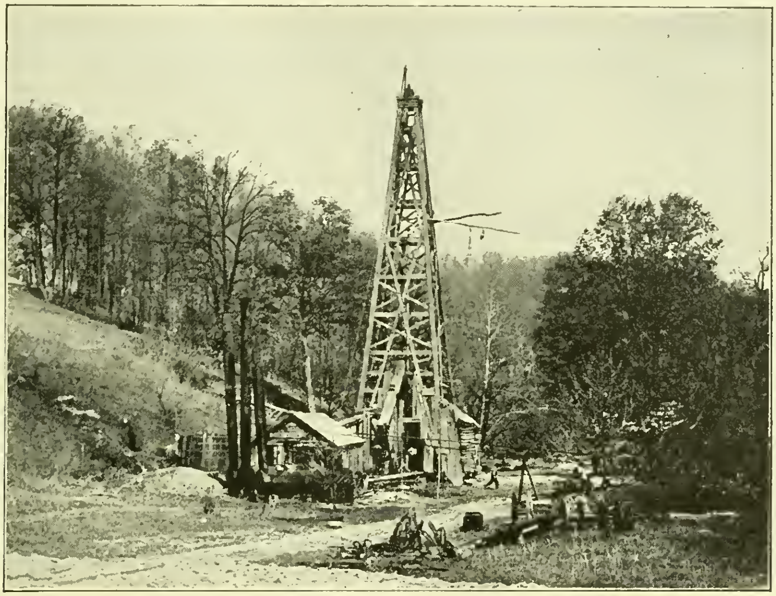


SUMMERLAND OIL-FIELD, CALIFORNIA.

If the oil-driller thought he would strike oil out in the bottom of the ocean he might at least dream of drilling a well. As this picture shows, water has no terrors for him.

Drilling is the principal part of oil production. A heavy string of tools is suspended at the end of a cable, which is given a churning motion by a walking-beam rocked by a small engine. The tools are dropped to the bottom of the hole and then hauled up for another blow. As they fall under their own weight they pulverize the solid rock and actually punch their way down. To prevent the caving in of the hole and especially to avoid the inflow of water from any water-bearing formations through which the drill bores, the well is lined or "cased" with sections of iron pipe screwed together and forced down into the hole as the drilling proceeds.

Dozens of derricks in a field may be pumping, pumping, with scarcely a human being in sight. Yet the derrick is not an invention of the oil industry. It was well known before Drake drilled his first well, for by its means salt wells, 400 or 500 feet deep, had been drilled years before, as we have seen.



THE DEEPEST WELL IN THE WORLD.

This is the Lake well in West Virginia. It did not strike oil. A depth of 7,579 feet was reached —almost a mile and a half.

Except for shallow wells the rate of progress varies from sixty to ten feet a day. As greater depths are reached the drilling is slower. The deepest well in the world is the Lake well, in West Virginia, which goes down 7,579 feet, according to the United States Geological Survey—almost a mile and a half. The second deepest well is the near-by Goff well, with a depth of 7,386 feet. Neither well struck oil.

The deepest wells are not necessarily the heaviest producers.

The Great Lake View gusher, in California, struck oil at a depth of 2,230 feet, and spouted for some days over 50,000 barrels a day. On July 4, 1908, what was at that time the greatest oil well of the world, struck it rich near Tampico, Mexico, at a depth of 1,824 feet. So rapidly did the oil leap up that before the fire in the boiler of the drilling engine could be extinguished, the flowing oil reached it, and burst into a blaze which for two months burned 60,000 to 75,000 barrels of oil a day. A flame from 800 to 1,400 feet in height, and 40 to 75 feet in width could be seen at night by ships one hundred miles at sea, and a newspaper could be read seventeen miles away. After $3,000,000 worth of oil was thus lost, the fire was extinguished by the salt water that followed the oil from the hole. Then came the Cerro Azul well, in Mexico, the greatest of all wells, which for a time yielded the incredible amount of 260,000 barrels of oil a day, although the depth was but 1,752 feet. The capping and control of this huge flow of oil was a notable engineering feat.

Such stupendous gushers are the exception and not the rule. Wells usually flow with less violence, and many, for lack of sufficient gas pressure, yield only to pumping. All wells soon reach a point of maximum production, after which they pass into a period of decline, and eventually cease to produce at all.

The Torpedo and Its Inventor

Soon after Drake drilled his famous well, Colonel E. A. L. Roberts conceived the idea of exploding torpedoes of nitroglycerine in wells to increase their flow. In 1862 he patented the "Robert's Torpedo," which has since increased the flow of oil by millions of barrels. For several years he encountered only opposition; the oil men feared their wells would be destroyed utterly. In 1865 he was allowed to experiment upon the Lady well, on Oil Creek, with the result that his torpedo considerably increased the flow. Shortly afterward he used a torpedo in a "dry hole," a well that had never produced any oil, and obtained twenty barrels a day, which was increased to eighty barrels a day by the explosion of a second torpedo. Later he converted another dry hole into a big producer by a heavy torpedo explosion. Roberts suddenly sprang into fame. He could not make torpedoes fast enough. Since his first experiment thousands of wells have been torpedoed, but the charge of nitroglycerine has been increased from four or six quarts to sixty, eighty, one hundred, and more. Tall tin cans of "soup," four or five inches in diameter, fitted with exploding caps, are carefully lowered into the wells, one on top of the other. To explode the charge, a "go-devil" iron was at first dropped into the well; later the dangerous "go-devil" gave place to electric ignition, controlled from a distance. This "shooting" a well, as the oil men call it, not only cracks and loosens the rock at the bottom of the well and then allows the oil to flow in, but also "blows out" or cleans the well. With a big charge, oil, water, and accumulated sand may be blown 100 to 150 feet into the air.

Colonel Roberts was not the first to conceive the idea of torpedoing. In the very early days of oil wells, Frederick Crocker drilled a well on Oil Creek and struck oil. Because he had no tanks he plugged the well in the hope of saving the oil. Later, when he removed the plug the oil had vanished; it had found another outlet. Hoping to start up the flow again, he lowered a heavy charge of gunpowder into the well and fired it. This was probably the first "shooting" experiment ever made. Crocker brought no oil to his well, but he did succeed, unwittingly, in increasing the flow of a neighboring well. Although the attempt was a failure, so far as Crocker's own well was concerned, the conception was correct.

An equally brilliant failure was that of Lewis H. Smith, who came to Oil Creek in the early days. After sinking his money in a well that yielded barely a trickle, he too conceived the idea of tearing up the bottom of the well by an explosion. He had never heard of Colonel Roberts, and had never seen a torpedo, yet he planned one in his mind. The result was a galvanized iron tube, or can, four inches in diameter, and five feet long. The firing head, substantially the same as that patented later by Roberts, consisted of four gun tubes, or nipples, which were struck by a falling weight. Smith charged his tube with rifle powder and twenty-five pounds of giant powder. To transport the machine to his oil well, more than

200 miles distant, was his next problem. The only possible way was to carry it in his arms. The feat required courage, but Smith had it in abundance. With his torpedo under his arm, disguised as a bundle of maps, he set out jauntily. The performance was all the more startling because Smith weighed not more than 130 pounds, and his infernal machine one-quarter as much. After imperilling his life and the lives of hundreds in cars and stage-coaches, he arrived safely on Oil Creek. Mechanically, his torpedo was a great success; it ripped out the bottom of the well with the thoroughness expected of it; but it did not increase the production because the well was past all help.

How Compressed Air Increases the Flow

It has recently been discovered that although a well may cease to yield, the sands are far from exhausted; from fifty to ninety per cent. of the oil remains in the ground. When the drill "strikes oil" it taps not a lake or pool of oil, but "oil sand," which is not sand at all, but hard sandstone, or other rock saturated with oil. A pailful of coarse sandstone will absorb a quarter of a pailful of oil.

The oil and gas in some of the oil sands are confined under such enormous pressure that, when the overlying cap is pierced, oil and gas are driven out with such force that the wonderful spectacle of a gusher spouting oil at the rate of 100,000 barrels a day is presented. Just as the gas in a siphon of seltzer forces the water out when the spring-valve is pushed open, so the confined, natural gas forces the oil out of the "sand" even after the flow has ceased, and it is necessary to pump the oil. When the gas has all escaped the oil ceases to flow even with the aid of pumps. The well is abandoned because it is said to be exhausted; in reality it is not the oil but the gas which has been exhausted. The old Bradford oil-field in Pennsylvania, now considered "exhausted," has yielded about 230,000,000 barrels from 85,000 acres, an average of but 2,900 barrels per acre, hardly enough oil to saturate three feet of sand. Since the oil sand has an average thickness of forty-five feet, this "exhausted" field must still contain about 3,000,000,000 barrels of oil.

How is this oil to be raised and made to flow in the channels of industry? The solution came to T. L. Dunn when he was operating in the Macksburg pool of Ohio, in 1903. Why not pump the oil sands full of gas again? He forced in natural gas, and the well started to flow again.

STORED OIL SOMETIMES CATCHES FIRE.

A pillar of smoke ascends that can be seen for miles. Such tank fires are now extinguished with a special foam.

There is no virtue in gas as such. The pressure of the gas drives out the oil. Air is a gas. Why not try it? With the aid of Harvey E. Smith, Dunn tried air successfully on the Wood farm of the Cumberland Oil Company, near Chesterhill, Ohio, in August, 1911. Within a week the production of the surrounding wells had greatly increased, after which the use of compressed air was extended to other parts of the property. In the nearest adjoining well the production was only 9,500 barrels a year. The new process almost immediately increased the flow to 16,000 barrels. In good oil territory there may be a hundred or more wells to a square mile. When the yield of such a property begins to run low the whole field is now rejuvenated by connecting compressed-air pumps with every fourth or fifth well, and thus "recharging" the entire underlying oil sand. In many cases the flow of wells has been doubled, quadrupled, and in some cases increased as much as nine fold. It has been possible, however, to apply this striking economy in comparatively few oil-fields.

Piping Oil Across the Continent

To transport oil through a pipe-line in bad as well as good weather, regardless of mud, frost, or labor shortage was so obvious an expedient that it occurred to many energetic oil men. As far back as 1860 S. D. Karns proposed the laying of a six-inch pipe from Burning Spring, West Virginia, through which oil would flow down hill to the Ohio River, a distance of thirty-five miles. This line was not constructed. Two years later L. Hutchinson laid three miles of small pipe from the famous Sherman well to the railroad, but the line was a failure because of excessive leakage.

The first practical pipe-line was built by Samuel Van Syckle of Titusville, the sections of which were carefully screwed together. It was only a little pipe and less than four miles long, but it carried about eighty barrels a day. So hard was it to get oil to market in the sixties that we find in an old copy of the Titusville *Herald* the news item that: "Hundreds of oil boats are lying high and dry on the banks of the Allegheny River waiting for a rise in the river to carry them and their cargoes of oil to the Pittsburgh market," and that there were "about 250,000 barrels of oil in barges and tanks awaiting shipment." Other news items mention enormous destructive fires caused by locomotive sparks, lightning, and open flames. Clearly there would be little danger and loss if oil could be carried in pipes.

At this time Charles P. Hatch, the energetic, resourceful manager of the Empire Transportation Company, who had demonstrated the value of tank-cars, induced his company to purchase two of the lines that had been laid soon after Van Syckle had demonstrated the practicability of piping oil. When the lines were completed he became their manager. In 1866 he operated the first regular pipe-line in the United States from the Pithold oil district to Titusville.

The Empire line was ten and one-half miles long, and was built with three pumping stations. Hatch believed that one pump could force the oil the entire distance. No one else thought so. The oil teamsters and the old oil boatmen shook with laughter over this notion of pumping oil for miles in a pipe over rough, up-and-down country. Stationing himself at the Titusville end of the pipe-line Hatch telegraphed his engineer at Pithole to begin pumping slowly and steadily. The pipe was two inches in diameter, and it took about 180 barrels of oil to fill it. Hatch waited and waited. Not a sign of oil. Had the pipe sprung a big leak or burst? Hoping against hope, at last a faint hissing of air from the end of the pipe was heard. The hissing grew louder and louder. "There she comes; there she comes!" shouted Hatch. Then with a great gurgling, after four hours of watchful waiting the oil flowed forth. The problem of long-distance pumping of oil through pipes was solved. The line could pump 2,000 barrels a day. It played havoc with the business of the teamsters, who vented their wrath by cutting and plugging it.

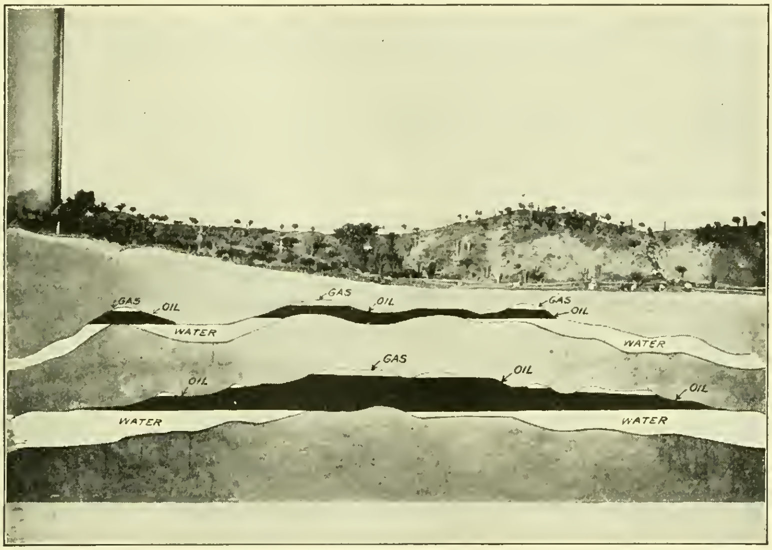
Soon other pipe-lines were laid; the lines grew in length; short lines multiplied; pipe-line after pipe-line from the producing fields to the refineries and the railroads crossed and paralleled one another in every direction. Competing companies waged war upon one another. The only logical outcome was consolidation of pipe-lines, and this soon followed. J. J. Vandergrift, a prominent figure in early oil history, and George W. Foreman, completed the first trunk line in 1874 from the Pennsylvania oil region to Pittsburgh—a line of four-inch pipe sixty miles long, a giant for the period, both in size and length, which carried 7,500 barrels a day. Trunk lines were then laid from the various oil-fields to Cleveland, Buffalo, New York, Philadelphia, and Chicago. By 1900 the major portion of the country's oil was transported through the pipe-lines of the big companies. To reduce the power necessary to force the oil through the pipes J. D. Isaacs and Buckner Speed conceived the idea of rifling the pipe like a gun barrel. This was a great improvement, especially for transporting the thicker kinds of petroleum.

We have now 40,000 miles of oil pipes in main lines, and another 40,000 miles of tributary or gathering pipes, in all over 80,000 miles, more than enough to girdle the world three times at the equator. Sometimes these oil pipes lie on the surface; usually they are buried several feet beneath the ground. Because the oil must be forced along its way up hill and down dale, thousands of pumping stations are necessary, many of them handsome little villa-like structures in the midst of fine hedges and lawns.

Most of the trunk pipe-lines of to-day are eight inches in diameter, and a pumping station is to be found, on an average, every fifteen miles. On some lines stations are forty or fifty miles apart; on others only three or four miles. Through an average pumping station with an eight-inch pipe, 30,000 barrels of oil are pumped every twenty-four hours. In that time the oil will travel ninety miles. The longest continuous pipeline reaches from gathering points in Texas to the refineries in Bayonne, New Jersey. It takes the oil sixteen or seventeen days to reach its destination. There are also ten-inch pipelines, and some even twelve inches in diameter. The capacity is 47,000 barrels a day for the ten-inch pipes, and 67,500 barrels a day for the twelve-inch pipes. Simply to fill the pipe system of the United States would take more than 14,000,000 barrels or about seven days' production from all the wells of the United States, or, about three and one half million barrels of oil. The estimated cost of this great network of pipe is $750,000,000.

The Rise of Natural Gas

In the process of removing an old mill from a small stream at Fredonia, New York, in 1826, a great bubbling was noticed. The cause was an inflammable gas, which was promptly piped into the houses of Fredonia, at a charge of $1.50 a year for each one hundred lights. In 1872 Titusville, Pennsylvania, followed suit. Since that time the natural-gas industry has grown rapidly and continuously. No other region of the earth has produced so much natural gas as the United States and Canada. Many of the natural-gas areas in the United States are associated with the petroleum-producing areas, but natural gas is also obtained in regions where there is not a trace of oil.



DISTRIBUTION OF OIL, GAS, AND WATER UNDER GROUND.

It is the pressure of the gas that forces up the oil and later the water.

At first natural gas was regarded as an unavoidable nuisance by the oil-driller. He wasted it in ways now considered appalling. "Wild" wells were permitted to burn for years. Their flames, visible at night for miles, were considered a unique advertisement for the region. Nowadays the well is capped and the gas confined for future use. In the oil regions it is piped and used as fuel for the oil-well pumps. The amount produced and consumed in the United States in a year is about 675,000,000,000 cubic feet.

For nearly two generations it was not suspected that large quantities of the highest grade gasoline could be extracted from odorless, colorless, invisible natural gas. Last year about 500,000,000 gallons of commercial gasoline were literally squeezed and sucked out of natural gas by special machines, and all this gasoline is a direct and distinct saving, worth to the American motorist at least $100,000,000 a year. Much of it is called "casing-head" gasoline, because it is associated with the gas that escapes from an oil well.

Early oil wells were drilled into the rock without a casing for the hole. In 1865 Benjamin S. Tinker invented the casing to prevent the walls from collapsing. The next obvious need was a head or cap for the casing above the ground, a kind of drum. As the oil is brought to the surface it is piped off through this casing-head to tanks or pipe-lines. With the oil there also comes up much gas "wet" with gasoline. In 1904 the first "casing-head" gasoline was squeezed out of such gas by A. Fasenmeyer, near Titusville, Pennsylvania. His crude plant was within sight of the old Drake well. That year he recovered 4,000 gallons of gasoline, and received ten cents a gallon for it. Tompsett Brothers, in the same region, claimed they had extracted gasoline from gas even earlier. Both ventures proved so successful that other operators proceeded to install gasoline plants. Various improvements were made and patents granted to different inventors. By 1913 there were nearly 300 plants. with a total output of about 24,000,000 gallons of casing-head gasoline.

Casing-head gas is a "rich" or "wet" gas. If 1,000 cubic feet of gas, natural or casing-head, contains as much as one gallon of gasoline, it can be profitably compressed to squeeze out the gasoline, just as we squeeze water out of a sponge. Even so-called "dry" natural gas contains some gasoline. When gasoline became an automobile necessity it occurred to G. N. Saybolt of Hastings, West Virginia, that it might be sucked out, when it did not pay to squeeze it out. He devised his absorption process, which leaves the gas dry as a bone. Saybolt's process pays even though there may be as little as one pint of gasoline in 1,000 cubic feet of gas.

Certain oils easily absorb gasoline from natural gas. Saybolt sprays such an oil down through long pipes or towers, and at the same time forces gas upward. When the gas emerges at the top of the pipe its gasoline has been absorbed by the descending oil. The gasoline is then distilled from the oil, and the same oil does duty over again. A large absorption plant will extract from 80,000,000 cubic feet of gas at least 8,000 gallons of gasoline a day. Such gasoline absorption plants are now to be found in nearly all the natural-gas regions.

The Refining and "Cracking" of Petroleum

Petroleum is extraordinarily complex, and out of its complexity a thousand and one valuable compounds are obtained. Heat breaks petroleum down into liquids and solids, which are in themselves complex. Different compounds are boiled off at different heats. They are not allowed to float off into the air, but are collected. The process is therefore one of distillation. At the lower temperatures the light compounds evaporate and pass over into the collecting vessel. As the temperature increases, heavier compounds are distilled off. The temperature is gradually raised until finally 625 degrees Fahrenheit is reached. Thus, benzine, gasoline, kerosene, fuel oil, heavy lubricating oils, paraffin and asphaltum are successively obtained.

Just what is kerosene and what is gasoline is more a matter of terminology than of chemistry. "Sugar" is a chemical term; "gasoline" is not. What passes for "gasoline" this year was not "gasoline" ten years ago. The earliest refiners wanted as much kerosene as possible; gasoline was a nuisance. Hence their kerosene was almost as explosive as our gasoline; laws had to be passed to prevent them from selling kerosene that was too light. Then the automobile came. Now with millions of motor-cars we find it hard to obtain gasoline enough. Each year the refiner is compelled to sell as gasoline distillates which are more like kerosene than ever. Indeed the gasoline situation is alarming. Motor-cars are consuming gasoline faster than wells are producing the petroleum from which the gasoline is distilled. It seems unlikely that new oil-fields of sufficient extent will be discovered, so thoroughly have the geologists and the "wildcatters" done their prospecting of the entire world.

Heat acts upon petroleum as a hammer acts on stone. It breaks up the petroleum. We call the pieces benzine, gasoline, kerosene, lubricating oil, or paraffin. They are still very large, complex pieces, chemically speaking. What if they could be broken up still further by more heat? Now there is a limit to which heat can be applied under ordinary conditions. Water, for example, boils at 212 degrees Fahrenheit in the open air at sea-level. But clamp a lid down tight on the vessel, and the boiling-point can be raised to 300, or 400 degrees, so that more heat can be applied. The boiling-point of any liquid is determined by the pressure on the liquid. Increase the pressure—and this is exactly what happens when the lid is clamped down tight on a water-vessel—and the boiling-point is raised.

Here, then, is a way of applying more heat to petroleum, of knocking it, chemically, into smaller pieces. Increase the pressure and more heat can be applied. With what results? Chemists tried to find the answer as far back as 1860, as a matter of scientific interest. Williams (1860), Young (1865), and Peckham (1869), were the earliest experimenters. Kray, in 1887, devised a real pressure-distillation process, but he was concerned chiefly with obtaining lighting oil from tar and the residue left in petroleum stills after the last drop of valuable vapor had passed over and been condensed. This process of breaking up apparently valueless petroleum residue was called "cracking." The substances were really cracked up into simpler chemical compounds. Dewar and Redwood patented an improved cracking process in 1890, but it was not until the automobile demand created a crisis in the petroleum industry that any serious industrial effort was made to crack up kerosene and similar heavy oils into lighter gasoline. Among others, William M. Burton, a noted chemist of the Standard Oil Company, worked for years on this cracking idea to obtain more gasoline. In 1913 he secured a patent for a "cracking" process which is extensively used at the present time by the Standard Oil Company. His cracking process marks one of the milestones in the history of petroleum refining. There are half a dozen other "cracking" processes, all more or less the same in principle, and all serving the same purpose of knocking six or seven gallons more gasoline out of every barrel of crude oil than was possible twenty years ago.

What Shall We Do When the Wells Run Dry?

If there is little waste in modern petroleum refining, it is because the reserve supply of petroleum in the United States, and in fact the world's reserve, is nearing exhaustion. The late Franklin K. Lane, when Secretary of the Interior, once described petroleum as "a priceless resource, for it can never be replaced. Trees can be grown again upon the soil from which they have been taken. But how can petroleum be produced? It has taken ages for nature to distill it in her subterranean laboratory. We do not even know her process. We may find a substitute for it, but we have not done so as yet. It is practically the one lubricant of the world to-day. Not a wheel turns without being smoothed by it. We can make light and heat by hydroelectric power, but the great turbines move on bearings that are smothered in petroleum. From it we get the quick-exploding gas which is to the motor and the airship what air is to the human body. To industry, agriculture, commerce, and the pleasures of life petroleum is now essential."

WHERE OIL IS FOUND IN THE UNITED STATES.

From the oil-fields of the United States, indicated by black spots on this group, 6,000,000,000 barrels of oil have thus far been extracted.

While we have contributed two-thirds of the oil that the world has used in the last sixty years, we have already reached the point where we consume more than we produce. In 1923 we consumed the enormous amount of 714,000,000 barrels of oil. We have thus far produced in the United States about 6,000,000,000 barrels of oil, and our untouched reserves, according to the United States Geological Survey, are about 9,000,000,000 barrels—not enough to last fifteen years at our present rapidly increasing rate of consumption. What shall we do for oil a few years hence?

It has been discovered that in Colorado and Utah we possess mountain ranges of oil shale which may yield many billion barrels. Some day we will have to tear the mountains down and distil out the oil in their shale. The United States Geological Survey during the past few years has made extensive studies of these shales, and has found that there are millions, indeed, tens of billions of tons of them that contain from thirty to fifty gallons or more of high-grade oil to the ton—a far greater oil reserve than we ever possessed in liquid petroleum. Even now we are beginning to distil oil from these shales. Not many years hence our oil will be mined with steam-shovels and rock crushers instead of pumps.

CHAPTER IV

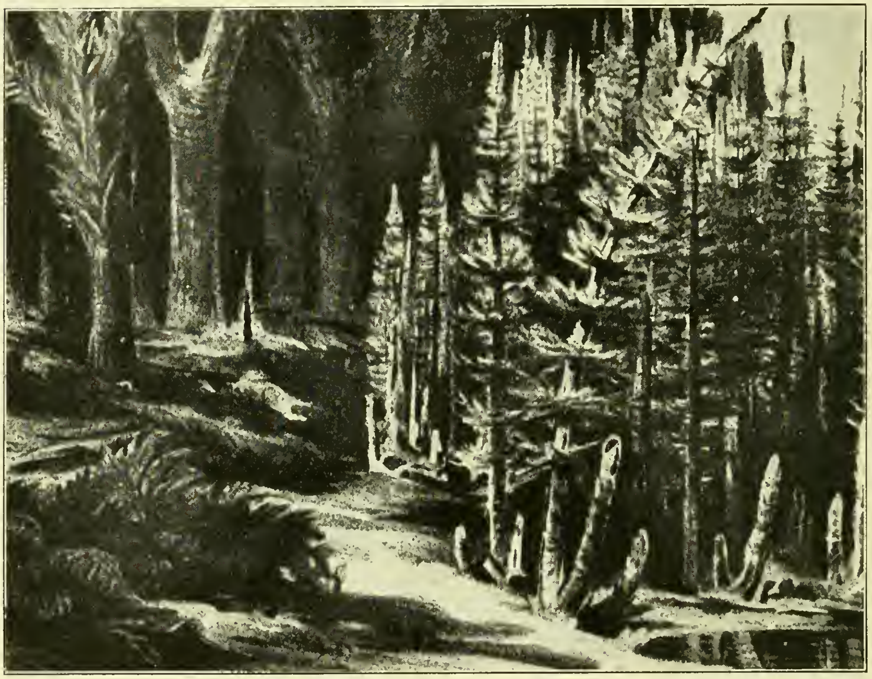
BURIED SUNSHINE—THE STORY OF COAL

WHEN, in 300 B. C., Theophrastus, a Greek orator and friend of Aristotle, wrote a description of coal, he did not know that he was introducing one of the most fascinating stories to be found in the pages of Nature. Little did he dream of the vast industrial era which in a few short centuries would be entirely dependent upon this black, stony substance that kindles and burns "like wooden coals." In that early day his vision did not take in deep mines with their grimy toilers, innumerable smoking chimneys, the steam-engine, the blast-furnace, swallowing 400 tons of coal a day, iron rails that span continents, floating palaces of steel, big guns and armor-plate, huge skyscrapers, and an age of electricity—all of which would be impossible without these black rocks dug from the depths of the earth.

Coal is the symbol of power. Together with its twin brother, iron, it has spelled dominion; first over the material elements of Nature, then over industry and the military and political course of empire. Along its black trail we trace the ever-expanding growth of the world's industrial life. Without coal nations wither and decay. Coal and yet more coal is the never-ceasing cry of every workshop in the world.

THE ORIGIN OF COAL

Coal is crystallized buried sunshine. Millions and millions of years ago this planet passed through what geologists call the carboniferous period. The continents, then arranged somewhat differently than now, were enveloped in an atmosphere dense, hot, and humid. Tropic climates extended far beyond the present torrid zone. Along the borders of the sea or about the shores of inland lakes were vast swamps. In them grew a most luxuriant vegetation. At no other time has the earth seen its like. Huge tree ferns and other forms, similar to modern horsetails and scouring rushes, often eighty or ninety feet high, ferns like the maidenhair of China and Japan, and immense trees similar to our club-moss and ground-pine filled these swamps in dank profusion. Breathing through their leaves the carbon dioxide of the air, and drinking with their roots the soluble plant foods in the rich soil beneath, the energy of the sunshine, in Nature's greatest laboratory, united these substances into the woody fibre of the tree.



Courtesy of American Museum of Natural History.

A JUNGLE IN THE CARBONIFEROUS ERA.

Coal is the result of a chemical change in giant tree-ferns and conifere which sank in the swamps where they had grown in the course of centuries. The chemical change is called carbonization, and it occurred in the carboniferous era.

From time to time these swamps sank beneath the water and the plants were killed. Then the rivers, pouring in their sediment, buried this vegetation beneath deep layers of mud and sand. At first peat bogs were formed similar to those existing to-day in Ireland and along our Atlantic coast. Gradually, as the layers of sediment grew thicker, their tremendous pressure, and the heat developed by it, squeezed out the gaseous matter and changed the vegetation into coal. Here is Nature's coke-oven. In it have been produced every variety of coal, from peat and lignite to bituminous and anthracite, the particular kind depending upon the amount of heat and pressure to which the vegetation was subjected. The anthracite coal contains the largest percentage of carbon and the least oily and gaseous matter. It is the hardest of coals, and burns slowly and with the least smoke.

Early History of Coal

That coal was used by the Britons previously to the Roman invasion, in 54 B. C., seems evident from tools and cinders found near the ancient Roman wall. Indeed, it would be an exception to the usual course of progress, had not some primitive man, building his fire on an outcropping ledge of black rock, discovered that the rock would burn. Before the Christian era coal was also mined in China.

The first known record of the use of coal in England takes us back to 852. In that year the Abbey of Petersboro gave a receipt for "twelve cartloads of coals." In the books of the bishop of Durham for the year 1180, we find the first account of actual mining operations. But even a century later the use of coal was very slight; for a Venetian traveller, who told his countrymen of a "kind of black stone used like firewood," was not believed. The first shipment of coal to London was made in 1240. Marco Polo, the famous Italian traveller of the thirteenth century, mentions its use in what he called Cathay, in 1275. And in 1612, coal was first used in a blast-furnace for the production of iron.

Those intrepid Jesuit missionaries, Joliet and Marquette, who explored the Mississippi Valley, discovered coal in the United States near the present site of Utica, Illinois, in 1673. Later, in the year 1689, Father Louis Hennepin published a map showing a "cole mine" along the Illinois River. That the Indians were acquainted with numerous coal beds and used the black stones for fuel, and that they actually mined it, there is no doubt. In 1766, they complained to the governor of Pennsylvania of the robbery of their mines by the white settlers.

The oldest coal-mines in America are those in the bituminous fields near Richmond, Virginia. It is said a boy discovered these beds in turning over stones in his search of bait for fishing. This was in 1702, but it was not until 1750 that the mines were opened. During the Revolutionary War coal was in common use throughout this region. Although coal had not then been discovered in Pennsylvania, the Wyoming and Lackawanna coal-fields were purchased from the Five Nations by the Susquehanna Company in 1754. Then, in 1760, anthracite coal was discovered in Rhode Island, and two years later settlers from Connecticut discovered anthracite in the Wyoming Valley, Pennsylvania. There, in 1763, they made the first reservation of coal lands in what was to be the largest and most important anthracite region of America.

With the great abundance of virgin forests in this new country, forests that were long an actual bar to industrial and agricultural expansion, a substitute for wood fuel did not appeal very strongly to the pioneer population. But it was inevitable that the superiority of coal to wood should soon prove itself. Gradually but surely it came into use. In 1769, Obadiah Gore, a blacksmith of the Wyoming Valley, first burned anthracite in his forge, and his example was soon followed by others. Farmers and blacksmiths began to mine it for their own use. But most people looked upon it with scepticism, and advocates of the new fuel were frequently subjected to ridicule.

The rich beds of the Schuylkill were discovered in 1770, but were not developed until 1834. In 1775 the government of Pennsylvania floated coal down the Susquehanna to Harrisburg—then Harris Ferry—and hauled it by wagon to the arsenal at Carlisle for use in the manufacture of ammunition. Judge Jesse Fell, one of the pioneers in introducing coal to the public, used the fuel in the manufacture of nails at Wilkesbarre, in 1788.

There is an interesting story connected with the Lehigh Valley region. Philip Ginter, whose name would otherwise be totally unknown to history, discovered coal there in 1791. Ginter was a poor man who supported his family by hunting and trapping. One rainy night after an unsuccessful day in the woods, as he was returning tired and discouraged to his log cabin, he came down the side of Bear Mountain. His foot struck a shiny black stone, driving it on before him. He picked it up and decided it was coal, the new fuel that people were discussing. Ginter started to investigate. All about him he found the black rocks in abundance. The next day he reported his find to Jacob Weiss at Fort Allen, and a quarry was soon opened. In the following year the Lehigh Coal Mining Company was organized.

About this time another hunter, Nicholas Allen, found coal near Pottsville, Pennsylvania. He, too, had been hunting all day and at night had built his fire under a ledge of black rocks. After preparing his supper he wrapped himself in his blanket and was soon sound asleep. Some time in the night he was awakened by a strong light shining in his eyes. Leaping to his feet, he discovered to his amazement that "the mountain was on fire." When morning came he found that he had built his fire on an outcrop of coal. This fortunate accident led to the location of one of the richest coal regions of the State. Yet another hunter, John Charles, in digging out a woodchuck, came upon coal, for in Pennsylvania the coal in many places lies very near the surface.

Gradually the coal industry grew. In 1795, a blacksmith named Whetstone began to mine and use coal in the Schuylkill region. In 1800 it was being shipped from Pottsville to Philadelphia. But its use for domestic purposes had not yet been demonstrated. The burning of coal and its substitution for wood was still in the experimental stage. People were laughed at for buying the black stones. Criticism seemed justified when, in 1803, the Lehigh Coal Mine Company shipped two boatloads to Philadelphia, and the stuff, refusing to burn, had to be used in place of gravel on the sidewalks.

But its importance as a domestic fuel could not long be delayed. In this same year, in Philadelphia, Oliver Evans, the great American inventor of the steam-engine, first burned coal in a grate, and Frederick Groff, also a citizen of the Quaker City, repeated the experiment shortly after. The new fuel, however, was slow in coming into favor. Another boat-load sent to Philadelphia, in 1806, was rejected. Even as late as 1812, Colonel George Shoemaker narrowly escaped arrest as an impostor when he offered nine wagon-loads of coal for sale in Philadelphia. He succeeded in selling only two of them, then gave the other seven away. In 1808 Judge Jesse Fell gave a public demonstration in which he burned coal in the grate in the barroom of his hotel at Wilkesbarre. This was regarded as a great event, and people came from far and near to witness the strange spectacle of rocks superseding wood in the fireplace, and burning merrily.

One of the wagon-loads of coal sold by Colonel Shoemaker had been purchased by White and Hazard, wire manufacturers located at Schuylkill Falls. After spending all night in unsuccessful efforts to make the stuff burn, they gave it up in despair. Fortunately they left the furnace door shut, and when a workman returned some time later to get his coat, he found a red-hot fire. People did not understand, at first, that a coal fire should be left alone and not poked.

In 1805–6, John and Abijah Smith from Derby, Connecticut, settled at Plymouth, Pennsylvania, and immediately formed the coal firm of Abijah Smith and Company, the first in America to devote itself exclusively to the mining and marketing of coal. In 1807 they shipped fifty-five tons to Columbia, Pennsylvania, and, from then on, 400 to 500 tons annually to New York and Baltimore, for which supply they received from $10 to $12 a ton. When one considers the purchasing power of money then, coal was certainly an expensive luxury. The Smith brothers shipped their coal in crude boats called "arks." They were ninety feet long, sixteen feet wide, and four feet deep. Each "ark" carried sixty tons of coal and was manned by a crew of four men. Seven days were required to reach tide-water on the Susquehanna.

These industrious brothers realized that if they were to succeed in marketing their product they must teach the people how to use it. They therefore devised a special kind of grate, and with infinite patience did the pioneer work of introducing coal as a domestic fuel. From their records we find that New York began to use coal in 1812, and in that year consumed 200 tons. The first anthracite coal firm in New York was that of Price and Waterbury. They retailed coal at $25 for 3,000 pounds.

The Lehigh Coal and Navigation Company, the oldest coal company in America still in existence, was organized in 1818 and began business in 1820, in which year they shipped 365 tons of anthracite to Philadelphia. This company was a tremendous factor in developing the coal-fields of the East. Another of the old coal companies is the Delaware and Hudson Canal Company, which was organized in 1823 and began to make coal shipments in 1828.

The first use of anthracite in the smelting of iron occurred at the nail and wire mill of White and Hazard, at Schuylkill Falls, in 1812. To generate steam power, it was first used in this country in Thompson's rolling-mill at Phœnixville, Pennsylvania, 1825. Coal had been thus used in England for nearly a century. First in Savery's, then in Newcomen's, and finally in Watt's steam-engines, coal was the source of power for pumping water from the mines. In America, with the coming of the steamboat and the locomotive, coal rapidly came into use as the most important source of energy. In the old "Pioneer Furnace," at Pottsville, Pennsylvania, built by William Lyman, of Boston, anthracite was first used in the smelting of iron ore. Publicly recognizing the fact that Lyman, with the use of anthracite, had produced pig iron continuously for 100 days, Nicholas Biddle and a number of other far-seeing public-spirited men, in 1839, awarded him a prize of $5,000. The first successful blast was blown in October of that year.

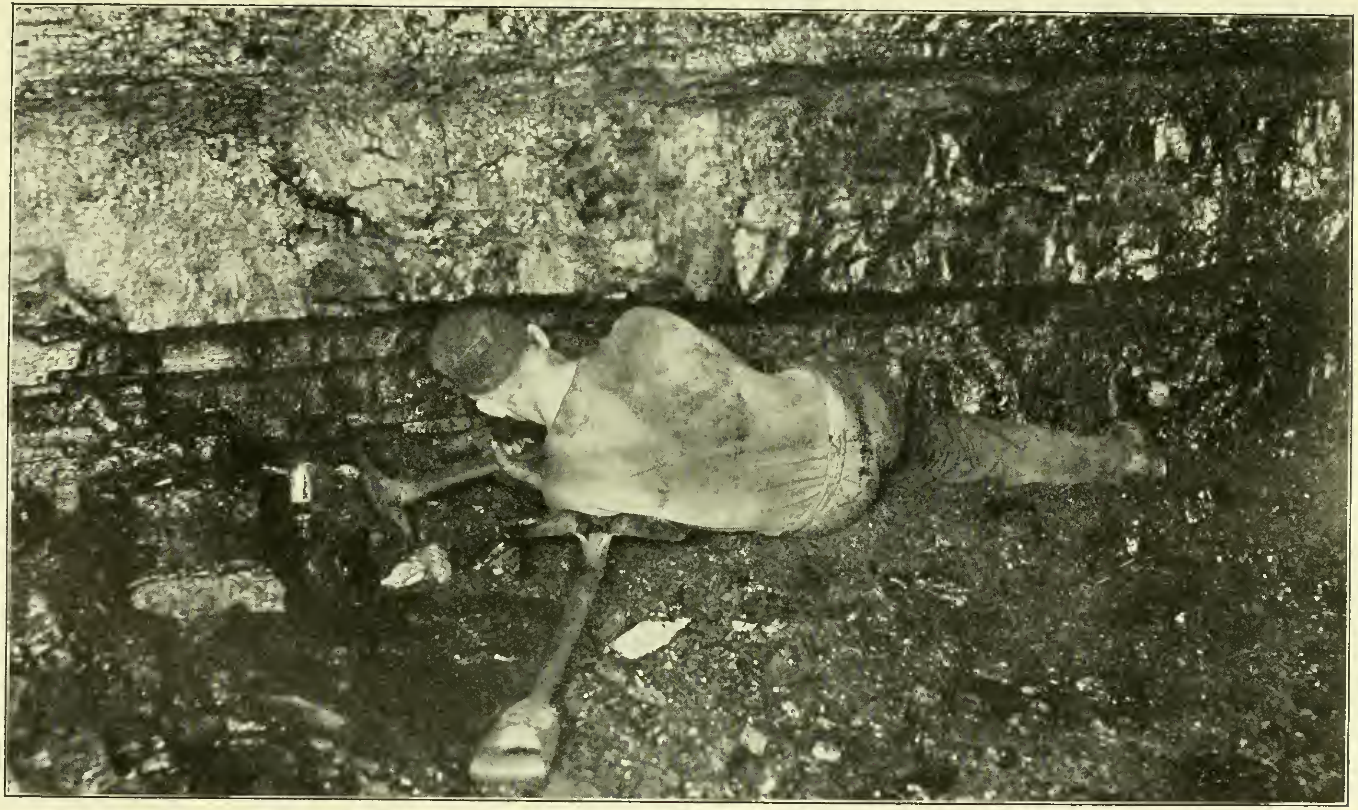
Early Coal-Mining Methods

From the earliest times the coal-beds, or seams as they are called, have been reached by one of three methods: the "shaft," the "slope," or the "drift." The shaft, either round or rectangular, is sunk vertically down to the coal. The slope is a tunnel driven downward at a steep angle; a drift is a horizontal tunnel leading into a coal seam. Where a shaft is sunk through water-bearing strata, a water-tight lining, or "tubbing," must be provided to prevent the flooding of the mine. All water that enters the mine flows into an excavation called a "sump" and must be pumped out. From the bottom of the shaft one or more main entries are driven, and off from these lie the headings or rooms in which the coal is mined.

Photograph by United States Bureau of Mines.

PICKING COAL BY HAND.

The picking-table was first added to the breaker about 1870.



HOLING COAL IN THE OLD WAY.

Before Francis M. Lechner invented the machine pictured on page 125, coal was "holed," or undercut, by hand.

In the earliest mines the coal was broken loose from its long resting-place with crude picks and thrown into baskets strapped upon the backs of carriers who toiled up and down long ladders or rough stairways. Later it was placed first in sleds, and then in carts, which were dragged by women and children to the foot of the mine shaft. From there a bucket and windlass, operated by horses or mules, brought the coal to the surface. Gradually mules did the work of the women and children, and eventually steam and electricity hoisted the coal to the surface. Coal-mining has now been placed almost entirely upon a machine basis.

The Breaker—The First American Contribution

In the following pages we shall tell the story of American achievement in revolutionizing the coal industry of this and other lands. In this, the first distinct contribution of American inventors to the art of coal-mining was the coal-breaker.

A breaker is a large structure, usually of steel, but formerly of wood, in which anthracite coal is prepared for market. It is not used for bituminous coal. It was in 1830 that the first attempt was made to prepare coal after it had been mined. By means of rakes, workmen in the mines separated the large lumps from the small ones. Only the larger lumps were brought to the surface, where they were dumped upon perforated cast-iron plates and broken up with hammers into sizes suitable for use.

In 1844, two brothers, J. and S. Battin, invented the roll-crusher and used it in their coal yard at Philadelphia. In that same year Gideon Bast, of Minersville, Pennyslvania, erected the first breaker with circular screens. With it he could break and clean 200 tons of coal in a day. Thirteen other breakers were built, in 1845, in this same field. In the first breaker steam was used to drive the machinery, but at many of the smaller plants horses furnished the power. The first rolls were made of cast iron, but the teeth were brittle and easily broken; so, in 1876, steel teeth were substituted, being driven into a cast-iron shell. At the Hill and Harris colliery, at Mahonoy City, Pennsylvania, the picking-table was added to the breaker in 1870. On it the slate was picked from the coal by men and boys. Then the jig, another device for separating the slate, was introduced in the lower anthracite regions.

The man who was most closely associated with the later development of the breaker was Eckley B. Coxe, one of the most prominent coal operators of the anthracite region. His grandfather, Tench Coxe, as far back as the Revolutionary days, foresaw with remarkable clearness the future value of coal to industry. He acquired vast tracts of coal lands, which two generations later were developed by his grandsons, Eckley and Alexander. As a young man, Eckley studied chemistry and physics at the University of Pennsylvania, and spent his summer vacations prospecting in the family coal-fields. Very quickly he became familiar with coal-mining in all its details. After a year of study abroad, he returned in 1864 to develop his coal properties. By 1889 he was producing nearly a million and a half tons a year.

At the Red Cross collieries, and later at Drifton in his native State, Coxe devised new machinery for sizing coal. The coal is first carried in cars to the top of the breaker building, from where it makes its way down to the waiting railroad-cars and storage bins below. As it does so it is separated into grades of various sizes. For this purpose he invented gyrating screens and oscillating bars, that is, bars with a to-and-fro movement. These resulted in better methods of feeding the coal and in increased speed of operation. Coxe also introduced corrugated rolls with continuous teeth from end to end to break up the lumps. He provided a regular series of these rolls adapted to the various sizes of coal required.

To separate the slate he adopted an automatic slate-picker, depending upon the fact that slate is thinner than coal and will drop through a slit over which the coal will pass. Improved forms of "jigs," another American invention for separating slate, formed a part of the Coxe breaker. The jig consists of two compartments. In one compartment a plunger descends, forcing water through a grate up into the other on which rests the coal and slate; the coal being lighter is forced to the top, while the slate settles to the bottom. Stephen R. Krom, of New York, John H. Paddock, of St. Johnsbury, Vermont, and

Collom and Hartz are among those who have taken out patents on various forms of jigs.

Although Coxe set the standard in breaker construction, other operators have made improvements. Many of these make the work more nearly automatic, avoid rehandling, and eliminate waste.

Coal-Cutting Machinery

The first mining machine on record was patented in 1761 by Michael Menzies at Newcastle-on-Tyne, England. His purpose was to transmit power from the surface, by means of rods and chains, to a heavy pick in the mine below. Little more was accomplished until 1867, when Howit, another English miner, invented a "percussive" machine operated by compressed air. Such a machine, as its name indicates, delivers a hammer-blow. Although Howit's machine was not a success, it served as a model upon which other inventors soon improved.

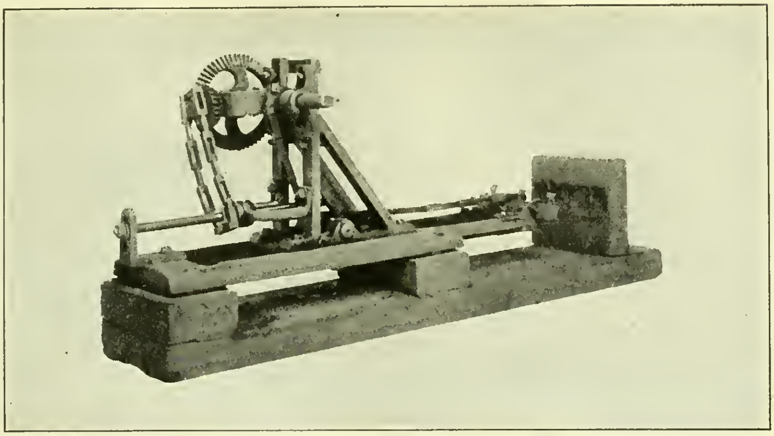
The first coal-cutting machine in America was invented after four years of work by Horace F. Brown, of Indianapolis, in 1873. Brown called it the "Monitor Coal-Cutter." The machine was mounted on a cast-iron frame, and its chief feature was a revolving rim which carried cutting teeth. It was operated either by steam or compressed-air engines, and ran on a track. This first American machine, and one of the first in the world, was used in June, 1873, in the Coal Brook Mines at Brazil, Indiana.

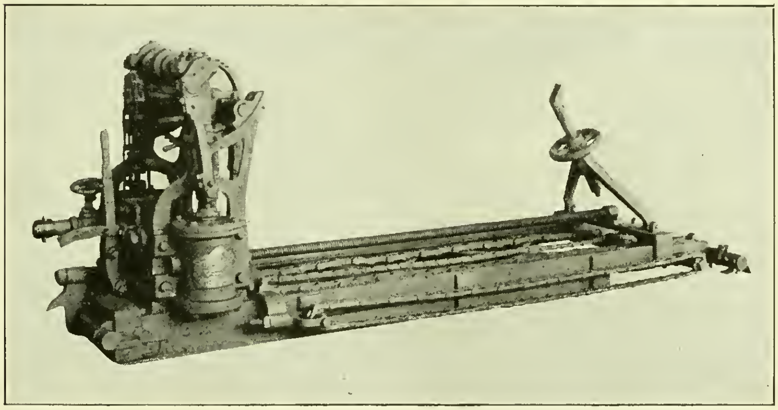
The first patent on a pick-mining machine in the United States was issued on Christmas Day, 1877, to J. W. Harrison. Although not a decided success at first, this machine was improved, and manufactured later by the George D. Whitcomb Company, of Chicago.

That the pick should form the basis of experimentation was perfectly natural. But, although the mechanical pick was a vast improvement, and is still used, it has been largely displaced by more rapid machines.

Joseph A. Jeffrey and His Coal-Cutter

Standing foremost, perhaps, and one of the pioneers in this field of invention, is Joseph A. Jeffrey, of Columbus, Ohio. One





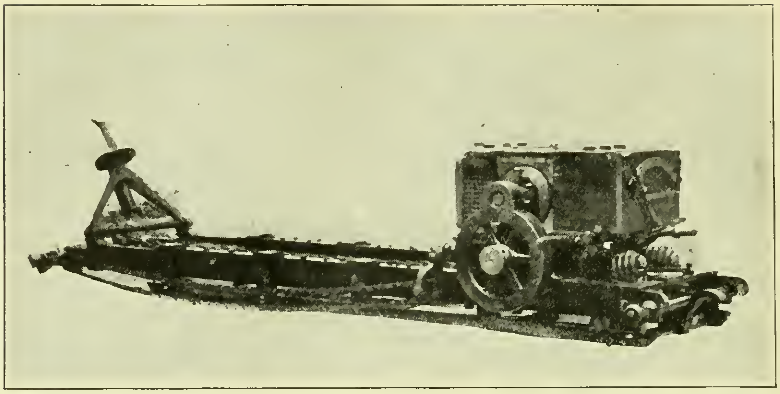
(Above) MODEL OF LECHNER MACHINE FOR UNDERCUTTING COAL.

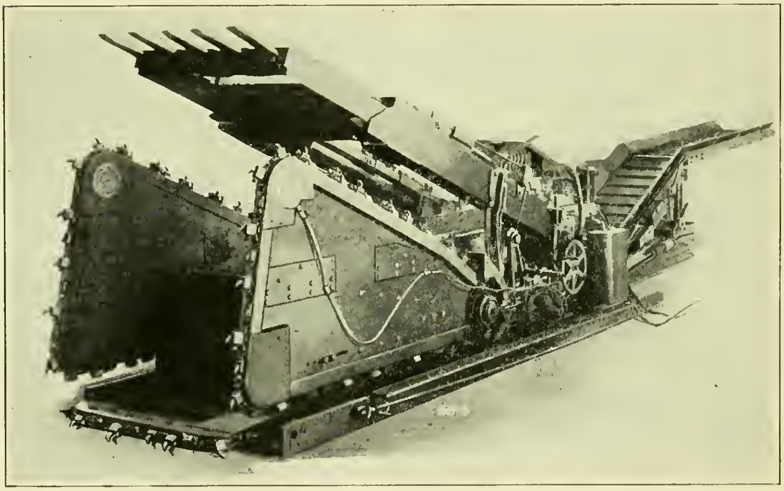
Francis M. Lechner had exhibited in a store window in 1877 the model which attracted the attention of J. A. Jeffrey. The machine was intended to show the feasibility of undercutting coal before it was blasted.

(Below) MACHINE BUILT ABOUT 1878 ACCORDING TO LECHNER PRINCIPLES.

The first commercially successful coal-cutter. A pair of vertical engines driven by compressed air furnished the power. Coal was cut by a chain-driven revolving cutter-bar, the coal being cut by "bits" inserted in the bar. Later the engines were mounted horizontally to reduce the height. This machine paved the way for the modern electrical coal-cutter.

day in 1877, as Jeffrey, who was connected with the Commercial National Bank of Columbus, Ohio, was passing a store window, he noticed on exhibition the model of a coal-cutter. Francis M. Lechner, the inventor, had placed his model there for the purpose of interesting some one of means and ability





(Above) THE JEFFREY-DIERDORFF CHAIN-BREAST MACHINE.

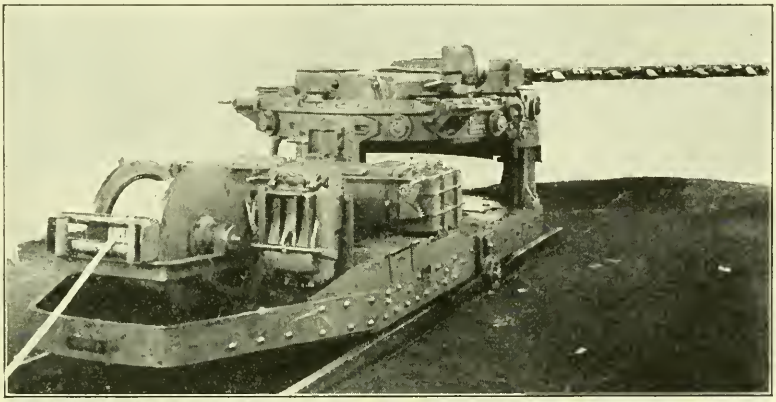
This machine, for which H. B. Dierdorff was responsible, was known as the "chain-breast" machine. It consisted of a movable frame inside of a stationary frame. The motor was mounted on the movable frame; so were the gearing and triangular cutter-bar, around the periphery of which ran an endless cutter-chain composed of alternate strap and solid lugs. The lugs carried removable cutter-bits. The stationary frame was jacked down to the bottom. As the movable frame was fed forward the cutter-bar was forced under the coal, cutting the kerf about five inches wide, and six feet deep. After the cut was made the machine was moved to a new position by crowbars in the hands of the machine runners.

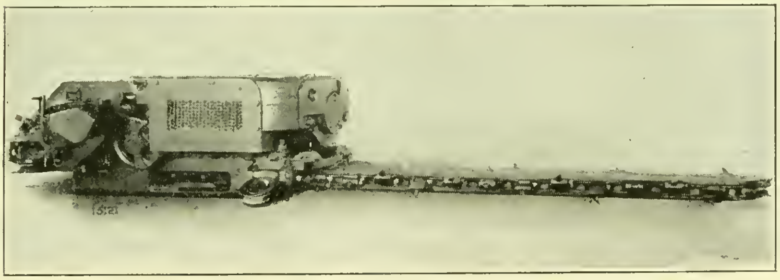
(Below) A MODERN JEFFREY CUTTING-AND LOADING-MACHINE.

This machine not only cuts coal, as does the breast and shortwall type of machine, but picks it down, conveys it back and loads into mine-cars. The first machine dates back to 1911. A machine of this type is fed into the coal to the limit of its bed-frame (about seven feet). All of the coal up to a height of forty-eight inches within reach is taken out. The machine is then withdrawn into the frame and moved by its own power four feet (the width of the cut), and the operation repeated. One hundred tons of coal are thus cut and disposed of in nine hours.

toward its development and manufacture. Lechner was one of the great designers of coal-mining machinery, and his death on January 30, 1915, marked the passing of one who contributed much to the development of his country's resources.

Jeffrey was immediately interested, and through his efforts the Lechner Mining Machine Company was organized. He was embarking upon a new field. An imperfect and untried invention needed both time and money for its development, but this was an invention that would work a revolution in the methods of coal-mining if it proved successful. The original model convinced Jeffrey that the idea was a sound one.



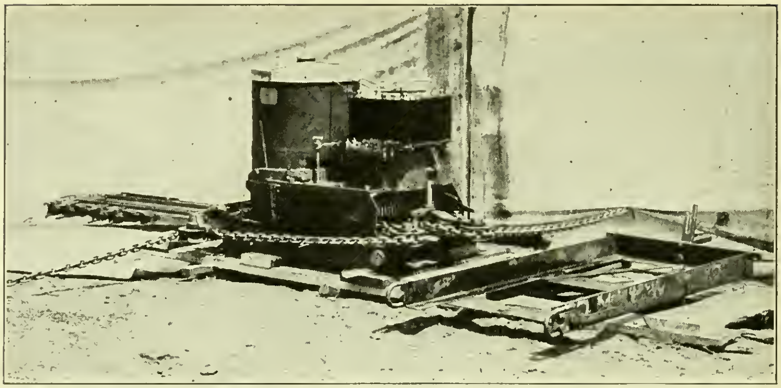


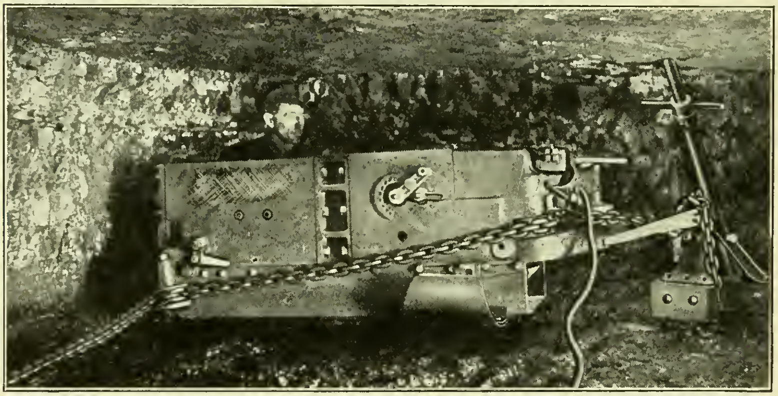
(Above) LATEST TYPE OF JEFFREY ARCWALL CUTTER.

The arcwall cutter, of which this is the latest Jeffrey type, met the demand for a machine which would cut coal at the top or in the middle because of the greater amount of dirt found at the bottom. The face of the cut is left in the form of a semicircle; hence the name "arcwall."

(Below) LATEST FORM OF JEFFREY SHORTWALL CUTTER.

Originally developed about 1906. Here the Lechner chain principle is also applied.





(Above) FIRST SULLIVAN ELECTRIC ROOM-AND-PILLAR MACHINE.

This had the new feed-and-control chain arrangement, the pan or starting frame (at right), and the friction clutch drive. This was an air machine remodelled about 1897.

(Below) SULLIVAN IRONCLAD CUTTER.

The machine consists of a motor section or power plant, a cutter section (including the cutter-bar and cutter-chain), and the driving gear by which power is applied to the cutter-chain and to move the machine along the face or about the mine by means of the feed-chain.

The machine was designed to undercut the coal previously to blasting, and to take the place of the laborious method of hand-picking and of the crude pick-machines in use. It was of the cutter-bar type; that is, the cutting was done by a bar with rigid, sharp bits. The machine was placed with the bar to the face of the coal, and compressed-air engines drove the revolving cutter-bar forward into the coal. The feeding-and-cutting machinery was mounted on a stationary frame, and when the bar had been driven forward to the limit of this frame, the machine was backed up and pushed over another width. This was the earliest of the so-called "breast machines." They were first used in the New Catfish Mine in Clarion County, Pennsylvania, and in a mine at Straitsville, Ohio. They were not very robust; while they worked fairly well in cutting soft coal they quickly went to pieces in the anthracite mines. But there was no damping the enthusiasm of the inventors. Despite the fact that these early machines were constantly on the road between the mine and the repair-shop, no one lost faith in them. It was felt that a perfect machine of this order was sure to be sooner or later developed.

Among the difficulties which these pioneers had to overcome was the opposition of the miners themselves. Here was a machine calculated to ease their burdens as nothing else had ever done, and yet they looked upon it as an enemy. In consequence, many of the machines were deliberately wrecked. It was Charles H. Welch, popularly known as "Uncle Charlie," who, at the Straitsville mine, put fear into the hearts of these foes of a new and better day. Gun in hand, he presided over the cutting-machine by day, and protected it by night. Welch also made many suggestions for improvements in the original types. Other men of the Jeffrey Company whose inventions went into the improvements which made possible ultimate success were H. B. Dierdorff, H. H. Bliss, Benjamin Legg, Albert Hoermle, and Bromley.

Later Types of Machines for Cutting Coal

Although these were the first commercially successful attempts at machine mining, the results were pitifully small as compared with those of present-day methods. The improved cutter-bar machines were still unsatisfactory. Then, in 1893, under the direction of H. B. Dierdorff, the first successful breast-type chain cutting-machine was invented. Instead of using a cutter-bar, the bits were set in an endless iron chain. The first of these new machines was put to work in February, 1894, in the mines of the Sunday Creek Company at Congo, Ohio. It proved an instantaneous success. The operation, however, was the same as before; after undercutting to the limit of the stationary frame, it was necessary to back up and set the machine over, a long and laborious process, but the machines were now driven both by compressed air and electricity.

Although the chain cutting-machine of the breast type required less power, needed less repair, and was more economical, still the goal had not been reached. From 1896 to 1898, there was brought out simultaneously by a number of companies, including the Jeffrey Company, the Sullivan Machinery Company, the Morgan-Gardiner Electric Company, and the Link-Belt Company, a new machine vastly superior to any of its predecessors. This was a continuous cutting-machine. It carried a long, narrow cutter-bar, like the cutting-bar of a farm mowing-machine. Running about this bar was an endless iron chain in which were set the cutting-bits. The bar could be moved in a horizontal plane through an angle of 190 degrees. Starting at one corner of a mine "room," the machine cut its way straight into the depth of the cutter-bar, and then moved directly across the face of the coal to the opposite side of the room. With frequent improvements this machine has been developed into the standard present-day coal-mining machine. It is used wherever coal is mined, and stands as one more monument to the genius and enterprise of American inventors.

With the machines thus far developed the cutting was always done at the bottom. But on account of dirt bands, rock layers, and other impurities often present in the coal, it frequently became desirable to be able to cut coal at the top or the middle of the face. To meet this need the Jeffrey engineers developed what they call the "Arcwall" machine. It carries an elevated cutter-bar which makes possible the cutting of coal at any desired point.

It was inevitable that American ingenuity should not rest. We now have a single machine that undercuts, knocks down, and loads the coal into the mine-car—all in one operation. This, too, is a product of the inventive genius of the Jeffrey engineers. They made their first attempts at producing this type of machine in 1911. The first one was tried out at Kilsythe, West Virginia, in 1912. It was not very satisfactory but it showed the way, and soon a highly successful machine was the result. An undercutter, two vertical shearing arms, a pick frame, a coal-conveyer, and a motor are its chief features.

Two Pioneers in Building Mining Machinery

In 1850 there graduated from Dartmouth College a young man named James Phineas Upham. His father, of Claremont, New Hampshire, had been for many years a member of Congress, riding to and from Washington on horseback. In 1851 the younger Upham started a small machine-shop at Claremont. Among the products which he turned out were engine-lathes, iron planers, paper-mill machines, circular saws, and water-wheels. At the Crystal Palace, in New York, in 1856, he was awarded the highest prize medal for water-wheels.

As the years passed, Upham was establishing for himself a profitable business. But a still larger business awaited him. One afternoon, in 1868, as he was trimming apple-trees near the roadside of his estate, two strangers drove up and inquired for James Upham. They were Albert Ball and Roger Love, from Windsor, Vermont. Having invented and patented a diamond channelling-machine for quarrying stone, they wanted Upham to build it for them. Then and there over the stone wall by the roadside an agreement was reached, and in that moment the Sullivan Machinery Company had its real beginning. It took its name from the county in which the business was located, a county named in honor of General John Sullivan of Revolutionary fame.

Ball, for fifty years the chief mechanical engineer of the company, was born in 1835, in Worcester, Massachusetts, where as a youth he learned the machinist's trade. He made many inventions, one of them being a repeating rifle, which was bought by the Prussian Government. Many thousands of these rifles were used in the wars from 1866 to 1871. At the request of our own government he invented a machine for lubricating bullets easily and cheaply, and it became the model for almost every other similar device. In mining machinery, he invented rock-drills and drill mountings, the early continuous chain cutting coal machines of the Sullivan Machinery Company, and their air-driven coal-pick machine.

Since the early nineties of the last century, the Sullivan

Machinery Company has been a foremost manufacturer of coal-mining machinery. Their "Ironclad Coal Cutters," particularly those of the "Longwall" type, are used in every part of the world. One of the early inventors of Sullivan machinery was Jonas Mitchell.

How Rock-Drills Were Developed

Among the earliest of the rock and coal cutting tools were drills. At first they were driven by hand, then by steam, compressed air, and finally by electricity. The original and still one of the most important uses of drills is for making holes preparatory to blasting out the rock. The air-driven pick-machine is really a larger application of the principle of the drill.

One of the earliest drills made in this country was the "Burleigh." * It was used in 1874 on the Hoosac Tunnel, but its life was only fifty hours, and it required four machines to keep one drill in operation. At this time there were in operation four drills of American make: the Burleigh, the Rand, the Ingersoll, and the Waring. Another American inventor who did pioneer work in this field was Sergeant. Although all of these men have now passed from the scene of action, the names of three of them—Rand, Ingersoll, and Sergeant—are still associated with well-known companies devoted to the manufacture of drills and other mining machinery. Three of these early drills had automatic feeding devices, and the Waring was able to make a speed of two inches per minute. One of the first successful electric drills was invented by W. A. Box, of Denver, about 1903.

But the man who contributed more than any one else to the art of removing rock and uncovering the mineral resources of our country was John George Leyner. Taking the crude, imperfect drilling devices of his predecessors, he fashioned patterns with the expertness of a skilled mechanic and the insight of real genius, which, for more than a decade, have set the standard of excellence in every mining-camp of the world.

Under the magic of Leyner's hand and brain, the rock-drill passed through the percussion stage, in which clumsy machinery

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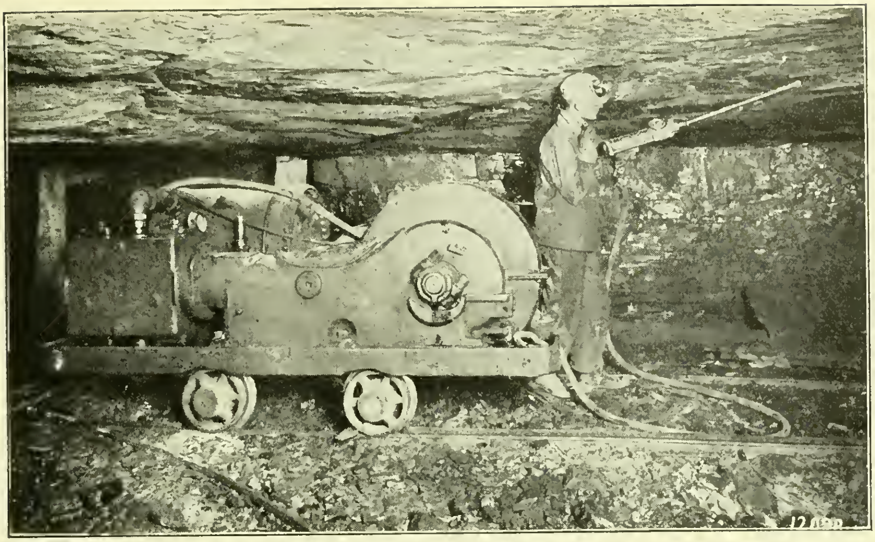
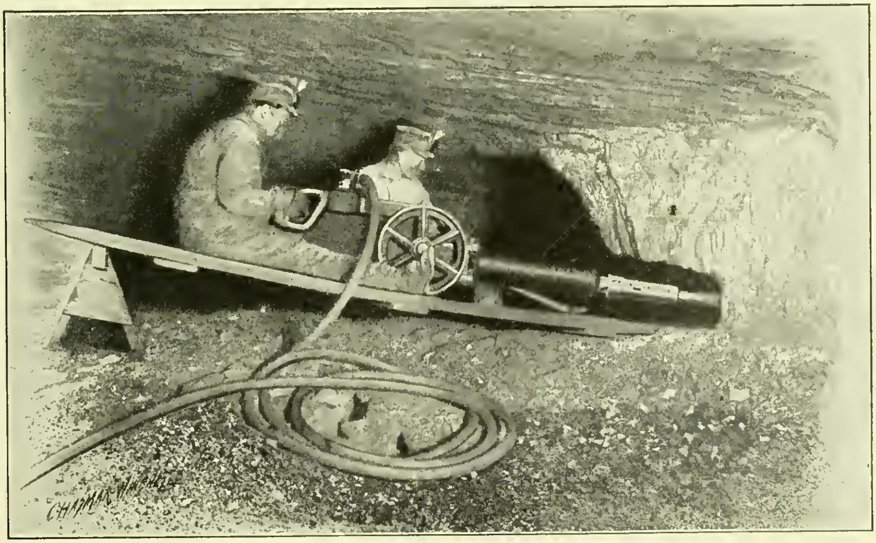
* See chapter on "Mining Copper and the Nobler Metals," p. 47.



MINE POWER ON WHEELS.

Ingersoll-Rand mine-car compressor and Leyner jack-hammer outfit working in the Lynch Kentucky mines of the United States Coal and Coke Co.



SULLIVAN COMPRESSED-AIR PICK-MACHINE.

Although pick-machines of this type are still used, they have been largely displaced by coal-cutters.

and heavy weights had been employed, to the compact, small, and highly efficient drill of to-day. Together with Ingersoll and Joseph Githers, he developed the "jackhammer" or piston type of drill. Up to Leyner's time, this had been considered an impossible feat. How to reduce its weight, simplify its mechanism, and yet make it strong and efficient, had baffled his predecessors. But Leyner saw that the future of mining operations demanded a perfect machine of this type, and after nine years of patient work he achieved success. As a novel feature of the drill, he first introduced a water-jet through the piston for clearing out the cuttings. More about Leyner's work and his drills is told in the chapter on "Mining Copper and the Nobler Metals."

In 1902 he organized a company and, employing the highest quality of material and workmanship, he evolved many of the standard rock-cutting tools of to-day—tools that are very widely used in coal and other mining operations. The "jackhammer," the most generally used rock-drill of America and Europe, is built on the Leyner principle. This drill holds the world record for fast tunnel driving. Leyner also invented the drill sharpener that now sharpens ninety per cent. of all machine-sharpened tools. His great achievement, however, was reducing the cost of rock and ore removal. In 1911, he sold his patents on mining machinery to the Ingersoll-Rand Company, and turned to other fields of invention. The "Little Tugger" mine hoist and the perfection of a farm tractor, on which he was engaged at the time of his death, proved the versatility of his inventive genius.

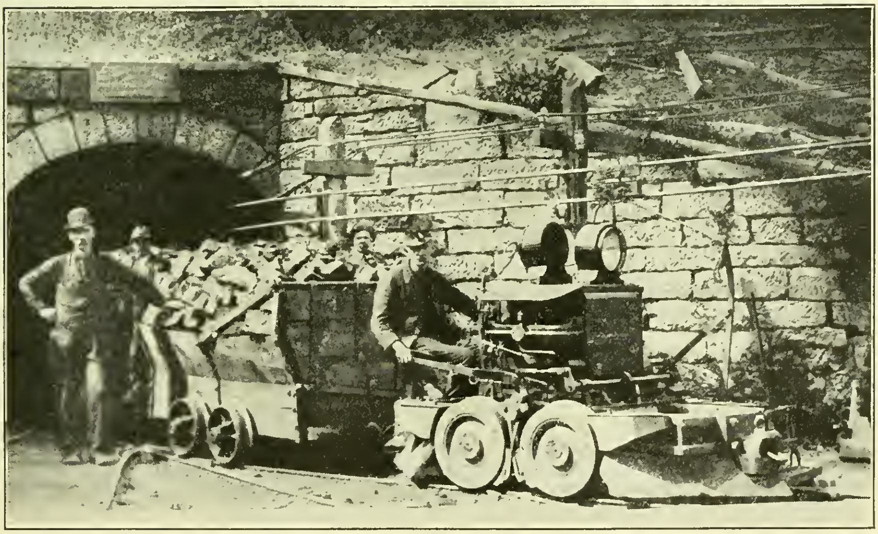
Electrifying the Coal-Mines

The first electric locomotive operated by current from a dynamo was not exhibited, even as a curiosity, until 1879. But three years from that date these remarkable locomotives were doing service in the coal-mines of Saxony.

The first electric surface railway in this country was built at Richmond, Virginia, in 1887; that same year the first electric mine locomotive was put into service at the Short Mountain Colliery of the Lykens Valley Coal Company, at Lykens, Pennsylvania. The installation was designed by W. M. Schlessinger,

Courtesy of United States Bureau of Mines.

THE PREDECESSOR OF THE ELECTRIC AND COMPRESSED-AIR MINE LOCOMOTIVE.



THE FIRST ELECTRIC MINE LOCOMOTIVE.

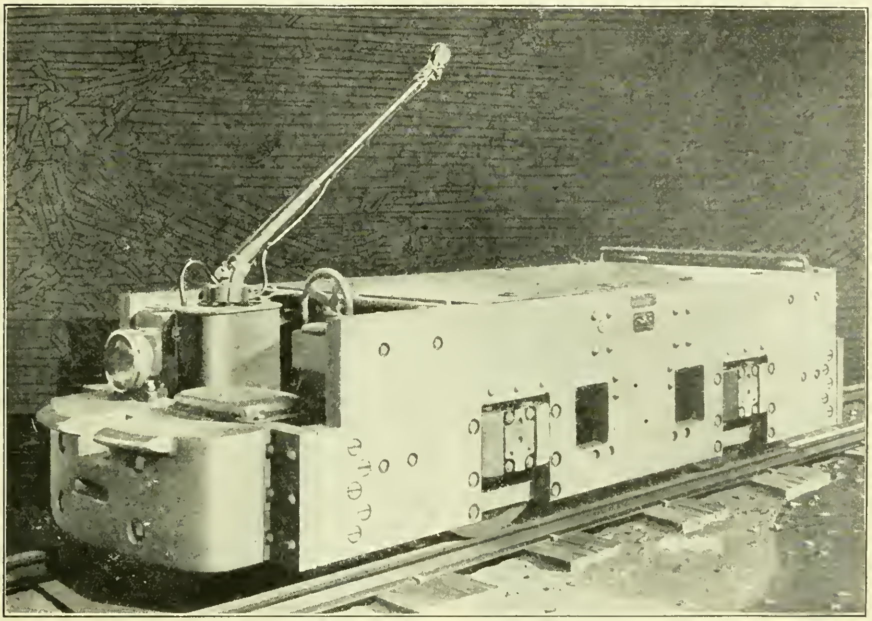
Jeffrey electric locomotive built in 1888, the first used in the bituminous mines of the United States. Galvanized-iron pipes served as the electrical conductors instead of wires.

and consisted of two motor-cars, each weighing about five tons and equipped with a thirty-two horse-power motor. This work was done under the direction of Irving A. Stearns, of Wilkes-barre, one of the most prominent mining engineers of the anthracite region.

In the following year, 1888, the Jeffrey Manufacturing Company designed and built the first electric locomotives used in the bituminous coal-mines of the United States. They were installed in the mine of the Upson Coal Mining Company, at Shawnee, Ohio. A unique feature of the equipment was the use of one-inch galvanized iron pipes, instead of wires, for conductors. To H. H. Bliss and H. B. Dierdorff, of the Jeffrey Company, belongs the credit for originating the idea of these locomotives and carrying out their construction. Jeffrey had previously applied to several of the leading electrical firms of the United States, asking them to equip his coal-cutting machines with electric motors and supply him with electric locomotives. It should be remembered that electric machinery was then in the experimental stage, and this state of affairs resulted in the failure of the different firms to meet Jeffrey's requirements. He then secured the services of several electrical engineers, and with the aid of his own staff began, within his own plant, to apply electricity to coal-mining machinery.

From that day to this the electric locomotive for every type of mine service has constantly grown in favor. It unites a high degree of efficiency, great mechanical strength, and simplicity of control with a compactness of form unattainable in any other mine tractor. These locomotives have now reached a very high state of perfection, and are both of the trolley and the storage-battery type. For more than thirty years the General Electric Company has pioneered in the development and manufacture of electric mine locomotives; other companies also contributing. To-day more than ninety-five per cent. of power-driven coal-mining machines use electricity. In 1888, in the shops of the Jeffrey Company and under the direction of H. H. Bliss, the first electrically driven coal-cutting machine was built. It was put to work in the Whip-Poor-Will Mine, in Perry County, Ohio, where it gave good results from the start. The Jeffrey engineers then made six electric drills for the Ellsworth and Morris Coal Company, at Sand Run, Ohio, the machines doing excellent work for many years. In 1891, E. A. Sperry, of Chicago, made the first electric pick-machine, and a little later the Morgan Electric Company became conspicuous in this field of invention and manufacture.

Electric lighting in the coal-mines was introduced about the same time as the electric locomotive. Samuel Hines and Captain W. A. May, of the Hillside Coal and Iron Company at Scranton, Pennsylvania, first used electric arc lights in their breakers in 1886. Soon after this, the mines themselves began to be electrically lighted.



LATEST TYPE OF MINE LOCOMOTIVE.

The modern electric mine locomotive unites high efficiency, great mechanical strength, and simplicity of control with a compactness of form unattainable in any other mine tractor.

From these early beginnings, the applications of electric power in coal-mining have steadily grown. Not only does electricity light the mines, cut the coal, and drive the locomotives, but it also lifts the coal to the surface, pumps the water, runs the conveyer-belts and picking-tables, drives the ventilating-fans and air-compressors, operates the crushers, and keeps in motion the machinery of the breaker and the tipple.

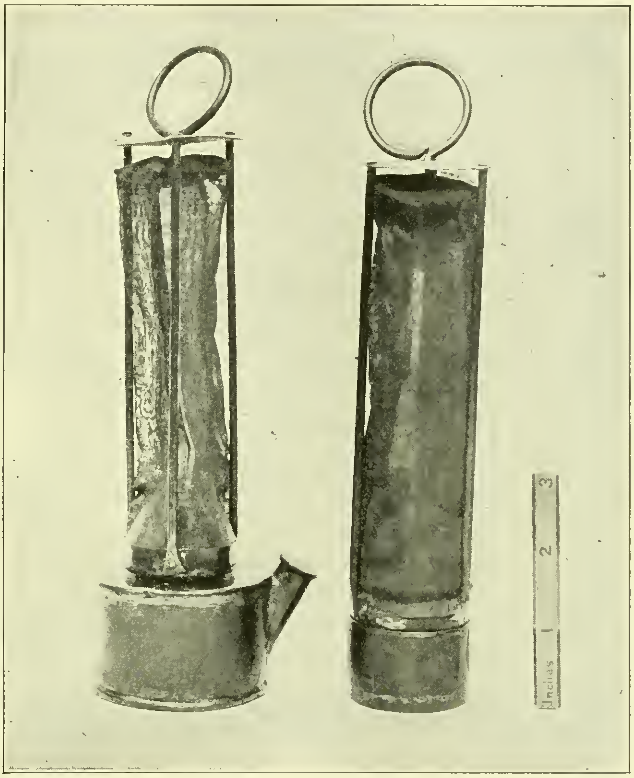
Compressed Air in Coal-Mining

One of the earliest sources of power for operating mining machinery was compressed air. Drills, pick-machines, and coal-cutters were all dependent upon the energy stored in the elasticity of compressed air. This medium of applying power is still very extensively used.

The pioneer in the field of mine haulage is the H. K. Porter Company, of Pittsburgh. Back in 1866, this company, then known as Smith and Porter, began to build steam-locomotives for service in the coal-mines and, in 1891, the company brought out its first compressed-air locomotive. Since coal-mines are often filled with highly inflammable gas, there could be no such thing as a fire-box. The first Porter steam locomotive, called the "Black Dwarf," was built and was sold to Wood, Morrel and Company, of Johnstown, Pennsylvania. These early locomotives were manned, as a rule, only by one man—an engineer. Since they travelled but two or three miles, only a small quantity of fuel was required, and this, about 700 pounds at the most, was carried in a box in the left-hand side of the cab. Later fireless mine locomotives were introduced. In these, highly heated steam —what is called "superheated" steam—is forced under high pressure into a boiler-like container, and enough of it is thus stored up to drive the engine for a few hours.

The first Porter compressed-air locomotives were built under the direction of Horatio Nelson Sprague. In the immediate years prior to this time there had been built in this country ten compressed-air locomotives; but they were only curiosities, and the mule and the donkey engine continued to hold sway in the coal-mines of the world. Under the advice of Richard P. Rothwell, the Lehigh Coal and Navigation Company was one of the first to employ underground locomotives at their Mauch Chunk Mines, in 1869. Now steam locomotives have practically disappeared, and the mules have been largely banished.

In many respects the compressed-air engine is the ideal form of power for mine haulage. There is no danger of sparks or short circuits, which would quickly result in fires and explosions—a recurring black page in the history of the coal-mine. In 1908, under the combined efforts of E. B. Lord, C. B. Hodges, and H. B. Ayres of the Porter Company, the two-stage compressed-air locomotive was built. This is a double-expansion engine, and highly efficient. It has been very widely introduced, and has hauled millions of tons of coal in this and other countries.



ORIGINAL DAVY SAFETY-LAMP IN THE SOUTH KENSINGTON MUSEUM, LONDON.

Davy Invents the Safety-Lamp

Probably the earliest devices to lessen the dangers of coal-mining were safety-lamps. The flint-and-steel mill, invented about 1750, represents the first attempt in this direction. It consisted of a steel disk which was rapidly rotated against a piece of flint, thereby producing a shower of sparks. A very crude and laborious way of producing light, but it was thought that these sparks were not hot enough to ignite the explosive mine gases. This proved to be a delusion, however.

Among the early experimenters in this field were Doctor William R. Clanny, of County Down, Ireland, and George Stephenson, the inventor of the steam locomotive. They made more or less successful lamps, but not until Sir Humphry Davy attacked the problem in 1815 was a really successful safety-lamp devised.

The "Society for Preventing Accidents in Coal-Mines" asked Davy to invent a safety-lamp. Very soon he brilliantly succeeded in applying the principle which ever since has remained the basic feature of all safety-lamps of the fuel-consuming type. He surrounded the flame with a cylinder of copper gauze. So good a conductor of heat is copper, that, although the explosive mine gases pass freely through the gauze and burn on the inside, the flame will not pass through and ignite the explosive mixture in the mine outside. The gauze, because of its large area, conducts the heat of combustion away so rapidly that the mine gases cannot be raised to their kindling temperature.

This lamp also enables the miner to detect the presence of small quantities of the explosive gases, fire-damp and carbon monoxide. These gases being light naturally rise, and by holding the lamp close to the ceiling and proceeding cautiously the miner is aware of their presence by the appearance of a long blue flame.

Although many improvements and new designs in safety-lamps have been made in this and other countries, no radical change came until the appearance of the electric lamp in recent years. W. J. Richards, vice-president of the Philadelphia and Reading Coal and Iron Company, originated the idea of an incandescent lamp, and the General Electric Company developed it. Probably the most successful electric lamp is the one invented by Edison. It employs his famous storage cell strapped to the belt of the miner, as a source of current.

How Fresh Air Is Supplied to the Miners

As a means of preserving the health of the miners and preventing disastrous fires and explosions, the mining engineer encounters no more vital problem than that of ventilation. In the earliest mines the only ventilation known was that obtained from the natural circulation of the air, due to differences in temperature. But it gradually came to be realized that the noxious gases issuing from the coal seams and the after-damp from blasting must be carried away and fresh air supplied. To begin with, this was accomplished by providing two shafts, an "upcast" and a "downcast." The upcast was always placed at a higher level than the downcast, and at the foot of it a fire was built. The heavy cold air then settled through the lower shaft and, in circulating through the mines, forced up the warmer, lighter air through the upper shaft; the principle employed in every furnace chimney to produce a draft. So that no portion of the mine will be missed by the incoming air, mine doors placed at various points in the passageways direct its course. Many of these doors are automatic in action. As a locomotive approaches, a spring is tripped, which opens it, and, when the locomotive has passed, a weight closes it again.

Within the last twenty years, particularly in the United States, expensive machinery has been invented to provide artificial ventilation. The airways are laid out and the mine doors arranged so as to insure perfect circulation in every part of the mine. The fire has been discontinued and instead of it, at the top of the downcast, powerful steam or electric centrifugal fans have been installed, which continually force immense volumes of fresh air throughout the mines. Here, again, the Jeffrey Company was a pioneer; while the B. F. Sturtevant Company, of Boston, also deserves praise for its work in this line.

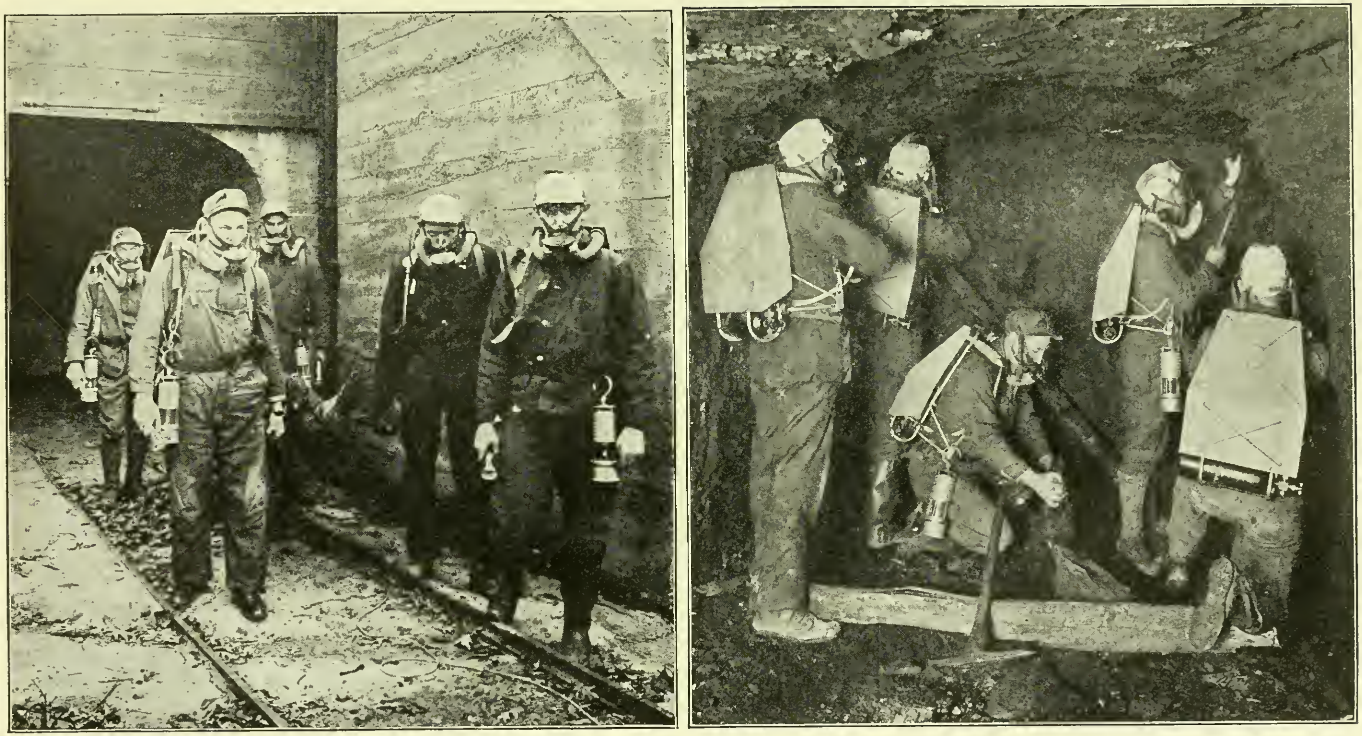
Mine Rescue Equipment

Although the electric safety-lamp was an immense improvement over the feeble-light-giving, smoky, foul-smelling oil-lamp, it does not provide any means of detecting the presence of combustible gas. To meet this need the Bureau of Mines has developed the Burrell gas detector. This device is so simple that any miner may operate it; it enables him to determine within one-tenth of one per cent. the proportion of combustible gas present. It is ten to twenty times as accurate as the safety-lamp, weighs less, and has fewer and more durable parts. In using the detector, the miner opens a valve, which admits a sample of the air to be tested. By means of an electrically heated platinum spiral, any combustible gas in the sample is immediately burned. A water-gauge and scale on the side of the apparatus then indicates the exact percentage of combustible gas.

One of the foremost leaders in the development of rescue equipment and accident-preventing devices is George S. Rice, chief mining engineer of the Bureau of Mines. Rice was born at Claremont, New Hampshire, in 1866. Educated at the College of the City of New York and the Columbia School of Mines, he went West and assisted in developing the early coal-mines of Colorado. He designed the modern, standard steel "tipple," the structure at a bituminous mine which takes the place of the anthracite breaker. After being appointed to the Bureau of Mines, Rice went abroad to study the causes and prevention of European coal-mining disasters.

His most important achievement was the introduction of rock dust to prevent coal-mine explosions. First the coal dust is removed as completely as possible from all mine roads, then by means of a "rock-dusting machine" all surfaces are thickly coated with dry pulverized rock dust. In case of an explosion the pressure-wave that travels ahead raises a dense cloud of this rock dust which, being non-inflammable, blankets the flame and smothers it. The "rock-dust-barrier," another of Rice's inventions, consists in placing at the entrance to each section of the mine a number of boxes or shelves containing rock dust. When an explosion occurs these boxes are automatically dumped, thus blanketing the flame.

An oxygen-breathing apparatus for mine rescue work, designed by W. E. Gibbs, an engineer of the Bureau of Mines, was brought out in 1917, after a long period of experimentation. This apparatus automatically regulates the supply of oxygen to the immediate needs of the rescuer. It keeps the air fresh and cool, the pressure-gauge can be read by touch, and thirty minutes before the oxygen supply is exhausted it rings an alarm. A pump within the mouthpiece removes saliva as fast as it is formed, a light aluminum cover incloses the whole ap-



(Left) MINE-RESCUE CREW OF THE BUREAU OF MINES, FULLY EQUIPPED WITH OXYGEN-BREATHING RESCUE APPARATUS, CARRYING AN UNCONSCIOUS MAN FROM MINE.

(Right) RESCUE CREW REPAIRING BRATTICE FOLLOWING AN EXPLOSION IN A MINE.

paratus, and the weight complete is only thirty pounds. With this apparatus a miner may penetrate anywhere, however poisonous the atmosphere or dense the smoke.

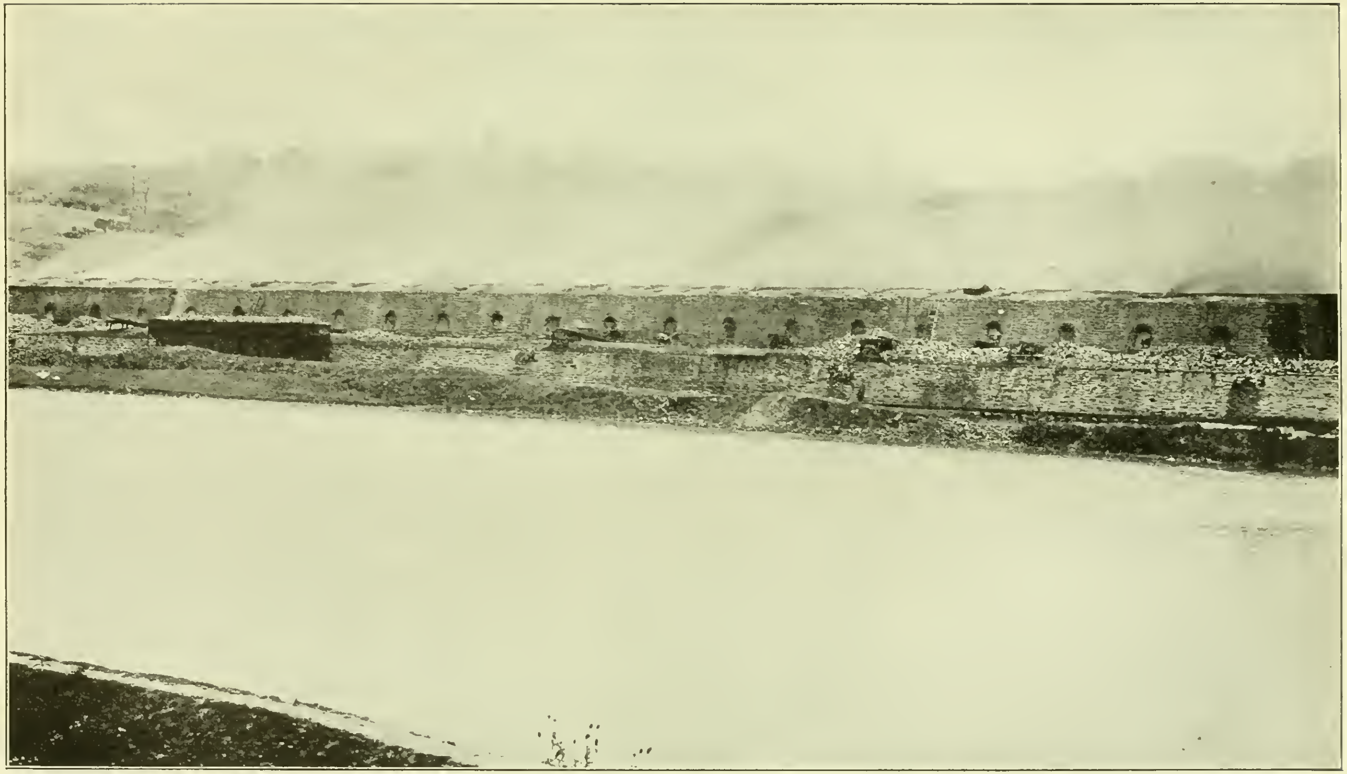
The Bureau of Mines has also developed the "Rescue Car," ready to proceed at a moment's notice to the scene of any disaster and equipped with helmets, oxygen cartridges, gasoline-tanks, lamps, shovels, picks, axes, saws, hammers, sledges, pipe-wrenches, rubber gloves, disinfectants, stretchers, fire-extinguishers, rubber hose, pulmotors, flash-lights, and complete first-aid equipment.

A new device, developed by French scientists during the war and improved since by American engineers, is the "geophone." It works upon the principle of the seismograph, the instrument for detecting earthquake tremors, and is extremely sensitive to sound-waves. It enables the blows of a pick to be heard through solid rock 2,000 feet thick, and speech through rock fifty feet thick. With this instrument it is possible to determine the location of entombed miners.

Coke and Iron

The history of coke-making in the United States begins with 1817. In that year a small quantity was produced by partially burying a mound of coal in dirt and sods, and then setting fire to it. Such coke was used in the rolling-mill of Colonel Isaac Meason, at Plumcock, Pennsylvania. No mention occurs of coke from then until 1825, when William Strickland was sent to England to study the methods of producing and using coke employed there. As a result of his report coke-making was again taken up, and by 1837 coke was being used in some furnaces as the sole fuel in the smelting of iron.

The first record of the use of coke-ovens dates from 1841, when Provance McCormick, James Campbell, and John Taylor, of Pennsylvania, formed a partnership for the manufacture and sale of coke. They produced coke in brick ovens and sent it down the Ohio River to Cincinnati, but the demand was so small that they gave up the venture in disgust. Not much more coke was produced until 1859, when Graff, Bennet and Company, of Pittsburgh, demonstrated for all time the success-



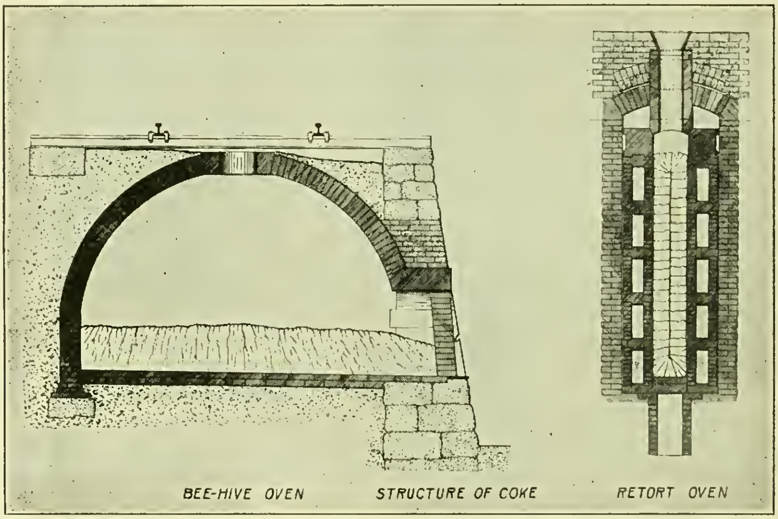
A WASTEFUL BEEHIVE COKE-OVEN.

The valuable by-products (gas and ammonia) go up in smoke. Considering the value of the by-product of coal-tar, this is the equivalent of burning the corner drug-store.

ful use of the new product as a blast-furnace fuel. From that time on the coke industry has grown at a tremendous rate.

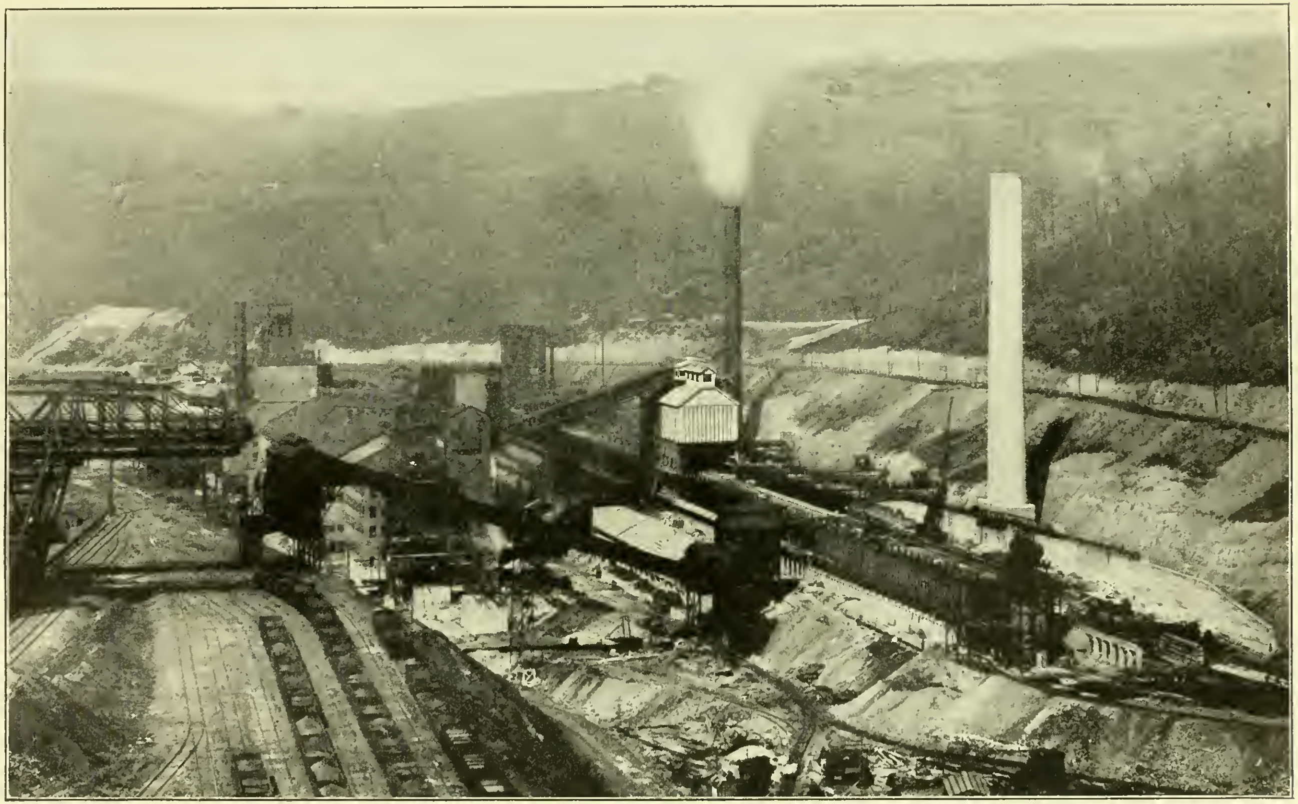
The closing decades of the last century marked the rise of the United States to world leadership in the manufacture of iron and steel. The two men to whose foresight and energy this remarkable industrial expansion was chiefly due were Andrew Carnegie and Henry Clay Frick.

Frick was a pioneer in developing the coke industry. In the early seventies, with the help of a friend, he organized Frick and Company, and acquired fifty-one ovens in the Connellsville district, and 300 acres of soft-coal lands. In the panic of 1873, Frick bought out his partners and enlarged his purchase of coal lands. Coke then sold at ninety cents a ton, but it soon rose to five dollars, and before he was thirty years of age Frick was rated a millionaire.



VERTICAL SECTIONS OF BEEHIVE AND RETORT OVENS ILLUSTRATING RESPECTIVE METHODS OF COKING.

A little later, Frick associated himself with Andrew Carnegie in the steel business, and together they became the largest users of coke and the greatest producers of steel that the world has ever known.



ALL THE BY-PRODUCTS ARE SAVED.

General view of by-product coke-oven plant of the Cambria Steel Co., Johnstown, Pa. There are 208 ovens. The capacity is 4,000 tons of coal per day. A plant such as this saves all the gas, ammonia, and coal-tar.

Coal-Tar and the By-Product Oven

In the "beehive" coke-ovens in use almost exclusively in this country until the beginning of the present century, the valuable by-products—gas, ammonia, and coal-tar—went up in smoke. Yet back in the early fifties of the last century a young English chemist, named George Mansfield, began the distillation of coal-tar to recover the valuable products it contained. After attracting attention to his experiments, he unfortunately lost his life in the explosion of his still. In 1856, Sir William Perkin, then a lad of seventeen, extracted mauve, the first coal-tar dye, and soon laid the foundation of a vast industry.

It is interesting to know that as early as 1857 coal-tar was distilled in this country by Samuel Warren, of Buffalo. The process, as a distinct industry, was started in 1887, by the H. W. Jayne Chemical Company, of Philadelphia, the forerunner of the present Barrett Company. Not until the beginning of the present century, and indeed not much before the outbreak of the World War, did the manufacture of coal-tar products become of great importance in the United States.

The pioneers in the invention and introduction of by-product ovens have been Coppée, of Belgium; Knab, of France; Simon, of England; and Otto and Koppers, of Germany. The ovens were introduced in this country in 1893, but were not really successful until 1906. In that year the United States Steel Corporation appointed a committee to investigate the by-product ovens of this country and Europe. As a result they built at Joliet, Illinois, 280 ovens of the Koppers type. An American firm which has been a large builder of by-product ovens is the Semet-Solvay Company, of Syracuse, New York.

America's Coal-Supply

When America was discovered there were locked up in its underground storehouse 3,541,000,000,000 tons of coal, of which we have used to date about 14,000,000,000 tons. This leaves us 3,527,000,000,000 tons, a seemingly inexhaustible supply. This enormous reserve is divided as follows: 17,000,000,000 tons of anthracite, 1,510,000,000,000 tons of bituminous, and 2,000,000,000,000 tons of lignite, the poorest variety of coal. In addition we have an estimated peat-supply of 14,000,000,000 tons. Our supplies of peat and lignite are still untouched; from the bituminous store we have drawn less than one per cent. At the present rate of consumption and the natural increase with the expansion of population and industry, it is estimated, however, that the anthracite coal-mines will be exhausted in seventy-five years. This will necessitate the coking of vast quantities of bituminous coal, in order to insure a supply of clean smokeless fuel for domestic use. But the by-products are valuable and this is an entirely feasible undertaking.

In 1870, we mined but 33,000,000 tons of coal, while now we are taking nearly 700,000,000 tons a year from our fuel estate. In 1870, the steam-engines in our factories, mines, and quarries developed only 2,460,832 horse-power, whereas these industries now use 31,250,000 horse-power; and if we add the steam power used on ocean liners, naval vessels, electric power-plants, railroads, and other enterprises we shall have a total of 96,000,000 steam-generated horse-power, most of which is produced by burning coal. More than 150,000,000 tons of the coal mined each year are burned under the boilers of railroad locomotives, and burned in a very wasteful fashion. Although our reserves seem ample, there is still a very large opportunity for the mining engineer to develop more efficient methods of fuel conservation.

CHAPTER V

THE STORY OF THE AMERICAN LUMBERING INDUSTRY

America's Primeval Forests

IN the fifteenth century, when Columbus discovered the New World, most of North America was covered by vast, primeval forests. In the region now known as the United States these forests reached from the Atlantic coast to the grass-lands lying almost entirely beyond the Mississippi River. West of the fertile plains of mid-continent they began again, practically covered the lofty Rockies, down to the edge of wide desert areas separating them from the heavy wooded slopes along the Pacific.

Naturally the first settlers who landed on the eastern seaboard found timber everywhere. Low swamps and high slopes were alike teeming with trees of all variety. There seemed to be no end of them. Nowhere on the face of the earth, perhaps, had man found bigger and more magnificent forests. Here, in America, was a sylvan realm of nearly 900,000,000 acres. The early settlers found this original timber-land far richer than any of which they had dreamed.

Europe has only twenty-five important timber trees, few of which reach an unusual size or attain a great age. In North America there are at least 525 different kinds of native trees, many of them famed throughout the world for their huge bulk and antiquity. In the Eastern States there are white oaks standing that were acorns when William the Conqueror took England, 500 years before the white man came to this country. On the Pacific coast were redwoods, erect and towering to the sky, that had withstood the storms of 2,000 years before the first caravel sailed the blue waters before them. Some of those grand old redwood-trees had been there since the days of Greece and Rome. They were among the oldest living things on the face of the earth. They were approaching middle age when the Christian era began, and they were full-grown long before Europe had even heard of Jamestown and Plymouth Rock.

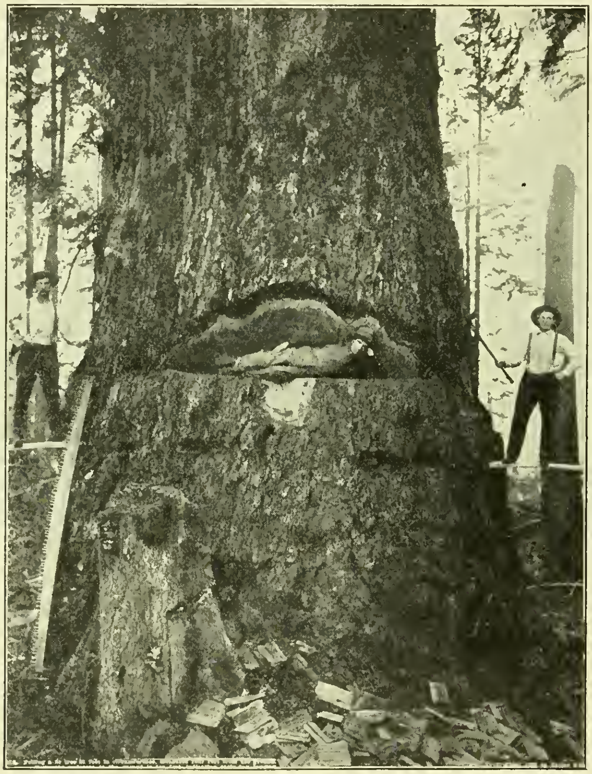
In an effort to find room for themselves and their families by redeeming the wilds from the rule of beast and savage, the early colonists became our first lumbermen. They began the gigantic task of reducing the forests with crude axes and saws. To begin with, they made small clearings in the forest, getting wood for their log cabins, and at the same time gaining land on which to sow and cultivate their first crops. It must have been a heartrending struggle. After their homes were built and they had a patch of corn around them, they still found themselves completely isolated. Huge trees hemmed in their advance on every side. The forest was both friend and foe, for though it supplied them with shelter, food, and fuel, it also blocked their progress. Thousands of acres of the very finest timber had to be destroyed in order to make room for additional farms and buildings.

Courtesy of the United States Forest Service.

A HEAVY STAND OF TIMBER ON THE RAINIER NATIONAL FOREST, WASHINGTON.

Sawtooth and Bird Mountain left of centre. Nowhere on the face of the earth were there such stands of timber when the United States was first settled.

During this initial development of American civilization, the pioneers began to realize the great wealth and worth of the forests. Not only were rough logs used for homes, schoolhouses, and churches, but for strongholds, forts, and stockades to shelter the brave frontiersman and his family from the attacks of the Indians. With the establishment of trading-posts, more lumber was needed for construction, and as water transportation was developed there began a commercial demand for timber.



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THIS GIGANTIC FIR, FIFTY-ONE FEET IN CIRCUMFERENCE, WAS STANDING LONG BEFORE COLUMBUS DISCOVERED AMERICA.

In North America there are at least 525 different varieties of trees, many of them famed for their bulk and age.

That demand grew in leaps and bounds. Thousands of colonists came, cities and settlements had to be built. Ships, fashioned of native oak and pine, carried the riches of the New World to the Old. As industry increased, factories were erected. Yet more wood was required for the making of furniture and wooden implements. Wider and wider grew the inroads into the thick forests. Trees were cut down and worked into matches; they were ground to a pulp to make the paper on which news is printed; they were required for turpentine and resin; they were put into the still, so that we might have alcohol for varnish and fuel. The children's toys, the farmer's scythe and plough, a thousand necessities added to the call for lumber. Vast quantities were shipped to Europe, where there was not much timber of the quality found in America; and as the demand upon our resources became greater and greater, the means and methods for acquiring it had to be increased.

Remarkable as has been the enlarging of the facilities for the employment and usages of wood in trade, the work of felling trees and making the trunks ready for the factory and sawmill is done almost entirely by the axe and saw, implements which in form are little removed from those used by our forefathers. Who made the first axe? This is very much like asking who first ate an oyster. Long before recorded history, man swung an axe. At first it was simply a pounding instrument or a weapon, made of flint and rock. Some ingenious inventor of the Stone Age probably bored a hole in this tool and drove in a handle. It gave him a lever, adding force to his blow when he broke up dead branches that had fallen from trees during a storm. Some early tribes, and among them the North American Indians, chipped a groove about the stone head and bound a piece of pliable wood around it, holding it down in place with withes and gum. Then one end of the head was chipped down to a fairly thin edge, and the axe—as specimens from the oldest dwellings and caves show—developed into a cutting tool. To this day most axes are made so that they may be used both for chopping and pounding.

The American Woodsman's Axe

When man learned to use metals, as he did in the Bronze Age, he made axes with a sharper edge. Then only did he try his hand at felling the first tree. There are carvings and drawings of ancient Egypt showing workmen hewing with axes not very different from those of the present day. The broad axe was a popular weapon of the Crusaders. Centuries ago, the Arabs and the Turks gave the axe a still keener edge, making it of steel; consequently it was lighter to handle.

The European settlers of America had fair hatchets and axes that had been perfected in pattern by long years of experience. They found the Indians still using stone axes and flint hatchets, with an occasional copper or iron one. But the handles of their war axes or tomahawks had a bulge or curve in the lower ends and were flared out somewhat to give a better grip. Taking the hint, the colonists began to improve their European tools, so that at the present time there is no better implement in the world than the American axe. Its well-shaped handle, or helve, is made of that king of native woods, hickory, a very strong wood with a spring, or "give," to it. The shape varies according to the locality in which the axe is used. In the north woods, where logging is done in the winter, the lumberjacks wear heavy, warm gloves. The axe-handles

Photograph by the United States Forest Service.

A LUMBER CAMP.

For the most part lumbering is a winter trade. In the summer-time headquarters for the cold weather are built and everything made ready. A large bunk-house is erected for the men, and a separate kitchen or cook-houses are usually built near it.

are therefore made rather thin. In the southern lumber camps they are much larger, partly because the negro choppers of the mild South need not wear gloves, and also because their hands are usually bigger than those of the northern woodsmen.

The metal from which the head of the American axe is made has been constantly getting better. For many years axe-heads were made of iron, and the cutting edges were strips or "bits" of steel inserted and welded into them. It was thought necessary to have the head made of iron or soft steel, so as to prevent its breaking through at the thinner part, in which was the eye, and into which the handle was forced. Axes often broke in this way during cold weather.

Strangely enough, the quality of steel for axes might never have been perfected had it not been for the demands of the American navy. It is a far cry from battleship to lumber camp, but it is a fact that many axe-heads are now made of armor-plate. The metallurgists of the Carnegie, Bethlehem, and Midvale steel companies had huge orders for armor-plate with which to protect battleships from the heavier guns then coming into use. As a result of many tests it was found that remarkable changes in the quality of steel could be gained by what is called "heat treatment." Although the various steel companies tried to keep these processes to themselves, the secret leaked out, and the American axe-makers got the benefit of it.

Fayette R. Plumb, an axe-and-hatchet manufacturer of Philadelphia, produced an axe in 1911 which was of the same kind of steel throughout. It was a tool with a one-piece body, or head, made of metal which could be hardened so as to hold a keen edge, and through special heat treatment or tempering, it had greater toughness and ductility about the eye than had the old-style, soft-steel axes. Sometimes the heads of such axes are tempered so that they can be used for battering and pounding, and yet not be hard enough to splinter when driving. Those who know only the common axe have no idea of the razor-like edge and wonderful balance of the axes used by the skilled woodsmen of the American lumber industry.

"It can be said, therefore," to use the words of Mr. Plumb, "that while the early development of the axe and the handle was a slow growth of composite experience, its latest develop-

Photograph by David Kinsey, Seattle.

CAMP TRAIN AND LOGGING-CREW OF THE MODERN TYPE.

The structures run into the forest on rails, and are really large, comfortable cars.

Photograph by Darius Kinsey, Seattle.

A MODERN LUMBER CAMP ON WHEELS.

Rows of camp cars on rails, each now a train in itself. On one side are the bunk cars or houses; on the other a nurse-house and kitchen.

ment is due to the genius of American metallurgical engineers. It is a part of the progress which gave us armor-plate for battleships, and the steel-piercing projectiles that render all older fortifications useless."

The perfection of the American saw has been brought about in the same way. Various manufactures have improved upon an implement which was old when Moses was at the court of Pharaoh. According to one old legend the original saw was suggested by the well-known weapon of the sawfish; according to another, one of the Greeks copied it from the toothed sting of the wasp. Saws of flint have been found among the remains of the caveman, and with the increasing skill gained by primitive man in the use of metals, saws became effective implements. For work in the felling of trees, the cross-cut saw, a blade six or eight feet in length, with handles on each end, is used. The big developments in saw-making have come largely through adapting the notched blade for work when the logs have been sent to the mills. These improvements will be taken up at a later stage. We are now prepared, with the

Photograph by Darius Kinsey, Seattle.

INTERIOR OF A MODERN BUNK-HOUSE.

A part of a whole train of houses on rails. The sleeping accommodations are about as good as those to be found in a tourist's sleeping-car.

weapons we have at hand, for the first phase in the age-long battle with the forest.

How the Lumberman Works

Lumbering, as it is now carried on, is indeed warlike in its methods. The attack upon a great tract of timber-land is planned and timed like a campaign. First to appear on the scene is the scout or "cruiser," a man of good judgment and wide experience, whose business it is to map out the operations. With one or two companions, he makes his way into the deep woods and gives his judgment on the value of the "stand," as the trees there are called. He estimates the age of the trees, their condition, and marks places where the felling is to begin. The services of a lumber "cruiser" are valuable. On his opinion, projects involving millions of dollars are set in operation.

Photograph by Darius Kinsey, Seattle.

WHERE THE FLAPJACKS ARE FRIED.

In the modern logging-camp of the west coast the kitchen car is equipped with the cooking appliances of the city restaurant. Unlike the cooks of old-time camps, the men who prepare food for the western lumberjack of to-day wear the familiar white uniform and cap of the hotel chef.

Under the direction of the advance courier, the first attack is made by blazing what is called a "tote road," that is a broad path into the forest, over which is taken lumber for the building of the camp, and all kinds of tools and supplies. For the most part, lumbering is a winter trade; in the summer-time the quarters for the cold weather are built and everything made ready. A large bunk-house is erected for the men, a separate kitchen or cook-house is usually built near it, the two connected with a board passage. There are stables for what horses or mules may be needed. Another structure, a combined office and store called the "van," houses the superintendent, the bookkeeper, and the timekeeper. A blacksmith's shop is provided for the sharpening of tools, making repairs to machinery, and for other such jobs. Such is the settlement which, far from civilization, springs up in a forest clearing.

On a winter morning, the men, snuggled in blankets, are soothed in sleep. Out of the still cold comes the annoying sound of an alarm-clock; then the instantaneous pounding of pots and pans, and the boom of a deep voice:

"Roll out, you bench-legged wood-hicks!" The order resounds through the bunk-house.

Out they roll, these big-chested, broad-shouldered lumberjacks, all eager for flapjacks and for coffee, hot as molten lava —an amber brew that would scald the gullet of most men. Swedes, French-Canadians, Poles, Russians, a motley gang they appear as they finish their bacon and eggs and corn bread, then struggle into their red-plaided Mackinaw jackets.

Up the main road, the broadened tote road of the earlier days, either in wagons drawn by mules, by sledge, or, if the work has just begun, by foot, go these bewhiskered, tumble-haired lumberjacks, smoking their foul-smelling pipes, their hot breath forming little white clouds in the chilly air. On they go to their stations, eventually separating into smaller groups, and soon the sound of steel against wood echoes among the tall, straight boles.

The lumberjack must so adjust his attack that the tree will fall where the "head feller," or boss, says it must; otherwise other valuable trunks may be damaged, or somebody hurt. The direction of the fall is so nicely calculated that a lumberjack can place a wooden peg lightly in the ground, if the earth is not too frozen or stony, and drive it home by the fall of the tree-trunk he fells. By varying the point at which the axe notch is made, the direction of the descent is determined. This notch having been made deep enough, two men, working by hand a ponderous cross-saw, cut into the living wood, until they meet the notch. Further guidance is given to the fall by driving wedges into the cut made by the saw. The wedges also keep the blade from becoming wedged, and the sawing is made easier by putting a little kerosene on the moving steel. Again, were it not for the notch on the opposite side the trunk might split upwards under the strain, as it grows weaker, and thus spoil the log.

"Timber!" yells the axeman, and the tree topples, and down it goes to its appointed place.

The warning is merely a flourish, for the lumberjacks know almost to an inch where the forest monarch will come to earth. But often there are amateurs about, who are in danger of being hurt.

One day, in the southern pine woods, a moving-picture photographer asked the boss if he might cut down one of the smaller trees. He wished to prove that he could wield an axe with any man.

"Well, don't take that axe, stranger," said the boss. "I'll get you a spare one." Axes such as first-rate woodsmen use are too sharp to be trifled with by beginners.

The camera man began operations. After he had struck half a dozen blows all the lumbermen got up and moved back. They did not go to right or left, they retreated out of range of the top branches for the final crash. No one could tell in what point of the compass the unskilled chopper would deliver his handiwork. Presently the boss began to shift about uneasily. Approaching one of the motion-picture men, he said, briefly:

"If that man is a friend of yours, you'd better tell him, without hurting his feelings, to stop that there fool chopping."

"What's the matter? Is he likely to do any damage?"

"Don't think he'll do much damage to the woods, but in about three clips more he'll kill himself."

It was true; the trunk would have fallen on top of him had he not been led away to safety.

Once a tree is down, it is soon dissected. Sometimes huge trunks for special purposes are brought out of the woods in full length. The custom, however, is to saw them in twelve and sixteen foot lengths, according to whatever standard may be adopted. The cross-cut saw may be driven by steam, compressed air, or electricity where the forest floor is level enough to permit the transportation of power machinery. If one can get a traction engine of the simplest type into the deep woods, it is an easy task to rig it up to do the sawing.

Copyright 1909 *by David Kinsey, Seattle.*

THE WORK OF SAW AND AXE.

The work of felling trees and making the trunks ready for the factory and sawmill is done almost entirely by the saw and axe.

Felling Trees by Machine

Power-driven saws for felling trees are well enough where the surroundings are entirely favorable, as they might be on the lawn of a Long Island country house. But owing to the uneven surface of the woods, and to the ravines and slopes, none of the patented machine tree-fellers has been highly successful.

Many efforts have been made to place a fool-proof felling-machine on the market. Most of the earlier machines were useless because of some weakness in the mechanism. Some of the devices were too heavy, others were too difficult to operate. With all there was a certain risk, for in case a tree should "kick back" during the fall, the machine would be smashed and put totally out of commission. Up to the time of writing, although several inventors have worked on the idea with great hope of success, we still lack an infallible tree-felling machine. Great improvements have been made, and perhaps in the future power fellers may take their place in large lumbering operations.

Photograph by Cress Dale Photo. Co., Seattle.

BACK-CUTTING DOUGLAS FIR WITH THE CROSS-CUT SAW.

First the axe cuts a deep notch, then two men with the cross-cut saw cut into the wood until they meet the notch.

Most of the tree-felling and log-bucking or sawing machines known to this date have many points in common. They consist of strong frames, usually made of metal, which may be readily tied or lashed either to a standing tree or the felled trunk. Stout saw-blades extend out from the frames, or over them, and to these are attached the driving-rods. The power may be supplied by a gasoline-engine, or electricity may be used; in the Western States there is abundant water-power which drives electrical installations and permits the distribution of current over a large territory. When the transportation of engines is practicable, compressed air and steam may be employed. The engines usually vary from four to six horse-power, and drive the heavier saw-blades at the rate of from 140 to 145 strokes a minute. The movement of the blades is controlled so that the sawdust is removed at each stroke, and that the steel strip may be freely and rapidly drawn forward and back.

One of the original American machines on the market, the Ransome, had a trial in Hyde Park, London. Among the spectators was the late William E. Gladstone, the great British statesman, who for exercise often chopped down trees on his estate before breakfast. Gladstone approved the machine, saying that, although it gave the human frame little exercise, it accomplished in three minutes what would take an axeman three hours. This machine was too heavy in its original form, as it weighed about 350 pounds. Many improvements have been made since then, and there are tree-felling appliances now which weigh only 125 pounds.

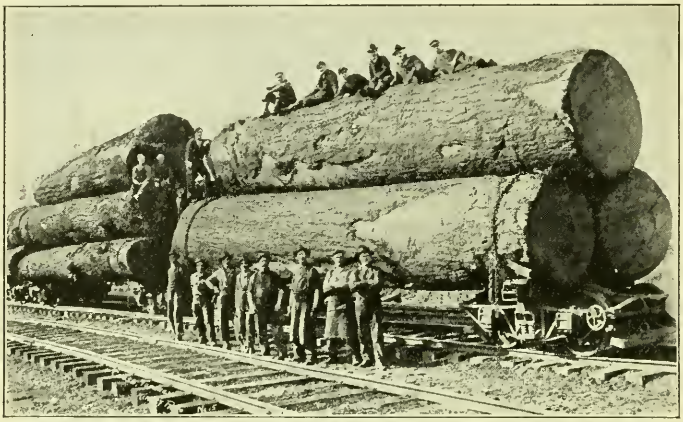
Stephen Tracy, a lumberman in the heart of a pine country in the State of Washington, having studied the problem of tree-felling for several years, perfected a machine in 1921. With it he cut down trees six feet and two inches in diameter in twenty-one minutes, using a seven-foot blade. The big advantage of this machine is that the saw may be changed to three operating positions, or angles, in about twenty seconds.

Hauling the Logs Out

In the early days of lumbering, when the wood was used only a short distance from the points at which it was obtained, transport was a simple thing. Logs could then be hauled out by gangs of sturdy settlers, all working together as friends and good neighbors. This primitive type of transportation is called hand-logging. It is a method still in use in Europe and the

Orient, and was common for many years in the Appalachian Mountains, and in the cedar regions of Maine. That it is even now practised to a limited extent in British Columbia is shown by the fact that the Provincial government still issues permits to hand-loggers.

As soon as the sawyers and the "swampers" have taken off the branches of a tree and cut it into logs, the problem is how to get the trunk to the yard or mill as quickly and cheaply as possible. The first time-saving step called for the aid of animals, a process of transit in the lumber regions that was called skidding or "snaking." Teams of horses, mules, or oxen were, and still are, taken into the woods, dragging after them long steel chains, to the ends of which are metal hooks. The driver fastens this chain to a big log, or winds it around and secures it by the hook, cracks his whip, and then the log starts on its way to the open. Sometimes it stops short, for a snag in the path, a stone, or some such obstacle causes it to stick; it then takes more horses, more whips, and strong language to get it on the move again. This makes logging slow and tedious and unprofitable, especially if the ground is soft or uneven. The timber



Photograph by C. K. Kinsey, Seattle.

MODERN MACHINERY HAS MADE IT POSSIBLE TO HANDLE LOGS OF THIS ENORMITY.

Sometimes huge full-length trunks for special purposes are brought out of the woods. Usually the trunks are sawed up into lengths according to a standard. The three Douglas-fir logs on the front car total about 18,000 feet of lumber (log scale).

sticks in the earth, and every time a log digs in its nose, there is a waste of horse and man power.

In casting about for some means to make the passage of the logs quicker, the lumberjacks in various parts of the country put sleds or wheels or similar devices, on the front ends. Such devices appeared at the same time in various regions of the United States, and sprang from an obvious need. In the North, a rough-skidding sled for each log was called a "go-devil," while in the South, a natural fork of a tree placed under each log to be snaked, was known as a "lizard." The lizards were especially helpful in the swamps of Louisiana, where their strange name seems to have originated.

From a photograph by United States Forest Service.

LOGS HAULED UP A ROAD BY A STEAM-WINCH AND A CABLE.

William Baptist, a Michigan lumberman, who went South to undertake some logging work for several large lumber firms, invented, in 1893, a steel cone which could be fitted over the ends of logs and spiked in place. To a hook on the end of this cone was attached a chain or cable by which the log could be drawn over rough ground, or over swamps. The tapering end permitted the log to slide more easily than would otherwise have been possible. Later, tongs were fastened to the edge of the cone which bit into the bark and held the metal cap more or less firmly. These cones are still used, either for animal hauling or power skidding, in some parts of the country, and are worked with side lines on the logs.

Perhaps the better method of holding up the end of the log was the use of a pair of wheels at the forward part, the hind end being dragged. These wheels were made bigger, until they were often six or eight feet, carrying under them bunches of smaller logs. These "bummer carts," although they are used extensively in the South, had their origin among Michigan loggers, who, perceiving that the stands in their native State were becoming exhausted, had gone to seek new forests to conquer below Mason and Dixon's line.

From a photograph by United States Forest Service.

THE "BUMMER CART."

This type of cart, invented many years ago in Michigan, is extensively used in the South. It consists primarily of a single pair of wheels, sometimes twelve feet in diameter, drawn by horses or mules. One end of the log drags on the ground, and acts as a brake on down grades.

The "big wheels," as these carriages are also named, came into use in all parts of the United States, and many of the largest, with huge masses of logs under them, may be seen in California and Arizona. To accommodate such loads the "big wheels" are made twelve feet in diameter, and are drawn by from four to six horses. Another type of this carrier, known as the "slip-tongue," has a movable shaft bolted on the axle.

The axle lever is fastened to the shaft by an iron rod, and when the horses begin to pull the first thing that happens is that the drawing out of the shaft pulls out the lever, and raises the load. If the cart should start to run down-hill, its progress will be checked by the lowering of the load, which scrapes along the ground, acting as a brake.

While skidding or snaking was being developed, the woodsmen of the North were taking advantage of the winter snows and ice to speed their logging enterprises. From their efforts were developed many picturesque devices. First a snow road was opened, and then it was converted into ice by going over it with sprinkling wagons, such as one sees in summer in the city streets. On the frozen road horses can draw long sled loads of logs. At Ann River, Michigan, in 1892, there was hauled in this way a load consisting of sixty-three logs, of which fifty-eight were sixteen feet long, and the remainder had a length of eighteen feet each. The whole consignment contained 31,480 board feet of lumber and, including the chains used in keeping it in place, weighed 114 tons. Pulled by four horses, it was regarded as the largest of its kind ever drawn under such conditions, and it was placed on exhibition, in 1893, at the World's Fair in Chicago.

Glover and the First Forest Tractor

From Manistee, Michigan, from where sprang many a big idea in the lumbering industry, came George T. Glover. He was a lumberman, who started to make his own ice road for hauling logs without taking the trouble to have it sprinkled, and he was the first to apply the tractor to the hauling of logs. Glover started out with what looked very much like one of the traction engines which haul threshing-machines about the country in harvest time, but the lumberjacks soon saw that he had something quite different.

The machine was run by steam generated by burning wood. There was plenty of steam, for some of it was intended to rush out in big jets on the iron wheels of the engine, heating them so that they would cause the snow to melt. The water would then be expected to freeze, providing a slippery passage for the sleds of logs which the Glover engine was to haul. Steam also slightly warmed the water in the tank carried at the back of the engine, so as to prevent it from freezing.

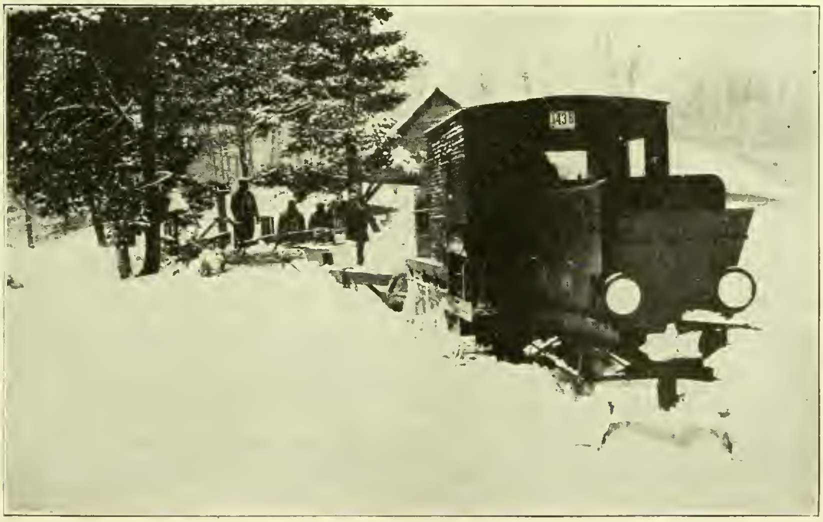
The general idea of the invention was good, but in his complicated machine the designer had attempted a little too much. He took out a patent for it in 1889, and actually built four machines, which were offered for sale by a Chicago firm. Although not a success in a commercial way, largely because it could not be made to meet so many demands of service at once, the Glover tractor was the forerunner of the Lombard tractor, the most effective machine in lumber transportation.

Lombard Makes the Tractor a Practical Success

Alvin O. Lombard, a true son of the woods, did much to make a success of power log-hauling. He was born in 1856, at Springfield, Maine, and was hardly out of his teens before he was learning the lumber industry from the ground up. His father owned a little water-power-driven sawmill in which was a primitive saw of the reciprocating or up-and-down type; he was really a farmer who conducted milling and dealt in shingles as a side line. In the winter time he worked in the woods getting the logs to keep his mills running in the warmer weather. Alvin Lombard, consequently, became a lumberjack, and followed the gangs in the woods or drove logs down the streams with the coming of spring. Interested in mechanics, young Lombard took contracts to build and operate sawmills. From this he ultimately saved enough money to erect a mill of his own, cutting logs during the cold months. His interest in mills caused him to invent a water-wheel regulator, and later various machines for the barking of wood-pulp logs. The idea of inventing a log-hauler, which would stand service in the Maine woods, came to him out of the hard school of experience. He knew practically nothing about drafting and machinery construction until he was more than thirty years old, but he soon made up for lost time. His belief that a steam log-hauler could be made amused the leading lumbermen. When he took a model of his device to one of the largest lumbermen in Maine, a man who, years afterward, became one of Lombard's enthusiastic customers, he was told that it was useless to talk about

ALVIN O. LOMBARD'S FIRST LOG-HEADER.

It was a steam-tractor with an endless, belt-like tread instead of wheels. From it he evolved at a cost of half a million dollars this gasoline auto-tractor, which can carry five tons on its own body, and from thirty to fifty tons behind it.



THE LOMBARD TRACTOR AT WORK.

One hundred horse-power, with special cab and with sled-runners instead of wheels for winter work. Thus equipped, the tractor will move through snow-drifts of four and five feet depth.

hauling lumber over a snow road by steam; it could not be successfully done.

But after Lombard had convinced the lumber bosses of the value of his invention, he had to overcome the prejudice of the lumberjacks. At first, there was the usual outcry against the invention because it was depriving both men and horses of their jobs, for a big hauler could do the work of about sixty animals and thirty drivers. These teamsters eventually graduated into engineers and firemen, and learned to take great pride in their new calling.

Lombard's first log-hauler, still used in various parts of the country, was a steam-tractor with an endless, belt-like tread instead of driving wheels. This chain of plates, roughened, was able to get a firm hold even on broken boughs and stony earth. In winter, a sled was substituted for the front wheels, and the whole machine steered by a lever. In the north woods the machine, not unlike a trackless locomotive, is still popular, and it can be run fairly well with refuse branches instead of gasoline as fuel. It will haul 250 tons on level ground, and as high as 300 tons on a firm, smooth road. One of these Lombard tractors pulled fourteen sled-loads in a train, each load holding from 6,000 to 7,000 board feet of newly felled trunks. Another, used in Franklin County, Maine, from January to March, 1921, hauled 531 sled-loads, measuring three and a half million board feet of logs. It would have taken sixty-two horses to have drawn the same amount of lumber in that period.

The success of the steam-tractor gave Lombard the backing he wanted. He began experiments which cost him about half a million dollars in all, and out of them came the auto-tractor truck. For several years he worked on all kinds of metals and alloys to get something for his machinery which would stand the extreme cold of the woods. He wanted a machine that would survive a temperature of thirty-seven degrees below zero. Year after year Lombard drew on his expense account at his shops in Waterville, Maine. All shapes and sizes of parts were put through the most gruelling tests. Forty gasoline-engines were made and sent out into the coldest parts of the State and kept there for three years. Chain-belt treads and wheels were knocked about and tumbled hither and thither, in imitation of the service expected of them. Experimental auto-truck tractors were guided through thick underbrush, and they came out coated with mud and ooze from the swamps. Back to the works went these experimental machines, there to be doctored up and sent out again.

The first patent for the auto-tractor was issued in 1901, but it was not until fifteen years later that Lombard was really satisfied with it. His final product was a combination of wagon or truck with a gasoline traction-engine. It weighs nine and a half tons, but its bearing weight per square inch is less than that of the hoof of a horse. When at work it will carry five tons on its own body, and, according to the conditions of roads and weather, will draw from thirty to fifty tons behind it. Its speed varies from two to six miles an hour, and it can make good time, dragging four to eight loads of pulp-wood behind it as it plunges through snow-drifts five feet deep.

The River-Driver

Despite the signal progress made by men like Lombard in fashioning tractors, a great deal of timber is transported by water; and one of the most thrilling phases of the lumber industry is river-driving. At first, our forests were cut along watercourses, so that the trees would either fall athwart, or they could be skidded or slid down inclines into them. In the winter-time the logs were left on the ice until spring set them free and sent them oceanward on the rushing currents. A picturesque, daring gang of men, called river-drivers, do the piloting. Taking their lives in their own hands, these hard-working river-drivers vault lightly from log to log in the swelling streams. The soles of their heavy boots are studded with steel brads to prevent their slipping on the slimy and uncertain bark. With long poles, the ends of which contain pike and hook, the river-drivers shove logs on their way which have been caught on snags or rocks. They must prevent the forming of jams, which would delay the passage of the huge trunks down-stream. The key-log, which is the cause of the stoppage, must be removed, so that the bodies of the trees move smoothly once more on their way to weir and mill. A false step, the least error in judgment, and the river-driver may be ground in the whirl of the moving timber and maimed or killed. To the ordinary man such a life as this would be terror; to the river-driver it is the very joy of living.

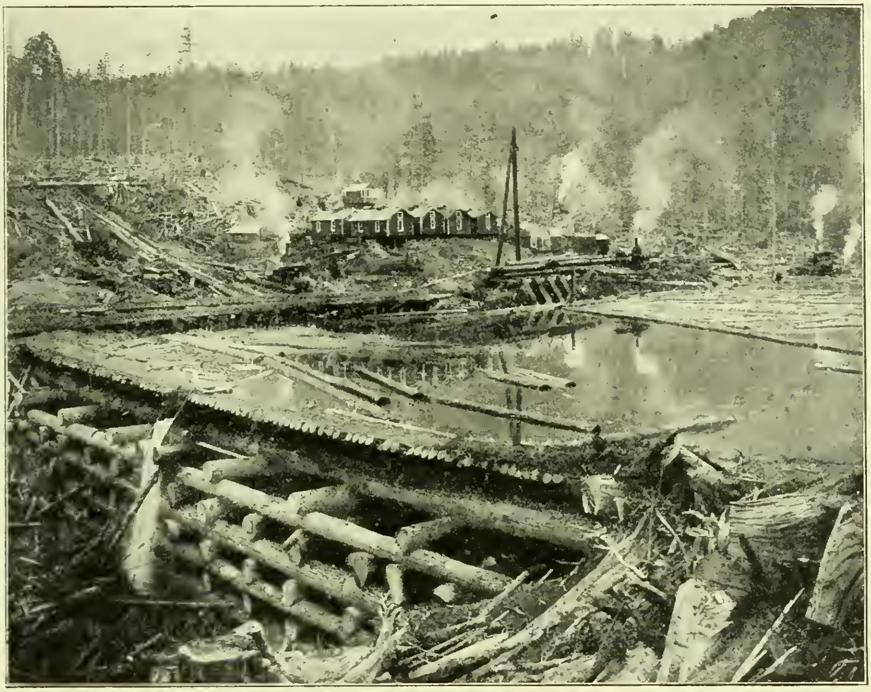
Despite the hard work of the river-drivers, however, nature is often too much for them, and there have been log-jams which have glutted large streams for weeks. The enormous accumulation of logs in the St. Croix River, Wisconsin, in 1892, stretched up-stream for six miles. The Chippewa River, in 1866, was choked from bank to bank with cut timber for ten miles. Expert and daring river-drivers were recruited from all over the country; with their aid and a little dynamite, the stream was finally cleared and the logs finally sent on their way.

From a photograph by United States Forest Service.

RIVER-DRIVING.

Much timber is transported to the sawmill by streams. "River-driving," as it is called, demands courage and skill. The heavy boots of the river-drivers are studded with steel brads to prevent slipping. With long poles, bearing on their ends both pike and hook, the river-drivers push on their logs which have been caught on snags or rocks and which threaten to cause a jam.

But river-driving is declining because of the great losses which attend that method of transport. Although logs are marked by the private sign or brand of the owner, it is no easy task to recover them all. It has been estimated that the losses from all causes in river-driving amount to from ten to thirty per cent. Logging men, despairing of government aid, at their own expense cleared the channels of these streams of as many snags and as much underbrush as possible, so as to let the logs slip by easily and prevent jamming. To stop the logs from getting into sloughs or being stranded on low mud flats, stream banks were often fortified against them.



From a photograph by Cress-Dale Photo. Co., Seattle.

A TYPICAL DAM.

Logs must be brought down on stream during the six or ten weeks when water is high, and, because of the uncertainty involved, dams are built to insure having enough water.

In order to permit log-driving in streams where there was a limited supply of water, dams were built across stream beds for the purpose of stopping the flow. The water, suddenly released, flowed down the stream bed with such force that all the logs were carried along with it. This system prevented the logs from being hung up on rocks and snags, over which they were now carried by the volume of water. The size and character of these dams vary greatly. At Wind River, in the State of Washington, is an unusually large one; in Blount County, Tennessee, is another, which can raise the water level thirty-five feet. Such structures range in size from small ones, which can be built for $1,000 or less, to enormous concrete bulwarks, costing as high as $200,000.

Despite all the drawbacks of the transportation of logs by merely throwing them singly into the streams, it is astonishing to realize how long this old method continued. When swift and turbulent streams were available the procession of logs stretched through several counties. In the Penobscot River, in Maine, for instance, log-drives, ranging from 150 to 240 miles in length, are common. The uncertainty of the flow of streams, however, grew more and more of a factor. Both in the driving of loose logs and in rafting them, it is necessary to bring them down-stream during the six to ten weeks when the water is high, in the spring of the year. In that short period, if the supply is obtained only by depending upon the water transportation, there must be brought within reach of the mills enough logs to keep their saw-tables busy for the whole year. In order to store reserves for that purpose reservoirs, called "booms," were located along the banks of streams, where there are suitable pockets of quiet water. The success of lumbering operations under the system of stream transport really depended upon the establishing of suitable storage basins for the floating of the logs. Out of this situation came one of the boldest exploits in lumber-industry promotion known. It came of the often repeated visits of "The Mysterious Stranger."

The Coming of the Stranger

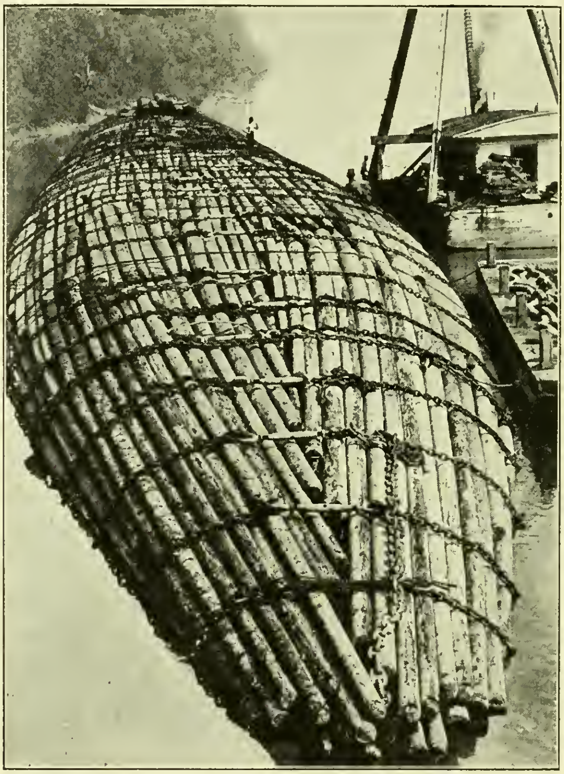
He appeared in the cold winter of 1836, in the town of Williamsport in Pennsylvania: a tall, lean, lank man, with the spirit of the woods about him. From his headquarters in the leading hotel he took long walks or sleigh-rides into the heart of the country. He was always alone.

"Queer as Dick's hat," intimated the farmers, as they watched him walking among the pineries or exploring the in-lets and backwaters along the banks of the Susquehanna. The stranger was John Leighton, an Easterner who had come all the way from the Penobscot, down in Maine. He returned about every two years, in December or January, and each time he got options on timber-land and river property. According to his idea there were in Lycoming County as good pine forests as were to be found in the land of the moose.

"He says he is going to build a boom here, whatever that is," was the rumor that went round Williamsport. Then they got it that a boom such as he planned would be the largest reservoir for logs in the world. Nobody took any stock in the idea, but still the Stranger kept coming and looking.

He was back again in the winter of 1844, this time with a man whom he introduced as Major James W. Perkins, of Lincoln, Maine, a capitalist who said he would furnish the money to begin the boom provided the legislature would grant a charter to a company. Along came the charter in 1846, and several years later were begun the cribwork and the gates for the great Susquehanna Boom, which was to put millions of dollars into the pockets and the tills of the thrifty folk of Lycoming County, Pennsylvania. The receiving centre for the logs cut from neighboring slopes was built and filled, and huge piles of lumber were turned out daily from the busy mills established at its edge. The great Susquehanna Boom, as it was then called, had by 1860 become a focus for a new prosperity for Williamsport and all the countryside. Then came a flood which sent the river into a mad torrent capped with foam, and one night there echoed through the city the crash of cribwork and the thumping of heavy timbers on the throbbing throat of the river.

"The boom has gone out!" were the tidings which spread from house to house. The people realized they had lost a veritable bulwark of prosperity and power. More than 50,000,000 board feet of logs had been hurled out of what had been thought a safe haven, and were being tossed on the swelling stream toward the Atlantic. The damage was repaired, and Williamsport settled down into its accustomed calm. When a similar disaster came in 1861, however, the boom was long left as it was; owing to the uncertainty of the money market due to the Civil War, it was impossible to raise the funds for reconstruction. Rebuilt at the close of the conflict between the North and South, the cribwork was again swept away in 1889, and 300,000,000 feet of lumber were turned loose.



From a photograph by A. M. Prentiss, Portland, Ore.

A CIGAR-SHAPED RAFT READY TO BE TOWED TO SAN DIEGO.

Ocean-going rafts of this kind are often bigger than an ocean liner, measuring as they do from 700 to 1,000 feet in length and drawing from twenty-five to fifty feet of water. These rafts are towed 1,000 miles down the Pacific coast from Portland to San Diego. About one out of forty-four is lost.

This world-famous boom had, up to the year 1898, held 39,993,470 logs, which yielded 6,407,094,182 board feet of lumber; in other words, had the logs been sawed into planks one inch in thickness, they could have been made into a walk forty-nine feet wide which would have reached clear around the world.

The Lumber Raft

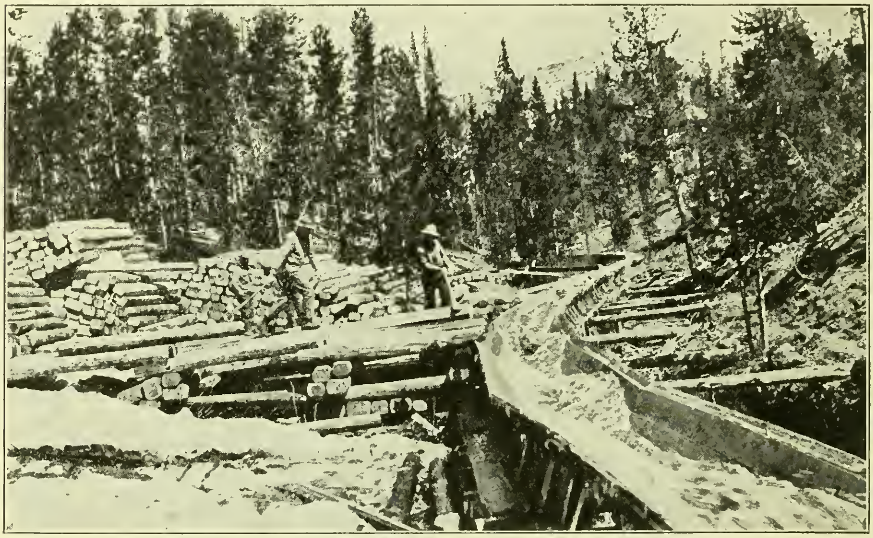
The enormous losses which lumber men met even under the best conditions caused them to look around for safer methods of transportation if they were to depend upon water as a carrier. They obtained a better control by building their logs into rafts secured by chains or frames. Usually the raft floats on the stream with the current, while on larger rivers and on lakes it is convoyed by tugboats. Many logs and enormous quantities of lumber were brought down the Mississippi and the Susquehanna River when that method of transportation was at high tide.

Next the ocean was braved. In the year 1884, James D. Leary, of Brooklyn, New York, a wealthy contractor, hit upon the idea of sending a huge raft of logs from Nova Scotia down to New York in charge of a tug. Not far from the coast of Massachusetts the tug left the raft to go into port for coal, and when she returned there was no sign of the logs. Months afterward the raft, or what was left of it, was washed ashore on the coast of Norway.

Better success was reached in ocean-rafting in the Pacific, where milder weather conditions prevailed. The Benson Lumber Company, of San Diego, California, which has been building rafts for the last twenty years, declares that it has lost only one out of forty-four in all that period. Rafts of this kind are bigger than an ocean liner, being from 700 to 1,000 feet in length, containing from 7,000 to 10,000 tons of timber, and drawing from 25 to 30 feet of water. These structures make a voyage of 1,000 miles down the coast, from the Columbia River, near Portland, to San Diego. They are held together by a cradle-like construction of timbers into which the logs are guided and lashed with chains.

Conveying Logs by Flumes

Another method of water transportation, popular in States of the Pacific slope, is that of the artificial or controlled stream, called the flume. The flume is a long V-shaped wooden trough, differing but little in principle from the aqueducts which the Greeks and Romans built in stone. Flumes came into use in the Western States in order to convey water down from the mountains for irrigation purposes, and also for washing the gold from the pay dirt. They began to be used in the redwood industry in California, in 1890, for the transportation of logs, though preferably for conveying dressed or sawn lumber. The lumber was put in the big trough and borne slowly by the few feet of water therein to its destination. Another type of flume was built with square corners, on the model of a packing-box. Both forms may be seen in use for the needs of agriculture and lumbering all along the Pacific coast, and far back into the Western States.



From a photograph by the United States Forest Service.

IN THE WEST THE FLUME IS USED TO TRANSPORT LOGS.

The flume is a water-trough, which may be as long as sixty miles. It began to be used in the redwoods about 1890.

One of the most useful flumes in the far West is that of the Fresno Flume and Irrigation Company, built originally for purposes of irrigation, but, in 1891, first used for the carrying of lumber from a sawmill at Shaver, to a planing-mill at Clovis, a distance of sixty-five miles.

"A good example of a log-flume," says Mr. F. A. Leete, of the Imperial Forest Service of India, who recently made a tour of America's woodlands, "was seen at Addio, Idaho. A flume for sawn lumber was also observed at Bridal Veil, Oregon, and another at Lamoine, California. The tract worked by the lumber firm is high up in the mountains, the lowest part being 3,000 feet above the public railway. Sawmills are situated up above the wooded area and the sawn timber is sent down the flume, five miles long, in one case, and ten miles in the other. It takes from fifteen to twenty-nine minutes for a piece of timber to come down."

Like the mountain torrent the flume is serviceable only down-hill. In lumbering and milling operations many heavy supplies, such as machinery and tools and food, have to be taken to the base, and the cost of doing so over rocky and wooded crags is large. Some of the best engineers in the country have aided development of the flume for lumbering. One of them, F. M. Kettenring, lives in the city of Vancouver, from which he goes forth to superintend the building of flumes of his design. As a civil engineer he has made a special study of the trestleworks and supports, and reduced construction costs.

Logging by Wire Ropeways

Nearest to aerial transportation is the overhead skidder, the invention of which, in 1883, revolutionized the entire lumber industry. On November 23 of that year, Horace Butters, of Ludington, Michigan, obtained the first patent for power log-skidding machinery ever issued in the United States. Butters was a member of the firm of Butters and Peters, logging contractors, who at the time were clearing a large tract near Ludington. There were reaches of rough ground in the pine woods where he was at work, and delays were many because logs were always getting into pitholes or striking roots and snags. When a lumberman undertakes a contract to deliver a certain number of thousands of logs to a mill, every minute is precious. Butters had been brought up to the lumbering business, and had tried every plan he could think of to get his timber to the sawmills on time. He wanted more power to "snake out" his logs, and so decided to get a steam stationary engine of the hoisting type to do it. Whether he was the first man to think of that idea is hard to tell; there is a story that several Southern lumbermen hit on the scheme of yanking the logs out of the woods over the ground by using steam-winches or donkey-engines. Butters, however, rigged up an overhead cableway, connected at each end of its 800-foot span with a towering tree. On this he put a carriage or trolley, and by steam hoisted to it a log. Then he used the same power to pull the loaded carriage along his wire cable to its destination. By this device, he avoided the bogs and the pitfalls and the uneven ground.

By courtesy of Lidgerwood Mfg. Co.

HIGH-LEAD SYSTEM OF GROUND SKIDDING AND LOADING.

Illustrating the use of two tail-blocks and showing method of side-lining.

Butters bought his hoisting-engine from the Lidgerwood Manufacturing Company, of Brooklyn, New York, a circumstance which ultimately brought capital and engineering talent into the development of power-skidding. The history of the invention from that date is closely linked with the careers of two able inventors, Spencer Miller, chief engineer, and J. Haines Dickinson, logging engineer, for the Lidgerwoods. The company was the successor of the old Speedwell Iron Works, established in 1802 at Morristown, New Jersey, in whose shops Morse designed and operated the first telegraph. There, too, was built the machinery for the steamship *Savannah*, the first steam-vessel to cross the Atlantic.

The firm had already developed many types of hoisting engines, but logging was only an incidental customer. When the demand for engines for log-hoisting came Miller needed some help, and he engaged Dickinson, who had graduated from Cornell University in 1890. While a student in the engineering department there, Dickinson saw some lumber magazines belonging to his brother who was studying forestry. He was impressed with the idea of applying power in the deep woods, and decided to take up machine-logging as a profession. He wrote a thesis on logging in which he referred to the Butters invention and its possibilities. After a brief stay with an iron company in Trenton, he entered the Lidgerwood organization. With Miller he worked out fifty patents applicable to log-skidding machinery, and the details connected with them. The perfecting of blocks and carriages of various kinds and of means for hauling in the slack has made it possible to bring lumbering of that kind to the highest plane of efficiency.

Butters made a connection with the Lidgerwoods and the first year sold ten of his machines to his fellow loggers. The first lot of these mechanisms were crude enough, but they certainly did the work. Power-skidding is now a wonderful triumph of engineering skill, and is used everywhere. The original Butters patent has run out, but the many improvements of the Miller-Dickinson patents have kept pace with the needs and the progress of the industry. The cableways can now be made 2,000 feet long, and if there is a deep ravine for them to be crossed, as in a mountain country, they can be lengthened out to 5,000 feet, or nearly a mile. Although there are slack-hauling devices with the new power-skidders, there is always more or less sagging which must be allowed for, either by very high towers or by making use of the mountains as supports and anchors.

The skidding of logs can be carried on over a wide area with only one plant. The cable is attached to a stout, well-guyed tree, known as the head spar. Near it are the hoisting engines and drums which hoist the logs into position and haul them either entirely off the ground, or slightly dragging the surface.

The other end of the cable is attached to another tree, known as the "tail tree." After all the logs within easy reach of this overhead line have been skidded away, the end of the cable is removed, and secured to another tail tree. This changing is continued until the cable anchorages at the tail end have been swung completely around a circle, with the head spar as centre, and the length of the cableway as a radius. Thus large tracts of territory can be cleared of logs at moderate expense, before it is decided to move the head spar to a new locality.

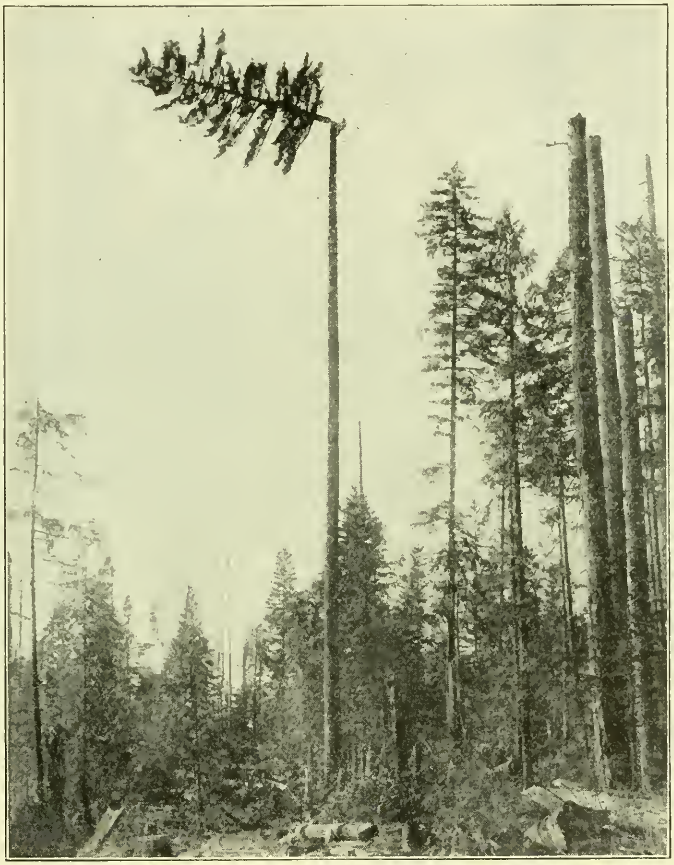
Copyrighted by Wesiter.

THE HIGH-CLIMBING "TOPPER" ASCENDING A FIR.

See picture of topping on page 183.

Lumbermen consider the Lidgerwood improved, quick-moving overhead skidder the latest and highest development in methods which keeps the logs entirely clear of the ground.

In this device, the head spar is of steel, and is mounted on a portable platform from which it can be readily lowered for quick moving. It can also be readily transported by railroad. One of the features of this mechanism is the interlocking drum.



THE "TOPPER" AT WORK.

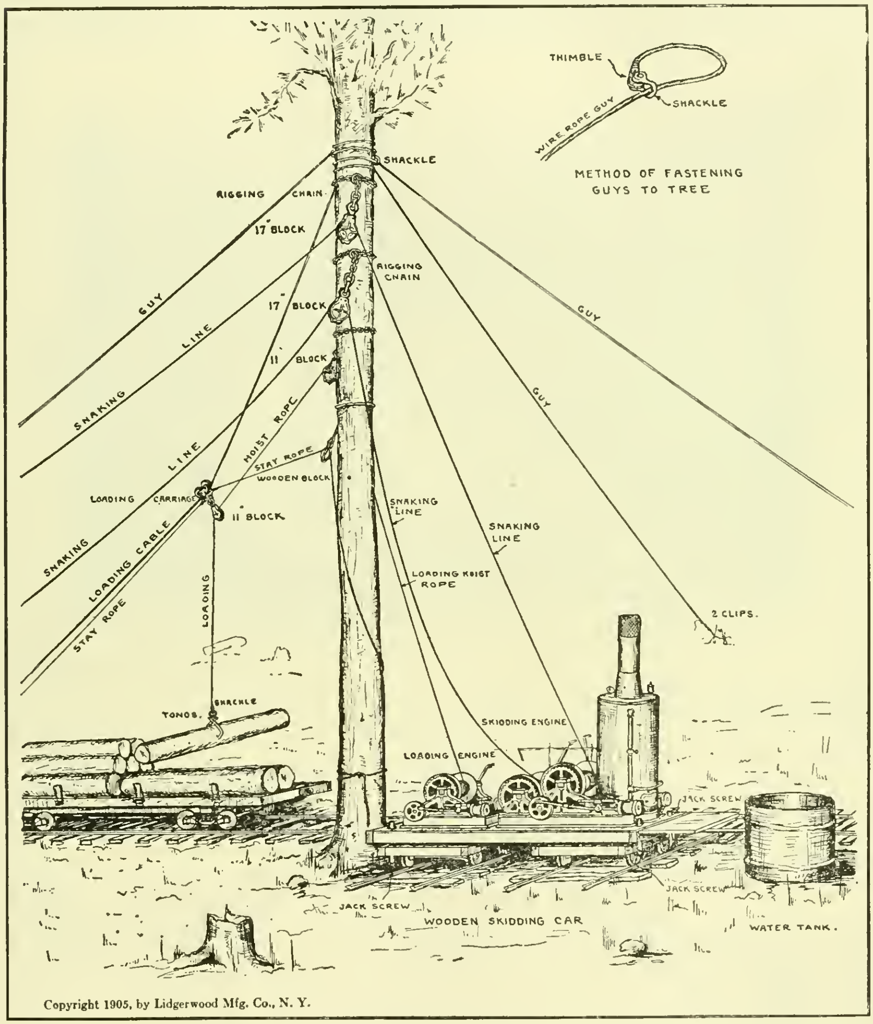
The "topper" has the dangerous task of cutting off the thin, weak top of the tree that is to serve as the head spar of a wire-rope log-transporting system.

The outhaul and the skidding or inhaul drums of the engine are so cogged that the man at the lever who controls the machine can have complete command of it, whether the load is being skidded up-hill or down, carried over level ground, or swung across the deepest canyons. The device is also equipped with a mechanical slack-puller, and its capacity is increased by multiple skidding lines, which permit other loads of logs to be attached in the woods, while one is being hauled into the head spar.

TRANSPORTING LOGS BY WIRE ROPEWAYS.

Horace Butters is credited with the invention (in 1883) of the system whereby logs are transported by wire ropeways. The system was brought to its present perfection by Spencer Miller and G. Haines Dickinson. The wire cable is attached to a stout, well-gauged tree (here shown) and known as the head spar. The other end of the cable (not shown) is fastened to another distant tree—the "tail spar." The logs are then transported on the cable, as shown. When all within reach have been removed, the cable is attached to another tail spar. Thus the cable is fastened to successive tail spars until a complete circle has been described. Sometimes, as in this case, two or more cables transport logs simultaneously.

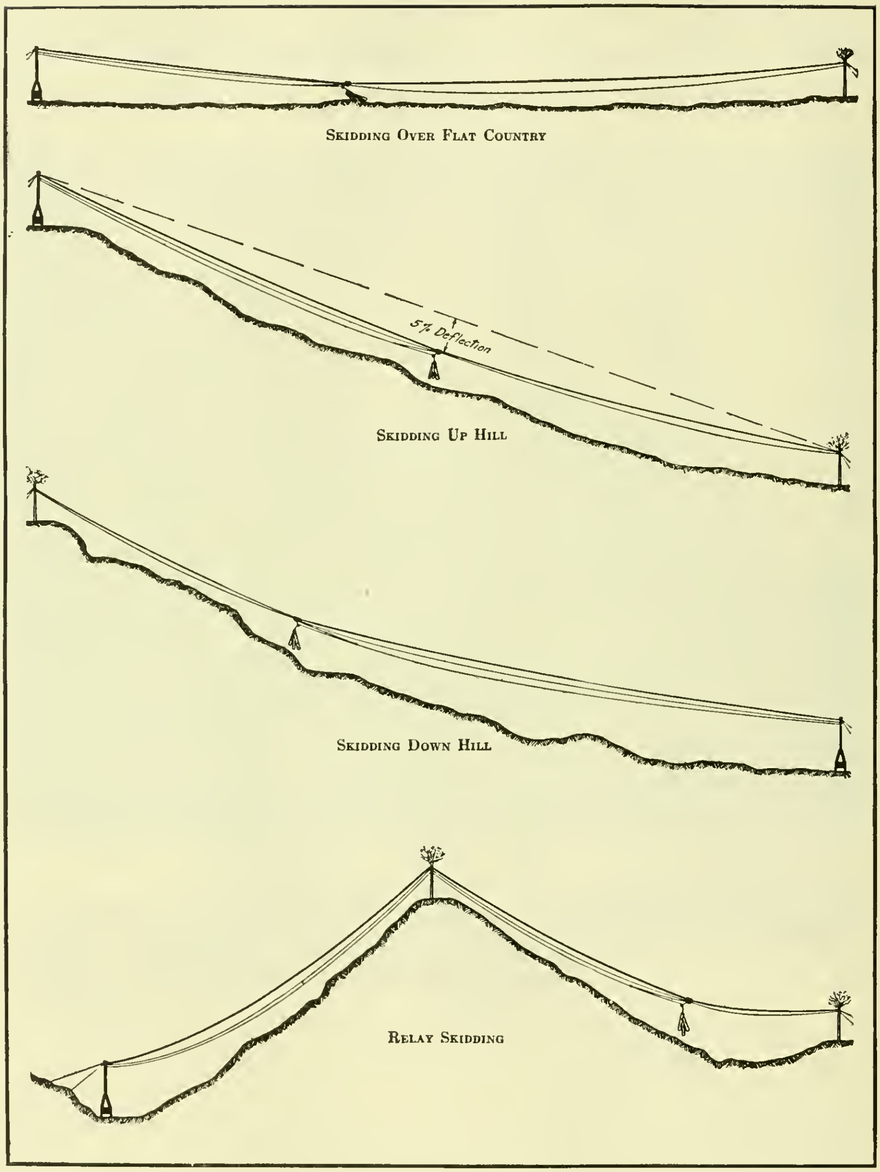
In order to get the logs out of the Southern swamps with less effort than formerly, powerful hoisting-engines of the Lidgerwood type were mounted on scows. As far as is known the first operation of this kind was in 1893, when the firm sold a two-drum engine to the Louisiana Cypress Company. Among



Copyright 1905, by Lidgerwood Mfg. Co., N. Y.

METHOD OF RIGGING LIDGERWOOD TREE-RIG GROUND SKIDDER AND LOADER.

the inventors who were busy with the problem of skidding at this time was William Baptist, of Michigan, whose name has already been mentioned in this account of lumbering. He was a

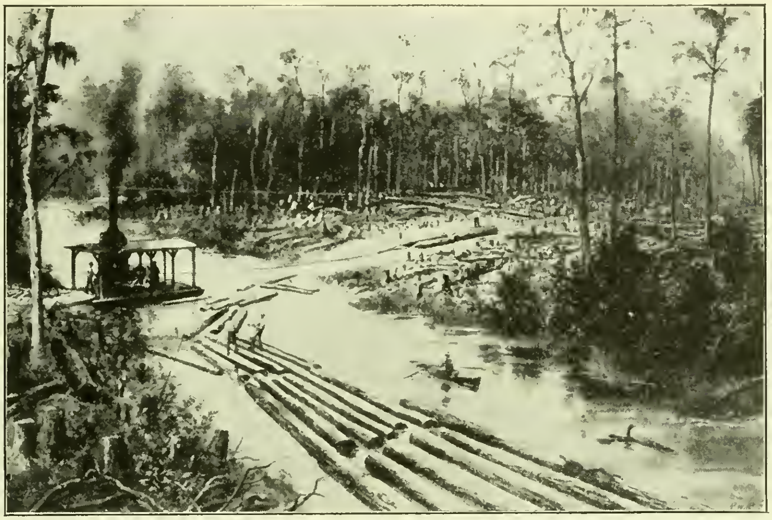


By courtesy of Lidgerwood Mfg. Co.

PORTABLE HIGH-SPAR SKIDDERS.

The high spars make long span possible. Deflection in main cable with load at middle is 5 per cent. of total length of span.

man of little education, but had a vast fund of common sense and ingenuity as well as an unusual reserve of patience. If anything failed to work, he stuck to it until it did. The Southern lumbermen took to the idea of jerking or pulling their logs out of the swamps, and Baptist went down South to help them with their problems. There he originated and introduced the method known as "pullboat logging."

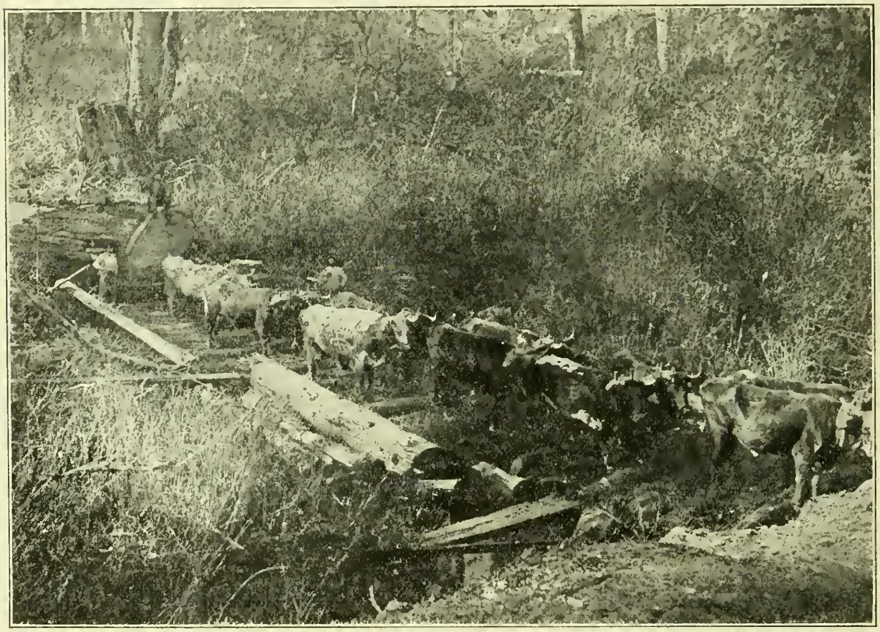


HAULING LOGS OUT OF SOUTHERN SWAMPS.

To accomplish it powerful Lidgerwood engines were mounted on scows in 1893. Probably William Baptist, of Michigan, was the first to apply the idea. As developed by the Lidgerwood Manufacturing Co., a heavy pulling cable and a lighter cable for returning the pulling-line from the river to the point from which the logs are to be dragged are used. Logs are pulled over distances as great as a mile to the river-bank.

Meanwhile, the various types of skidders were being perfected. The first ground skidder with power was put into operation in the pine regions near Pitcock, Georgia, in 1896. In 1897, W. A. Fletcher, a lumberman of Kirbyville, Texas, invented the first pine logger. Then various loading devices were devised to get the logs more quickly upon the railroad-cars.

By means of the skidding system, logs are assembled at central points, a plan known as "yarding." The object is to deliver them by overhead cable to the actual tracks; but this is not always practicable. Often they have to be taken to the main railroad. The logs are collected together and laid on beams, known as skidways. The piling of the timber, either on sled, wagon, or railroad-car, no matter how good the machine aid may be, requires the use of a pole with a hinged claw on it.



Copyrighted by Darius Kinsey, Seattle.

DRAGGING FIR LOG, FOURTEEN FEET IN DIAMETER, ON A SKID ROAD.

Long steel chains are hooked to the logs, and when the road is fair this method of logging answers well enough, but when the ground is uneven and full of snags and roots it is tedious and sometimes too expensive.

This device, used in handling logs by hand, is also employed in adjusting the top log on a load, and is known as a "peavey hook." It is certainly a man's work to handle one.

Railroading in the Forest

The decrease of log-driving and the fact that the timber had to be cut farther and farther away from the streams led to another epoch-making development in the industry. Important as the overhead skidder is in rough and mountainous country, there are often operations in which it pays to build a railroad into the woods, to connect with public trunk lines. This now seems so obvious a plan, that one wonders now why it was that the man who first built such a means of transportation in the forest was denounced as a crack-brained visionary.

From a photograph by the Dale Photo Co., Seattle.

LOADING LOGS ON FLAT CARS.

Powerful steam-derricks load gigantic fir logs on flat cars in the mountain "draws" of the west coast. Wherever it is possible to do so, the logs are hauled out on cars drawn by special logging locomotives.

Why any one should have opposed the introduction of an actual railroad into the realm of trees is all the harder to understand in view of the fact that rude tracks made by putting two poles a few feet apart were early used in lumbering operations. Upon these poles were placed cars with flanged wheels, which were pulled backward and forward by animal power, and sometimes by hand. As soon as the sawmills created a great demand for lumber, the poles were crowded out by sawn or hewn stringers. Skidways of smooth timbers, a short distance apart, which were in effect incline or gravity railroads, needing no power, had also been installed. Roads with wooden rails were in use in many sections of the country, and just who started them first is not recorded, but similar tracks had been used, for that matter, in the British coal-mines for generations.

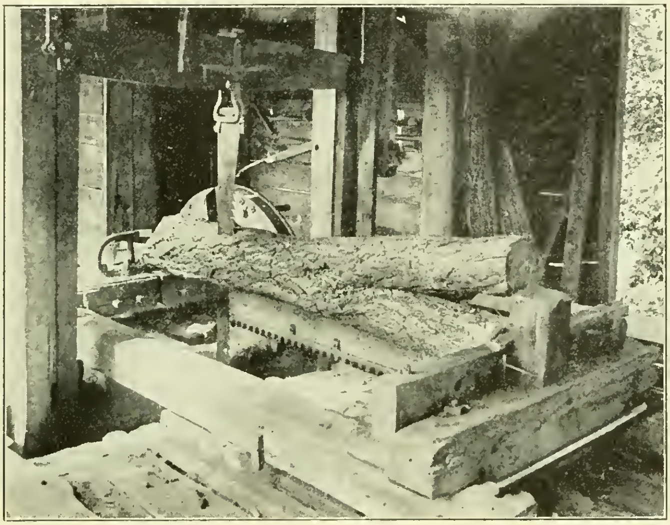
Real railroad logging, however, we owe to W. Scott Gerrish, a logger who did much contract work in southern Michigan. He went to the Centennial Exposition at Philadelphia, in 1876, to celebrate with many other good Americans the hundredth year of their independence. In the Machinery Hall he saw a small steam-locomotive which was being offered to the manufacturers of the world as an easy and quick way of carrying finished or unfinished products about their plants. When he went back to Michigan he began to put in practice his theory that a steam-railroad could be used in the woods. He was told that he was getting foolish. Soon he had in operation a seven-mile railroad, connecting Lake George with the Muskegon, the construction beginning at Ferwell. The first cars run had only four wheels, but they were soon superseded by the eight-wheel type, as the original cars were found to be too rigid on curves, and they had an unsteady motion when loaded with heavy logs.

There are no spring-cushioned Pullmans on the logging railroads, even in this day, as revealed in the description of an English visitor, who says that for the most of his trip on one of them his heart was in his mouth. But the Gerrish experiment was such a success that five years after it was started there were seventy-one logging railroads in operation in Michigan alone, and five in Wisconsin. Now there are approximately 2,000 logging railroads, with 30,000 miles of tracks, in various parts of the United States.

Conditions in the lumber regions brought into use new types of locomotives which would meet peculiar conditions. It is remarkable how many of the Michigan loggers, men without any special technical training in engineering or mechanics, have aided in the making of engines and machines for transporting logs. E. E. Shay, a logging contractor in the Wolverine State, decided that the kinds of locomotives then existing did not suit him, and he started in to design one of his own. In 1885, the first Shay locomotive, now made by the Lima

Locomotive and Machine Company, was given to the transportation world. Its gears were adjusted so as to give it the largest possible amount of drawing power.

The constant improving of the power-skidding devices, and of loading apparatus, naturally has enabled the railroads to handle more lumber. In some of the mountainous regions of the far West, aerial tramways, which are really modifications of the overhead-skidder idea of Horace Butters, swing logs directly down upon the platform cars on the railroads. In the sky-line or aerial tramway, the Pacific slope, which for years rejected the skidding idea, has made a rediscovery of a device which came originally from the woods of Michigan. The tramway, as it has intermediate supports, can be made larger than a skidder.

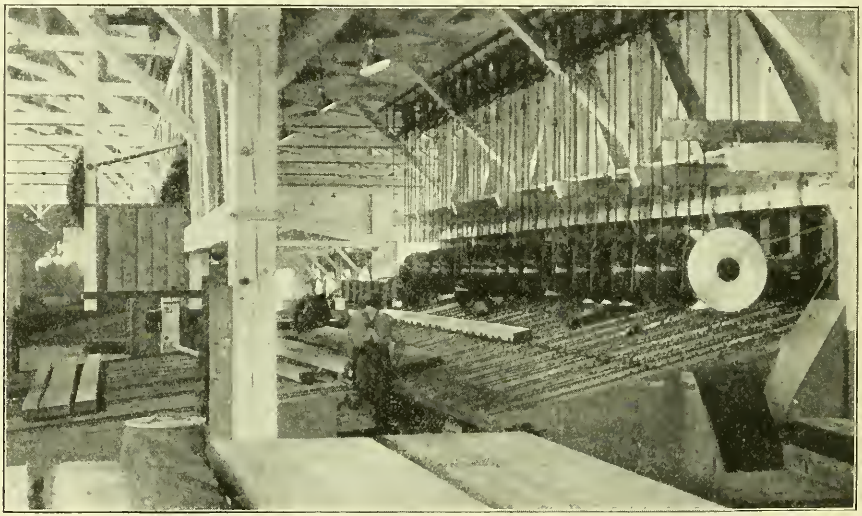


AN UP-AND-DOWN SAW STILL IN OPERATION IN THE BACKWOODS OF PENNSYLVANIA IN 1921.

THE MODERN SAWMILL

Hand in hand with the rise of lumber transportation in the United States, came the development of the sawmill. The early colonists had been content to use a big saw, which was operated by two men, one of whom stood in a pit across which the log was placed, while the other was over the pit. They pulled the blade up and down, after the manner which they had inherited from European forebears.

Sawmills operated by wind-power, by horses, treadmills, and steam had been established in England, Germany, and Holland after much opposition from the pit-sawyers, who thought that their livelihood was in danger. The first American sawmill run by water began work in 1634, on the Falls of the Piscataqua on the line between Maine and New Hampshire. The logs were fastened on the carriage and shoved toward the reciprocating saw, which worked along on the up-to-day and down-to-morrow principle, yet with a great deal more speed than could have been reached by pit-sawing. Gang-saws—that is, notched blades put side by side—were soon introduced in this country. Such devices had been known in Europe for several centuries, the first having been employed, so far as is known, in 1575, in Ratisbon, on the Danube.



From a photograph by the Cress Dale Photo Co., Seattle.

PNEUMATICALLY OPERATED TRIMMER-SAWS.

In the box sits a man who brings down any combination of saws that he wants for trimming. The first circular saw of this type was fashioned in America by Benjamin Cumming in 1772.

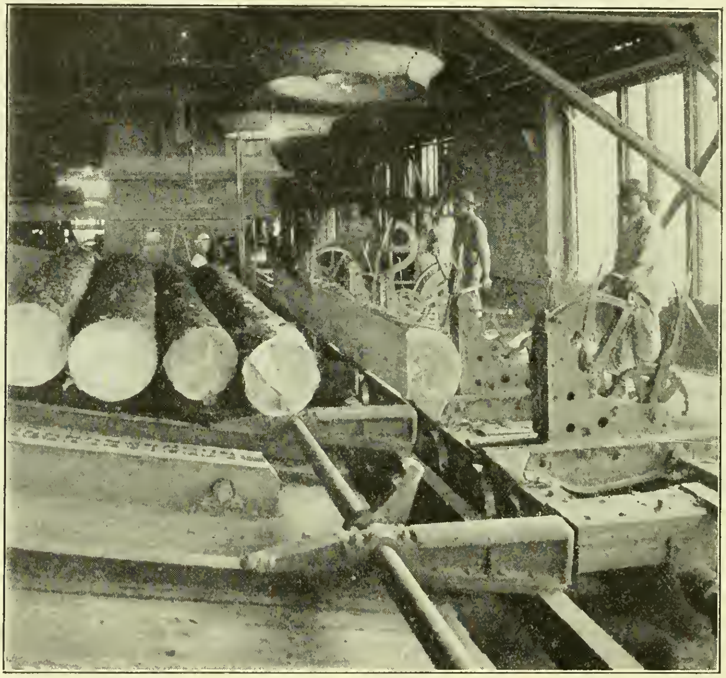
The lumber industry was never able to make a high-speed record until the introduction of the circular saw. This saw was really a rediscovery, as a small tool like it was used by Hippocrates in cutting holes in the skulls of some of his patients in ancient Greece, to relieve pressure on the brain; an operation which physicians and surgeons call trepanning. Samuel Miller obtained a patent for a circular saw for wood-working in 1777, in England. His invention would have been practically unknown, however, had not General Sir Samuel Bentham, once with the British Admiralty, and later a manufacturer of power tools, taken an interest in it. He took up the inventions of Miller and Trotter, and also invented a circular saw of his own. Later circular saws were adopted for shipbuilding, at the Portsmouth Navy Yard, England.

Benjamin Cummings is credited with being the first American inventor to make a circular saw. He knew little or nothing of the progress of saw-making in Europe, but started out on his own account. He was born at Bentonville, New York, 1772, and came of old English stock. A millwright by trade, he made the first circular saw ever seen in America in his own blacksmith-shop, while the villagers looked on in wonder. He intended it for use in his own sawmill at Schenectady, New York, and although it took some time to adjust it to the existing power, he was finally successful.

Hammering out the first American circular saw in 1814 was only one of Cummings's many accomplishments. He accumulated some capital and engaged in various contracting enterprises, including the digging through a mile and a half of bed-rock for the Erie Canal, and the construction of the first low bridge. He also aided in the construction of the first ten miles of the railroad built between Albany and Schenectady.

The day of the circular saw had been hastened by the granting of an American patent to Robert Eastman and J. Jacquith, of Brunswick, Maine. Eastman arranged for putting into the rims of his saw some extra notches, which he called "false teeth." About 1840, circular saws appeared into which teeth had been fitted. Then, in 1846, an inventor named Spaulding, of Sacramento, California, devised a curved socket which held the "false teeth" more securely. This plan made circular saws popular because they could be easily repaired by putting in a new tooth when one was broken.

The band-saw, a narrow bit of metal made into an endless strip, with teeth on both edges, was a most important addition. It is indicated that early attempts to make a saw of this nature failed on account of the difficulty of joining the ends. The French have always declared they invented the band-saw, although a very strong claim is put forth for William Newberry, who obtained a patent for such a saw in 1808, which to all appearances solved the problem of the welding of the ends. Many French inventors gave their attention to the band-saw, and among them was Mademoiselle Crépin, a young woman of Paris, a member of a family of high social standing. She did not care for a life of fashion, and devoted herself to mechanical pursuits. Among her inventions was a band-saw, for



INTERIOR OF SAWMILL OF GREAT SOUTHERN LUMBER CO., BOGALUSA, LOUISIANA.

which she obtained a French patent in 1846. Its merits were seen by Périn, a saw-manufacturer and an inventor of saws, and he bought her rights. He exhibited a band-saw—a composite invention—in 1855, at the French International Exhibition in Paris.

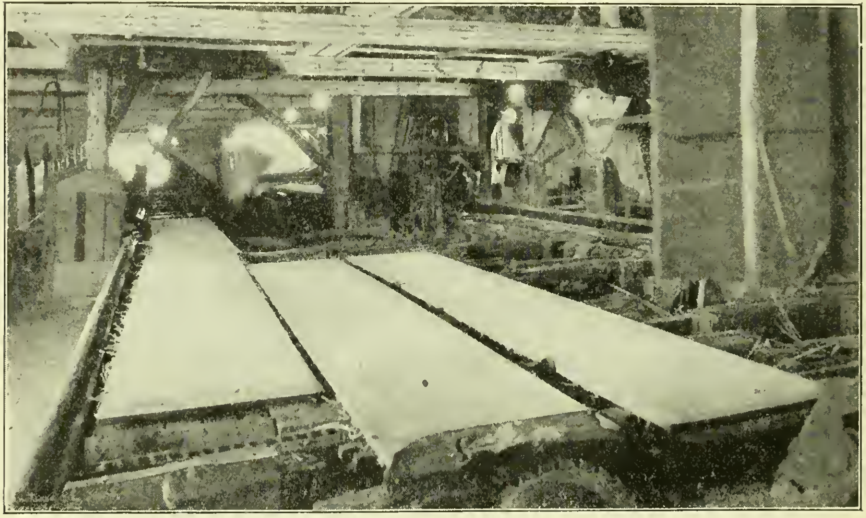
One of the sensations of the Centennial Exhibition in Philadelphia was a band-saw in swift operation, which had been just perfected by the well-known saw-manufacturers, Henry Disston and Sons, Incorporated. From that date may be traced the introduction of the band-saw into the American mills.

There has long been a keen rivalry in American mills between the band-saw and the circular saw. For the portable mills the round form is more popular, as it can be taken easily about the country and into remote places near the lumber camps. The standard circular saw is fifty-four inches in diameter, although one of the type, said to have been the largest in the world, was 108 inches across.

Since it saves kerf, time, and power, the band-saw has a front place in all the big mills. Mill operators in the larger towns, and in the centres of industry like the band-saw, because its thin blade, rapidly revolved over wheels, makes a very narrow cut and wastes little wood in dust. In the seventies, a six-inch band-saw was considered remarkable, but now eighteen-inch ones are common. In length these saws vary from forty to sixty feet. They travel at the rate of about one and a half miles a minute, which is faster than the swiftest express-trains.

The great demand for American saws, for they are now sent to all parts of the world, is due not only to their form, but to the peculiar excellence of their steel. Saws were once imported exclusively from Europe, and even after the industry of making them was started here, the metal came from abroad.

Technical men have done much to perfect saw steel, but the saw-makers have also done a great deal to help themselves in getting the raw material which suited their requirements. The success of such makers as Henry Disston is a case in point. Disston was a mechanic in Philadelphia, working in a small shop where saws were made. When the concern failed he took it over in payment of a claim for wages, and without any capital built the great house which now bears his name. He realized that the quality of the steel available was not what he wanted, and therefore, in 1855, started a small works of his own where he made crucible steel. The product was so good that other industries asked him to sell them some. Thus to this day the firm has a large steel trade independent of its main business, which is that of making notched cutting-tools.



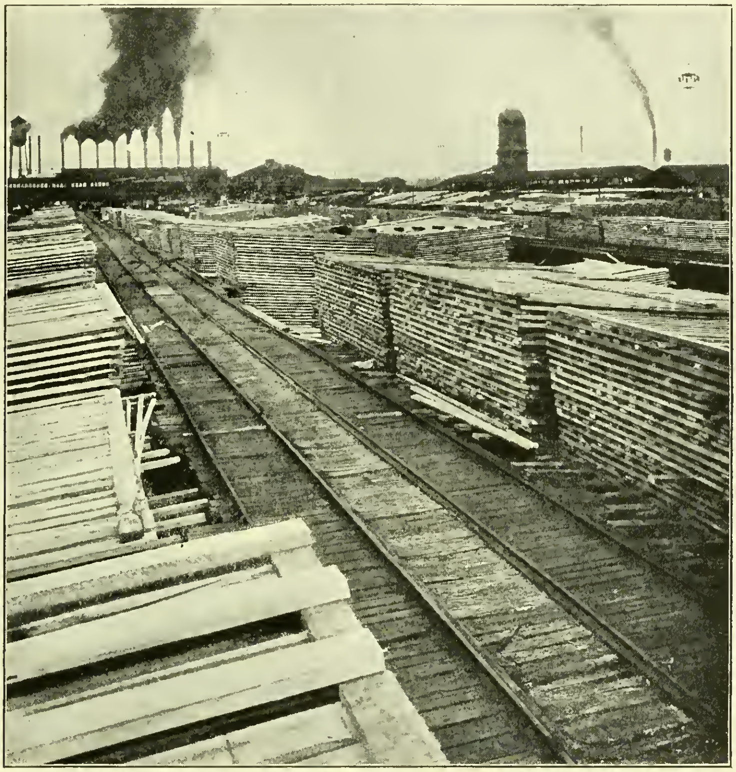
From a photograph by the Cress Dale Photo. Co., Seattle.

WIDE SPRUCE SLABS IN A WEST-COAST MILL.

Another famous firm of saw-makers, the Simonds Manufacturing Company, of Fitchburg, Massachusetts, has a steel plant of its own where it makes high-quality material for its goods. This company began many years ago as a scythe-factory.

Saw steel must have qualities different from those required in other cutting instruments or in chopping tools, because the heat from the friction must be considered in the operation of the saw. It is a delicate question to determine when steel of this character is too hard or too soft, and what ductility it should have. In most American saw steels there is from eight to eighteen per cent. of tungsten. Saw-makers have secret processes and formulæ which they guard jealously, as competition among them for the trade of the 30,000 sawmills in this country, to say nothing of an extensive foreign market, is very keen.

The superior saws and axes and other wood-working appliances which have been developed in this country, owe their origin largely to the demands of those men who are closest to the timber. The ingenuity of manufacturers has been taxed to the utmost to fill the wants of the lumberjacks and the contractors, and often to develop the inventions which those woodsmen either made or suggested.



From a photograph by The Great Southern Lumber Co.

A GREAT LUMBER YARD AND SAWMILL.

The thirty thousand sawmills of this country produce about 40,000,000,000 board feet of lumber each year—enough to load 1,600,000 railroad-cars.

The lumber industry of America is so big that it is almost impossible to comprehend its size. About 30,000 sawmills that now operate in this country turn out something like 40,000,000,000 board feet of lumber each year. Think of it! This amount of lumber would load 1,600,000 railroad-cars, and if made up in a single train would reach two-thirds around the world. In addition to sawmills there are about 75,000 other wood-using establishments at work utilizing the wood that is taken from our forests, and making it into usable household and factory products. We are a nation of wood-users. Perhaps no other people use so much wood as we do. It ministers to our wants continuously from the cradle to the coffin. It supplies us with countless conveniences and many necessities, from toothpicks, shoe-pegs, and matches to big buildings and large factories.

CHAPTER VI

FROM PLANTATION TO LOOM

A LITTLE more than a hundred and fifty years ago practically all clothes were made in the home. Cotton and woollen yarns were spun by hand by some member of the family, sometimes by the children, woven or knit into coarse fabrics, and fashioned into various articles of clothing by the older members of the household, or by a mendicant tailor, who wandered from town to town, plying his trade.

Generally, the kitchen was the "living-room" of the house. Light, streaming in through leaded window-panes, fell on strings of dried fruits, vegetables, and corn, hanging from the rafters. The floor was spotless and covered, not with carpet or oilcloth, but with fine white sand. Beside the window was a spinning-wheel and a smaller wheel for flax. There was also a great wooden loom, with its beam for warp and its shuttle. Cotton was brought by stage-coach from ships that arrived from England or the East. In the farmhouse this cotton, and the fleece sheared from the sheep grazing on the hills, were cleaned, carded, and spun or woven into cloth.

As late as 1791, this domestic or home method of production was still in practice in Europe and America, although the invention and use of textile machinery abroad had resulted in the beginning of what is known as the "factory system." In that year, Alexander Hamilton reported to Congress that "there is only one branch of the wool manufacture, which as a regular business, can be said to have acquired maturity; that is the manufacture of hats." He then went on to say: "There is a vast scene of household manufacturing which contributes more largely to the supply of the country than could be imagined. . . . Great quantities of coarse cloths, coatings, serges and flannels, linsey-woolseys, hosiery of wool, cotton and thread, coarse fustians, jeans and muslins, checked and striped cotton and linen goods, bedticks, coverlets and counterpanes, tow-linens, coarse shirtings, towellings and table linen, and various mixtures of wool and cotton and of cotton and flax, are made in the household way, and in many instances to an extent not only sufficient for a supply of the families in which they are made, but for sale, and even in some cases for exportation. It is computed in some districts that two-thirds, three-fourths, and even four-fifths of all the clothing of the inhabitants are made by themselves."

COTTON WAS ORIGINALLY REGARDED AS A VEGETABLE WOOL.

This picture is taken from a book published in 1654. Travellers had brought back stories from India that wool there grew on trees. An imaginative publisher undertook to make this clear, with the result here shown.

Twenty years previously, Hamilton had voiced a belief that the development of the cotton-growing and manufacturing industry in the colonies would be of great benefit. Visualizing its possibilities in the Southern States, he wrote: "If, by the necessity of the thing, manufactures should once be established and take root among us, they will pave the way still more to the future grandeur and glory of America."

The great change which has taken place since Hamilton's time is the result of the inventive genius of a little band of courageous men who sacrificed everything to an idea, and who persisted in the face of every discouragement in order to lighten the task of spinning and weaving.

The process of making a piece of cloth involves several steps: cleaning the fibre (as in the case of cotton), carding the fibre, spinning the fibre into yarn, and finally weaving the yarn into a fabric. To trace the history of textile invention we will take up each of these steps in order.

Cleaning Cotton—the Great Invention of Eli Whitney

Mechanical improvements had brought cotton manufacturing to the stage where the need for raw material was greater than the supply. The necessity of obtaining more raw cotton was a growing problem, yet few planters in America seemed interested in the cultivation of the plant. All that could be produced in the United States, in 1792, was 138,234 pounds; the balance coming from India and the West Indies.

The solution of the problem was achieved by Eli Whitney. Born on a farm at Westborough, Massachusetts, in 1765, Whitney was a bright and somewhat precocious lad, with a penchant for making things. He thoroughly disliked agriculture and preferred to spend his time in his father's tool-house rather than in tilling the soil. As a lad, he made violins. His father thought this a waste of time, and informed his other sons that since Eli preferred to make fiddles, he would have to take his portion of the family inheritance in the things that he created. But that did not in the least bother young Whitney. He continued to make his fiddles, playing on them at neighborhood dances, and was consequently far more popular with the younger folks than were his brothers.

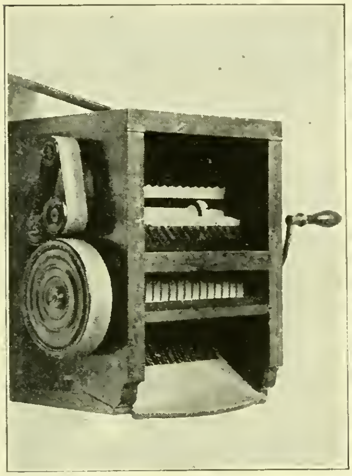
One day, he took his father's watch apart; then, in fear of a caning, hurriedly tried to put it together again. To his delight, he found he had succeeded, and that the watch ran as perfectly as before. He did not tell his father about it for many years. It was an accomplishment, however, that started him to making all sorts of things. During the Revolutionary War he was too young to shoulder a musket; but he knew all about one. His contribution to the cause of Liberty was the production of nails, which the colonists sorely needed. In those days, nails were made by hand, and the process was difficult. When the struggle for independence was over, Whitney employed his nail-making experience in the manufacture of ladies' hairpins. He also fashioned walking-sticks, and sold so many of them that he was able to pay his own tuition through Yale when his father declined to supply him with the necessary funds. He supplemented this sum by working out of study hours for seven dollars a month and board.

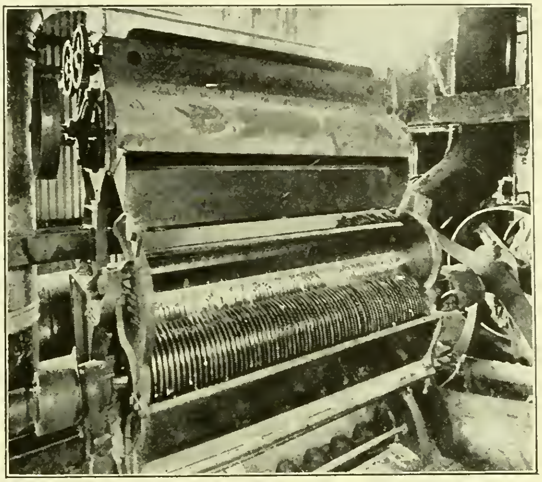
Courtesy U. S. Department of Agriculture.

A COTTON-FIELD SUCH AS THIS WAS UNKNOWN IN ELI WHITNEY'S TIME.

Then the entire cotton crop of the country could have been raised on a field comprising not more than two hundred acres.

Whitney was twenty-seven years old when he graduated, and shortly before leaving the university startled one of his professors by repairing a mechanical apparatus which that learned gentleman had intended to send abroad because he did not think any American had the skill. Receiving his degree, Whitney started South to accept the post of tutor to the children of a rich Georgia planter. On his arrival he was dismayed to find that some one else had been engaged in his stead. He was about to return North, but having met the widow of the famous Revolutionary general, Nathanael Greene, he accepted her hospitality and made his home at her beautiful house on the banks of the Savannah River. It was then his intention to study law; but his inventive genius, quickly manifesting itself as he was devising a labor-saving embroidery frame for Mrs. Greene, turned him in another direction.





(Left) MODEL OF ORIGINAL WHITNEY COTTON-GIN IN THE NATIONAL MUSEUM, WASHINGTON.

Forward-pointing teeth or saws projected from a cylinder and passed through slits between bars. The wire teeth caught the cotton and carried it between the bars, which expelled the seed because it was too large to pass through. A set of brushes removed obstructions and prevented the clogging of the machine.

(Right) MODERN COTTON-GIN WITH BREAST REMOVED AND GRIDS AND SAWS EXPOSED.

The principle of operation is the same as that originally applied by Whitney in his gin.

At that time, astonishing as it may seem, the cotton crop of the entire country could have been raised on a field comprising not more than 200 acres. The price of cotton was exceedingly high because of the cost of preparing it for the market. The chief expense was in cleansing it of the dirt, leaves, and the seeds which clung to the fibres. It appeared unlikely that cotton could ever be raised in large quantities in this country because of the cost of preparing it for the use of the spinner.

One evening Mrs. Greene was entertaining a distinguished gathering of Southern gentry, and the conversation turned to this particular problem.

"Surely, Mr. Whitney can supply your needs," said Mrs. Greene, with confidence in her protégé. Her guests regarded the remark as a pleasantry, but young Whitney took it in all seriousness. Never having seen a cotton-plant, the next day he went into the country and obtained samples of the bolls. Ten days later he had a model of a cotton-cleaning machine. Mrs. Greene summoned her friends to see the invention, and Whitney proudly set his device in motion.

It proved to be a cylinder four feet in length and five inches in diameter. Arranged upon this were a number of forward-pointing wire teeth or saws, projecting two inches above the surface of the revolving wheel. The saws passed through narrow slits between bars. The wire teeth would catch the cotton and carry it between the bars, which latter would expel the seed because it was too large to go through.

At first the machine moved smoothly, and, to the delight of the spectators, the cotton was cleaned most thoroughly. Then, after a few minutes, the saws clogged and the machine stopped. Whitney was first embarrassed, then alarmed. He feared that he had failed. However, he solved the problem by removing the obstructions with a brush. His later model had a cylinder with a set of stiff brushes fixed to it, by means of which the cotton gin was able to clean itself as it cleaned the cotton.

The results of Whitney's simple invention are truly startling. Eight years before he perfected the gin, eight bales of cotton, sent from this country to England, were seized by the customs agents at Liverpool on the ground that they "could not have been produced in America." The world produced 490,000,000 pounds of cotton in 1791, of which, as we have seen, America supplied only 138,234 pounds. In 1792, the year of the Whitney invention, this country exported 189,316 pounds. The following year, America exported 487,000 pounds; the year after saw this increased to 1,601,000 pounds; the next raised this to 6,276,000. By 1800, the total production of this country was 35,000,000 pounds, of which no less than 17,790,000 pounds were sent abroad. To-day, the United States produces over 7,000,000,000 pounds of cotton.

The invention of Whitney's cotton-gin had not only profound economic effects, but also political consequences. Before the gin was introduced many southern planters were seriously thinking of emancipating their slaves, who were engaged in cultivating indigo, rice, and tobacco. Then came the gin and with it fortunes to be made out of cotton. Slaves could hardly pay for their subsistence as hand-separators of cotton from its seed, but they could be made to earn enormous profits as cultivators of cotton. Whitney's gin converted the slave from a liability into an asset. Strong, healthy slaves rose in price. Taking slaves with them, younger sons pushed out into the wilderness, acquired great tracts of land, and made cotton king of the South. Hence the fervent defenses of slavery as an economic necessity, made by ardent Southerners before the Civil War, would never have been uttered if Whitney had not invented and introduced his cotton-gin.

Although Whitney's gin has since been improved upon, its basic features are practically unchanged. As a result of his ingenuity, a thousand pounds of cotton could be cleaned in the time it originally took one slave worker to seed five pounds by hand. At the old rate the slave would have taken a month to seed an average bale of 300 pounds.

How Whitney's Idea Was Stolen

Whitney had become acquainted with Phineas Miller—later the second husband of Mrs. Greene—and the two formed the firm of Miller and Whitney. They had foolishly hoped to monopolize the ginning of cotton. This was a fatal error, and did not tend to endear them to the Southern planters. Whitney was a level-headed business man as well as a clever inventor, and he soon realized his mistake. In an attempt to regain the confidence of the public the firm offered to lease machines on a royalty basis, but opinion continued to be against them. The building in which Whitney's model was stored was broken into and the machine stolen. It was copied freely, used even before he received his patent, and, although he appealed to Congress, no relief was forthcoming. A flood of lawsuits against the infringers was at once begun, but before Whitney obtained a single favorable decision, he had been forced to bring some sixty actions.

Much as his machine meant to America, Whitney claimed that he made no profit out of his labors. In a letter to his friend, Robert Fulton, Whitney tells the story of his troubles:

"My invention was new and distinct from any other; it stood alone. It was not interwoven with anything before known and it can seldom happen that an invention or improvement is so strongly marked and can be so clearly and specifically identified; and I have always believed that I should have had no difficulty in causing my rights to be respected, if it had been less valuable, and had been used only by a small portion of the community. But the use of the machine being immensely profitable to almost every planter in the cotton districts, all were interested in trespassing upon the patent rights, and each kept the other in countenance. Demagogues made themselves popular by misrepresentation and unfounded clamors, both against the right and against the law made for its protection. Hence there arose associations and combinations opposed to both. At one time but few men in Georgia dared to come into open court and testify to the most simple facts within their knowledge, relative to the use of the machine. In one instance, I had great difficulty in proving that the machine had been used in Georgia, although, at the same moment, there were three separate sets of this machinery in operation within fifty yards of the building in which the court sat, and all so near that the rattling of the wheels was distinctly heard on the steps of the court house."

Persecution and discouragements followed one after another. In 1795, Whitney's workshop and models, on which he had worked for two years, were burned down. He and Miller went

North to continue making gins, but they had difficulty in raising money, even at the interest of from twelve to twenty-five per cent. Abroad, manufacturers claimed that ginning injured the cotton, and this prejudice had to be overcome. After a long litigation, however, Whitney received due credit, in a decision handed down by Justice Johnson in a United States court. This was in 1807, when Whitney was suing Arthur Fort and a man named Hodgin Holmes, who had made a machine somewhat like Whitney's, but with teeth cut in plates of iron.

Judge Johnson's charge is interesting. In part, he ruled: "The machine of which Mr. Whitney claims to be the inventor, so facilitates the preparation of this species (green seed domestic cotton) for use, that the cultivation of it has suddenly become an object of infinitely greater national importance than that of the other species (foreign or black seed cotton) can be. Is it then to be imagined that if this machine had ever before been discovered, the use of it would ever have been lost, or could have been confined to any tract or country left unexplored by commercial enterprise?"

Judge Johnson granted Whitney a perpetual injunction, and those who claimed that he had stolen their idea, with those accused by Whitney of stealing his, were legally silenced. After long delays, Whitney was finally awarded $50,000 by the State of South Carolina, and the State of North Carolina voted him a percentage of profits on all cotton-gins used within its territory for a period of five years. Other States promised to do likewise, but conveniently forgot their promises.

Whitney, disgusted, decided to remain in the North and to devote his attention to other pursuits. Tall and dignified, with cultivated mind and manner, he was on the most friendly terms with the leading men of his time, and enjoyed the acquaintance of every President of the United States during his lifetime. Whitney's friend, Robert Fulton, remarked that: "Arkwright, Watt, and Whitney were the three men who did most for mankind of any of their contemporaries," which was, indeed, praise from Cæsar, in view of Fulton's own achievements. Macaulay expressed the opinion that "What Peter the Great did to make Russia dominant, Eli Whitney's invention of the cotton gin has more than equalled in its relation to the power and progress of the United States."

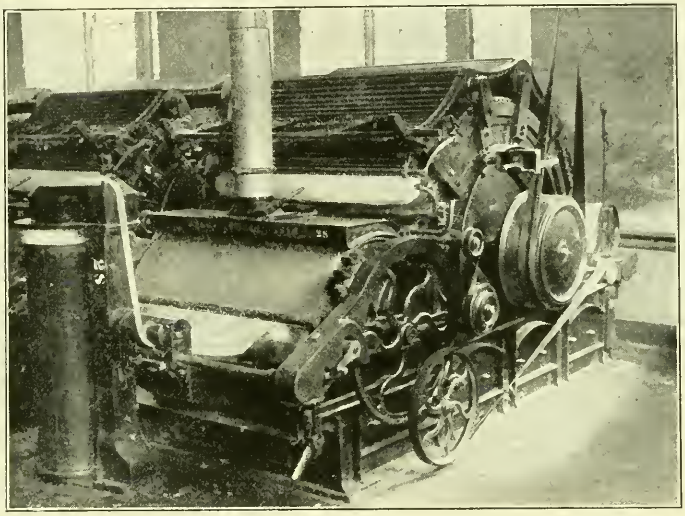
With Whitney's gin making possible an increased supply of cotton, there were 140 cotton manufacturers in operation within thirty miles of Providence by 1815. They employed some 26,000 hands and operated 130,000 spindles. The census of 1910 gave the country a total of 33,998,648 spindles, of which 28,178,862 were cotton; 1,332 establishments employed 387,252 hands; and it was estimated that the cultivation, handling, and manufacturing of cotton gave employment to 9,000,000 persons. In that year, 4,799,000 bales of cotton were used by the country.

Carding the Fibre

Before fibres can be spun they must be carded; in other words they must be combed, just as we comb hair. It is the object of carding to disentangle and straighten the fibres. Carding is as old as human industry. The hand-cards used in the seventeenth and eighteenth centuries were wire brushes. One brush was nailed to a table, teeth up, and the other to a two-handled bar wielded by a man. The fibres were spread over the fixed brush or card and the carder drew the movable brush over it. To strip the fibres from the card teeth a rod called a "needle-stick" was inserted in the wires and worked in and out. The strip or "sliver" thus secured was then ready to be spun.

James Hargreaves, about whom more will be recounted when the subject of spinning is taken up in this chapter, conceived the idea of doing away with the two-handled movable card wielded by hand. He attached the movable card to the ends of cords passing through pulleys in the ceiling and hung counterweights to the other ends of the cords. With this pulley system, fibres were more easily carded, although carding was still a matter of muscular power. Moreover, Hargreaves could operate two and three cards instead of only one with this system of pulleys and cords, so that he invented a real labor-saving device.

But the man who made the first important mechanical improvement in carding and brought us measurably nearer our own automatic day was Daniel Bourn, of Leominster, England. In 1748, he patented the principle of carding by cylinders; a principle that reminds one somewhat of Whitney's saw gin for removing the seed from cotton. Bourn's appliance had four rollers studded with teeth or "cards." The fibre passed from the first roller to the second, then to the third, and finally to the fourth. When the first roller had done its work of combing, a grid stripped the fibres from the teeth. Ever since Bourn's day this method has been called "cylinder carding."



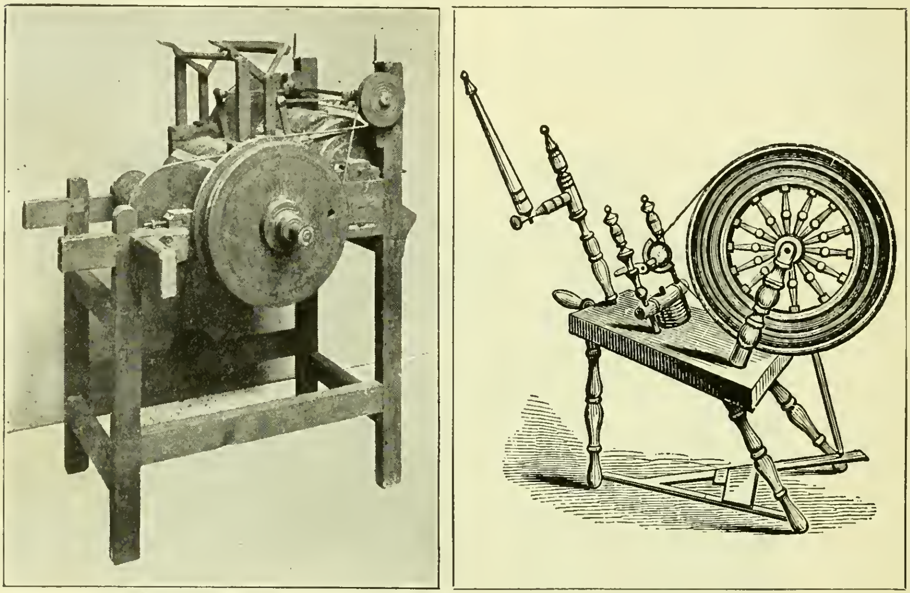
Courtesy of the U. S. Department of Agriculture.

A MODERN CARDING-ENGINE IN ACTION.

Note how sliver is coiled in the can.

There is another method called "flat carding," which was also patented in 1748. The inventor was Lewis Paul, of Birmingham, England. Paul also used a cylinder studded with teeth or cards. The cylinder fitted in a rounded trough likewise studded with teeth. By feeding fibres between the cylinder teeth and the trough teeth, and turning the handle of the cylinder it is easy to see that the fibres would be combed.

But the man who gave us the modern, automatic method of carding was Richard Arkwright, one of the great figures in the history of textile machinery, a man of whom more will be said in the proper place. Arkwright saw that the methods of Bourn and Paul, while good, would never provide enough thread for fast spinning machinery, such as he was engaged in devising and introducing. Arkwright concentrated upon this problem between 1773 and 1775, and succeeded in mastering it. He contributed nothing new in principle. He simply combined the ideas of Bourn and Paul, and eventually produced a machine which would card fibres continuously. His work was not so much invention as textile engineering, although he had never



Courtesy South Kensington Museum, London.

(Left) ORIGINAL CARDING-MACHINE MADE BY ARKWRIGHT ABOUT 1775 AND PRESERVED IN THE SOUTH KENSINGTON MUSEUM, LONDON.

In the large wooden wheel a hole will be noticed. This is intended to receive a crank by which the wheel is turned.

The purpose of carding is to separate the fibres, which are entangled in small tufts and knots so as to draw them out in parallel strings and to remove impurities. Carding-engines are brushes of bent iron wire fixed on a set of cylindrical and a set of plane surfaces, the former being made to revolve so as to sweep over the surfaces of the latter at rest. Sometimes, as here shown, large cylindrical cards work against the surfaces of smaller cylindrical cards, moving at a slower speed; and occasionally both plans are combined in the same engine. The tufts are held fast by the stationary or slow-moving cards, while the quick-moving cards tease out the fibres and disentangle them.

(Right) A COLONIAL SPINNING-MACHINE.

had an engineering training, and was so poor a mechanic that he could not even make his own models. But his principles were so sound that his automatic carding-engine has not been very much changed to this day.

In 1777, Oliver Evans, an American genius whose name occurs repeatedly in this book, devised a machine which could turn out 1,500 card teeth a minute. Evans asked the Pennsylvania legislature to supply him with funds to introduce his machinery, but he was refused, and in 1788, others began to make cards by his method. Oliver Evans had caught the inventive fever, however, and in 1808, became the first regular steam-engine builder in Philadelphia. He applied steam to textile machines, built up a thriving business, and contributed many machines for a multitude of uses.

Spinning the Fibre

After the fibre has been carded it is ready to be spun into threads or yarns. The cotton or other fibre, as it comes from the card, is a thin sheet of fleece, called a "sliver" or "roving." Until about 1730, all yarn was spun by hand from slivers or rovings. A pinch of sliver was held between the forefinger and thumb, about six inches from the spindle. As the wheel—the old spinning-wheel treasured as an antique in many a household—was turned with one hand, the sliver or roving was drawn out about a yard with the other. The spindle then was made to revolve so as to twist the drawn-out, cord-like sliver into a thread, which was then wound up on the spindle as yarn. To-day, swift-running machines perform the whole operation with a simplicity, smoothness, and rapidity that seem little short of miraculous. Instead of laboriously working upon a strand at a time, one trained attendant can take care of 125 spindles in operation, and these spindles rotate at the dizzy speed of 10,000 revolutions per minute.

The man who made the first advance over the old cumbrous method of hand spinning was the same Lewis Paul who invented the flat-carding machine. He must have been an extraordinarily ingenious person. Scarcely anything is known about him except that he was a weaver. Paul patented, in 1738, a startlingly new method of spinning with the aid of rollers. He describes the principle thus in his patent;

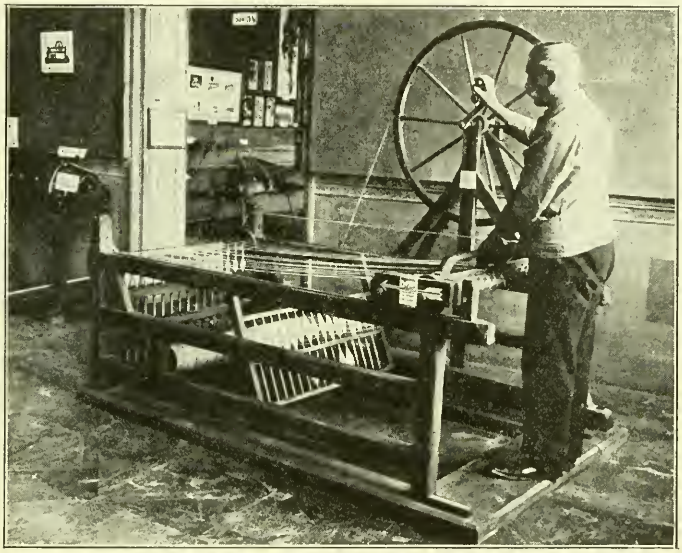
". . . One end of the sliver is put between a pair of rollers, or cylinders, or some such movement, which, being turned round by their motion, *draw in* the raw mass of cotton to be spun in *proportion* to the *velocity given to the rollers.* As the cotton passes regularly through or betwixt these rollers, a succession of *other rollers, moving proportionately faster* than the first, *draw the sliver into any degree of fineness that may be required.*"

It is clear that Paul's rollers were nothing but mechanical fingers and thumbs. He had evidently analyzed spinning with an eye to mimicking the motions of the fingers. Paul's method of spinning with the aid of rollers inspired dozens of inventors in after-years, among them the famous Arkwright. Paul's rollers did not prove a commercial success, although he did grant a few licenses under his patent.

Hand spinners were further alarmed by the activities of James Hargreaves, the previously mentioned illiterate weaver of Blackburn, England, who startled them with a machine that could spin eight threads at a time. A rapid weaver could use as much yarn as six expert hand spinners, working treadles and wheels, could produce. Here was a man who would do away with these spinners. Hargreaves was inspired by the necessities of his own situation. As a weaver, he was dependent on a spinner for yarn, and the spinner was his own wife, who could hardly produce thread fast enough for him.

Strangely enough, it was an accident that set him on the right track. While he was brooding over his enforced idleness and waiting for his wife to furnish him with more yarn, her spinning-wheel was upset by her daughter Jenny. Hargreaves noticed that the wheel continued to revolve, and the spindle, now in an upright position, instead of a horizontal one, did not cease to receive the yarn. This gave him just the hint he needed. He at once set to work to make a spinning-frame with eight upright spindles and a wheel. It proved a success, and because of the accident which had given him the thought, he christened the device a "jenny"—the name of the daughter who had upset the wheel.

Later, Hargreaves' invention made it possible to spin as many as 120 threads with no more labor than had previously been expended in producing one. However, the "jenny" could spin only yarn to be used as weft, as the yarn lacked the necessary strength to make it suitable for the longitudinal warp threads, and the spinner was obliged to draw off the threads by hand. It remained for Richard Arkwright to supply its deficiencies.



Courtesy of the Deutsches Museum, Munich.

HARGREAVES'S FIRST SPINNING-JENNY OF 1764.

While brooding over his misfortunes Hargreaves noted that a spinning-wheel, accidentally upset by his daughter Jenny, continued to revolve, although the spindle was upright instead of horizontal. This gave him the inspiration he needed. He invented a spinning-frame with eight upright spindles and a wheel and called it a "jenny."

But despite the fact that thinking men promptly set to work to improve Hargreaves' discovery, most of his fellow craftsmen were instantly up in arms. They claimed that Hargreaves and other seekers after increased production were robbing human hands of their just labor. Thus the inventor found himself the centre of a storm of anger and abuse. A brutal mob broke into his humble cottage and smashed his jenny to pieces. In fact, Hargreaves and his wife barely escaped with their lives.

He died unacclaimed after a long, bitter battle against starvation.

Hargreaves never dreamed of the modern improvements upon his idea, nor had he any conception of the progress being made in his lifetime on what is now known as the Jacquard machine.

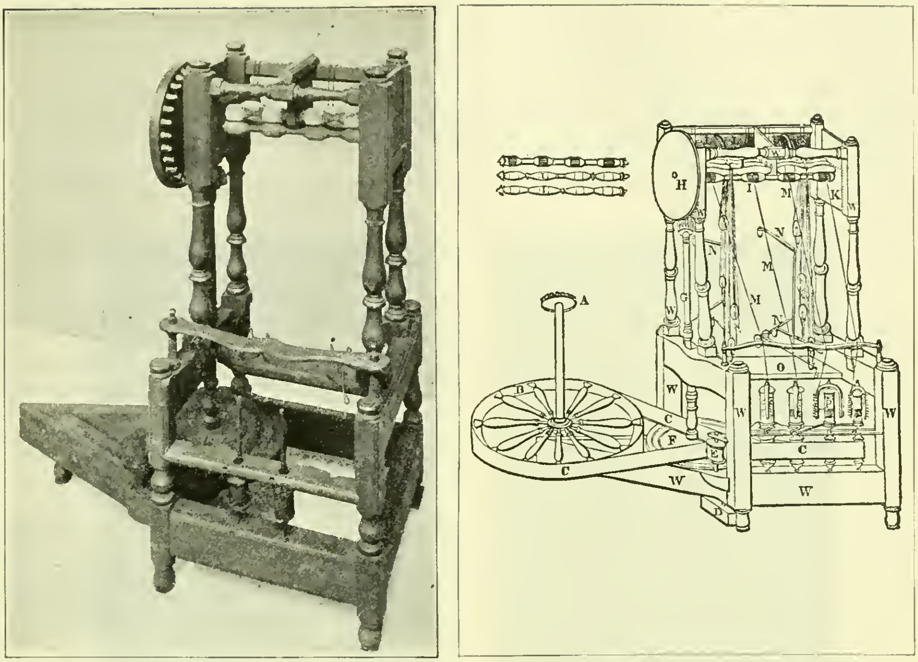
ARKWRIGHT THE FIRST TO SUCCEED IN MECHANICAL SPINNING

These undeserved and pitiful experiences of the early pioneers in textile endeavor, make the story of Richard Arkwright much more pleasant reading. He was in a better position to weather the storm of popular disapproval than his predecessors, and fortunately he was able to reap material benefit from his work, although he, too, faced the severest persecution.

Unlike most inventors, Arkwright proved himself a rather good business man and a splendid organizer, so that he was able to laugh at his enemies and to gain for himself fame and fortune. His beginning was humble. Amid the grimy old houses and narrow lanes of Bolton, England, in 1750, stood an inn known as the Old Millstone. Swinging over the door was the sign of a "Subterranean Barber," whose shop was in the cellar. There, it was advertised, one might be shaved for a penny. The proprietor of the place was Richard Arkwright, then a youth of twenty-one. He was a tall, bright-eyed, active young man, and like all of his clan, a great talker. Most of his customers were either spinners or weavers, and Arkwright loved to hear them speak of the new machines which were then attracting such attention.

He was one of thirteen children, and his boyhood had been far from happy, for his father was poor, and consequently Arkwright the barber was a man of little learning. However, he had a bent for machinery, and he lost no opportunity to study it. By the time he was thirty, he grew tired of shaving for a living, and set himself up as a wigmaker, travelling through the countryside to purchase hair from the heads of poor farmer's daughters.

It was on one of these excursions that he fell in love with a country lass and brought her back with him as his wife to Bolton.



Courtesy of the South Kensington Museum, London.

ARKWRIGHT'S ORIGINAL SPINNING-MACHINE OF 1769.

Hargreaves' spinning-jenny could supply thread useful only as weft because it did not have the requisite firmness or hardness required for longitudinal threads or warp. Arkwright overcame the difficulty by inventing the spinning-frame. The machine was patented in 1769.

In English none too good Arkwright thus describes his original water-frame spinning-machine, patented 1769: "*A*, the cog-wheel and shaft, which receive their motion from a horse. *B*, the drum or wheel, which turns *C*, a belt of leather, and gives motion to the whole machine. *D*, a lead weight, which keeps *F*, the small drum, steady to *E*, the forcing-wheel. *G*, the shaft of wood which gives motion to the wheel *H* and continues it to *I*, four pairs of rollers (the forms of which are drawn in the margin), which act by tooth and pinion made of brass and steel nuts fixed in two iron plates, *K*. That part of the roller which the cotton runs through is covered with wood, the top roller with leather, and the bottom one fluted, which lets the cotton, etc., through it; by one pair of rollers moving quicker than the other draws it finer for twisting, which is performed by the spindles. *K*, the two iron plates described above. Four large bobbins with cotton rovings on, are conducted between rollers at the back. *M*, the four threads carried to the bobbins and spindles by four small wires, fixed across the frame in the slip of wood *V*. *N*, iron levers with small lead weights hanging to the rollers by pulleys which keep the rollers close to each other. *O*, a cross piece of wood to which the levers are fixed. *P*, the bobbins and spindles. Flyers made of wood with small wires on the sides lead the thread to the bobbins. Small worsted bands are put about the whirl of the bobbins, the screwing of which tight or easy causes the bobbins to wind up their threads faster or slower. The four spindles run in iron plates. *V*, explained in letter *M*. *W*, a wooden frame of the whole machine."

She proved to be an extravagant girl, but Arkwright was doing well and did not mind that trait. He had discovered a new and improved way of dyeing hair, and was prospering. One day, while on a visit to a manufacturing town, he heard some weavers discussing the threads they used in making cloth. These consisted of a linen thread interwoven with cotton. Although Hargreaves' spinning-jenny had increased production and was now being generally used, it still failed to provide enough yarn for the growing demand. It must also be remembered that its thread was not strong enough to be used for warp.

SAMUEL CROMPTON. SIR RICHARD ARKWRIGHT.

(Left) Samuel Crompton, inventor of the spinning-mule. He played the violin for eighteen pence a night in order to purchase the tools he needed in the development of his spinning "mule."

(Right) Sir Richard Arkwright, inventor of the modern method of spinning. Carlyle described him as a "plain, almost gross, bag-cheeked, pot-bellied Lancashire man, with an air of painful reflection, yet also of copious, free digestion."

The situation interested Arkwright, and finding a jenny, he proceeded to study it. He believed that he could develop a machine that would not only spin faster but finer, and he began to experiment. He became wrapped up in the idea and soon began to neglect his business to devote his whole time to his invention. His money dwindled and his extravagant wife became furious. Arkwright endured her scoldings and continued to stay home, bravely battling with discouragement.

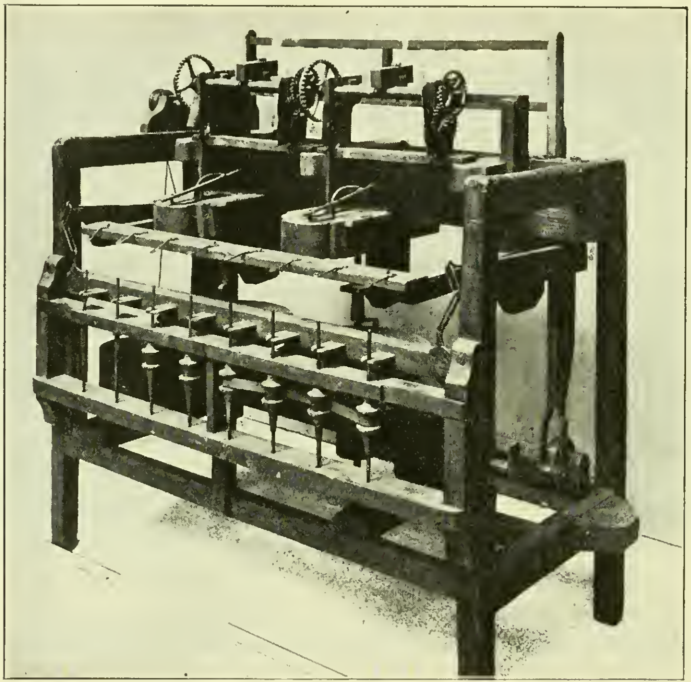
But Mistress Arkwright finally lost her patience. One day, in a rage, she deliberately smashed her husband's model. She wanted to teach him a lesson and bring him to his senses. Much to her surprise, he drove her out of the house and told her never to return. Then he proceeded with his work, and after several years completed the invention that made his name immortal.

It is said that Arkwright conceived his idea of spinning with the aid of rollers while watching the men in an iron foundry passing a billet of red-hot iron between two pairs of rollers, the second pair revolving faster than the first. It seems more likely that he heard of Lewis Paul's method of using rollers that turned at unequal speeds. It is certain that he knew of a roller-machine used by Thomas High. At all events, he drew the sliver or roving through four pairs of rollers, as Paul had done before him, then twisted the threads delivered by the rollers by means of four spindles. It must not be supposed that Arkwright merely copied the machines of other men. Every great invention is an evolution, a natural growth. Arkwright made Paul's roller-drawing principle practical, and that is why he is esteemed a great inventor.

Arkwright's machine did not have to be stopped to wind the lengths of yarn, as did the spinning-wheel. It performed, by itself, the whole process of spinning. All the workmen had to do was to feed it with cotton roving, and join or piece a thread when it broke. The thread it produced was fit for warp as well as weft. As a result, cloth could now be made wholly of cotton. Arkwright used almost his last penny to employ others to help him construct his machine. He went to John Kay, a watchmaker of Warrenton, for his first rude model, in 1767.

Remembering Hargreaves' fate, Arkwright kept his invention a secret until he secured a patent; and that took about two years. Even with this protection, he found himself and his machine targets of rioters; so he smuggled it to Nottingham, where he proceeded to improve it. When his funds were practically gone, Arkwright found a friend in John Smalley, of Preston, Arkwright's birthplace. Later, in company with Samuel Need and Jedediah Strutt, he erected a spinning-mill of his own in Woolpack Lane, Nottingham, the first "mill" in all England.

Envious capitalists claimed that Arkwright had stolen his invention, and they sought to have his patents annulled. Years of litigation followed, and, unfortunately, Arkwright got the worst of it. Then a mob, spurred on by those who hated him, burned his mills at Chorley, while the local constabulary and soldiers stood looking on in amusement, without making the slightest effort to interfere.



Courtesy of the South Kensington Museum, London.

ARKWRIGHT'S IMPROVED SPINNING-MACHINE OF 1775, PRESERVED IN THE SOUTH KENSINGTON MUSEUM, LONDON.

In this machine improvements were incorporated to facilitate the processes of carding, roving, and spinning.

Arkwright's organizing ability, however, proved more than a match for the methods of his adversaries, and soon he grew rich. He purchased a country estate and built a fine house known as Willersley Castle. In time, he was chosen high sheriff of the county, a great honor in those days. When, in 1786, George III visited the vicinity, it was Arkwright who received the king and congratulated him upon having escaped from an attempt upon his life. The speech so pleased the king that he knighted Arkwright, and the man who had been a poor barber became Sir Richard Arkwright.

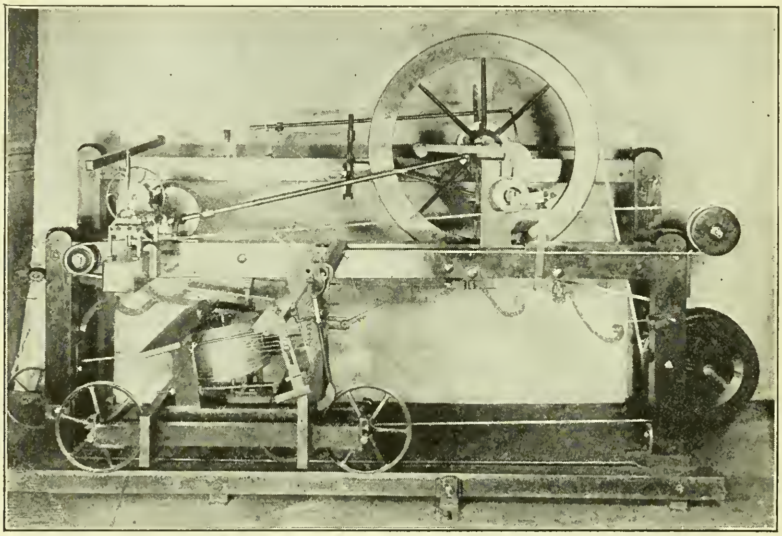
It was Sir Richard Arkwright, the prosperous mill-owner, who introduced the factory system into the textile industry, the man who left a fortune of £400,000, and not plain Dick Arkwright, the barber, whom Carlyle had in mind when he wrote: "He was a plain, almost gross, bag-cheeked, pot-bellied Lancashire man, with an air of painful reflection, yet also of copious, free digestion." In spite of his great gifts, Arkwright found reading and writing difficult; even at the age of fifty he pored over a grammar and a spelling-book several hours a day.

Samuel Crompton Improves the Jenny

It remained for a youth who composed hymns and whose hobby, like that of Eli Whitney, was the construction and playing of violins to combine the inventions of Hargreaves and Arkwright and enable England to make the fine muslins she had long imported from India. He was Samuel Crompton, a sensitive, superstitious, proud, hard-working, rather artistically inclined man. Born near Bolton, in Lancashire, in 1753, like many Lancashire children he trampled the dirt out of washed cotton and learned how to spin before he ever went to the Bolton day-school. Almost from the cradle the difficulties of spinning were driven home to him. He was cuffed and scolded because the Hargreaves jenny he worked broke the soft threads.

Hargreaves' spinning-jenny, with the improvements made upon it, had a series of vertical spindles, each of which was supplied with a ribbon or roving of cotton, fed from a separate spool. It had a clasping mechanism by which the operator could catch and draw out all of the roving at one time, during the operation, and then feed the threads to the spindles for winding. The process was almost exactly that of hand-spinning, except that from eight to twenty threads could be handled at once. The great trouble was that the individual skill of the user of the ancient distaff, and later of the wheel, was missing. The machine had no judgment and did not improve its product with practice.

Crompton seriously began to apply himself to the improvement of the jenny when he was twenty-one. He worked steadily on an invention, which would remove its defects, between the years 1774 and 1779. He played the violin for eighteen pence a night in the Bolton theatre to earn the money he needed for the purchase of tools. At first his family did not know of his ambition and his experimenting. The old "Hall-in-the-Wood" where the Cromptons lived, was always regarded as a queer place by the countryside. The strange lights and noises which came from the place, and which finally made secrecy impossible, gave the old tumbledown mansion the reputation of being haunted. Curiosity overcame fear, and a few daring Lancashire



Courtesy of the Deutsches Museum, Munich.

CROMPTON'S FIRST MULE, AN IMPROVEMENT OVER HARGREAVES' JENNY.

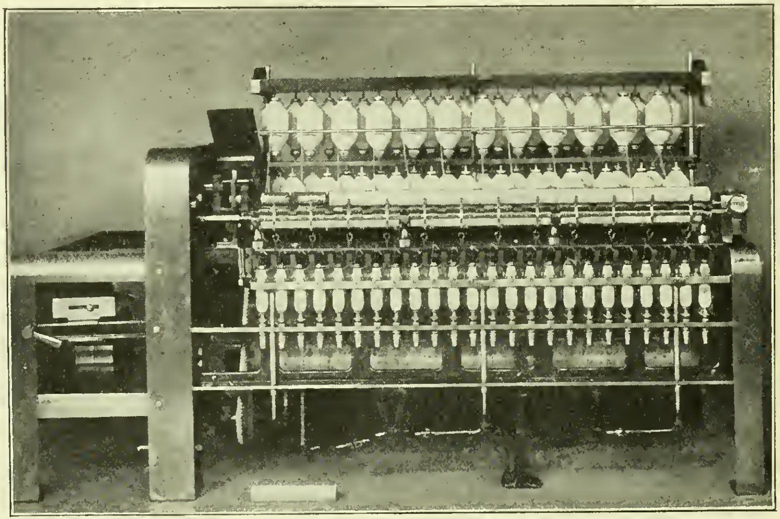
The mule was a combination of the drawing rollers of Paul and Arkwright, and the stretching devices of Hargreaves. As the rollers paid out the elongated thread, the spindle was made to move back so as to slacken the thread, and not until it was ready to be wound up on the spindle was any strain placed upon it, and then only enough to carry out the winding operation.

weavers peeped in now and then to find out why Sammy Crompton was staying up so late at night.

At last Crompton finished what was at first jocularly called a "mule"—a name that has now become part and parcel of the spinner's vocabulary. Crompton saw that if the threads were to be prevented from breaking, on the Hargreaves jenny, they must be relieved of strain during the process of drawing them out. His "mule" was a combination of the drawing rollers of Paul and Arkwright and the stretching devices of Hargreaves. As the rollers paid out the elongated thread, the spindle was made to move back so as to slacken the thread and relieve the strain. Hence the rollers could stretch the thread, and not until it was ready to be wound up on the spindle, was any strain placed upon it; even then, the strain of winding was not sufficient to break it.

Crompton's yarn was the marvel of Lancashire. "How did he make it?" all the weavers asked. He was flooded with orders for yarn. But also he was continuously spied upon. Curious eyes were glued at gimlet-holes in his loft. Remembering what happened to Hargreaves and how the mob had smashed his first jennies, he took his machine apart and removed to Oldham. There he began to spin fine yarns in secret. Finally he did start to sell his machine, but at such unfavorable terms that he made no money. Arkwright's patents had been thrown open to the public by a decision of the King's Bench. Appropriating both Crompton's mule and Arkwright's rollers, weavers of fine fabrics became so wealthy that they strutted about the streets of Manchester with five-pound notes stuck in their hats.

Parliament voted £10,000 to Cartwright, inventor of the power-loom in recognition of his services. Crompton hoped that as much might be done for him. He succeeded in arousing the interest of Spencer Percival in his case. Percival, then prime minister, promised to obtain £20,000 for him. Elated, Crompton went up to London, in 1809, on the day the petition was to be put before Parliament. But his joy soon changed to sorrow. The powerful Percival greeted him at the entrance to the Houses of Parliament, but suddenly a pistol-shot dashed the inventor's hopes. The premier had fallen victim to the bullet of the crazy assassin, Bellingham. Thus robbed by fate of his patron's support, Crompton was given only a grant of £5,000. He spent all of this in attempting to establish himself as a bleacher, cotton merchant, and spinner, and remained poor until he died in 1827, a disappointed man, fully realizing the benefit his sacrifices had given to mankind. His "mule" is now an automatic device; but its essential principle has not been changed.



Courtesy of the South Kensington Museum, London.

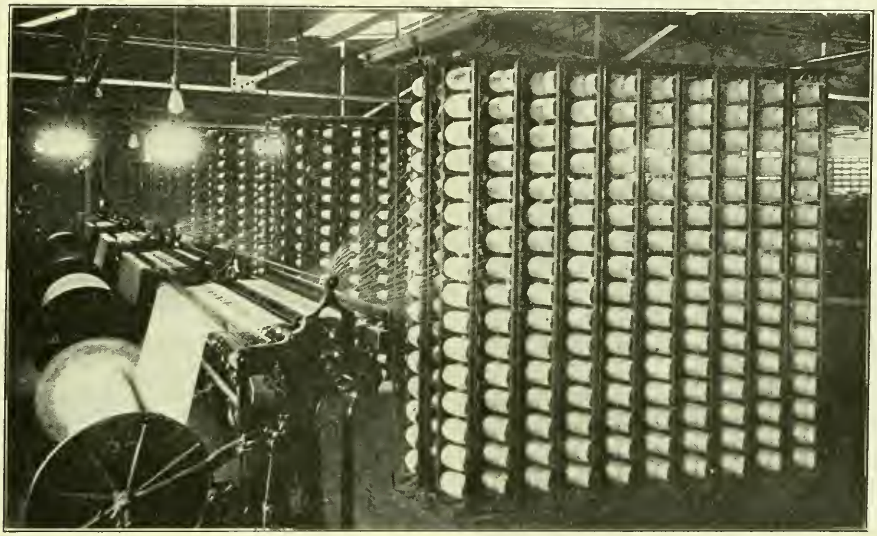
THE RING SPINNING-FRAME OF RICHARD ROBERTS.

Crompton's mule prompted Richard Roberts to experiment with the "ring frame," another method of spinning yarn which would not easily break. The principle was introduced in the United States in 1828 by J. Thorpe long before it was known abroad.

Crompton's mule had prompted Richard Roberts to experiment with the "ring frame," another method of spinning yarn which would not easily break. However, an American conceived the idea before it was tried in England, and in 1828 J. Thorpe introduced it in this country, long before it was known abroad.

The Invention of the Power-Loom

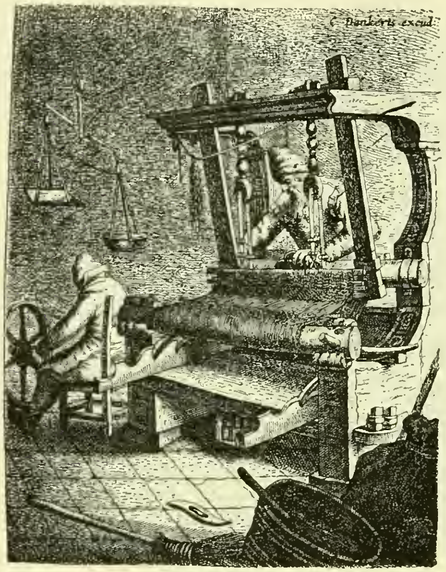
We have now briefly traced the development of ginning, carding, and spinning. There still remains the last phase of weaving the carded, spun thread into fabric. Suppose we take a peep into the home of an English weaver, and then try to realize what the invention of John Kay, of Bury, meant to him. Imagine a quaint, thatched cottage with a great clumsy loom of wood set up in the main room. The weaver and his assistants are ready to set to work. The yarn, either spun by the weaver's family or purchased from a neighbor, is ready to be fashioned into cloth. First, the assistants attach a strand of yarn to a long wooden needle known as a "shuttle." The shuttle is heavy and the weaver needs both hands and plenty of strength to use it. His first task is to "set" the warp-threads —which run the long way of the fabric—and these he stretches across a wooden frame by means of his shuttle. Then the "woof" or cross-threads are woven horizontally across the warp, much as our Indians still weave their woollen blankets.

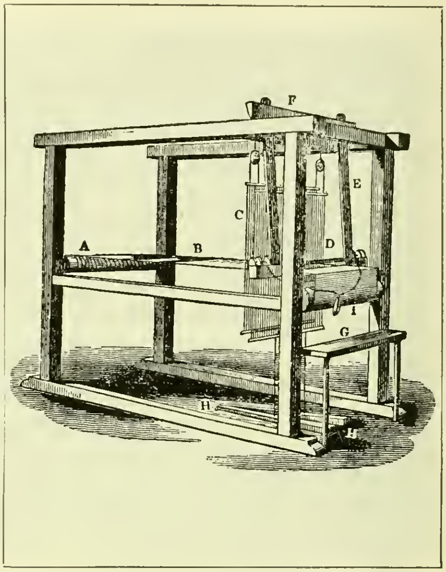


Courtesy U. S. Department of Agriculture.

HOW THE WARP YARN IS WOUND IN A MODERN MILL FOR USE IN THE LOOM.

It was the shuttle of such a loom that John Kay improved. He was a machinist and engineer, born in 1704 and educated abroad. While still a mere youth, he was put in charge of his father's woollen-mill. His inventive genius soon showed itself, and he made improvements in dressing, batting, and carding machinery. His first patent was for a machine that twisted and carded mohair and worsted, and twined and dressed thread; a patent granted when he was but twenty-six. His "fly shuttle," so christened because of its speed, improved the quality of the cloth, lightened the work of the operator, and more than doubled the output. Before him—as we have seen—the shuttle was





(Left) SEVENTEENTH CENTURY WEAVING-ROOM WITH A LARGE LOOM.

From a copper-engraving of Jan van Vliet, made in 1635. It was not until John Kay invented the "fly" shuttle (so-called because of its speed), that the loom was radically improved.

(Right) EARLY FORM OF KAY FLY-SHUTTLE LOOM.

In the commonest form of Kay fly-shuttle looms the warp is wound about the beam *A;* the lease is preserved by the rods at *B;* and the heddles at *C* consist of twines looped in the middle, through which loops the warp-yarns are drawn, one half through the front heddle and the other through the back one. The yarns then pass through the reed under *D*, fixed in a swinging frame *E*, called the batten, lay, or lathe. This lay is suspended to a cross-bar *F*, attached to the upper part of the side uprights so as to vibrate upon it. The weaver sits upon the board *G*, presses one of the treadles at *H* with his foot, which, raising one of the heddles and sinking the other, sheds the warp by lifting and depressing each alternate thread a little way. Thus a pathway is opened for the shuttle to traverse the warp. The weaver holds the picking peg *I* in his right hand and by a smart, jerking motion drives the shuttle swiftly from one side of the loom to the other, between the warp yarns. The shuttle having left behind it a shoot of weft, between the reed and weaver, he now pulls the lay, with its reed, toward him with his left hand, so to drive home the weft yarn to the web, made by the preceding casts of the shuttle. The cloth is wound upon the cloth beam over *I*.

cast through the warp from side to side with one hand and caught by the other. The weft-thread was driven home by the hand which had just released the shuttle. For heavy fabrics, a weaver had to stand on either side of the loom.

Kay simplified this by making a shuttle with a handle and spring. His invention enabled the weaver to throw the shuttle with one hand, leaving the other free to drive home the weft. Simple as Kay's invention was, it astonished his associates. Yorkshire clothiers realized its advantage, but they had no intention of paying Kay for it. They stole it and formed the "Shuttle Club," agreeing to pay each other's fines if Kay went to law. The weavers, however, were furious, and Kay had to flee to Leeds. He encountered similar hatred there. Weavers broke into his quarters, demolished his machines, and would have killed him if his friends had not secretly carried him off, wrapped up in a sheet.

Kay sought refuge in France and reconstructed the broken machines he had smuggled out of England. He told Parliament that he had many more devices in mind, but would not show them unless he was guaranteed better treatment. He also pleaded that he needed money to pay his debts and support his family. He died in France in obscurity and in poverty. Yet his inventions, since modified, are still in daily use.

Kay's son, Robert, had been caught in the fire of inventive enthusiasm, and, ignoring his father's fate, he produced the "drop-box," by which it became possible to work many different kinds of weft or cross threads into the same fabric—a hitherto unheard-of thing.

Cartwright and the Power-Loom

What the loom now needed was some way of driving it mechanically. The inventions of Paul, Hargreaves, Arkwright, and Crompton had made it possible to spin yarn faster than any loom could weave it. It remained for a minister, a man who wrote poetry in his youth, to think of applying power to looms for weaving. The inventor was the Reverend Doctor Edmund Cartwright, born at Nottingham in 1743, the scion of an excellent family. He was a graduate of Oxford University and fellow of Magdalen College, and until his fiftieth year, he seemed to have little interest outside the pursuit of his pious studies and of literature.

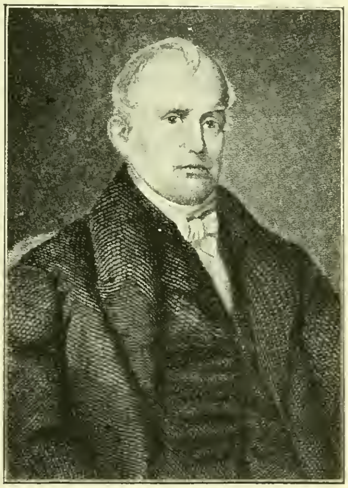
In 1784 he was invited to dine at an inn. The conversation turned toward the need for further textile development. He listened intently and finally expressed the opinion that he saw no reason why yarn might not be woven as fast as it was spun. He even predicted that the world would soon have "weaving johnnies as well as spinning jennies."

Before long Doctor Cartwright became the laughing-stock of his neighbors. He would go on long walks through the country, making strange gestures with both arms, and talking to himself. But, crazy as his actions seemed, he was only imitating the motions of his new machine which was beginning to assume physical form in his mind.

At last he did complete his power-loom, but himself admitted afterward that it was but a crude affair, so crude as to be hopelessly impractical. He did not realize this until he saw hand-looms at work. His machine would never do; it was not nearly so simple or so effective as the machines which it was intended to displace. As Cartwright himself admitted, "it required the strength of two powerful men to work the machine at a slow rate and only for a short time." After further attempts, he obtained another patent on August 1, 1787. Even this device was not a brilliant success. He had the right idea, but he never brought it to fruition. He had conceived the seemingly impossible, and had even made a loom which could be stopped automatically when a single thread might break. The trouble was that no mechanism, no matter how perfect, could be successful so long as warps continued to be starched or "sized" while a loom was stationary. Cartwright realized this defect, and tried to overcome it, but without success. He knew that if continuous operation could be attained, his power-loom would thrive. Incomplete as Cartwright's invention was, he too found masters and men arrayed against him. The goods he made were damaged. His workmen were bribed away, and his patents openly infringed. One Manchester firm did contract for 400 looms, but before delivery could be made the mill built to receive them was burned by an angry mob.

At first the minister had been well able to secure financial aid, but as the defects in his loom grew apparent, the capitalists withdrew and his own resources faded. With a grant of £10,000 from Parliament, he bought a farm in Kent and spent the rest of his life there.

Cartwright seems to have been a sort of universal genius. A memoir of the man, published in 1843, says: "He made bread in his own kitchen; published a scheme for rendering houses fireproof; invented bricks on a geometrical system; made a machine for biscuit-making; helped Fulton with his first steamship models; brought chemistry to bear upon the science of agriculture; introduced a new three-furrow plough; got the Agricultural Board's gold medal for experiments in manure, and their silver medal for an essay on the culture of potatoes; and obtained patents for calendering linen, making ropes, and cutting velvet pile. Indeed, it may be said of him that he went to the grave



SAMUEL SLATER.

DOCTOR EDMUND CARTWRIGHT.

Samuel Slater introduced into America knowledge of Arkwright's method of spinning, and is, therefore, the father of the American textile industry.

Doctor Cartwright was fifty before he became an inventor. Although his name is associated with weaving he was an extraordinarily prolific inventor in other fields. He made bread after his own fashion; devised a method of fireproof construction; worked out a system of geometrical bricks; made biscuit machines; applied chemistry to agriculture; received medals for his agricultural innovations; and patented machines for calendering linen, making ropes, and cutting velvet pile.

inventing. Being sent to Dover, in his eightieth year, for warm sea-bathing, he invented a method by which the bath-man saved the labor of two men pumping water. A few weeks later, he designed the model for a new centaur carriage; and a day or two previous to his death, in 1823, he wrote an elaborate argument to a friend on a plan he had discovered of working the steam-engine by gunpowder instead of steam."

Although several hundred Cartwright looms, driven by animal and steam power, had been introduced, his invention was not a technical success because, as we have seen, it had to be stopped so that the thread could be sized by hand. Evidently a way had to be discovered for sizing the warp—that is, covering it with adhesive starch paste for certain kinds of weaving—while it was in motion. The needed invention was supplied in 1802 by William Radcliffe and his assistant Thomas Johnson. It was called the "dandy loom."

Samuel Slater Comes to America

It has been thus necessary to trace the course of textile invention in England because the American colonies, long after they had become an independent nation, were utterly dependent on the mother country for everything but homespuns. England had invented and introduced most of the inventions described long before the United States had time to catch its industrial breath.

Great Britain desired to retain as long as possible the commercial supremacy which exclusive possession of spinning and weaving inventions had brought about. Consequently, in 1744, and again in 1781, the most drastic laws were enacted to protect them. Penalties of fine and even imprisonment were provided for the "putting aboard of any ship or vessel not bound to some place or port in Great Britain or Ireland, of any tools or utensils commonly used or proper for the preparation, working up, or finishing of cotton, silk, or linen manufacture." This made it impossible for the colonists to establish a textile industry on their own account, and it was not until 1845 that spinning and weaving machinery was freely permitted to be sent out of the United Kingdom.

During all these years not a single complete textile machine seems to have been successfully smuggled into this country, although it is said that a few models of Arkwright's machine were surreptitiously brought across the Atlantic in 1786.

Arkwright established the factory system in England; Samuel Slater in the United States. Slater was the son of an English yeoman, and was born in 1768. Reared in the midst of England's cotton-mills, he was early apprenticed to Arkwright's partner, Jedediah Strutt.

Hearing of the bounties offered for the development of cotton machinery in America, he escaped from England in disguise—for even weavers could not leave the mother country freely—arrived in New York in 1789, and read in a Philadelphia newspaper an account of the defective jennies there in use. He wanted to go to Philadelphia, but the captain of a Providence packet told him of the conditions in New England. Upon the captain's advice, he wrote to Moses Brown, a cotton manufacturer of Providence, who had made a fortune in the East India trade. Brown answered: "If thou canst do this thing, I invite thee to come to Rhode Island and have the credit of introducing cotton manufacture into America." Slater went at once, presenting in support of his claims, his indenture papers to Strutt, and stating that he had an "oversight" of the Arkwright machines.

"Under my proposals," he told Brown, "if I do not make as good yarn as they do in England, I will have nothing for my services, but will throw the whole of what I have attempted over the border."

Arriving at Brown's house, Slater found almost heroic efforts to establish cotton manufacture under way. He was told that the Hartford Manufacturing Company had inaugurated a subscription through the neighborhood in 1778, and had secured a capital of £1,250. In all, there were thirty-five stockholders, headed by Colonel Jeremiah Wadsworth, Oliver Wolcott, a signer of the Declaration of Independence, and Peter Colt. Within a year after its founding, this plant produced enough cloth to offer it for sale. But, owing to unskilled labor and ramshackle machinery, its product was not of good quality. It had to compete against English-made goods, which, even after paying five per cent. duty, undersold the domestic fabric and gave greater satisfaction. Other mills had experienced similar troubles. As a result, at the time of the first federal census, in 1790, there were, in the whole United States, only three woollen-mills worthy of the name. Their capacity was about 15,000 yards annually, valued at $75,000.

The firm of Almy, Brown, and Slater was formed, and young Slater, little more than twenty years of age, set to work. He went to board with Oziel Wilkinson, who, with his sons, had been trying to make cards. They had not been successful, but Slater soon pointed out where they had erred.

Four years before Slater's arrival, what is claimed to be the first woollen factory in America, operated by power, was opened at Byfield, with Arthur Schofield in charge of the work. He, too, had been attracted to this country from England, and had slipped in secretly. Thus, 1794 is accepted as the authentic date of the beginning of wool manufacture in this country.

Slater had set out to reproduce spinning-machines from memory. He had no patterns and the task was greater than he had imagined. Hence, it was not until November, 1790, that he was really in operation. It was of his mill that Alexander Hamilton said, in 1791: "The manufactory at Providence has the merit of being the first, introducing into the United States the celebrated cotton mill, which not only furnishes materials for that manufactory itself, but for the supply of private families, for household manufacture."

Slater's first real mill, built in 1793, had as its motive power an old negro known as "Primus" Jenks; but this colorful method of operation proved too slow, and the first water-power spinning plant in America soon succeeded the clumsy efforts of the faithful "Primus." The mill still stands—in Pawtucket, Rhode Island—a monument to its founder.

Slater's wife, Oziel Wilkinson's daughter, also caught the inventive fever. In 1793, she conceived the idea of twisting fine Surinam cotton yarn which her husband had spun, instead of linen twisted yarn, for sewing thread. She did it on her own spinning-wheel, and so satisfactory was the result that her brothers established a manufactory to produce such thread.

Although Slater died rich, his early compensation was not great. His salary for superintending two mills was three dollars a day, and an interest in the profits. But to him belongs the everlasting credit of having established the textile industry of the United States on a firm basis.

How the Textile Industry Was Fairly Started

Meanwhile, in 1764, James Davenport, an American mechanic, earned the distinction of taking out the first patent granted in the United States, for his spinning and carding machines. He set them up in the Globe Mills at Philadelphia, where he also had weaving machinery which enabled boys who worked ten hours a day to make about twenty yards of sail cloth. Davenport went to Boston, hoping to sell his machinery, but grew discouraged and soon died. Unfortunately the machinery was scrapped and sold in such small parts that it could not be assembled again.

With knowledge of the later improvements made abroad—particularly those which made Cartwright's power-loom successful—John Slater, younger brother of the immortal Samuel, arrived here from England in 1803. The older Slater had advised him to visit the Manchester and Oldham Mills before coming over, and as a result, John had learned many secrets of which Samuel was unaware.

In 1805 the younger Slater took the trail through the wilderness on horseback to select a site for a new spinning-mill. He chose a place on the banks of a river which the Indians called Monhegan, and founded the town of Slatersville. It was to the younger Slater that John Gilmore soon came with his idea for a new loom. He offered to build and operate it with the understanding that he was to receive nothing if it did not prove successful. John Slater was willing to accept Gilmore's offer, but the conservative Samuel vetoed it. Gilmore then approached Judge Daniel Lyman, at North Providence, who financed its construction and operation. Thus, in 1815, the power-loom was introduced into New England.

As early as 1804, Rowland Hazard first attempted to card wool by water-power. He had been a commission merchant, and married Mary Peace, for whom the great textile centre of Peacedale was named. He allied himself with Thomas Williams, and the two built up a great cotton-manufacturing enterprise which made them wealthy.

In February, 1813, the first mill in the world in which the whole process of cotton manufacturing, from spinning to weaving, was carried on by power, was established at Waltham. It was first known as the Boston Manufacturing Company, but later took the name of the Waltham Company. Francis Cabot Lowell was the sponsor of the enterprise, in company with Patrick Tracy Jackson. After graduating from Harvard, Lowell visited Scotland, in 1811, and became interested in the textile activities there. He not only succeeded in seeing closely guarded machines, but obtained a sufficiently clear idea of them to enable him to work on similar models. He knew that shrewd management, plenty of capital, and cheap labor, were great advantages enjoyed by British manufacturers. He believed, however, that New England offered superior water-power and cheaper raw material. He saw no reason why America might not break the monopoly enjoyed by the British. This view was shared by his brother-in-law, Jackson, who agreed to aid Lowell in the attempt.

Returning to Boston, Lowell began his experiments with a power-loom, assisted by Paul Moody, a mechanic of Amesbury. They conducted their work in an old store in Broad Street, and by the end of 1814 they had a practical loom ready to install in the new mill at Waltham. Lowell's loom differed from the ones he had seen abroad. It necessitated certain changes in the spinning process and in the sizing of the warp. To meet this, Moody invented a new warper. Then a new bobbin and fly were required, and Moody and Lowell together devised the double speeder. This called for the nicest mathematical calculations, but Lowell proved equal to the task. In subsequent patent litigation, an expert, called to testify, expressed surprise that any one in America except himself could have worked out the problem.

Later, Moody overcame the waste and expense of winding thread for filling, from the bobbin to the shuttle quills, by providing what is called the filling-throstle. In the first construction of his dressing-frame, Moody found that the wooden rollers had warped so that they would not fit accurately. This was because they were constantly wet. He tried coating them with pewter, but this was not satisfactory. He then made a mould of soapstone in which to cast the coatings, but his brother suggested that he make the rollers of soapstone itself. When tried, this worked perfectly.

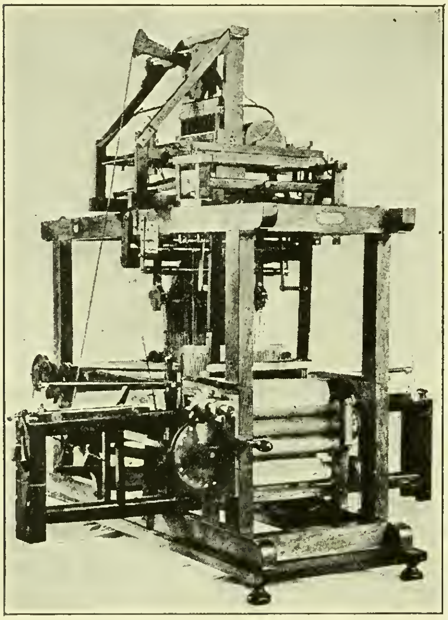
It is told how Lowell and Moody, searching for new machines to improve, called upon a man named Shepard, at Taunton. He had a patent for winding-machines which were highly thought of, but he wanted too great a price, and they were shrewd buyers. Shepard thought that Moody would pay, as he imagined he could not do without the machines, but Moody suddenly conceived the idea of spinning directly upon the bobbins.

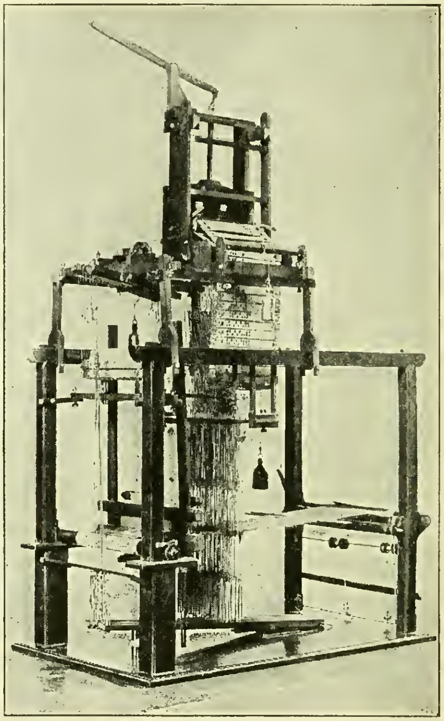
"You be hanged!" exclaimed the angry Shepard. "I'll accept your offer."

"You're too late!" broke in Mr. Lowell, and the two went back to their mill and began to spin caps directly upon the bobbins, thereby dispensing with the Shepard device.

It was the influence of Slater that prompted Colonel Joseph Durfee, who served in the Revolution, to build a mill at Fall River, in 1811, which was in operation when the British tried to raid the territory during the War of 1812. Durfee, although sixty-one years of age, mobilized and armed his employees and neighbors and repulsed the attack. His enterprise supplied work for the surrounding country, as the cotton was sent to the farmers to be picked and cleaned. It was spun at the mill and then sent away to be woven, finally being finished at Durfee's plant. The mill was never a financial success, and the doughty colonel died poor. The successor to his mill exists today, under the name of the Globe Yarn and Laurel Lakes Mill Company. On its old pay-rolls are the names of the ancestors of some of the most influential men of Fall River at the present time.

One of the most important improvements this country ever produced, was the work of Asa Arnold of Rhode Island, who invented the compound gear, in 1823. It combined a train of three bevelled wheels to regulate the varying velocity required for winding filaments of cotton. He secured a patent, but before he received the papers, his invention was stolen and re-patented in England, so that Arnold did not profit by his own. A similar misfortune befell Charles Danforth, of Paterson, New Jersey, who invented the cap spinner in 1828. This device improved the spinning of weft before the later aids of the self-acting mule were known, and he readily secured a patent. Again an Englishman appropriated the idea, and Danforth found himself protesting helplessly.





(Left) REDUCED MODEL OF A VAUCANSON LOOM (1746).

In 1725 Basile Bouchon invented a method of using perforated paper (like that of a modern automatic piano) by which the simples for any shed could be selected. In 1728 Falcon substituted perforated cards, but his mechanism was attached to the simple cords and required a boy to operate it. Vaucanson combined the two machines, and the combination was later improved by Jacquard.

(Right) ORIGINAL JACQUARD LOOM PRESERVED IN THE CONSERVATOIRE NATIONAL DES ARTS ET MÉTIERS, PARIS.

But little as seemed to be the reward of textile invention, those pledged to its cause did not falter. In 1812, spurred on by the blockade of the British fleet, American inventors, alone, took out 237 different patents covering all manner of appliances for weaving and spinning, and many other processes in the working up of cotton, wool, flax, linen, and even silk.

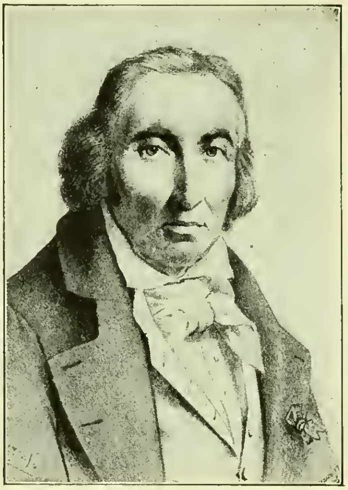
Energetic as these inventors were, and self-reliant as they proved to be, they nevertheless wished to know what was being done abroad. In 1838, William C. Davol bought some "mules" in Manchester. To get them out of the country, however, was another matter. He had purchased them from Sharp and Roberts, and intended to make like machines in America on a royalty basis. To get around the British embargo, he took down the mules and packed the various parts in small boxes, labelling them plate glass. These boxes were shipped to France, and then to the United States, where, after two years in transit, they were reassembled and put to work in Davol's mill at Metacomet.

A great problem in weaving was that of producing figured effects in threads of different colors. To the Frenchmen, Basile Bouchon, Falcon, Vaucanson, and Jacquard belongs the credit of having applied perforated paper or cards to the solution of the problem, a principle with which any one who has ever seen a modern automatic player-piano in operation is familiar. Although machines in which perforated paper or cards are thus applied are commonly supposed to have been invented by Jacquard alone, they combine the ideas of several men. A Jacquard machine is such a complicated combination of hooks, needles, springs, cards, and cylinders that it is hopeless to give a comprehensible, simple description of its ingenious method of automatically picking out the right threads to be woven in a figured pattern. The underlying idea of Jacquard is still applied, but modern automatic looms have been vastly improved by American inventors employed by Crompton and Knowles, and by the Drapers.

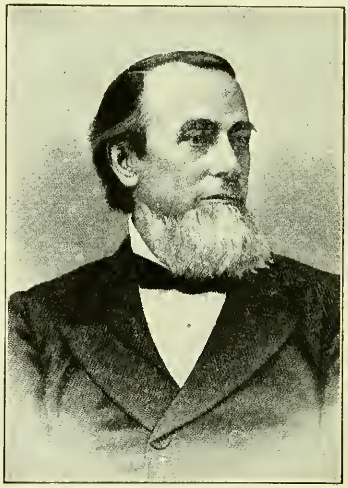
The Development of the Crompton and Knowles Loom

In the last twenty years those interested in loom construction have been primarily concerned with making every new loom automatic, so that a lower cost of weaving would result. Aiming for greater speed, they also sought to lighten the task of the operator, so that each weaver might supervise a greater number of looms. Two outstanding American figures in this field of twentieth-century improvement are William Crompton and Lucius James Knowles, who founded a great textile-machinery firm at Worcester, Massachusetts.

In 1837, William Crompton took out his first patent for a loom to weave figured patterns on what was called the chain principle. This is a method of raising and lowering the "harness" or wooden frame through which the filling threads are passed by the shuttle through the warp. Originally, cams, placed at intervals, would raise certain portions of the harness, so that some of the threads would not pass through the warp when they were not desired in the pattern. This cam method permitted the weaving of only simple designs. The new chain or belt method, however, provided "lifts" at any desired interval. These would raise or lower any number of the many warp threads desired, and either permit them to pass through



J. M. JACQUARD.



LUCIUS JAMES KNOWLES.

J. M. Jacquard, of whom this is a portrait, was a weaver, and therefore familiar with the machines of Bouchon, Falcon, and Vaucanson. He combined the ideas of these men in a single machine, simplified the operation, and produced the Jacquard loom.

Lucius James Knowles, who improved the loom of his associate, William Crompton, was one of the American pioneers of the automatic loom.

the warp or to be omitted from the weaving process. Thus, more intricate patterns could be woven.

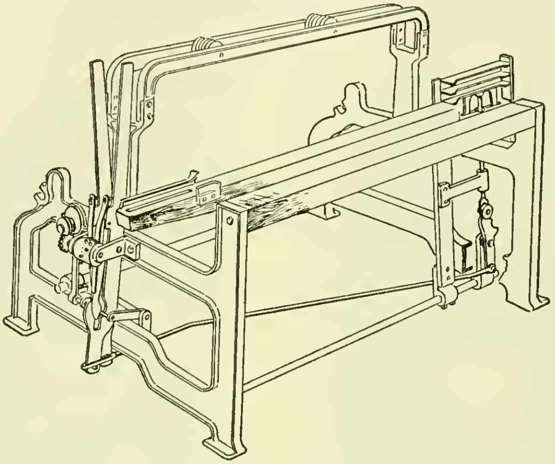
Since the expiration of Crompton's initial patent, professional inventors associated with his organization have produced more then 750 innovations and improvements in weaving machinery. In this group we find some seventy men. One of them, Horace Wyman, has to his credit 103 personal patents and 67 taken out in conjunction with others. Another, E. H. Ryon, has received nearly 100 patents, while others have obtained from one to eighty-three assigned to Crompton and Knowles.

William Crompton's first loom was the pioneer in the weaving of fancy woollens by power. It was put into operation at the Middlesex Mill at Lowell, in 1840. The goods it produced were found to compare favorably with the finest foreign cassimeres. This invention made it possible to change easily from one pattern to another. The most complicated designs could now be woven into cloth by power.

Crompton's son, George, followed in his father's footsteps, and in 1857 was granted a patent for a broad loom, nearly double the width of former looms. It had improvements which enabled it to run at what was considered an extraordinary speed, and it soon displaced the narrow loom. Then, in 1856, the younger Crompton and Horace Wyman, whose prolific inventions we have mentioned, further simplified the arrangement of the loom so that fabrics in the process of weaving were no longer subjected to damage resulting from the dripping of oil from the bearings upon the warp. This accomplished a great saving and avoided much waste.

The vital principle of the looms in use throughout the world to-day is the invention of Lucius James Knowles, who took out his first patent in 1856. This was an improvement upon the chain principle of his associate Crompton. The following year, after Knowles had made still further developments, his loom was exhibited at a fair in Worcester, where it attracted great attention. He apparently did not regard his improvement as being ready to patent, but the principle involved was protected in 1863, and is still in general use.

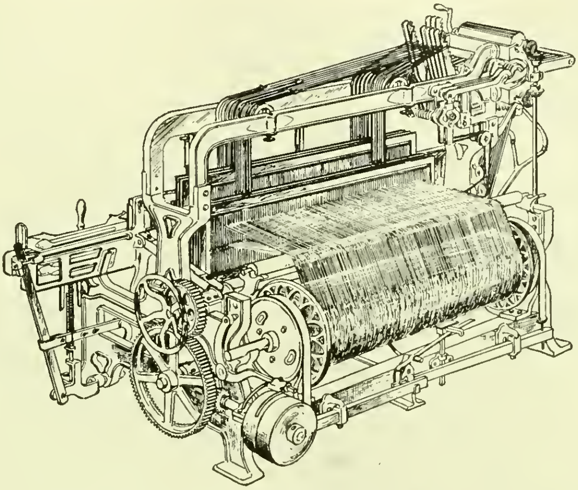
From the date of his first patent, Knowles was constantly at work, eliminating awkward features from his looms and adding desirable simplifications and improvements. One patent followed another with astonishing rapidity. The descendants of both Crompton and Knowles are also listed in the Patent Office records many times. But it was not until 1873 that Knowles secured protection for the idea which is regarded as the basis of the present-day Knowles loom. In the firm's exhibit at the Centennial in Philadelphia, in 1876, was a forty-harness loom, which astonished spectators by the fineness and rapidity of its work in weaving patterned cloth from warp and filling-yarn supplied by the American Mills, of Rockford, Connecticut. In that day, it was considered the triumph of progress in the United States.



SKETCH OF L. J. KNOWLES' LOOM WHICH WAS PATENTED IN 1856.

By this time inventors had turned their attention to pleasing the feminine fancy, and looms had been perfected to produce prettier patterns and finer fabrics for women's wear. Our grandmothers owe a debt to George F. Hutchins, the inventor of ninety-four different textile devices, for the completion, in 1883, of a fancy-dress-goods loom similar to the Knowles loom. It was so designed that silks could be woven in pleasing conceptions of figure and color. No longer was American textile invention confined to the production of clothing necessity, and the effort to attain greater luxury in fabric was under way.

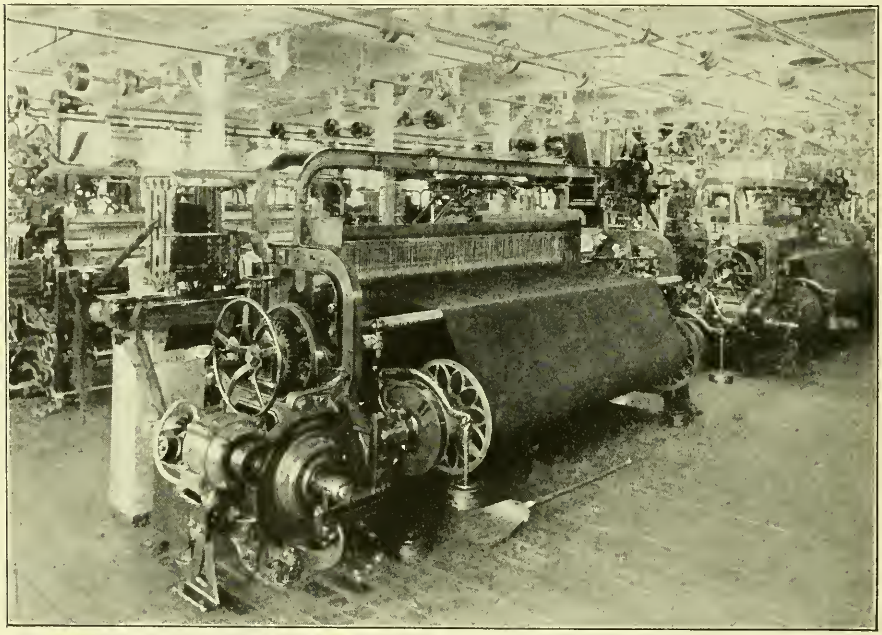
In the same year, the Knowles loom invaded the foreign field. After it had been exhibited at the Mechanics' Exhibition in Boston, it was shown at Huddersfield Fair in England, where it startled British manufacturers. The Yankee inventor was no longer laughed at. He was welcomed and eagerly sought out. America, despite her early handicaps, had now far outdistanced foreign competitors.



KNOWLES FOUR-HARNESS LOOM OF 1874.

Whenever a new weaving problem faced an American manufacturer of cottons, woollens, or silks, an appeal was certain to be made to Crompton and Knowles. The asking for an *invention* became as natural as the present-day woman's request of a store to show her a desired pattern and quality of goods! These appeals for aid resulted in innumerable improvements. One of the most important was accomplished in 1884, when a new loom made it possible to weave a stronger worsted. The first of these looms had been set up in the Oswego Mills at Providence, and the heavy Knowles worsted-loom became the standard among woollen manufacturers.

To E. H. Ryon are due many of the improvements on automatic looms, in which tremendous strides have been made in the past decade; and to B. F. McGuiness of the Crompton and Knowles staff, goes the credit for the "centre stop motion" now in general use. This is a small device placed in the middle of the contrivance on which the shuttles ride. It consists of three little wires which drop down if a single filling-thread breaks, and by this action stop the loom. Prior to its perfection, the snapping of a thread would result in a faulty pattern, and the imperfect goods would have to be picked apart and rewoven. The name "centre" distinguishes it from other similar devices, sometimes placed in other positions upon the loom.



MODERN MILL WITH CROMPTON AND KNOWLES LOOMS INSTALLED.

With the introduction of the Crompton and Knowles looms, it seemed certain that in time, all types of cotton and woollen looms would be equipped with automatic weft-changing devices, and to-day the versatile and gifted group of inventors associated with this company are bending unceasing energies to this end.

Ira Draper and the Firm He Fathered

Although much of the cloth we wear to-day could not readily be distinguished from that woven by old, discarded methods, the whole population of the country in 1770 did not require as much woven fabric as is turned out by one modern mill. In the early days of the last century, as the population increased and civilization progressed, more and better materials were sought for clothing. The cry throughout the infant American textile field was for greater production without sacrifice of quality.

In 1816, before the era of what may be termed the "factory system" of invention, Ira Draper was busy on improvements for the making of cotton cloth. Son of Abijah Draper, who had been an officer in the War for Independence, he was born in Dedham, December 29, 1764. Young Draper moved to Weston, Massachusetts, in 1808, and early showed signs of mechanical talent. He had a number of inventions to his credit when he took out his first patent for a "loom temple" or device to hold and guide the cloth in weaving. Draper's temple enabled the weaver to double the number of looms he could operate; but Draper was not satisfied, and later materially improved his temple.

His son James became interested, and in 1830 bought his father's patents. He advertised the new "temples" in the Boston *Transcript* of July 23 of that year, and continued to manufacture and sell them until he formed a partnership with his half-brother, E. D. Draper, in 1837. Five years later, the plant was moved to Hopedale, and in 1853 the firm of E. D. and G. Draper was organized to carry on the improving of cotton-machinery.

George Draper, the new partner, was born in 1817, and spent his boyhood years in a cotton-mill, where he gained much practical experience. He served as superintendent of several New England mills, and in 1840 and 1842 took out patents which further perfected the original "temple" of Ira Draper. Others became interested in this improvement, and Elihu and Warren W. Dutcher, of North Bennington, Vermont, took out patents on a totally different type of loom temple, in 1851. These were provided with cylindrical rolls, and so constructed as to hold the cloth closer at the last pick or blow which drives the loom shuttle.

The success of this invention threatened serious competition to the Draper interests and as a result, in 1854, the Dutcher and Draper firms were merged. Dutcher had taken out over twenty patents on temples and machines for making them; also machines for setting temple teeth, which are in use to-day.

The business went through various vicissitudes and changes until it became known as George Draper and Sons at the time of the Centennial Exhibition. From this period, an astonishing number of devices were turned out by the various members of the firm, which grew in success and importance under the guidance of William F. Draper, who presided over a department organized to invent new devices. Many were conceived, and their influence in cheapening spinning has been tremendous, saving manufacturers of yarns hundreds of millions of dollars.

Courtesy of the Draper Corporation.

(Left) IRA DRAPER, WITH ONE OF HIS SELF-ACTING LOOM TEMPLES PATENTED IN 1816.

(Right) JAMES H. NORTHROP.

Inventor of the Northrop loom, which with its automatic features has practically revolutionized power-weaving.

Toward the late eighties the men comprising George Draper and Sons began a series of extensive and costly experiments on automatic looms. These experiments resulted in the construction of what has been called the "Triumph loom," whose pioneer inventor, James H. Northrop, attained a fame as distinctive as that of the earliest English geniuses.

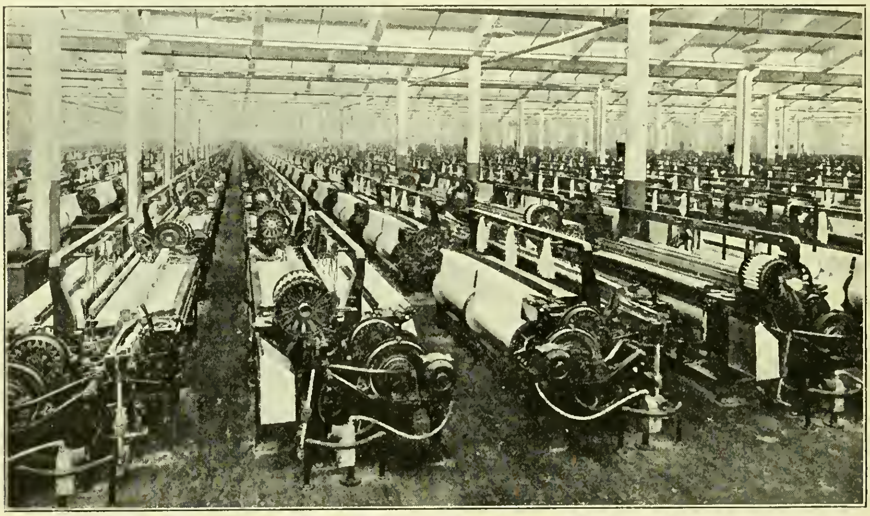
Up to thirty years ago each loom required the more or less constant supervision of an attendant, his watchfulness expending itself chiefly on the shuttle. After a short time, the loom stopped because the yarn in the shuttle was exhausted. Most of the weaver's time was spent in refilling the shuttle and restarting the loom. If there was any way of changing an empty shuttle for a full shuttle *while the loom was in motion* production could obviously be greatly increased. Yet more than this was required. The weaver had to thread the shuttle, and this took still more time. Hence the problem involved also the threading of the new, full shuttle, while the machine was still moving. It was this extraordinarily difficult problem that Northrop successfully attacked.

The Northrop Loom—A Revolution in Weaving

Northrop was an English mechanic who had secured work at the Hopedale plant while the predecessors of the present Draper Company were devoting their attention to the problem of an automatic shuttle-changer. A member of the firm had inspected such a device at Providence in July, 1888, but concluded that it was impracticable. Determined to overcome its defects, the firm appropriated $10,000, and assigned Alonzo E. Rhodes to the task of solving their problem. By February of the following year, Rhodes had a loom ready to demonstrate.

Meanwhile Northrop, who had invented a spooler-guide and other improvements in cotton machinery, had left the Drapers to devote himself to farming. He did not find rustic life to his liking, however, and soon returned to his place in the Draper plant. Hearing of the firm's activities, Northrop remarked, one day in February of 1899, that if they would let him do it, he could put a shuttle changer on a loom without spending more than one dollar, and that he could accomplish this within a week.

He was given the chance, and retiring to a hen-house on his farm, set himself to work. Early in March, he produced a rough wooden model. It delighted his employers and he was told to go ahead with the finished machine. By the fourth of July he had completed it. Three months later, a Northrop loom was in operation at the Seaconnet Mill, in Fall River, and by April, 1890, several filling-changing looms of the same kind were running. It was soon discovered that ordinary plain looms were not sufficiently uniform to permit of being equipped with Northrop's attachments, so the Drapers began the designing of another loom which would have a warp stop-motion as well as the filling-changer. This took several years to accomplish, and it was early in 1895 before the Northrop loom, as it is known to-day, was put in use in various mills throughout the country.



Courtesy of the Draper Corporation.

A MODERN WEAVE-ROOM EQUIPPED WITH NORTHROP LOOMS.

The weaver is relieved of the labor of withdrawing, filling, threading, and inserting shuttles, and the loom is automatically stopped when a warp thread breaks. As a result one weaver is able to attend more looms than ever before.

The Northrop loom revolutionized weaving as completely as had the power-loom. Reloading of the shuttle, once a hand operation, is now accomplished automatically without stopping the loom. The loom has a magazine just as an automatic pistol has, and the mechanism fills the shuttle, puts it in place, ejects the empty shuttle, and feeds the fresh yarn into the threading device.

The Northrop loom is the last word in textile history. Many of its operations seem to be almost human. At first, it was found that breaking threads resulted in throwing full bobbins out of the machine. The stop-motion overcame this. Devices to guard against misthreading were added. A feeler device to measure the quantity of yarn in the shuttle followed. Now, as long as a bobbin contains the proper amount of yarn, nothing happens. When it needs replenishing, the "feeler" starts this process. A "weft parter" removes the ends of yarn from exhausted bobbins; and a new warp stop-motion eliminates the need for watchfulness to detect the breaking of a single warp end. If the thread does snap, "drop wires" fall and close an electric circuit, resulting in the stopping of the loom.

This little story has briefly told of the progress of the world's effort to clothe itself since the era of the beginning of textile invention, and has pointed out mankind's debt to British and American inventors. The changes which have taken place have had astonishing effects on both sides of the Atlantic.

Because of them, labor has attained a new dignity and social conditions have been materially altered, both here and abroad. Western England has been transformed from an agricultural section into a manufacturing centre. The clear, swift-running streams of New England now flow by great plants whose power they once supplied, and still do in some instances. Not only has production itself increased, but the individual spinner and weaver of to-day is able to accomplish a thousand times more than those who toiled in the time of handcraft methods.

With this enormous expansion has come a marvellous increase in the production of cotton and a corresponding advance in the wealth of the Southern States. The West, too, has profited through the raising of sheep for wool. The silk-producing lands of the world also reap their share of benefit by supplying the silkworm's product for Yankee machines. The amount of capital invested in textile enterprises in the United States is now estimated at $1,343,324,605. Employees to the number of 739,239 earn about $250,000,000 annually, and their output is valued at $1,215,036,792.

CHAPTER VII

FARMING BY MACHINE

IN the days when farming consisted in stirring the ground with a crooked stick pulled by an ox, throwing handfuls of seed over the fallow soil, harvesting the ripened grain with a sickle, and stamping the kernels from the straw by driving animals back and forth over it, nearly every one had to be his own farmer. And so much labor was required to grow wheat for human subsistence with sufficient forage for the cattle that a farmer had little or no time for recreation and education.

The universal accomplishment then was fighting. European nations were aggressive peoples, distinguished alike for their military prowess and lack of agrarian instincts. War, rather than wheat, was their business. Farmers were looked upon as peasants. Artisans, except those who made armor and weapons, fared little better. There were power and honor, luxury and leisure for the man who could make or wield sword and pike; but only scorn, heart-breaking toil, and hardship for the man who raised corn and food.

Little wonder, therefore, that not until the dawn of the eighteenth century was a real plough devised, and that from the appearance of the Rotherham plough in Holland, in 1700, up to our Civil War, the ordinary farmer labored with a wooden instrument no better than the ploughs of the ancient Egyptians. Not until the middle of the last century did broadcast sowing of grain over the surface of the ground give way to drilling and planting. About that time, also, the reaping of grain with horses first became common through the invention of the reaper. The flail and the treading floor for threshing grain were not supplanted by practical machines for separating the grain until after Lincoln's administration. Farmers had no practical, mechanical means of harvesting corn, the greatest of all American crops, until the early eighties. Steam and gasoline engines have been at work in the fields only since the dawn of the present century.

THE PILGRIMS INTRODUCE THE PLOUGH TO AMERICA

Landing in Massachusetts in 1620, the Pilgrim fathers soon planted wheat and oats, the seeds of which they had brought with them from the Netherlands. The soil was virgin. The Indians had simply burned off the forests, scraped the surface of the ground into small mounds, and planted the kernels of corn within them, the work being done with bare hands by the squaws.

DEVELOPMENT OF THE PLOUGH EXHIBITED BY MODELS IN THE DEUTSCHES MUSEUM, MUNICH.

It was twelve years after the first landing before the Pilgrims began to use ploughs. The hard, packed, and stony soil had been broken with crude spades, hoes, and mattocks. Seed was scattered broadcast by hand and sometimes partially covered by means of logs dragged over the field. Naturally one farmer could till only a small area of land, and so could raise little more than was required by his own family. In 1637 there were but thirty-seven ploughs in the Massachusetts Bay colony.

The fortunate farmer who owned a plough was often paid a bounty by his town, and he hired himself out as a ploughman, much as traction-engine and threshing-machine owners, until very recently, made a business of doing farm work for the community.

The Puritan plough was a cumbersome contrivance of wood, twelve feet long, with a ten-foot beam and a four-foot landside. Eight to ten oxen were required to draw it, and a man had to ride on the beam to keep it in the ground. Another man followed with a heavy iron hoe to dig up the places where, despite the weight of the man on the beam, the plough had left the ground.

Had the Pilgrims not tarried in Holland on their way from England to Massachusetts, their ploughs would have been still cruder; but Holland was more advanced in plough-making than any other country, having developed the ploughshare in the seventeenth century. Before that the plough was simply a tool to loosen and stir the soil, no effort having been made to turn a furrow that placed the sod at the bottom and new earth at the top.

The Dutch had tried to make a plough which would accomplish this. Introduced into England and there slightly improved, the wooden Rotherham plough made its appearance. Clumsy though it was, it had a mouldboard and, after a fashion, could turn a furrow. About 1730 these ploughs were improved upon by a Scotchman named Small, who copied the Rotherham shape, but made some of the wearing parts of iron. In the same year Joseph Foljamb, in England, secured a patent on a plough. The ploughshares required constant hardening, however, and it was not until 1803 that Robert Ransome patented a device that removed such a necessity.

Ransome was half a century ahead of his time. Not only did he propose to make a plough of cast iron, but he actually described a method of chilling the surface of the share to harden it and yet leave the body of the metal soft and tough.

Newbold Patents the First American Plough

All of this activity meant little to the American farmer. He was still struggling along with the heavy wooden Old Colony plough. Charles Newbold, of Burlington, New Jersey, took out the first patent on a plough, in 1797. It was of cast iron, with a mouldboard similar to that of the Rotherham plough. The ponderous Bull ploughs, then in general use, were cut with broadaxes out of a crooked tree-fork, the mouldboard being shaped to suit the fancy of the farmer, and the angle of the point to the beam. Newbold realized their defects. Being well-to-do for that time, he dedicated his life and fortune to giving the farmer a better plough. His aim was a plough that could be worked by one man and two oxen, that could actually turn a furrow, and that would last for years without breaking down. Newbold, having built his plough, endeavored to prove to the farmers its advantages over the old wooden breaker. The New Jersey farmers watched the experiment. They saw the plough guided by one man and hauled by two oxen; they watched the furrows turned over neatly and smoothly; they noted the speed and thoroughness with which the ground was covered. Then they shook their heads. There was a catch in it, somewhere. Iron ploughs would surely poison the soil, they said, and stimulate nothing but the growth of weeds. Although Newbold showed these doubting farmers the splendid fields of grain that had grown where his ploughs had broken the sod, although he had spent $30,000 in an effort to introduce his new and better implement, he finally had to give up in disgust.

Until the time of Thomas Jefferson nobody had undertaken a scientific study of the mouldboard to determine just what its shape should be. The rules laid down in 1798 by Jefferson as a result of his study were somewhat modified and amplified by James Small in 1802. Jefferson and Small, however, did not put their theories into practice, and the American farmer, hearing nothing of them, continued to drag a rough-hewn tree behind a small herd of steers at ploughing-time.

Jethro Wood the Second Martyr to the Plough

But there was one farmer, a Quaker, Jethro Wood, of New York, who heeded the advice of Jefferson and Small, and also listened to Newbold. Although comfortably situated on his farm near Scipio, New York, a respected member of the community, friend of such men as Daniel Webster and Henry

Clay, he followed in the footsteps of Newbold, taking up the fight where his predecessor had been forced to leave off.

In 1819, as a result of his labor, he was granted a patent on a plough to be made entirely, except for the beam and handles, of cast iron. The various parts were to be made in separate pieces, so that any worn part might be removed and a new one substituted. Following up the rules of Jefferson and Small with some improvements of his own, he produced the best mouldboard of that time. Indeed, for a stubble or pulverizing plough the shape was practically identical with that in use to-day, although it was afterward found that different shapes were required for hillside work, prairie-breaking, and road work.

Cast-iron ploughs, copies of Newbold's early efforts, had proved costly; they soon wore out. Over them the new plough had a great advantage. But, like Newbold, Wood spent nearly all his money, exhausted his credit, and shortened his years in perfecting his iron plough. When success at last crowned his struggles, and farmers, forgetting the soil-poisoning superstition, sought his ploughs, scores of patent-infringers sprang up all over the country, backed by wealthy men and reinforced by clever lawyers who knew the financial limitations of the old Quaker. Summoning all his strength and gathering what little property remained to him, Wood charged into the fray. One after another of his infringers was sued, and the contest was carried to a long-drawn and bitter conclusion. Here even the law itself failed him, for his infringers invoked a provision in the law that public use of an invention for a certain time and under certain conditions before the patent was granted rendered the patent void. Of course Wood had tried his first models before patenting them, some of these trials having been witnessed by neighbors. In 1833, with only three more years for his patents to run, his friends laid the matter before Congress. In response to pleas by Daniel Webster and William H. Seward Congress extended Wood's patent for fourteen years. The cast-iron stove and range of later years were also the result of Jethro Wood's ceaseless and patient efforts to perfect his plough.

At the time of Jethro Wood's death, in 1834, thousands of iron ploughs were in use. The great tide of emigration westward carried these iron ploughs into the prairie country of Indiana, Illinois, Iowa, and Wisconsin. Here the farmers found very different soil from that which they had worked in New York, Pennsylvania, Virginia, and eastern Ohio. The Western soil was of rich loam, with fewer stones and boulders than those of the East, and it yielded more bountiful crops. But, as virgin soil, it was exceedingly difficult to plough into neatly turned furrows. The soft iron shares and "coulters" dulled rapidly, and were hard to pull through the ground. It was necessary for the ploughman to exert all his strength and struggle with the handles to keep from being roughly thrown to one side or the other as the plough continually careened, or jumped out of the furrow. The heavy, sticky loam would not slide easily from the iron surface; it would not "scour," as it is termed. The roots of the long prairie grass resisted the passage of the dull shares and would not permit the clods to turn over. The ploughs made trenches of irregular depth and direction, even in skilful strong hands.

Plough-founders were at their wit's ends. They tried all manner of shapes and all manner of iron, but they found that any change in the shape of the plough only made matters worse, and that hard irons broke too easily when striking stones. They tried long "toes" on their shares to hold the ploughs down, but found these would dig down and stop the plough altogether.

THE EVOLUTION OF THE STEEL PLOUGH

In 1833 a blacksmith, John Lane, in Chicago made a fresh start in plough building. He made a wooden plough, to which were screwed strips of the finest saw-steel obtainable. A sharp edge of saw-steel, braced with iron, was used for the share. This plough was probably the first that successfully turned a furrow of Illinois black loam. Lane did not realize the importance of his discovery at first, for he made no attempt to patent the idea or to introduce his steel-faced plough generally. But others heard of John Lane's plough, and soon every country blacksmith shop round about was busy fitting old saw-plates to wooden ploughs. The supply of old saws was rapidly used up, and hundreds of new saws were cut up for the purpose.

In Grand Detour, Illinois, dwelt a young smith named John Deere, a giant in stature and a Hercules in strength. He had realized the difficulties the farmers were having with their cast-iron and steel-tipped wooden ploughs, for he found much employment in repairing them, sharpening their shares and fitting iron patches where they had worn through. When the idea of the steel plough came to him he set about making one in a workmanlike manner. Although he was preceded one year by John Lane, it is likely that at the time he had never heard of John Lane or his plough.

The best steel obtainable was saw-steel, of course, but he was not satisfied with thin plates made from handsaws, screwed to a wooden mould-board. Instead he used the steel of a great circular mill-saw. To get the proper shape and curvature, he cut out his pattern on a log, placed the saw-plate over it, and then hammered the steel with a wooden mallet to fit the form. Out of the pieces trimmed from the edges he made the land-side, and bolted the two parts over a white-oak frame. The share and the mould-board were one; there was no coulter, no wood backing. It is said of this plough that it was so light that Deere slung it over his shoulder and carried it to the field where it was tested.

The plough fulfilled the inventor's expectations. It parted the sticky soil as easily as the iron ploughs had turned sandy furrows in Connecticut. The soil made a peculiar singing sound as it scoured the mouldboard and lay over, grass down, in the adjacent furrow. Soon Deere's little smithy was working to the capacity of its forges, making ploughs out of mill-saw blades. Deere gave up horseshoeing and blacksmithing to devote all his time and equipment to ploughmaking. He could hardly supply the demand.

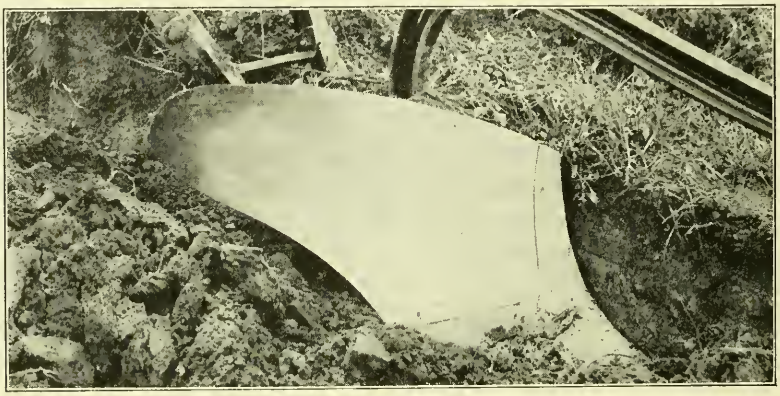
Because the Pittsburgh steel mills would not roll saw-steel in the sizes he required, Deere imported saw-steel from Germany, where he could get it in whatever size he wanted. In 1847, after he had moved his works to Moline, Illinois, to be nearer the vast empire opening up in Iowa, Missouri, Nebraska, and Kansas, he received his first shipment of American plough-steel, rolled to his order by William Wood, at the plant of Jones and Quigg, at Quincy, Illinois. He had turned from saw-steel to German case-hardened armor-plate, because saw-steel was not hard enough to remain sharp for a sufficient time. The German steel was hard enough, but it could not be tempered without warping; it required careful treatment by hand to reshape it after tempering. The Jones and Quigg steel was simply high-carbon steel, which, while harder than saw-steel, was still tough enough for ploughing and could be tempered without excessive warping. William Morrison, in 1868, secured a patent on a soft-centred plough steel which was the first successful metal of its kind. It consisted of a thick sheet of soft iron, sandwiched between thin sheets of steel. In this development, for once, the arts of agriculture stole a lead over the arts of war, for Morrison had unwittingly established the principle of compound armor-plate, which, however, was not applied to warships until 1877. Even though better materials have since been developed, it is generally conceded that Lane and Deere's contribution to ploughmaking made the cultivation of the great plains possible. Deere's steel soon came into general use among ploughmakers, and a royalty of three cents a plough was paid during the lifetime of the patent.

James Oliver and the Chilled Plough

It was thought that the steel plough would eventually drive the iron plough out of existence. Steel ploughs were not only lighter, but they scoured well, were easy to draw through the soil, and their shares remained sharp long after iron shares had dulled. Then came new experiments with the iron plough by James Oliver, a Scotch immigrant. In 1855, Oliver was filling in odd hours as a farmhand and iron-moulder in Mishawaka, Indiana. On a visit to South Bend, the young man, for he was only thirty-two years, fell in with a foundryman who faced ruin because his cast-iron ploughs failed to meet the requirements of his customers. Oliver purchased a fourth interest in the foundry for $88.96, and immediately set to work to make cast-iron ploughs that would give absolute satisfaction.

Others before him had experimented with chilled iron in an effort to make hard-faced ploughs. Iron or steel faces, or chills, were introduced into the sand-moulds into which the molten iron was poured, thus suddenly chilling the face of the casting. This imparted density and hardness to the metal. But the process had always made the castings brittle, producing internal strains similar to those causing a hot lamp-chimney to break if sprinkled with cold water.

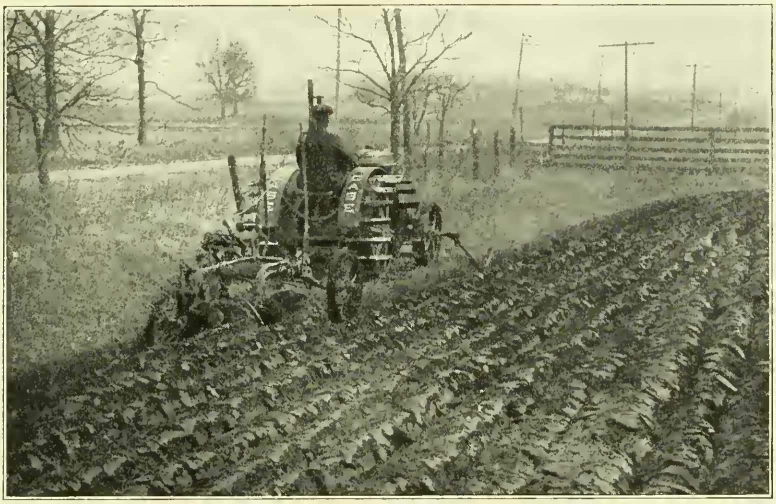
Oliver spent twelve years in overcoming these difficulties. He circulated hot water through the chills, so that he could prevent the castings from cooling too rapidly or unevenly, and he improved the patterns to secure flexibility during the process. By this method he was able to secure castings soft and tough throughout, that is, all but the wearing face, which was of even hardness for a shallow depth. Being a practical foundryman, Oliver soon found the sort of metal that should be used to get a fine-textured face, and take a mirror polish to resist rust. Finally he discovered he could anneal, or reheat, his plough-castings, so that the soft portions became pliable enough to work out their strains from shrinkage in cooling, without affecting the hardness of the chilled faces.



MODERN OLIVER CHILLED PLOUGH.

The production of a chilled mould-board was James Oliver's great achievement. Oliver discovered the process whereby chilling is possible without destroying the shape and thus preventing clean scouring. Coffin, the statistician, said: "My estimate is that for a single year, if all the farmers in the United States had used the Oliver chilled ploughs, instead of the regular steel or iron plough, the saving in labor would have totaled the sum of $45,000,000."

James Oliver became a successful business man. This he owed to his inventive genius rather than to his willingness to adapt himself to circumstances. Not only did he insist that Robert Burns was unequalled for his poetry, but he considered that Scotch Clydesdale horses and Ayrshire dairy cows had no superiors in the world. When heavier and heavier horses became necessary in order to haul the larger gang-ploughs, larger grain-drills and bigger grain-reapers, he would concede nothing to the French Percheron, the English Shire, or the Belgian draft-horses. The Clyde was the best workhorse, and even the best driving horse, and to make good his assertion a huge, stodgy Clydesdale was habitually hitched to his buggy. Oliver died in 1908, reputed to be the richest man in Indiana.



PLOUGHING TWO FURROWS AT ONCE WITH A TRACTOR.

Breaking up the Ploughed Soil

Even when ploughed, the soil is not quite ready for planting. To grow plants the earth must be further "pulverized" and broken up into a mulch. The oldest method of pulverizing known is beating the clods with sticks and reducing them to a mulch with the feet. In the past, the laborers who did this work were called "clodhoppers."

The Japanese used disk harrows so long ago that historians cannot place the date. In King David's time the ancient Hebrews wrote of iron-spiked harrows, used as instruments of torture. Modern inventions are concerned with spring-teeth instead of the rigid spiked pattern, so that the presence of roots, rocks, or like obstructions will not stop the harrow, deflect it from its course, or damage the teeth. Only within recent times has the disk been recognized as of value in ploughing as well as harrowing. There are two types of disk-harrows. One, known as a pulverizer, has wavy edges which chop the clods; the second, with smooth edges, stir and break up the clods into smaller parts.

G. Page seems to have been the first in this country to realize the value of the disk, having patented the combination of a single disk-harrow as part of a plough in 1847. So important has pulverizing and preparation of the seed-bed become that to-day it is common to employ from four to six separate tillage operations, such as breaking and turning with the plough, disk-harrowing to break up the clods, tooth-harrowing to break them up still more, disking with plain disks to refine the soil, harrowing, dragging, and rolling to smooth and pulverize it, and finally to roll the surface level and compact so as to hold the moisture beneath.

Mechanical Planting

"As ye sow so shall ye reap." Before the harvest there must be the planting. Methods of placing the seed in the ground have varied since time immemorial. Until recent days, vegetables, potatoes, and plants had always been planted with the hands, or with hoes and trowels; grass-seed and seed-grains, from the remotest beginnings of agriculture, have been sown broadcast by hand. This was usually done after the land had been ploughed and harrowed. Then it was again harrowed or dragged with brush or small log-drags. The method was a poor one. Either the seed was left on the surface to be eaten by birds or field mice, or buried too deep to sprout. What seed escaped such devastation was so badly distributed through the soil that the growth was uneven and unhealthy.

In the time of the American colonies, while the Dutch were first trying to improve the mediæval plough, a great English agriculturist, Jethro Tull, published a book, in 1731, called *Horse-hoeing Husbandry*. Tull, a small landowner, farming his own land, moderately well-to-do, with leisure enough to study the soil, plant growth, and the laws of mechanics, was unfortunately so far ahead of his time that few people paid any attention to him.

Tull saw the evils of broadcast sowing and permitting grain to grow rank and wild until harvest time. In his day, such a thing as land cultivation was very little known. In small gardens it was the custom to hoe between the hand-planted rows to keep down weeds, to loosen the soil to permit the plants to breathe, and to permit water to reach the roots. But with the grain sown broadcast, there were no rows, and consequently little or no cultivation. Tull reasoned that to permit hoeing in the wheat and rye fields, broadcast sowing must give way to planting in rows or "drills," as they are called from their resemblance to files of soldiers drawn up for drill. He established the fact that drilled and cultivated grain would yield many more bushels to the acre, but recognized that planting in drills by hand, and hand-hoeing between the rows required too much human labor.

Arguing that if a horse could be used to plough and harrow the ground, horses could also be used to plant and hoe it, he set about building a horse-drawn, grain-drilling machine, and a horse-drawn hoeing-machine. He had planted grain in drills by drawing a hoe through the fresh-tilled earth and dropping the grain in the furrow before the dirt fell back into it. He had hoed between the rows of young grain by slowly drawing a hoe through the earth. Accordingly he built a horse-hoe, consisting of a beam carrying several hoes. He then contrived a box in which the seed grain could be placed, with pipes running down to a point just behind each hoe, so that the grain would be planted while the furrows were dug, each furrow being covered to a uniform depth by brushwood dragged over the field.

He described what he had done in his book and travelled the length and breadth of England trying to introduce his principles. Later, he made a harrow attachment which followed the grain-drill and covered up the grain at once. When he told farmers to plant their wheat in rows, like beans, and to set their horses to hoeing in the fields, they tapped their foreheads significantly, and in some cases drove him from their villages as they would drive a lunatic.

In 1799 an American, Eliakim Spooner, invented a grain-drill, but so little attention was paid to it that to-day nothing is known regarding the device or the inventor. Many such other implements followed. It was easy enough to make a kind of "sulky" with a number of hoes or shoes connected by pipes with a grain-box, but it was another thing to insure even distribution of the grain between the shoes and along the rows. When gravity alone was depended upon, the grain would feed too fast, making huge piles where the seeder was turned around, and feeding too slowly when the machine went fast.

The first step toward a practical solution of the seeding problem came in 1840, when J. Gibbons, of Adrian, Michigan, patented a grain-drill with a regulating device, so that the amount of seed which was fed to the shoes depended upon the distance covered by the machine. In 1842, two Pennsylvania farmers, M. and S. Pennock, secured a patent on a machine so constructed that the drills could be stopped or started while in motion, individually and collectively. Their machines were so successful that in the course of the next few years several hundred were built and sold. Others eventually took up the manufacture of machines along the same line, mostly after the Pennock patents had run out. The original patent was renewed in 1849, so that it was not until after the Civil War that grain-drills were produced in any quantity. Modern machines drill as many as eighteen rows at a time, and are so designed that after the point has opened up a furrow and the correct amount of grain and fertilizer has fallen into it, the furrow is neatly covered with loose soil.

Modern Mechanical Tillage and Planting

It is indeed a far cry from the crooked sticks, hoes, and seed-bags of the ancients to the modern ploughs, harrows, and grain-drills which now serve to produce most of the cultivated crops all over the world. Civilization owes an inestimable debt to the inventors who released mankind from the serfdom and drudgery of early agriculture and raised the status of the farmer to one of great importance. But splendid as were their inventions and important as were the improvements they produced, greater strides have been made by modern engineers. Instead of proceeding singly, they have grouped themselves together and worked co-operatively as organizations. By so doing agricultural progress was rapid and certain. More was accomplished in a few months than the ancients accomplished in centuries. No longer do personalities dominate the phases of agricultural development, because results are now achieved by collective work instead of by individual genius.

For preparation of the soil, and for planting, modern machinery enables a larger acreage to be cultivated and reduces animal power to a minimum. Furthermore, it does this work better than before, permitting the raising of abundant crops in arid deserts and dank marshlands, and rejuvenating exhausted soil, thereby releasing a tremendous acreage for the production of human food which acreage was formerly dedicated to the growing of weeds and horse feed.

MODERN WHEAT DRILLER.

This large machine drills wheat in the ground at the rate of eighteen rows at each trip down the field. Compare this with the small, imperfectly seeded ground which could be covered in a day by one man broadcasting from a bag under his arm.

The petroleum-driven tractors of to-day plough very deep, and so bring virgin soil to the surface. Modern trenching and drainage machinery permits surplus water to be drawn away, while, inversely, irrigation carries water to the deserts and makes them fertile. Root-threshers remove old roots of wild grass and weeds, so that the soil may be properly cultivated; and modern machines have transformed the plough from a passive blade drawn through the earth into an active tool which forcibly cuts and pulverizes the clods into a fine mulch, making it many times more fertile than the tilled soil of the past. To-day, this is all done on a scale unknown to our grandfathers. So many thousands of acres are tilled and cultivated by one machine, the separate operations being combined in one passage over the ground, and all accomplished at a speed so great and a cost so low that older methods are entirely eclipsed.

Perhaps the most advanced of these modern tillage implements is the rotary plough, developed by Charles M. and Fletcher T. Hamshaw, of Seattle, Washington. This machine, driven by a tractor-engine, completely prepares the seed-bed and drills the grain in one operation; it can be applied to any sort of soil, and results in complete cultivation. It cuts, or mills, thin slices of soil to a depth of thirteen inches, throwing the sliced-off dirt to the rear, thoroughly pulverized. The drills then plant the grain, and a drag smooths off the surface and covers the seed. The cutting blades propel the entire machine forward, the tractor wheels serving to prevent too rapid movement.

It is thus seen that the tractor is really only a support for the power-plant, and a means of steering the machine. It also serves to carry the rotary plough to and from the field and around the turns, a hoist serving to raise it clear of the ground at such times. This machine serves to perform in one operation what ordinarily requires seven, and with the aid of but one man. Because the drum itself propels the machine, the great weight on the driving-wheels necessary with the conventional plough and tractor combination is obviated. Corn or potato-planters, of course, may be substituted for the grain-drills, and the drag may be adjusted for deeper or shallower ploughing than thirteen inches.

The Problem of Mechanical Corn-Planting

As far back as the records of the Department of Agriculture go, corn has been the leading crop of the American farms. In the sixties the corn crop exceeded by eighty-seven per cent., in number of bushels, the combined wheat and oats crop, and in value by twenty-six per cent. In 1920 the corn crop was forty-one per cent. greater in number of bushels, and eighteen per cent. more valuable than the wheat and oats crops combined. Great as was the boon of the grain-drill, it was of no assistance to the raiser of corn. In the sixties, ten per cent. more acreage was planted in corn than in wheat and oats combined, and four per cent. more in 1920.

Corn cannot be drilled. It must be planted in hills, spaced equally in two directions, and wide enough apart to permit a man and horse to walk between the rows for cultivation, even when the stalks are quite high. The Indians planted corn with their hands. The colonists followed the Indian methods of planting, even though they ploughed and harrowed the ground beforehand. Hundreds of patents were granted on devices to relieve the labor of corn-planting. The earliest were attachments to hoes, whereby a small can of seed-corn could be fed over the front of the hoe by the pressure of a trigger. Other types which became popular resembled a walking-stick, which planted a few kernels when thrust into the ground. Modifications of the perfected grain-drill were tried unsuccessfully for

Courtesy Department of Agriculture.

WALKING-STICK TYPE OF CORN-PLANTER.

This plants a few kernels when thrust into the ground.

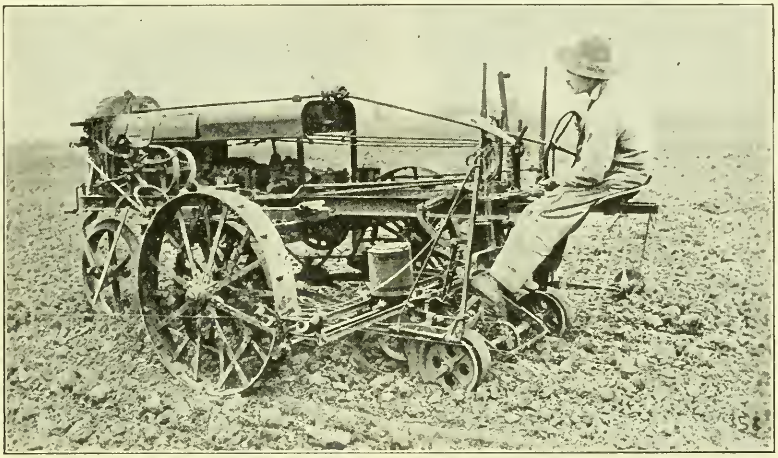
corn-planting. These eventually took form in single-row listers, similar to grain-drills in principle, but larger. Such machines proved successful for cotton-planting and hillside corn-growing in the South.

D. S. Rockwell was the pioneer inventor of a horse-drawn corn-planter, having patented a double-row planter in 1839. This machine was very crude and could plant the corn in rows one way only, there being no way to step off the cross-rows evenly. Later inventors made minor improvements, such as providing for adjustment of the distance between hills of corn, adjustment of the amount of corn to be dropped in each hill, and means to run the parallel rows equal distances apart. The machines did not gain in popularity, however, for the farmers were beginning to appreciate the importance of cultivating between the rows, and naturally preferred to cultivate in both directions, since cultivating in one direction only would leave strips of hard and weed-grown ground between the hills on the main rows.

MODERN CORN-PLANTER.

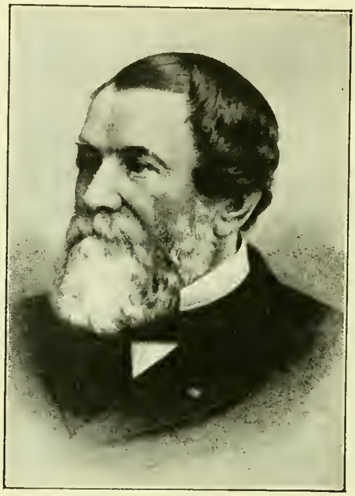
The modern corn-planter is almost a perfect instrument for planting corn, two rows at a time, putting down the kernels in hills of two, three, or four grains, single grains, one at a time, closely together. The dropping mechanism can be hand-operated in such a way as to seed by any one of these methods or combinations of them.

M. Robins, of Cincinnati, took the lead in successful corn-planting by inventing what is called the wire check-rower, which he patented in 1857. He saw that so long as the dropper depended upon the wheel to determine the location and distance between corn hills, no one could make cross-rows straight. Some farmers stopped their machines and set the wheel at the same place at the beginning of each row in order to check the rows across the field. But they always came out uneven at the end, and the trouble of setting the wheel at the beginning of each row was too great. Robins therefore proposed that a wire be stretched across the field from end to end, knotted at intervals one row wide, and that this wire be used to operate a dropper. But his method of operating the drop with the knotted wire was faulty, and for this reason his machine never worked properly. Robins exhausted his slender resources in building machine after machine. None were efficient. Although he had thought of the one thing that made the corn-planter practicable, it remained for others to name it, apply it successfully, and reap the reward. Robins died, a poor and disappointed man.


SELF-PROPELLED CORN-PLANTER.

John Thompson and John Ramsay of Aledo, Illinois, took up the knotted-wire corn-planter where Robins left off. They named it the "check-rower," and secured patents, in 1864, for its use in connection with a forked trip. Thompson and Ramsay worked for eleven years upon their invention, and solved most of the difficult problems involved in the principles of its operations. They were not skilled manufacturers, and they found that their experimenting had actually cost them more than they received for the limited number of machines they sold. However, in 1875, they secured a reissue of their patents, and assigned them to the four Haworth brothers, who were practical mechanics and manufacturers, and who did much to improve the check-rower corn-planter.

JAMES OLIVER.



CYRUS H. McCORMICK.

James Oliver, the Scotch emigrant who revolutionized ploughing. Oliver had a theory that a plough for our Middle West should be light yet strong, and that its mouldboards should scour so as to turn the soil with a singing sound, and that the share or cutting edge should be made separate so as to be easily and cheaply renewed. After twelve years of experimenting he perfected his chilled plough.

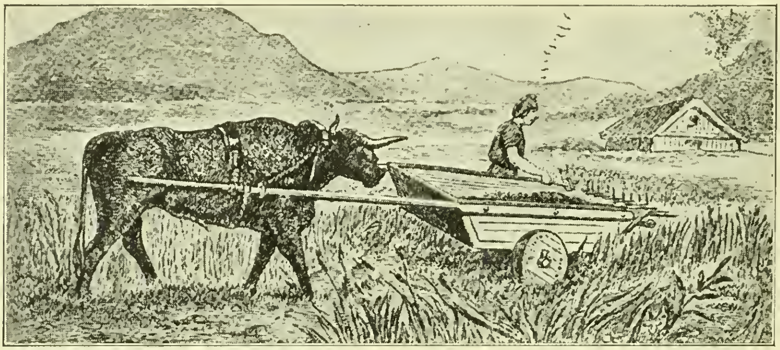
Cyrus H. McCormick, who invented the reaper and patented it in 1834. He was not only a great inventor but a great business man.

REAPING THE CROP

As we have already seen, the scientific development of the plough dates back but little farther than the history of this country. On the other hand, efforts to save harvest labor can be traced back to the beginnings of the Christian era. Side by side with the crooked stick, the plough of the early Egyptians, is the stone or bone sickle, their first harvest tool. Wherever antiquarians unearth the remains of ancient peoples, there also they sooner or later find traces of the sickle and of wheat. In the prehistoric age of bronze, men reaped their wheat with bronze sickles, and learned to shape them like hooks in order to sweep the grain to one side as it was cut. In Revolutionary days, American farmers were still using sickles much like those of Egypt and Rome, but made of steel. They were as sharp as swords, many being actually made from swords.

Yet, long before that time there had been farmers who had devised ways of reaping the ripened grain more easily and more quickly. Pliny, in his *Historia Naturalis*, describes, from personal knowledge, a header used by the barbarians of Gaul, comprising a two-wheeled cart, pushed through the field by an ox. On the front edge of the cart box was a sharp knife against which the grain heads were knocked by a man who walked along, wielding a stick. This man struck the heads from their stalks, so that they fell into the cart. The straw was left standing in the field for cattle to graze upon. The Gauls improved their header by adding a notched blade that would catch the heads and cut them off more readily. The Romans, too, had developed a scythe, having a wider, straighter blade and a longer handle than the sickle, and with this scythe a man might stand upright and cut a wider swath, closer to the ground. But after the decline of Rome, and throughout the long centuries of the Middle Ages, there was practically no progress in agriculture. With the Dark Ages both the header and the scythe fell into disuse. During that long period between the Gallic header of the first century, and the Gaelic reaper of the eighteenth, the farmer went back to and depended upon the ancient sickle.

About 1794, the Scotch reaper made its appearance and was heralded as a marvellous invention. Managed by one man, it could reap as much grain as could seven men using sickles. The Scotch, some time before, had revived the scythe, perfected the curves of its handle and the pitch of the blade, so that a man might swing long and freely and yet keep the blade parallel with the ground, cutting the stubble short. There is some doubt as to the origin of the "cradle," as the Scotch reaper is now called. Professor William H. Brewer, of Yale, is of the opinion that it was introduced into the colonies coincident with the signing of the Declaration of Independence, or eighteen



Courtesy U. S. Department of Agriculture.

THE GALLIC HEADER, DESCRIBED BY PLINY, A. D. 70.

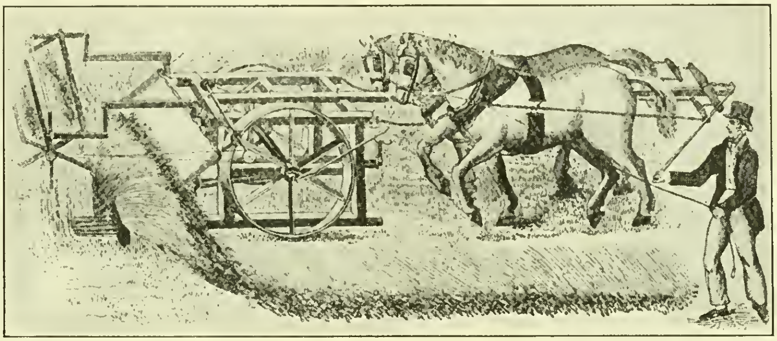
REAPING AND BUNDLING GRAIN.

The method pursued almost from Biblical times to the invention of the reaper. From a copper engraving by Veranzio, made in 1617.

years before it was so enthusiastically acclaimed by the Scotch. The "cradle" is simply a scythe with wooden fingers to gather the grain and deposit it in windrows.

SALMON'S MECHANICAL REAPER

In 1807 Salmon, of Woburn, secured an English patent on a reaper which he built and demonstrated the following year. His machine was pushed by hand through the field, mowing a swath of about two feet. Salmon not only avoided errors that were subsequently made, but he anticipated several features successfully applied years later. One of these features was the vibrating knife, consisting of a keen blade moved from side to side so as to cut the grain more readily; the grain was divided by fingers into tufts over the blade, just as a barber gathers hair into tufts before snipping it with his scissors. Another feature was a self-raker, comprising a curious long rake, swinging from side to side, which swept the cut grain from the platform into a windrow at the right side of the machine. Salmon's machine was abandoned because the smooth blade would not cut all the grain. Later inventors learned the value of jagged blades. Had Salmon's patience held out a little longer, the practical reaper might have come fifty years before it actually did.



Courtesy U. S. Department of Agriculture.

BELL'S SCISSORS REAPER.

In 1826 Patrick Bell built a reaper that worked on the principle of a pair of scissors, one that gathered the cut grain into a windrow, leaving the farmer nothing to do but drive the horses.

In 1812 Peter Gaillard, of Pennsylvania, patented a grass-cutter, similar to our familiar lawn-mower, except that the beater-blades were straight. Hence a mass of grain was brought against the blade at once, causing the beater to jam, and the driving-wheel to slide. Jeremiah Bailey, a neighbor of Gaillard, improved the machine by placing the horses at the side of the mower instead of behind it, as Gaillard had done, and by curving the beater-blades as they are in the modern lawn-mower, so that the grass would be sheared from side to side. As a reaper of grain it was a failure, since it broke the straw and knocked the heads off, strewing the kernels over the ground, leaving the grain strewn over the field in a tangled mass, and was easily stopped when a stick or stone lodged between the beater and the blade. But the Bailey machine certainly developed the modern lawn-mower.

Henry Ogle, an English school-teacher, in 1822, patented a reaper in which a cutting-knife was made to reciprocate from side to side behind a set of stationary fingers. The cut grain fell back upon a platform, and was raked off by a man who walked along. The machine was also equipped with a reel or beater to bring the grain more forcibly against the knife, and a divider to separate the swath to be cut cleanly and evenly from the rest of the field. But Ogle's reaper would not cut as cleanly as the scythe, because it was pulled through the field at slow speed. A woodsman cannot fell a tree merely by pressing his axe against the trunk; he must swing it so that the edge is driven forcibly into the wood.

Bell's Scissors Reaper

Patrick Bell, a Scotch minister, saw this defect in earlier reapers and made up his mind that a reaper which merely pushed a knife through the field would never harvest grain properly. He believed that grain should be reaped with shears. In 1826 he built a reaper that worked on the principle of a pair of scissors, one that gathered the cut grain into a windrow, leaving the farmer nothing to do but drive the horses. Bell was an exceptionally clever mechanic, and had he only been a good business man and promoter, men like Hussey and McCormick, who came later, might have had little to patent.

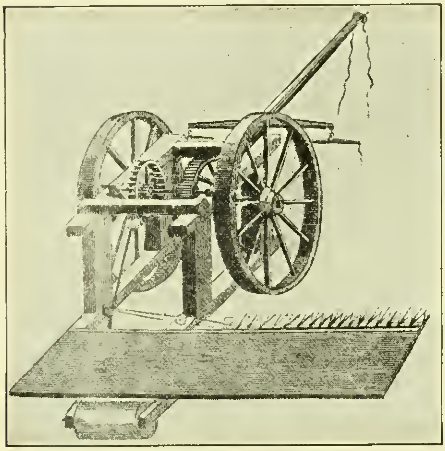
The Bell reaper consisted of a series of scissor-blades moving in unison, a canvas belt running on wooden rollers, which received the cut grain and carried it to the side of the machine. It was driven from one of the wheels through a jaw-clutch, which enabled the farmer to stop the machinery when the machine was being turned or driven to and from the field, and it was one of the most practical and workable machines invented up to that time. It cut the grain as fast as the horses could walk, and laid it neatly in a long mound. Only one man drove the team and operated the lever. The English farmer raised his grain on so small a scale, and was so tied down by tradition that he could not grasp the full meaning of mechanical reaping. Thousands of men looked to harvest-time for a chance to make the greatest earnings of the year. Consternation filled them when they saw that a team of horses and a half-grown boy could reap more grain with Bell's machine in a day than any six of them could reap with cradles. They set upon the machine, demolished it, and even threatened the inventor.

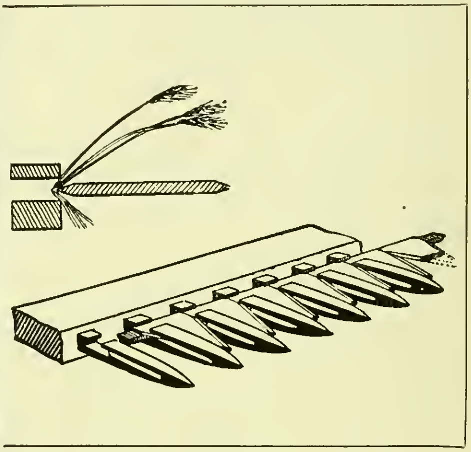
The Appearance of McCormick and Hussey

In 1816 Robert McCormick, a farmer of Virginia, tried to produce a machine to harvest grain. As he performed the arduous duties of the harvest each fall, he studied the oft-repeated mechanical motions of his arms and body in guiding the scythe and rake, and spent the long winter days trying to make pieces of wood and iron duplicate these movements. He gave it up as hopeless in 1831; but his son, Cyrus, determined to carry on the experiments.

About this time, Obed Hussey, a sailor who knew more of splicing and reefing than he did of mowing, commenced experimenting with a reaper. He was a Yankee, born in Nantucket, Massachusetts. McCormick was a Southerner. In almost every other way the two men differed. Hussey was a theorist: moody, generous, stubborn. He tired of things easily, and was inclined to be lazy, save when at work over an invention. McCormick was practical and willing at times to adopt the improvements of others, and pay for them. Determined and intolerant of opposition, he worked ceaselessly toward a fixed goal, from which he never swerved. Hussey worked in fits and starts, brilliantly, but not patiently.

Before 1832 Hussey had never thought of inventing a reaper, or even inquired whether it was needed or in existence. It is said that the idea was born of a challenge from a friend received while Hussey was perfecting a candle-moulding machine in Cincinnati. Before a year had past, Hussey had his machine working in the fields. He patented it at once, anticipating young McCormick by a year, although the latter had been working on a reaper ever since he had been old enough to hold tools for his father. Hussey's machine contained one feature, the cutter, of enormous importance which all others were forced eventually to copy. Accepting Bell's reasoning he had developed his cutter on the shear principle. He avoided the mechanical difficulties of shearing by inventing the notched cutter-bar and the slotted tufting-fingers. These improvements have since become standard on all mowers, reapers, and harvesters.





Courtesy of U. S. Department of Agriculture.

(Left) HUSSEY'S REAPER.

In 1833 Obed Hussey, a sailor, invented his successful reaper, anticipating McCormick. Hussey adopted Bell's shearing principles.

(Right) HUSSEY'S IMPROVED CUTTER OF 1847.

Hussey invented the notched cutter-bar and the slotting tufting fingers, now the standard on all mowers, reapers, and harvesters.

Hussey's cutter consisted of a blade with great, sharp, saw-teeth which moved from side to side in thin slots in a row of iron fingers. As the machine moved through the standing grain the fingers divided the stalks into tufts directly in the path of the rapidly moving cutter teeth. Moving from side to side, these teeth sheared off the stalks against the edges of the fingers. The grain was cut cleanly and evenly, close to the ground. This cutter was mounted at the side of a small sulky, so that the horses walked beside it. Behind was a platform, upon which the grain fell and from which it was raked by hand by the man who sat in the seat and drove the team. The machines sold well, and in seven years had become popular in the principal wheat-growing States of the country. They were exhibited at the London Exposition, in 1851, and received high honors. Hussey's obstinacy in refusing to adopt other men's ideas, which would have improved his machines, proved costly in the end. By 1858, he had fallen so far behind his rival, McCormick, that he sold out to William F. Ketchum for $200,000, and turned to the invention of steam-ploughing machines.

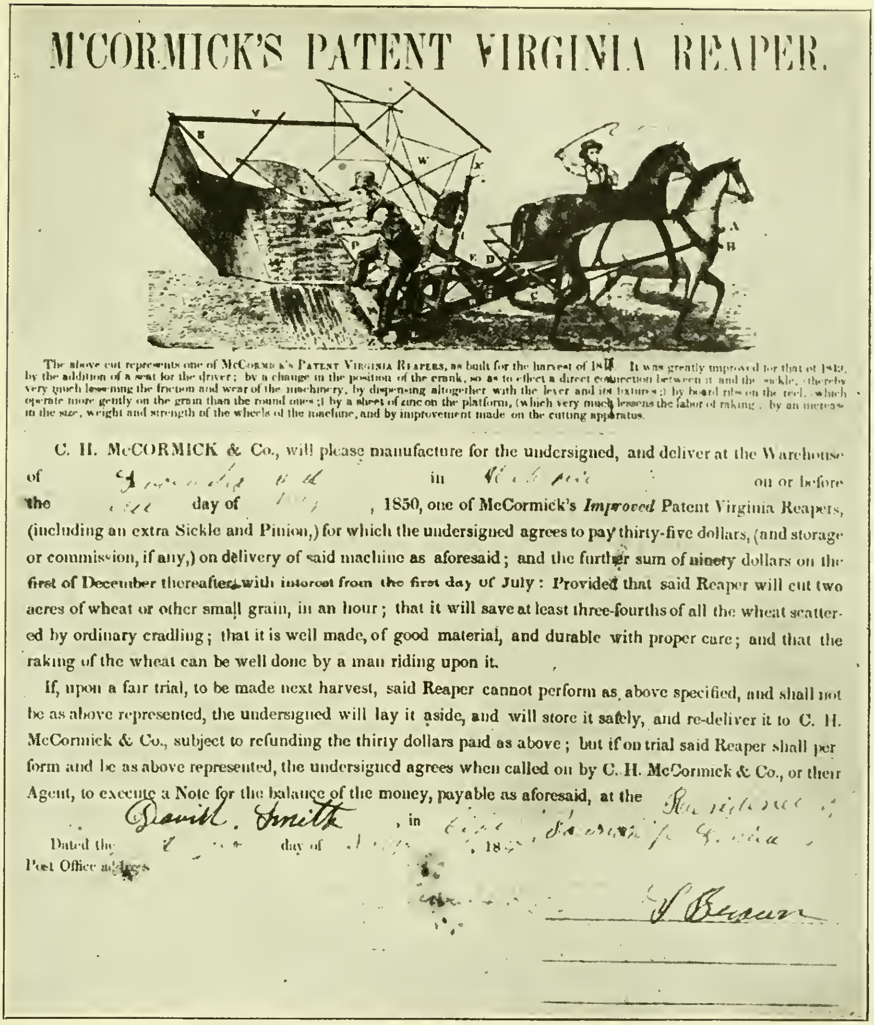
Hussey was well advanced on the invention of his reaper when Cyrus H. McCormick, at the age of twenty-two, was still a farm lad. For years Cyrus McCormick had watched his father's efforts to build a reaper, and now he attacked the problem himself. In 1831 he built a crude machine and ran it into a field. The stand of wheat, ripe for cutting, belonged to a neighbor, at Steele's Tavern, Virginia, and with four horses hitched to his contrivance, McCormick started around the field. Most of the neighbors were on hand to witness the test. Having watched the elder McCormick's experiments in the past, they were frankly sceptical, but the farm laborers, jealous of their hire, added hostility to a jeering attitude. The machine was crude and the field rough and hillocky. As a result McCormick did not make an impressive showing. Farmer Ruff, who owned the land, protested when he saw his wheat being chewed into bits, heads knocked off, and a ragged half-cut stubble left in the reaper's wake. A neighbor extended an invitation to reap on his field. There McCormick succeeded in cutting six acres in one day, proving that his machine was six times as efficient as a scythe. It was not until 1834, however, that McCormick patented his invention.

Cyrus McCormick owed his success and his position in the history of agriculture more to his character than to his mechanical ingenuity, great as that was. Only a man of his narrow doggedness, of his intolerance to opposition could have triumphed where others, more imaginative than he, had failed. The story of his life, chiefly a record of the reaper's evolution, is one long record of bull-dog persistency in the face of apparently insuperable obstacles. His father was the owner of two grist-mills, three sawmills, a distillery, and 1,800 acres of rough Virginia land. Shortly after the trial of his first reaper, Cyrus acquired 200 acres of his own and started farming. With his dream of the reaper still tormenting his brain, and hampered by the high price of iron, he induced his father and a friend to join him in building a small foundry, so that he could make his own castings. In 1839, a general financial crash plunged the McCormick family into poverty and debt, and Cyrus lost both farm and foundry.

McCORMICK'S FIRST REAPER.

Invented by Cyrus Hall McCormick in 1831, and patented in 1834. This machine embodied the following essential principles of the modern reaper—vibrating sickle-edged blade, fingers to hold the grain, reel, divider, and platform to receive the grain.

Returning to the old homestead, he labored with his three brothers and three sisters five years to stave off the sheriff and auctioneer. He still had his reaper, and he continued to improve it. In 1841, ten years after the first one was built, he sold two others for one hundred dollars each. In 1842 he sold



M'CORMICK'S PATENT VIRGINIA REAPER.

The above cut represents one of McCormick's Patent Virginia Reapers, as built for the harvest of 18[illegible]. It was greatly improved for that of 18[illegible], by the addition of a seat for the driver; by a change in the position of the crank, so as to effect a direct connection between it and the sickle, thereby very much lessening the friction and wear of the machinery, by dispensing altogether with the lever and its fixtures;) by board ribs on the reel, which operate more gently on the grain than the round ones;) by a sheet of zinc on the platform, (which very much lessens the labor of raking), by an increase in the size, weight and strength of the wheels of the machine, and by improvement made on the cutting apparatus.

C. H. McCORMICK & Co., will please manufacture for the undersigned, and deliver at the Warehouse of [illegible] in [illegible] on or before the [illegible] day of [illegible], 1850, one of McCormick's *Improved* Patent Virginia Reapers, (including an extra Sickle and Pinion,) for which the undersigned agrees to pay thirty-five dollars, (and storage or commission, if any,) on delivery of said machine as aforesaid; and the further sum of ninety dollars on the first of December thereafter, with interest from the first day of July: Provided that said Reaper will cut two acres of wheat or other small grain, in an hour; that it will save at least three-fourths of all the wheat scattered by ordinary cradling; that it is well made, of good material, and durable with proper care; and that the raking of the wheat can be well done by a man riding upon it.

If, upon a fair trial, to be made next harvest, said Reaper cannot perform as above specified, and shall not be as above represented, the undersigned will lay it aside, and will store it safely, and re-deliver it to C. H. McCormick & Co., subject to refunding the thirty dollars paid as above; but if on trial said Reaper shall perform and be as above represented, the undersigned agrees when called on by C. H. McCormick & Co., or their Agent, to execute a Note for the balance of the money, payable as aforesaid, at the [illegible] David Smith, in [illegible]

Dated the [illegible] day of [illegible], 18[illegible]

Post Office address

McCORMICK'S PLEDGE OF PERFORMANCE.

His reaper was so startlingly new a contrivance that Cyrus McCormick had to convince farmers that it would do all that he claimed for it. Accordingly he gave each purchaser an opportunity of verifying the claims made, and only then demanded his money. This is a copy of the agreement that the farmer signed.

seven more for the same price. By 1844 he had sold seventy-nine more, the whole family joining with hired hands to build the home-made machines. Eight orders had come from Cincinnati, the stronghold of his rival, Hussey.

Thus encouraged, McCormick, then thirty-six years old, decided to seek a wider field in the West, where the new farm lands were being opened up by progressive, pioneer people. Steele's Tavern was a hundred miles from a railway, and sixty from a canal. With sixty dollars in pocket, he rode horseback through the great prairie country. In the rolling flats of black loam he visioned future fields of wheat, oats, rye, and barley, and he realized he could make a million dollars with his reapers. He saw a land better fitted to grow great quantities of wheat than he had ever dreamed of. He saw farmers who were using the best ploughs in the world, but who, for lack of proper harvesting implements, were often obliged to turn cattle and hogs into the ripened grain.

To McCormick's mind there was but one answer—mechanical reaping. Nearly everybody wanted to reap at the same time. Since nobody had enough labor to perform the task alone, and since there was rarely time for the various farmers in a given neighborhood to band themselves together and harvest their fields in turn, there were but two solutions: slaves or machines.

McCormick had come North and West principally to find some one to build his machines. After having 150 reapers built for him in Cincinnati in 1845, and 150 more by Morgan and Seymour, of Brockport, New York, in 1846, he returned to Chicago, in 1847, and with William B. Ogden, mayor of the city as a partner, established his own factory. Ogden invested $50,000 in the business, but in a few years McCormick had bought him out. By 1851 he was building a thousand reapers a year. Six years later he had built 23,000 reapers, and made a profit of over a million and a quarter dollars. From that time on his business improved, until to-day the International Harvester Company, the enterprise he founded, is the greatest manufacturer of farm implements in the world.

The reaper was accepted. McCormick was a millionaire. But the machine was still woefully crude, and there were others who had reapers in mind. When McCormick set out to make a business success of his reaper, he had no time to give to further invention. His last important mechanical contribution to the reaper was in 1858. This was an automatic raking device, consisting of a large, heavy rake, moved over the fan-shaped platform in an awkward threshing motion, so that it raked the grain from the platform, rose, travelled back toward the cutter, and then came down to rake the platform clean again.

But rivals sprang up, eager to sell their reapers to farmers both here and abroad. An intense competitive battle ensued. McCormick, the biggest manufacturer, resorted to the courts to rid himself of meddlesome infringers of his patents, and even attacked the validity of patents granted to other inventors. If he failed in the courts he attempted, and often succeeded, in buying out his rivals. But he was not always successful. Better machines were certain to make their appearance sooner or later. A machine which would not merely mow the grain and deposit it in long windrows or gavels, but which would actually bind it into bundles, ready to carry away, would win the day. After the reaper had done its work, the grain had yet to be raked into piles, and bound by hand into bundles.

How the Grain-Binder Was Invented

In achieving this, the first step was taken by two young farmers named Marsh, at DeKalb, Illinois, in 1857. One day, while using a reaper to harvest grain, the idea occurred to them that the platform might be so arranged that the grain, instead of being unceremoniously thrown off to the ground would be brought up to a bin; a couple of men, riding the machine by standing on a running-board, could then bind the grain by hand and throw off the bound sheaves. Harvest-time is too busy for farmers to stop and work out "notions," but during the next winter and summer, the Marsh boys applied their attachment to their reaper and tried it out in the field the following autumn.

The machine worked very well. They were able to cut and bind grain with twice the speed that had been previously possible. The next year they went into the harvester business together with John F. Hollister, at Plano, Illinois. But the Marsh harvester was not favorably regarded by the farmers; it compelled them, they said, to work like slaves; they called it a "man-killer." To prove that the work of binding was not severe the Marsh brothers engaged tramps and even young girls for the task, and in 1864 W. W. Marsh went out on one of his harvesters all alone and bound an acre of wheat in less than an hour. That same year E. H. Gammon and J. D. Easter formed a partnership and secured a license from the Marsh brothers to make harvesters in Chicago.

The Marsh harvester was a success because it was simple. There was nothing new, mechanically, in the attachment of an elevator and bin to a reaper. Because of its simplicity, however, it was sure to be followed by something better, something more complete. It did not eliminate human labor, but merely improved the conditions under which that labor worked. Thinking men could see, even then, that abundant cheap labor was not to be had indefinitely. Every farmer knew that a machine which displaced a farm-hand saved him the farm-hand's wages and board.

The increase in population and the area expansion of the country had been remarkable. In 1776 there had been but four people to the square mile; in 1860 there were over ten, and in 1876, one hundred years after the Declaration of Independence, there were fifteen to the square section of land. Industrial expansion was at hand. Railroads had to be built. The Civil War was calling for every able-bodied man that could be spared from the shops and fields. There were over five acres of improved farm-land for every person in the country. That meant that for every man able to work in the fields there were about twenty acres to be farmed. The time was coming when there would be proportionately fewer farmers than city dwellers, when there would be more mouths to feed, more acres to be cultivated, and fewer hands to do the work.

The first recorded effort to eliminate the raking and binding of the grain, necessary with all successful machines up to and including the Marsh harvester, was made by Esterly, who, in 1848, patented a harvester consisting of a wide wagon-box, the front end of which was occupied by a lawn-mower type of cutter and beater, driven by one of the wheels. The complete machine was arranged to be pushed by horses. It proved a failure. The next year, Haines, of Illinois, built a push reaper with an endless canvas platform, the canvas running over rollers. The moving canvas raised the grain to a wagon which was pulled along with the machine as it went through the field.

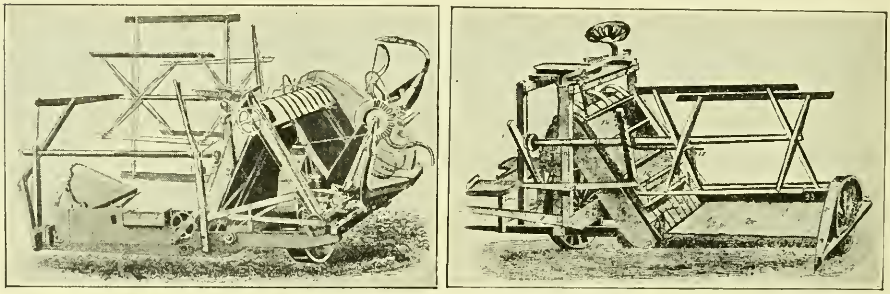
Haines' idea was to take the grain by the wagon-load directly from the field to the fanning-mill to have it threshed, thus eliminating raking and binding.

But grain needs to be sunned in the field before it is threshed, and the farmers preferred to bind it into sheaves and leave it in the shock for a few days. Moreover, threshing was a faster process than harvesting, at least in those days of small, crude harvesters and big, stationary fanning-mills. Consequently Haines' machine was not successful at first. Later, when the big bonanza farms of the West were opened up, the Haines harvester was adapted merely to cut the heads off the grain, leaving the straw to be burned off or turned under. Headers are extensively employed to this day. They fill wagons driven alongside, the principle being similar to that of the original Haines machine.

Heath, the Inventor of the Grain-Binder

Big, complicated and expensive machines did not appeal to the majority of farmers, although they would have welcomed any attachment to their Marsh hand-binding harvesters that would eliminate the extra hands needed for binding. John E. Heath, of Warren, Ohio, was the man to supply this want. The poverty of his parents had obliged him to learn the trade of wood-worker while still a boy. In Tollard, Connecticut, his native town, he had made axe-helves, and the great wooden oxen-yokes then in use. Seeing that he could never become skilful enough to earn a competence in this fashion, he set his brains to work to aid his hands. Before long he had perfected a machine which made better and more helves and yokes than a dozen men could produce with hand-tools. Heath prospered in a modest way, and had some leisure in which to employ his thoughts and his money for further advancement.

In 1840, Heath moved to Ohio. He had invented a mower which he considered better than others of the time, and he knew there were more farmers willing to buy mowers in Ohio than there were in Connecticut. He built his mower and exhibited it at the Illinois State Fair, in Chicago, in 1840. In the ten years which followed, he worked continually to perfect his mowing-machines, building and selling enough of them to enable him to continue his work. Observing the great amount of labor needed to bind the grain, once it was cut, he decided to incorporate a binding device with his mower so that the farmer might both cut and bind the grain by machinery. He wisely chose twine as the binding medium. Later, other inventors of binders tried wire, flax cord, hemp, or sisal twine, but only those who adhered to Heath's original idea of twine succeeded.



Courtesy U. S. Department of Agriculture.

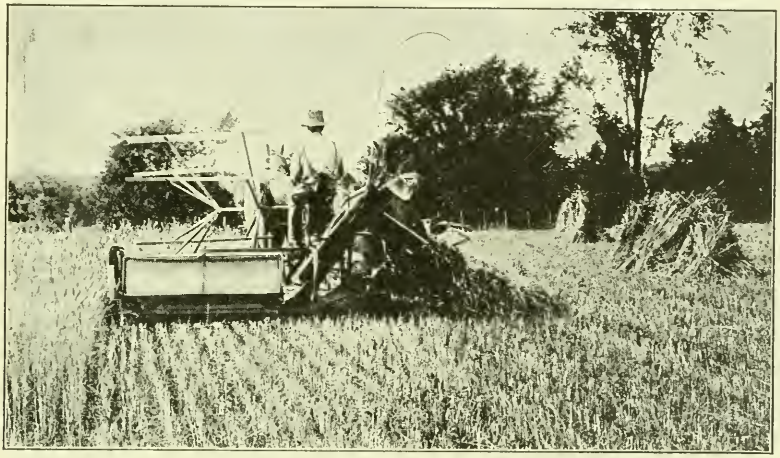
(Left) A SUCCESSFUL WIRE BINDER—LOCKE'S (1873).

(Right) THE MARSH HARVESTER AS IT LOOKED IN 1866.

Heath, in 1850, secured the first patent ever issued on a grain-binder, and started in to manufacture mowing-machines with binder attachments. He was a good mechanic and a clever inventor, but did not have the ability of McCormick, Hussey, and others to push his machines to the front, nor the wisdom to sell out at a good figure to the bigger manufacturers. Succeeding inventors avoided the mistake of applying their binders to only one kind of reaper. Had Heath applied his binder to the popular reapers and harvesters of the day, it might have survived.

In 1858, a young farm-hand, John F. Appleby, made a model of a twine-knotter: a machine that would tie a knot in a piece of twine. The idea of such a labor-saving device sprang from his own distaste of farm drudgery. He succeeded in inducing a country school-teacher to invest fifty dollars in the scheme, but the partner withdrew leaving him in debt. Appleby's first models were sold for seventeen cents at auction, the buyer presenting them to the inventor.

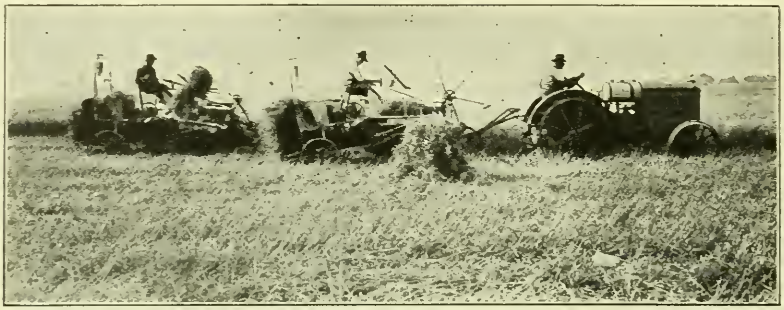
After the Civil War, during which he invented a rifle-attachment, Appleby returned to Wisconsin and at once began to develop his grain-binder. In 1867, his first working model was demonstrated, and Doctor E. D. Bishop became his partner by investing $1,500 in the enterprise. Meantime J. F. and J. H. Gordon, of Rochester, New York, had been working for five years on a wire binder. This machine was to collect a quantity of grain from the platform and then pass a piece of wire around it, twisting the two ends together and allowing the bundle to drop off behind. They secured patents on the machine in 1873, and after the Osbornes had secured an interest in it, they succeeded in selling the manufacturing rights to McCormick.



THE HARVESTER OF TO-DAY.

When William Deering heard of the Marsh binder and witnessed a test he saw that the wire-binder could not last. With the Marsh twine-binder he felt that he could dominate the field. He bought the invention. The harvester of to-day, here shown, is but a slight improvement on the perfected Deering-Marsh twine-binder.

About the same time Sylvanus D. Locke, of Janesville, Wisconsin, had approached the wire-binder problem from a different angle. His original intention had been to put out his binder as an attachment to the Marsh harvester and hand-binder, which was then being made by a number of different concerns, and of which about 100,000 were in use. Provided with packers, and binding the bundles more neatly than did the Gordon machine, it was extremely simple and did its work well. It had been developed to the practical stage by a farmer-mechanic, C. B. Withington, from whom McCormick purchased manufacturing rights, in 1874, thereby precipitating perhaps the greatest legal battle in the history of farm machinery, from which the Gordons and their allies, the Osbornes, came out victors to the extent of nearly half a million dollars.



MODERN TRACTOR PULLING TWO DEERING BINDERS WITH SHOCKERS

COMBINED HEADER AND THRESHER ON AN IDAHO DRY FARM.

Th emachine cuts the heads from the grain over a sixteen-foot swath, threshes it, and deposits the kernels in a wagon drawn along with it. A gasoline-engine furnishes power for the machinery and thirty horses pull it through the field. Tractors are now used instead of horses.

But the wire binder was not altogether popular with the farmers. The wire was liable to become mixed with the straw, endangering their cattle and horses. Objections also came from the threshermen and the fanning-mills; pieces of wire might injure conveyor belts and fans, clog the cylinders, and refuse to blow out with the straw.

Meanwhile Appleby had completed his twine-binder. In the course of his studies he had come across the knotting-bill, patented by Jacob Behel, of Rockford, Illinois, in 1864, which solved his greatest difficulty. It was easy to make a machine to tie wire about a sheaf of grain, because the wire did not require knotting, but could be hooked or twisted together. Appleby's binder not only bound the sheaves with twine, but it tied a knot in the twine.

A "COMBINE" OF THE HORSE PERIOD.

From 1841, when D. A. Church built what was probably the last of the early harvester-threshers, until about 1881, harvesting and threshing were regarded as separate and distinct operations. But when California became the greatest wheat-raising State, labor sufficient to harvest, haul, and thresh wheat in the old way could not be secured. Combined harvesters and threshers ("combines") were built. These were drawn by great teams of horses, as here shown. Gasoline-engines were used to supply the power for the machinery, the horses being used only for hauling. Nowadays tractors take the place of horses.

William Deering, who had joined Gammon, the original licensee of Marsh brothers, soon heard about the Appleby twine-binder. He sent for the inventor and witnessed a test of the binder. Gammon, his partner, was silent, but Deering, seeing that the hand and wire binders could not last with

Appleby's invention, promptly bought it himself. With this twine-binder he felt he could dominate the field, and he moved his factory to Chicago and started building Marsh harvesters equipped with Appleby binders. The harvester of to-day is only a slight improvement on the perfected Deering twine-binder.

In 1881, McCormick also started the manufacture of the Appleby binder. The original, basic patents having run out, it has since then been combined with Marsh harvesters the world over. Harvesters and binders to-day are made for all manner of crops, such as rice, clover, and other hayseed and grain. Mowers, reapers, and headers are also manufactured and used extensively.

The highest development of the harvester is the combined harvester and thresher, or "combine," as it is called. The machine, performing the complete harvesting operation on a wide swath of grain at one passage, is undoubtedly the largest and most complicated as well as the most wonderful machine used by the American farmer. From standing grain, it cuts, threshes, cleans, and bags the grain in one operation. These machines are operated by gasoline-engines, so that all the tractor has to do is to move them over the field.

Harvesting Corn, the King of Grains

The development of machinery for the harvesting of corn came later than that for the harvesting of wheat. One reason for this is that corn is a hardy plant and can be left on the stalk for weeks after it is ready for harvesting, while cereal grains must be harvested soon after ripening. Another reason is that the ears can be easily picked and husked at leisure. Corn is used principally on the cob, whether for stock fed or table use. Cereal grains have only a few small kernels per head, each head on the end of a slender stalk, whereas corn grows on great ears, from three to seven to the stalk. To reap a bushel of wheat or oats requires the cutting of 40,000 or 50,000 small straw stalks, whereas a bushel of corn is yielded by only from 150 to 175 corn-plants.

Probably more than ninety per cent. of the wheat crop is sold, but less than twenty per cent. of the annual production of corn in the United States is sold, the remaining eighty per cent. being fed to stock right on the farm where it is grown. To-day, however, the percentage of the corn crop that can be marketed is increasing; there is a growing demand for it as food, and industry is finding new uses for corn products. Also, many cattle-raisers and farmers have discovered that it is more profitable to devote all their land to pasturage, and the corn they once raised to feed their cattle they now purchase. Owing to this, added to the scarcity of farm labor and the steady increase in wages, economy in corn cropping became as necessary as it did in other crops.

The corn crop is the largest crop of the American farmer, amounting to about two and a half billion bushels annually. The value of the 1919 corn crop was three and a half billion dollars, or nearly one-fourth the value of all crops, and nearly twice the value of all wheat. It is thus seen that although the amount of corn which the farmer can sell is only one-fifth of what he raises, this fifth is worth one-third as much as the wheat crop, and is more valuable than any other.

Although corn was the first grain grown in this country, the methods of planting and harvesting it have been slow in developing. Before the discovery of America, Europeans had never seen corn. When they settled in the colonies, they learned to cultivate the wild maize of the Indians by Indian methods. The wheat, oats, and rye they brought with them had been cultivated by man since the dawn of civilization, but with corn the American farmer had to develop civilized methods of culture, and to transform a half-wild, stunted, and scrubby weed into the king of grains that it is to-day.

Departing from the Indian method of stripping the ripened ears from the standing stalk, the early planters of Virginia, New York, and New England soon found that it was better to cut the stalks close to the ground, using sharpened hoes to start with. The Mexicans, too, learned the advantages of this method and developed the *machete*, a heavy, sword-like knife, useful in cutting paths through the jungle, and valuable as a defense against wild beasts. The American planters developed shorter, lighter knives, the earliest being converted old scythe-blades. Later the corn-hook was substituted for the knife, the hook having a curved blade attached at right angles to a wooden handle. The corn-hook made stooping and swinging of the knife unnecessary, so that more work could be done with less fatigue and greater safety. Another form of corn-cutter was a sharp blade strapped to the boot and braced to the knee, somewhat like a telephone lineman's climbing-irons. With this the farmer merely kicked vigorously at each stalk to cut it.

Quincy and the Corn-Harvester

In developing mechanical corn-cutters, inventors at first attempted to follow the principles that had proved successful in harvesting wheat. The tough, thick stalks baffled these dreamers and their machines.

In 1850, Edmund W. Quincy, of Illinois, patented a machine to pick corn. In that day very little use was made of the fodder, the farmers raising the corn for the ears alone. The usual method of gathering the ears was to drive a wagon along the rows of corn while two men on foot tore the ears from the stalk and tossed them into the box. This work was generally one of the last tasks of the autumn, hogs being afterward turned out to browse on the trampled fodder, which was ploughed under next spring.

Quincy's machine picked the ears by means of wooden rollers, studded with iron pegs. As the stalks passed between the rollers, the pegs tore off the ears and dropped them upon a canvas belt, which carried them up to a trough from which they slid into a wagon driven alongside. Quincy spent forty years of his life trying to perfect his machine. Travelling from farm to farm, living in abject poverty, often without food or shelter for days at a time, he constructed his crude machines with the money given by sympathetic but sceptical farmers. He was known as Old Father Quincy throughout the corn belt.

After Quincy came a score of inventors who devised machines for the husking of ears, for snapping the ears from the stalk, and even for shredding the stalks. William Watson was simply an imitator. He obtained a patent on a corn-picker and husker, using picking-rolls similar to Quincy's. Most of these later machines were stationary, so that farmers no longer picked corn in the field, but cut the stalks with knives and hooks, after the manner of their forefathers, then carrying the stalks to the machines. What was needed was a machine that would cut corn in the field.

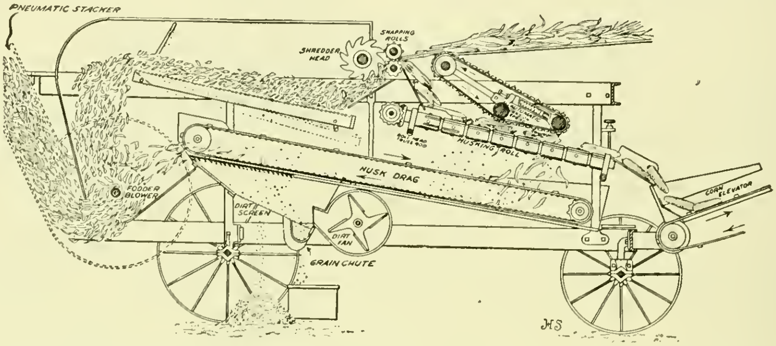
In 1886 J. C. Peterson, of West Mansfield, Ohio, patented a cutting device that became the forerunner of a long line of sled-cutters. It was simply a sled with a deep V-notch in front, lined with sharp, steel blades. It was drawn along the rows by two horses, while a man riding upon it gathered the stalks in his arms so that they were cut by the knives. Later types were arranged to cut two rows at once, and the runners were eventually replaced by wheels. These again were refined by several inventors, who added a vibrating knife to Peterson's notched cutter, and also divider snouts to raise fallen stalks from the ground. Later came gathering chains and shocking poles, which greatly reduced the labor of harvesting, and which can hardly be credited to any one inventor. In 1888, A. N. Hadley invented a machine which would not only cut the corn, but would assemble it in a large shock, which was carried by the machine, and which could then be lifted off by a small crane and set on the ground.

The Corn Husker and Shredder

About this time inventors began giving serious thought to the possibility of threshing and separating corn in the same manner as wheat is threshed and separated, so that the whole corn-plant, as cut by the corn-harvester, could be fed into a machine from which shredded fodder and husked or even shelled corn might be taken out. Sliced fodder, similar to silage, had been tried as cattle-food; it was found too tough and hard unless it had been wetted down and fermented in the silo, the air-tight wooden, brick, or cement tower, then popular with dairymen, and later adapted successfully to feeding beef herds.

Except for silage, the farmers had not experienced much success with corn fodder as forage for live stock. And yet the demand for corn meant an accompanying production of great quantities of fodder which would go to waste if not fed to the animals; also, by using corn fodder, every acre that could be spared from hay cropping meant one more acre for corn. It was thought that by threshing the corn the ears could be husked mechanically, and the fodder shredded, so that better feed for live stock would be obtained. The ordinary grain-thresher, of course, could not be used; hence efforts were made to combine corn shredders and huskers in single machines.

Among these developments, that patented by J. F. Hurd of Minnesota, in 1890, was the first. This original machine was rapidly improved, and many other machines of the sort appeared. As they were developed, refinements which had been added to grain-threshers were rapidly adopted, such, for example, as fans to blow away the shredded fodder, and self-feeders. It was found convenient to deliver the corn in bundles rather than as loose stalks, and this, in turn, led to a demand for corn-harvesters with binding attachments.



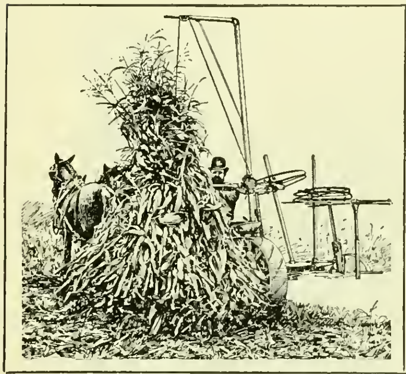
Courtesy U. S. Department of Agriculture.

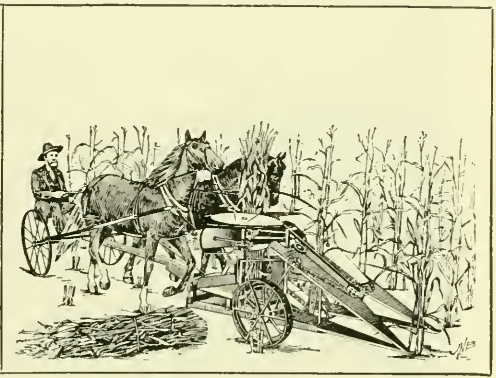
SECTION THROUGH A HURD CORN HUSKER AND SHREDDER.

The Development of the Corn-Binder

A. S. Peck, of Geneva, Illinois, secured a patent in 1892 which covered most of the fundamental features of successful corn-binders since developed. Peck built his machine but received very little recognition. It embodied no radical departures, but simply assembled into one compact, well-balanced machine the essential features of a successful corn harvester and binder. Peck used the machine with eminent satisfaction in his own fields, and built a number for his neighbors, who were likewise well satisfied. This attracted manufacturers to Peck's patent, some of whom acquired the right to mânufacture corn-binders under it, while others set out to evade it by building machines slightly different in principle.

Attempts were later made to produce successful combined corn-harvesters and huskers, which were operated by separate gasoline-engines, and hauled through the field by horses or light tractors. Some of these machines were designed to harvest two rows at a time, but none of them was developed much beyond the experimental stage. About 1902 interest revived in corn-pickers, and some very beautifully designed machines, based on old principles, were produced.





Courtesy U. S. Department of Agriculture.

HADLEY'S MACHINE FOR CUTTING AND SHOCKING CORN (1888).

This machine would not only cut corn but assemble it in a large shock, carried by machine. The shock could then be lifted off by a small crane and set on the ground.

A. S. PECK'S CORN-BINDER PATENTED IN 1892.

This machine includes most of the fundamental features of successful corn-binders since developed.

Other corn machinery of more or less importance was developed for stationary use. Corn-shellers are simply huskers operating under higher pressure, so that the ears are forced against spiked rolls hard enough to cause the kernels to be dislodged from the ear. Silo-fillers have been made which, when bundles of corn are thrown into a hopper, or upon a feeding-table, automatically slice the whole plant, and blow the slices through a large canvas or metal tube to the top of a silo.

Early Methods of Threshing

In the early days men threshed wheat by beating it with staves, or driving oxen over sheaves laid upon the hard ground. The Assyrians developed a threshing-sledge, or sled, a crude implement still used in parts of Syria, Greece, and Asia Minor. Primitive staves were subsequently improved upon by cutting them in two and joining the two pieces with stout thongs. This was called the flail; the standard threshing-tool for fifteen or twenty centuries. Better threshing could be accomplished with the flail, since the joined end, swinging loosely, struck the grain flat and with greater force.

A MODERN CORN-BINDER AT WORK.

But flails accomplished only part of the task and required a prodigious amount of hard labor. They merely dislodged the kernels from the stalks, leaving the more complete separation to a succeeding winnowing process. This process consisted generally in picking up the wisps from the ground, shaking out the kernels by hand, and casting the straw upon a stack. Then the kernels were swept up, sifted, and sent to the mill to be ground into flour. Pitchforks were later employed in the winnowing process to save labor.

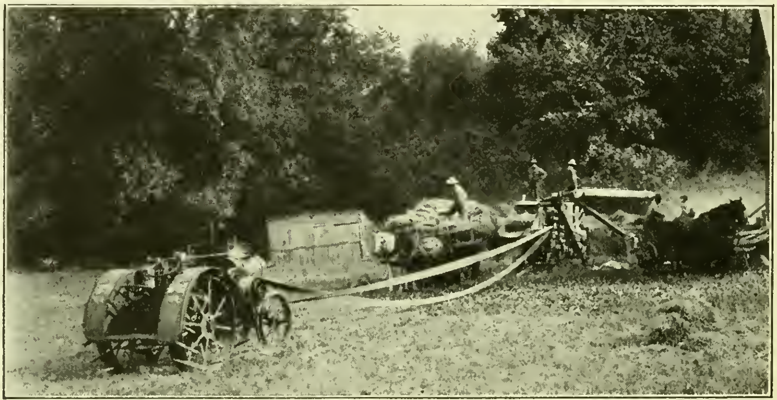
In this country, the flail and pitchfork were long the only tools known for threshing and winnowing the grain. A farmer hardly dared raise much wheat because he knew he could only use as much as he could thresh, and if he employed every man and woman on his farm he could thresh but little. To-day, we have progressed so far in the threshing of our grain that 4,000,000 Americans on 60,000,000 of acres of land can produce over 1,000,000,000 bushels of wheat in one year, averaging seventeen bushels to the acre.

Before the advent of modern machinery, it required about two and a half hours of human labor to plough, sow, and harvest fifteen bushels to the acre; this same amount of work is now done in seven minutes, with tractor-drawn gang-ploughs, grain-drills, and binders. The improvement of the plough, the invention of grain-drills and harvesting machinery reduced, enormously, the hours of labor necessary for the raising of a bushel of grain. Ancient ox-drawn ploughs, made of wood, took hours to do what a modern tractor-drawn gang-plough can do in minutes. Grain-drills plant wheat, and plant it with greater accuracy, in a fraction of the time it took by hand. By hand-reaping with the "cradle," an active man might possibly cut one acre before sundown, but it was more than he could rake together, bind, and shock the next day. A modern binder of the conventional type enables one man to reap, bind, and shock twenty acres of wheat in a single day.


HOW FARMERS ONCE THRESHED WITH HAND-FLAILS.

Before wheat is ready for the mill—where it is converted into flour, breakfast cereals, and other foods—the kernels must be separated from the straw and heads. This is known as threshing, and is perhaps one of the most important operations in grain culture. Not only was ancient threshing generally unclean, but it was also an exceedingly laborious business, taking up more time than all the preceding operations combined.

Therefore men dreamed of mechanical threshing long before they thought of mechanical tillage, planting, or harvesting. Yet despite the early start, progress has been much slower in thresher development than with any other type of agricultural machinery. This is because threshing is more difficult than the other operations. Wheat kernels are tender and easily injured. They are enclosed in a tight sheaf of chaff, strongly secured to the stalks in bunches or heads. A machine to extract this tender kernel, unharmed, and with the minimum of waste, must be extremely sensitive and precise in its action.



MODERN THRESHER WITH WIND-STACKER, SELF-FEEDER, BAGGER, WEIGHER, AND DUST-COLLECTOR, DRIVEN BY A SMALL TRACTOR.

The First Threshing-Machine

In 1732 Michael Menzies, a Scotch Highlander, patented a remarkable machine turned by a water-wheel. This was a great wooden cylinder on which a number of flails were mounted. As the cylinder turned, the grain was struck 1,320 blows to the minute; the equivalent work of thirty-three men with hand flails. But the farmer had to bring his grain to the machine to be threshed, winnow it himself, then haul it back to his farm. The result was that he was not much better off than if he had threshed it with flails on his own floor. Besides this, it was dangerous to approach too near the machine in order to pitchfork the grain under the flails, and the violence with which the flails beat the straw resulted in their frequent breakage.

Another Scotchman, named Leckie, improved upon Menzie's machine about 1758, by working the flails on a vertical pole within an upright cylinder, open at both ends. The pole was revolved at considerable speed by a water-wheel, and the grain fed into the top of the cylinder. The flails at once beat it against the sides of the cylinder, so that, as it worked its way down, the kernels were well beaten out. It was too violent, however; it threw whole heads down and bruised the kernels. As with Menzies' machine, the grain had to be winnowed after being threshed.

The first truly successful threshing-machine was invented in 1786, by Andrew Meikle, the third Scotch pioneer. He originated, in crude form, the fundamentals of all successful modern threshers. Meikle's machine consisted of a horizontal beater somewhat like a wide paddle-wheel, surrounded with a closely fitting concave casing. The sheaves of grain were fed head first between two rollers, like those of a clothes-wringer, in such a way that they passed between the beater and the concave casing slowly. The beater, turning at considerable speed, smashed the heads. After passing over the beater the grain dropped on a grating, where with the chaff it fell through into a hopper below. The straw passed over the grating, and out.

Meikle patented his machine in 1788, and continued to make improvements. In 1789 he added a second beater over the grating which, made to fit it closely, beat the kernels out of the straw. Then, back of the grating, he added a third which raised the straw as it left the grating and threw it back to a place where it could be pitched away into wagons or upon a stack.

Up to this time the threshing-machine was quite separate from the fanning-mill. Grain which had been threshed and winnowed from the straw was still unfit for the mill because the grain and chaff were not separated. About the time that Meikle began building his threshing-machine, others had started fanning-mills, often operated in connection with flour-mills. These old fanning-mills were simply large boxes containing several sieves and a huge fan or bellows. The grain was shovelled in at the top and gradually sifted through the sieves, which were violently shaken or vibrated by the power of a mill-wheel or windmill. The air-blast from the fan or bellows picked up the dust and chaff and blew them out through a hole at the back, the kernels dropping through into a hopper below.

In 1800 Meikle combined a threshing-machine and fanning-mill by placing the receiving hopper of the fanning-mill below the grating of the thresher. He built his machines to be driven by water, wind, or hand power. Some were of tremendous size, the windmills having sails which could be furled or unfurled to suit the breeze; the power with which to turn the mills and roll up the sails came from adjacent and smaller windmills. There were even roller conveyers to conduct the straw to a stack. The big stationary mills were of little use to the small farmer located at a distance from them, for they could not afford the long journey with the bulky loads of straw. But the hand-threshers, moved on a wagon and operated by three persons, became popular throughout Europe.

From now on, European threshers were speedily developed and improved. The most important improvement was the substitution for Meikle's first beater, of a revolving cylinder with teeth interlacing similar teeth on the concave casing. The other essential features of the Meikle machine remain to this day. As more and more of these machines were built and set up at points more convenient to the wheat-fields there was increasing dissatisfaction over water and wind power. Accordingly, horse-power machines were introduced. In these, the familiar horse-windlass principle, used by the Egyptians to raise water from the Nile before the Christian era, was employed.

American Thresher Development

A few of the crude European threshing-machines were imported into the United States as early as 1825. There was a persistent demand for a portable type, and this was met by open-cylinder machines, or "Bull" threshers. Mounted on wagon wheels and operated by horse-power, they were not equipped with fanning-mills or separators, since it was still thought impossible to compress the fanning-mill to portable proportions. Fanning-mills sprang up at every crossroads. American manufacturers copied the European machines, re-christening them "Ground Hogs."

Experiments were made with other types of threshers, in which power was obtained from the road wheels, horses hauling the machine about the field in order to keep the wheels turning as it threshed. Two advantages were claimed for this arrangement: the machine could go to the shocks of grain direct, thereby eliminating the haulage of the grain to the thresher; and it also spread the straw over the ground as it moved, ready for burning as fertilizer.

But the practice of hauling a clumsy piece of machinery over the ground by horse-power was hardly popular. Contemporary inventors tried to include rakes to gather the reaped grain from the ground, and even mowing attachments. A combined harvester and thresher was therefore an early nineteenth-century conception, and its advocates failed to produce a successful combination only because harvesters and threshers had not been perfected. Samuel Lane of Hallowell, Maine, secured a patent for a combined harvester and thresher, in 1828. He was also the inventor of the endless apron conveyor, to-day a part of every harvester. In his combined harvester he attempted too much, and although some parts of his machine possessed merit, they were ignored. He died in the poorhouse, in 1844.

Others followed his lead. E. Briggs and C. G. Carpenter secured a patent in 1836 on a travelling thresher with a detachable grain-cutter. In the same year H. Moore and J. Hascal of Kalamazoo, Michigan, patented the first American threshing-machine combining a fanning-mill. Like its predecessors, it was of the travelling type and designed to harvest as well as thresh; behind the threshing cylinder was a large sieve upon which the threshed straw fell. This sieve was vibrated in such a manner that the straw worked back until it fell to the ground, while the kernels and chaff fell through holes upon screens, where the fan blew away the chaff. The separated kernels were then elevated to the top and fed into bags. Though not perfect, this machine was superior to the "Ground Hogs," and it threshed more wheat from an acre's yield.

In 1830 Hiram A. Pitts, of Winthrop, Maine, secured a patent on an improved horse-power treadmill. He and his brother, John A. Pitts, formed a partnership and manufactured these horse-powers for use with "Ground Hog" threshers. The inventor, the more aggressive brother, introduced his machine to threshermen throughout New England. He operated these crude threshers himself, and became so disgusted with their poor work that he determined to invent a better type. With his brother, he built a combined threshing and fanning-mill in 1834. The machine had a cylinder, similar to that of the "Ground Hog," and back of this was an endless apron conveyor, as in the slat-type horse-power treadmill which they manufactured. Over it was a beater to agitate the straw, and a picker, or rotary pitchfork, to throw it off the end. The grain fell from the cylinder and the conveyor into a trough, which conducted it to the fanning-mill, mounted under the machine.

Hiram Pitts noticed that when the grain passed through the sieves, complete heads or parts of heads passed over and were blown out with the chaff, because they were too big to go through the sieves. He therefore arranged a trough, just behind the sieves to catch the heads, allowing the chaff to blow over and away. The bits of grain so saved, known as "tailings," were conducted by a small belt conveyor to the sieves to be refanned. He patented his thresher in 1837.

Pitts' threshers proved to be the best of their time, and were among the first to be driven by steam-engines. In 1840 John A. Pitts left his brother and established a factory at Albany, New York, which he later moved, first to Rochester, New York, then to Springfield, Ohio, and finally to Buffalo, New York. There he produced the Buffalo-Pitts thresher, and there he died in 1880.

Other inventors, among them being D. A. Church and Edward Boston, encouraged by the Pitts brothers' success, became active. Jacob V. A. Wemple and George Westinghouse, father of the air-brake inventor, formed a partnership in 1840 to perfect a threshing-machine. Wemple had been a blacksmith and wheelwright in Montgomery County, New York, and had repaired some of the crude open-cylinder "Ground Hog" threshers. About 1830 he became interested in improving them. He found that the round-peg cylinder-teeth then in use were inefficient, and that the usual practice of simply driving them into the wooden cylinders, like spikes, was untrustworthy.

EARLY STEAM THRESHING-ENGINE WHICH WAS PULLED BY HORSES.

The machine was available for belt work only.

They were apt to loosen and, at the speed at which the cylinders were turned, were sometimes hurled out with force enough to kill a man. On the other hand, if their renewal was necessary, it frequently happened that they could not be drawn from the wood without much difficulty.

So Wemple worked out a flat-blade type of tooth that did much better work, and also arranged a bolted connection, making their removal easy yet preventing accidental loosening. George Westinghouse, like his illustrious son, then not yet born, was a mechanical genius. He had manufactured "Ground Hog" threshers and could appreciate the value of Wemple's invention. Westinghouse and Wemple developed a combined thresher and fanning-mill, incorporating the Wemple flat-bolted tooth with a raddle or vibrating rack. The straw from the cylinder was raised to this raddle by a canvas belt-conveyer. The raddle rested upon square rollers, which as they turned, shook it violently, thus jarring more grain out of the straw. The grain dropped into the fanning-mill or shoe, as it is now called, and the straw was thrown to the rear. The machine was patented in 1843 and was built by Wemple and Westinghouse at Fonda, New York. Westinghouse soon after withdrew and established his own factory at Central Bridge, New York, where he built similar machines.

Hiram A. Pitts moved from Maine to Alton, Illinois, in 1847, and in 1851 to Chicago, where he produced the Chicago-Pitts thresher. The Buffalo-Pitts, Wemple, Westinghouse, and Chicago-Pitts machines by this time had demonstrated their superiority over the "Ground Hog," English "Bull" threshers, and "chaff pilers," as the travelling type was called.

John Cox and Cyrus Roberts, who were building threshers at Belleville, Illinois, improved on the Pitts and Wemple machines by developing a raddle violently pitched by cranks; they patented the idea in 1852. Nichols and Shepard took over its manufacture a few years later, John Nichols improving it by the addition of jagged fingers, so moved by cranks and pitmans that they gave the straw a rising and pitching motion and broke up matted portions. The original Cox and Roberts machine was short-lived because the severe motion of the raddle shook the machine too violently. Nichols corrected this by using two raddles working in opposite directions, a machine he christened the Vibrator. The Aultman and Taylor Company, of Mansfield, Ohio, was licensed in 1867 to manufacture Nichols and Shepard machines. Since then, practically all threshing machines have evolved from the vibrator principle.

More recent improvements have increased the efficiency of the cylinders and concaves by enlarging the cylinders or extending the concaves higher, thus giving more surface for threshing. The straw rack has been greatly improved to agitate the grain more thoroughly, and screens and drafts in the shoe have been developed to rid the grain of chaff, dust, and weed seeds. Tailings are now carried back to the cylinder to be re-threshed. Modern machines not only thresh and separate the grain automatically, but also weigh and bag it.

TEN-DOLLAR BILLS PROVE THAT A WIND-STACKER WOULD WORK

Originally the straw thrown out by the thresher had to be pitched away with forks, constituting one of the hardest jobs around a thresher and requiring in the operation from six to eight men. In the seventies a few machines appeared with long elevators that carried the straw straight back, and built up a stack some distance away. Reeves and Company, of Columbus, Ohio, developed a radial stacker of the belt-conveyer type in 1882, permitting the building of a horseshoe-type of stack. James Buchanan invented the first stacker worked by a fan draft, in 1879. He built a model and exhibited it at the Indianapolis Fair, in 1884. A powerful blower fan blew up a pipe, causing a suction on a branch to the end of the thresher, thereby picking up the straw and blowing it upon a stack.

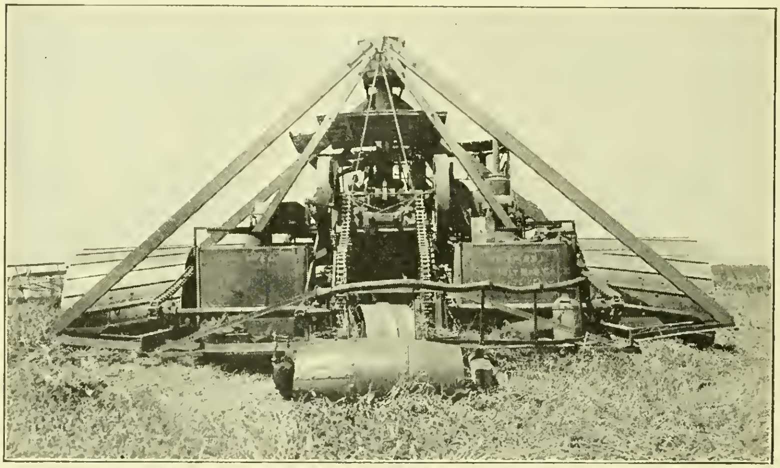
It was new and so it was opposed. Old threshermen declared it would pull the grain out of the pipe or shoe with the straw, and that it would consume too much power. To overcome these objections Buchanan's men ran the stacker by hand-power, and turning off the separator fan, laid ten-dollar bills in the shoe to prove that the wind-stacker would not draw the grain from it. In 1891 A. McKain bought Buchanan's and all other patents of importance, paid Buchanan $1,000 a year royalty and built up one of the most remarkable monopolies in the history of farm machinery. For two years he fought an apparently losing fight against the prejudice of threshermen and the opposition of manufacturers. By repeated demonstrations, however, McKain built up a demand for his stacker and exacted heavy royalties from manufacturers who were forced to adopt his principles.

SELF-FEEDERS

The next great improvement was the self-feeder, by which the bundles of wheat were automatically fed to the cylinder at just the proper speed, and their bands cut. The first self-feeder of importance was invented by F. H. Marshall, of Darlington, Iowa. The latest improvement is the dust-collecting fan, developed under the direction of the United States Department of Agriculture.

Combined Harvesters and Threshers

The combined harvester and thresher, which marked the first attempt at threshing-machine development in this country, was long regarded a hopeless dream. From 1841, when D. A. Church built what was probably the last of the early harvester-threshers, until about 1881, harvesting and threshing were considered as two separate and distinct operations. But in that time California had grown from a little-explored and lawless province of Mexico to the greatest gold-mining, fruit-growing, and wheat-raising State in the Union. On the great bonanza farms in the swampy delta country in the San Joaquin and Sacramento valleys, labor, sufficient to harvest, haul, and thresh wheat in the old way, could not be secured. Horse traction was almost as impracticable. Stockton Berry, Daniel Best, and Benjamin Holt, solved their own problems by building the largest

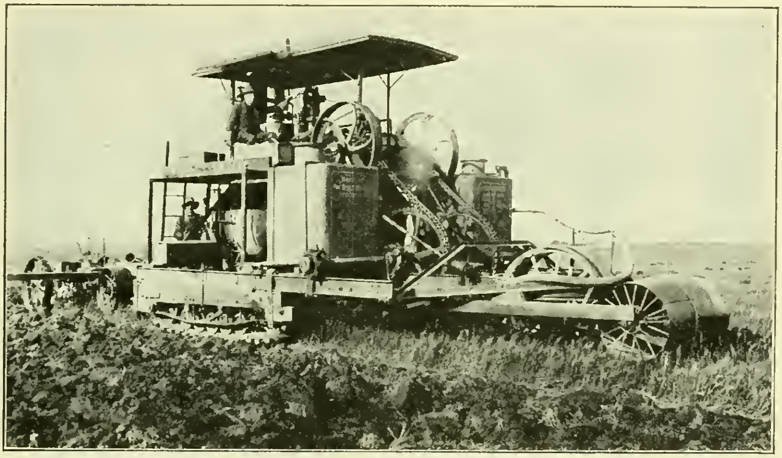


THE BIGGEST TRACTION-ENGINE EVER BUILT.

The Holt steamer. Designed to pull a combined harvester-thresher in California Delta country. Each wheel was eighteen feet wide so as not to sink into the soil.

agricultural machines ever known, before or since. They built steam-propelled combined harvesters and threshers, some of them having wheels eighteen feet wide. When the great dry farms of the open plateau country to the north and east were opened up, they offered another field for "combines," as the giant machines are called.

Some of these machines were entirely self-contained. Steam drove them and operated the harvesting and threshing machinery, straw being used under the boilers. Later, "combines" were equipped with steam-engines only, the steam being supplied through a hose leading to a steam traction-engine by which they were drawn through the field. With the advent of the gasoline-engine, horses in spans of twenty to thirty were used to haul the machines, gasoline-engines supplying power to operate the machinery. To-day "combines" are drawn by tractors.



THE FIRST HOLT CATERPILLAR, HAULING A GANG-PLOUGH.

It was steam-driven, like the round-wheel type, and was likewise very large.

Doing Away with the Plough-Horse

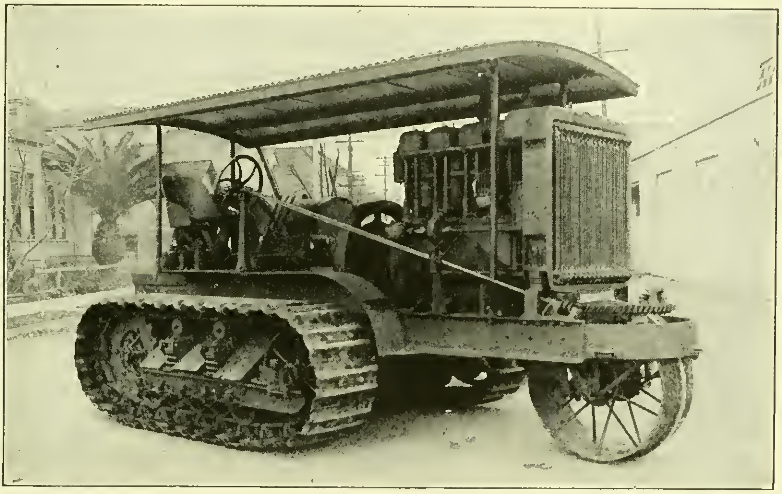
On the big bonanza farms of our own far West, as in Siberia and Australia, arose the cry for mechanical farm traction. To the ordinary farmer, the suggestion that he substitute a steam or a gasoline traction-locomotive for horses at first seemed fantastic. All farm machinery was built to suit the capabilities of the horse, and a fair proportion of the crop acreage and pasturage of the average farm was devoted to equine sustenance. The big ranchers, however, were not concerned with precedent. Existing farm implements, or any of the other considerations which lead farmers to cling so tenaciously to the horse, had nothing to do with their problem.

Either they had to develop their own machinery, or have it developed especially for them. They were engaged in a new kind of farming. Their operations were on such a huge scale that the cost of equipment was of no moment. On the other hand the cost of cropping their millions of acres mattered mightily, for the difference of a quarter of a cent per acre in the cost of ploughing the ground would amount to hundreds of dollars by the time all the mile-square fields had been cultivated.

The first use of power-driven farm machinery was in ploughing. The first recorded work in this direction was that of David Ramsay and Thomas Wildgoose, of England, in 1618, whose efforts, for want of a suitable propelling-engine, were fruitless. In 1854, Fowler and Smith, Englishmen, introduced the steam-plough, and in later years the English method of steam-ploughing enjoyed a considerable vogue. This method was to mount winches upon steam-engines, situated on opposite edges of the field, which engines drew ploughs back and forth across the field by winding cables. The ploughs used were in two sets, one set ploughing in one direction while the other set was carried high in the air. But the method never gained favor in America because the larger fields here would have required cables of excessive length.

The first and the greatest development of steam traction-engines in this country was in threshing. Here, as had been the case with steam-ploughing in England, investment in such expensive machinery paid only if the owner of the engine hired himself out to many farmers in the ploughing or threshing season. Threshing-machines have always been operated by specialists who hire out by the day or the bushel, rather than by the farmers themselves. These threshing-engines were designed primarily to furnish power for the belt which drove the threshers, and, if not designed to be drawn by horses, were equipped with a very light and simple drive to the wheels, adapted to move only their own weight at very slow speed.

In 1888, Jacob Price designed a steam-ploughing engine in which sufficient power was delivered to the rear wheels to draw, behind it, a gang-plough. About the same time Daniel Best produced a steam ploughing-and-harvesting engine which was widely copied. It was of immense proportions, comprising two enormous driving-wheels and a single front wheel for steering. Perhaps the largest of these steamers was built by Benjamin Holt at Stockton, California. These giants had wheels eighteen feet wide, or a total wheel width of thirty-six feet. In front was a large steering-wheel and ahead of this a barrel-shaped roller to smooth the ground, as illustrated on page 298.



GASOLINE-DRIVEN HOLT CATERPILLAR TRACTOR FOR HEAVY FARM DUTY.

The caterpillar tread (Holt's invention) distributes the weight so that the tractor will not sink into soft soil.

Despite the great width of tread the machine packed the soil to hardpan, making it extremely difficult to grow crops. This led Benjamin Holt to look about for a more practical form of traction-engine. In order to secure sufficient traction to pull the gangs of ploughs, or harvesters, great weight was necessary to prevent the wheels from slipping. Increasing the width of the wheels distributed the weight over a greater width of ground, but it did not materially increase the supporting area. Holt turned to the lag-bed.

A Machine that Crawls over Soft Ground

The origin of the lag-bed is somewhat obscure, but the basic idea seems to have been conceived by a man named Keeley, in England, in 1825. His steam-tractor was supported by a sort of belt, built up of wood and iron, which ran over two notched pulleys, front and rear, with intermediate wheels to distribute the weight over a large surface in contact with the ground. The engine was steered by a single wheel in front. In order to overcome the resistance to the necessary sidewise slipping, or skidding of these long belts when turning, each section was provided with rollers on its outer surface. These rollers were placed so that they could roll sidewise and acted as grouts or cleats to dig into soft ground, and provide traction. However, the machine was a failure.

In 1859, W. P. Miller, of California, designed and patented a steam-driven engine having a type of lag-bed, the sections of the bed or belt being joined by a shear-like hinge. Before 1900 about a hundred patents were granted on various traction devices, based on the lag-bed principle. In all of these the fundamental idea was to substitute a wide, flat bed for the small contact of a round wheel, this bed being made in sections or links. Within the endless belt so formed, were wheels supporting the machine, propulsive power being supplied by one of the end wheels or sprockets which supported the belt. As it rolled forward the bed was continuously being picked up behind and laid in front.

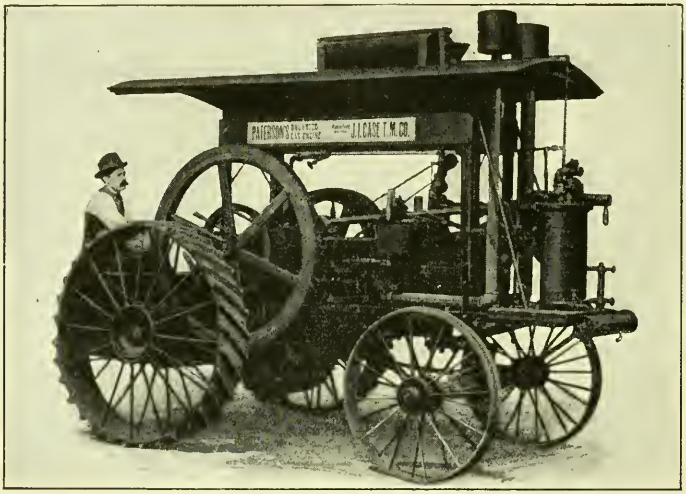
In 1901, Alvin O. Lombard, of Waterville, Maine, patented the first practical lag-bed tractor. His machine was practically identical with the familiar type of steam logging locomotive, so far as the engine was concerned, but instead of driving-wheels, it had a lag-bed of original design. To secure flexibility over uneven ground and the easiest running possible, Lombard substituted for small wheels a flat iron skid or runner, mounted on a single pivot, with a chain of rollers between the bed or belt and the skid. Thus, as the machine moved along, the skid rolled along over the bed on the many little rollers between the two. The belt was picked up by the rear sprocket and carried forward to the front sprocket, which set it down on the ground again. The chain of rollers, after passing under the skid, ran around a pulley at the back, then another at the front, and so under the skid again. At the front was a seat and a steering-wheel. Under this was a pivot on which might be mounted either sled runners for snow, or wheels for ground.

Benjamin Holt brought out his lag-bed or caterpillar steam-tractor in 1903, using the same general construction he had used for his round-wheel tractors, but substituting lag-beds for driving-wheels. Unlike Lombard, who was a lumberman, Holt developed his tractor primarily for agricultural work. He soon changed over to gasoline-power, greatly simplifying the machine and reducing its weight while increasing its pulling power. The success of the Holt machine, which is known as the "caterpillar," was so marked that a number of other manufacturers in the United States, and recently in Europe, have been encouraged to develop lag-bed vehicles. During the war the Holt caterpillar construction was extensively used in mounts for great siege-guns, artillery tractors, and "tanks," not only by the Allies, but by the Germans and Austrians as well.

The Gasoline-Tractor

Meanwhile, developments on the smaller farms of the Central and Western States had given rise to greater interest in smaller tractors. The growing scarcity and high wages of farm labor had induced the farmers to purchase larger machines and more powerful horses. Percherons, Clydesdales, Shires, and Belgian draft horses were in great demand on the farms. But these big horses, besides being costly, required more attention and care than the common farm horses. Pasturage and hay were becoming more valuable and land values were rising to a point where farmers were obliged to secure the utmost productiveness from their soil. For more and better power the farmer was compelled to turn to the machine.

Steam traction-engines had been extensively utilized in the Dakota and Minnesota wheat country, but had given little satisfaction. They were heavy and cumbersome, expensive to run, and dangerous on account of the sparks that poured from their smokestacks. The solution seemed to be the internal combustion engine which was fast driving the horse from the city streets and country highways. Gasoline-engines of those days were in the experimental stage and consequently gasoline-tractors were not successful.

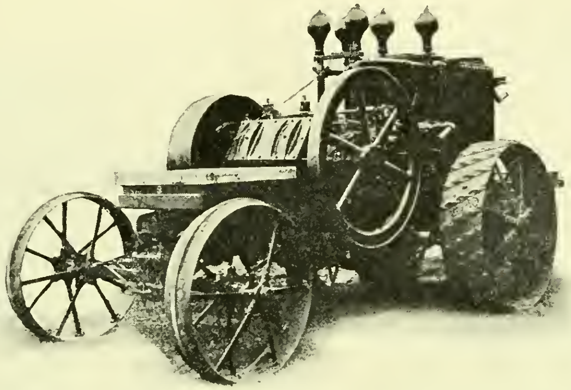


J. I. CASE PIONEER GASOLINE-TRACTOR, BUILT IN 1892.

In 1892 two young farmers, unknown to each other, set out along parallel lines. Both entered universities, determined to devote their lives to the application of power for farm labor. C. H. Parr, of Iowa City, Wisconsin, entered the University of Wisconsin, and C. W. Hart, of Charles City, Iowa, enrolled in the State College at Ames, Iowa. A year later Hart went to Wisconsin and there met young Parr. They became friends and devoted the rest of their stay at college to joint research on gasoline-engines.

On graduation, in 1896, Parr and Hart started a factory in Madison, Wisconsin, for manufacturing gasoline-engines. In 1898 the Hart-Parr Company produced the pioneer oil-cooled engine, the principles of which were later incorporated into their tractor in 1901, after the factory had been moved to Charles

City, Iowa. Only one of these was built the first year—a rough frame of structural steel with front and rear wheels similar to those used on steam traction-engines; the single-cylinder engine being a huge stationary type with a chain drive to the rear wheels; the oil-radiator of cast iron, being in fact a large steam-radiator, of the type once used for heating buildings. Despite its crudity, this machine ran continuously for seventeen years before it was broken up.



THE FIRST HART-PARR GASOLINE-TRACTOR, BUILT IN 1901.

The following year fifteen improved oil-cooled tractors were built in the Hart-Parr works. In 1904 and 1905 the Hart-Parr Company developed a method of burning kerosene instead of gasoline in the engine.

Modern Farm Power

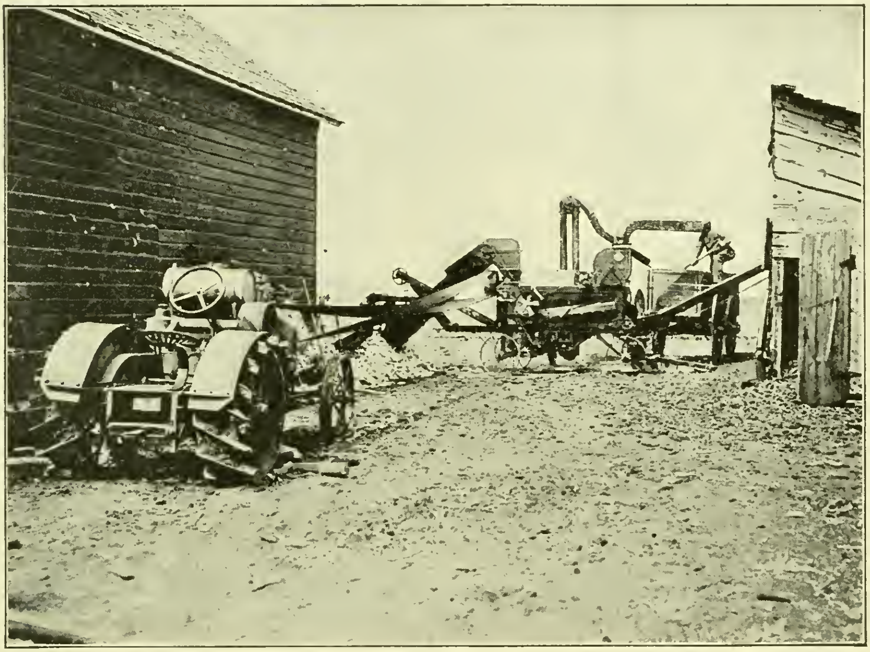
Following the gasoline-tractor pioneers — Holt, with his caterpillar, primarily produced for bonanza farms, and Hart-Parr, with their round-wheel type, originally intended for Middle-Western farmers—a host of farm-tractor designers and manufacturers sprang up. Caterpillars from 120 horse-power down to orchard machines of fifteen horse-power were developed and used on farms of all sizes in every part of the world. Round-wheel tractors, from eighty horse-power giants for fields measured in square miles down to garden tractors have been developed, burning anything from gasoline to unrefined oil. In 1920 nearly a hundred firms were engaged in building farm tractors, the annual production being over 200,000. In the development of tractors, much more originality and variety of invention have been displayed than in any other farm machines. No other machine has been called upon for such a variety of work as the tractor, and none has had so profound an effect upon the mechanical implements of the farmer.

At the time of writing, progress is proceeding at such a rapid pace and along so many radical lines that an attempt to summarize it would be vainly exhausting, since no one can foresee the eventual trend. Results show, however, that the old idea of a farm tractor as merely a field locomotive to be hitched to implements originally intended for horse-power and providing a pulley for belt work, must be abandoned. Patient inquiries by the Department of Agriculture have established that modern tractors have not made serious inroads upon the use of horses on farms simply because they were not sufficiently versatile. They could not perform a wide variety of tasks. They could not successfully cultivate between corn rows. They could not economically haul crops considerable distances over the road. They could not turn square corners, as horses do, and they wasted far too much space on the turns. Few of them could be used successfully for hillside work.

Nevertheless, each year sees improvement. Implement makers have been obliged to make drastic alterations in their machines to adapt them to tractors, and the application of the light-weight, economical internal-combustion engine promises amazing economies in farm operation by combining many operations into one. Such are the soil-millers, rotary plows, combined grain harvesters and threshers, and combined corn pickers, huskers, and binders.

What Machinery Has Done for Agriculture

Contemplating the miracles wrought by machinery since the year of American independence, one ceases to marvel that a single decade doubles the value of farm land, of buildings, implements, and of farm products; that with the same acreage of improved farm land per capita in 1920 as in 1850 the increase in yield of grain per acre has been nearly ten per cent., with a decrease in rural population per farm from twelve to eight. Not all these eight actually live on farms, however; rural population includes those living in villages and small towns, so that it may safely be said that the average farm shelters about six persons. One farm in three has an automobile, one in fifty a motor-truck, one in twenty-eight a tractor, and two out of five have telephones. The farmer is producing more food with less help and receiving more for his labor in the way of comfortable living and enjoyment of life than ever before in history.



CORN-SHELLER DRIVEN BY A SMALL TRACTOR.

Over-abundance of wild food, as in the tropics, deprives men of the urge to work, to scheme, to learn, so that they remain in contented savagery. On the other hand, too little food has a degrading effect. In time of famine men sink lower than beasts. Neither superabundance nor famine are conducive to a peaceful, enlightened, and cultured existence.

It is good for men to have to earn their bread by the sweat of their brows, but it is not well that all men should sweat at the same tasks. The farmer is the great civilizer. The first farmers were women, who in ancient time, as now, were the conservers. The farmer became a civilizer because he produced food in abundance, thus making plunder and butchery of other men unnecessary to the preservation of life.

In this scanning of the slow and painful rise of the farmer from the meanest station in society to the position he occupies to-day, it is seen with what insuperable obstacles the early seeker after mechanical relief from drudgery was beset. Strangely enough, it was the farmer and in particular the farm laborer who most opposed progress. The farmer was raised from serfdom in spite of himself. His productiveness has been trebled and his labors lightened. His comforts have increased and his financial condition has improved.

The average man consumes seven bushels of wheat per year. This means that the United States, which produces twenty per cent. of the world's supply of wheat in normal years, requires 770,000,000 bushels of wheat for itself, or only a trifle less than the average of 795,000,000 bushels produced during the second decade of the present century. Rural population continues to decrease, and the number of mouths to be fed increases. This means that the production of wheat must increase. Such an increase must take the form of increased acreage of wheat at the same rate of yield, or more bushels per acre for the same acreage. Yet, the acreage of wheat land has hardly increased at all in the same decade, while the yield per acre is actually less. We have been spared a shortage by the timely entrance of Argentina, Canada, and Australia into the European export field, lessening our wheat exports. Even so, the increase of demand in the face of an almost stationary production has caused the price of wheat to more than double.

Machinery has served agriculture and in so doing it has affected civilization profoundly. It has released the majority of men from farm labor and made the complex industrial growth of modern life possible. But the task is not yet done. Tillage machines are needed which will more thoroughly prepare the soil. Seeding and planting machines must be built which will plant even more effectively than those we now have. Perhaps the greatest need is for mechanical cultivators which will hoe around the growing plants, loosening the soil and keeping down the weeds. Harvesting-machines must be devised which will further reduce human labor, not only for wheat and grains, but for cotton, vegetables, berries, and that king of crops, corn. Farm power needs development for greater simplicity, reliability, economy, and, above all, versatility. All farm machinery must be improved along these lines and in addition greater accuracy and standardization is needed in manufacture to simplify the mechanical maintenance problems of the farmer.

PART V

AUTOMATIC LABOR-SAVING DEVICES

CHAPTER I

AUTOMATIC MACHINE-TOOLS

IT has been pointed out in the chapter "Putting Steam to Work" that when Watt gave the world his great invention he also created the machine-tool industry. By this we do not mean that he actually designed and made the wonderful lathes, planers, and shapers which do their work far more precisely and rapidly than saws, files, and chisels in human hands; but it is obvious that without some machine that would bore cylinders with reasonable accuracy he could not build engines. Indeed, when it came to "the practice of mechanics *in great*," as he called it, no one could bore a cylinder for him by machine or by hand, for which reason his first large engine had a cylinder which was actually hammered. For ten years he sought a man who could provide him with cylinders in which a piston would slide snugly. Unless such cylinders could be obtained, the steam would flow between the piston and cylinder-wall, power would be wasted, and his engine could not be a great mechanical success. The leading engineers of his day tried to help him. Smeaton, one of the most noted, declared that "neither the tools nor the workmen existed who could manufacture so complex a machine."

Before Watt's day there were engines of a kind, the cylinders of which had been bored out. The boring tool had simply followed the incorrect form given to the cylinder when it was cast; it made no pretense of shaving off all portions that were not wanted. In Watt's engine better work was demanded.

Luck was with Watt when he met gruff John Wilkinson, known all over England as an ironmaster of more than ordinary imagination and mechanical daring. He had devised ways of smelting iron cheaper than those of his competitors, and he made cannon for the British Government. Cannon must be bored. The cannon of Wilkinson's time—the time of the

American Revolution—fired shot more or less round. Wilkinson devised a machine which bored them more accurately than had been possible before, and it was this machine that overcame Watt's disheartening difficulty.

John Wilkinson's Boring Machine

The old machines could not bore true because there was no way of preventing them from following the irregularities of the casting. John Wilkinson did what we all do when we want to draw a straight line. He gave the boring tool a kind of straightedge or ruler, and this it had to follow as it dug its way on. The boring tool itself was a long shaft, which was driven by water-power and which carried a wheel with cutting blades. In this there was nothing new. The new idea was the ruler—a straight, heavy bar placed in the central axis of the cylinder and rigidly supported so that it could not move. The borer simply slid along this bar, just as we would slide a lead-pencil along a ruler's edge to draw a straight line. When the cutters encountered metal in their path they cut it away.

This was the first modern metal-cutting tool. It did its work for Watt in 1775. Wilkinson played as great a part in the history of the steam-engine as Boulton, Watt's partner. He had courage as well as gruffness. He bought the first engine that Watt turned out at Soho, while other ironmasters stood by, waiting and watching. Wilkinson was no mere waiter and watcher. He helped to erect the first iron bridge in 1779 and built the first iron vessel in 1787. Men feared and respected him. Boulton wrote of him to Watt:

"I can't say but that I admire John Wilkinson for his decisive, clear, and distinct character, which is, I think, a first-rate one of its kind."

"A first-rate one of its kind"—what a character he must have had! No wonder that he was constantly quarrelling with his family.

The Work of Joseph Bramah and Henry Maudslay

It was an opponent of Watt's, a man who testified against him in patent-infringement suits with no little bitterness and prejudice, who ranks with John Wilkinson as the father of the machine-tool. He was Joseph Bramah, who was born on a Yorkshire farm and who might have lived and died a farmer had he not been lame. His infirmity made it necessary for him to learn the trade of a cabinet maker. A Yorkshire farm was no place to ply a trade. He went to London, there to become famous in the history of mechanics. Like Wilkinson, Bramah had ideas and a will of his own. His head teemed with inventions, nearly all of them practical. He devised the hydraulic press, the beer-pump, the four-way cock, an automatic machine for numbering the notes of the Bank of England, a quill-sharpener, and important wood-working machinery.

It was a lock that paved the way for Bramah's entrance into the field of machine-tools, a lock of his own contriving, a burglar-defying lock. Bramah thought so much of this invention that he exhibited it in his shop in Piccadilly and offered two hundred guineas to the man who could pick it. The challenge was taken up time and time again. Sixty years after Bramah had posted his offer, Alfred Hobbs, an American, won the prize in 1851 after fifty hours' application.

This, being no ordinary lock, could hardly be made by ordinary means. To make it entirely by hand, as a watch was made, was out of the question. Locks had to be made by the hundred to sell at a reasonable price. Bramah saw that he needed machine-tools. But who could design and build them?

"Send for Henry Maudslay of the Woolwich Arsenal" said some one in Bramah's shop.

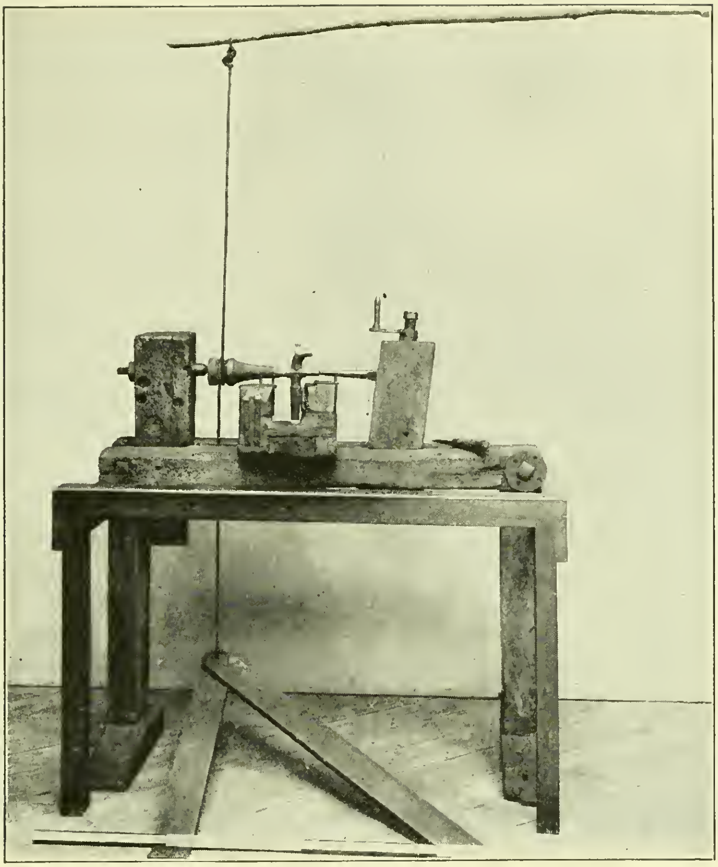
Bramah sent for him. A youth of eighteen presented himself. Bramah was amazed. A boy do his work! It seemed impossible. But the boy talked so convincingly, so intelligently, that Bramah engaged him. One year later Maudslay was the superintendent of the shop. He continued with Bramah for eight years and finally had to give up his place because Bramah would not pay him more than thirty shillings a week, which he did not consider enough to support himself and his family. Maudslay then set up in business for himself and eventually became a rich man.

Henry Maudslay was one of the ablest mechanics that ever lived. Even after he had become rich and hired men by the hundred he loved to go into the shop and do a particularly fine piece of work himself. Nasmyth, himself a fine craftsman, said of him: "No one I ever met could go beyond Maudslay in the dexterous use of the file. By a few masterly strokes he could plane surfaces so true that when their accuracy was tested by a standard plane surface of absolute truth they were never found defective; neither convex nor concave nor cross-winding—that is, twisted."

These two men, Bramah and Maudslay, were probably the finest mechanics of their time. Both were able inventors. The device with which their name is forever linked is the slide-rest, the value of which will be seen if we consider the lathe of the eighteenth century.

The lathe was set up between two centres so that it could turn freely, and a cord was passed around it. The cord was attached at one end to a light, springy pole fastened to the ceiling of the shop, while at the other end it was secured to a foot-board resting with one edge on the floor. When the workman stepped on the board the cord was pulled down and, in doing so, turned the work on its centres; as soon as he lifted his foot the pole, springing back, pulled the cord up and the work turned in the opposite direction. How the " pole lathe " worked will be evident after a glance at the picture appearing on page 317. By holding a chisel against the work the mechanic, if he was skilful, could turn out a very creditable piece of work in wood; but it was a far more difficult matter to turn brass and iron with such a crude lathe. Even when the lathe was improved by using pedals and a fly-wheel to turn the work always in the same direction, it took a skilled mechanic to hold the cutting tool steady while he was jigging up and down on the pedal.

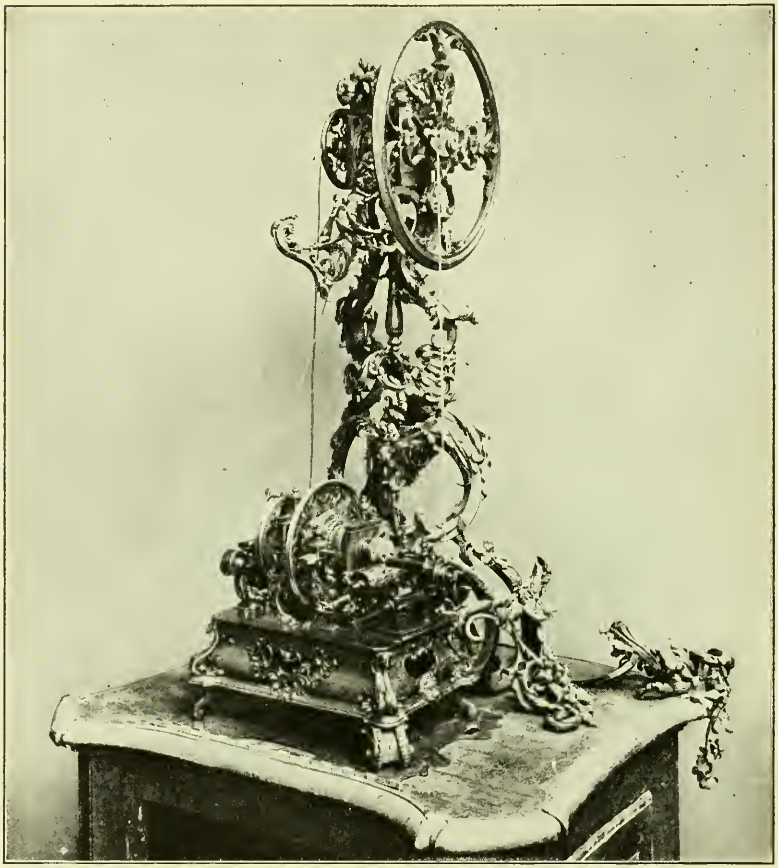
With such a pole-lathe the cutting tool could not be held firmly. The lathe needed an iron fist. Of course, the fist would have to move along the work, and to do this steadily Bramah and Maudslay made it in the form of a carriage that was fed the length of the lathe-bed by means of a screw. There were no quivering nerves in the iron fist, no throbbing pulse. It did not tremble or shake, but held the tool with a firm and rigid grip and made it travel along the work at a uniform speed. The output of the new lathe was far superior to anything turned out with the old pole-lathe and hand-rest. By means of gears, the



Courtesy of the South Kensington Museum, London.

THE EUROPEAN POLE LATHE OF THE SEVENTEENTH AND EIGHTEENTH CENTURIES.

The earliest known form of lathe, the pole lathe, consisted of two fixed centres between which the work was supported, and motion was given to the work by a bow, the string of which was wrapped around it, or by a cord the ends of which were pulled by an assistant. The turner was seated upon the ground holding a tool against a rest with one hand, and working the bow with the other, the cutting being performed during one-half of the motion when the work was revolving toward him. Such lathes are still used in the East. In Europe, probably owing to the erect position generally adopted by the turner, the fixed centres were placed higher, and an improved method of locating the work was employed. For the bow a spring-beam or pole above the lathe was substituted, and a cord was fastened to the free end of it, then wrapped around the work, and its lower end attached to a treadle to be worked by the foot. This method largely increased the power and left both hands free for the management of the tool. Machines of this type were used as early as the sixteenth century.



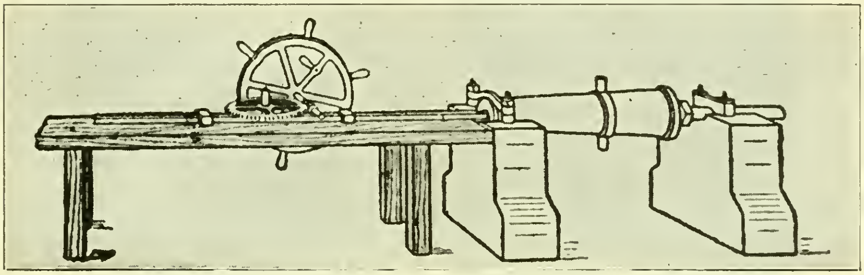
Courtesy of the South Kensington Museum, London.

A GERMAN LATHE MADE ABOUT 1750 FOR ORNAMENTAL TURNING.

This is the bench portion of the lathe which was driven from a pulley on an overhead shaft carrying a fly-wheel which received its motion from a cord connected with a treadle in the base. The shaft was supported in an adjustable bearing-box, carried by a frame-box secured to a massive wooden cabinet with which the lathe was combined, but the whole machine was covered with a mass of rococo decoration by which the frame was concealed. The art of rose-turning, or producing waved lines in the lathe, appears to have originated about 1650, and reached the height of its popularity about the middle of the eighteenth century, when all kinds of articles were ornamented in this way. After a revival about 1800 the art declined, and is now applied only to such articles as the backs of watch-cases.

feed-screw could be made to turn so fast that the tool would cut a spiral groove in the work. In this way screws were cut on the lathe.

It is not certain whether Bramah or Maudslay invented the slide. Probably it was a joint invention, certainly an invention that came out of Bramah's shop. Independently of Bramah and Maudslay, the slide-rest was invented in America by David Wilkinson, a man who built a steamboat long before Fulton, devised cannon-boring machinery, designed sperm-oil presses, improved the mechanical process of making nails, and did more than any other man, except his son-in-law Samuel Slater, to establish an American textile industry. His slide lathe patented in 1798 was not generally introduced for many years. In 1849 Congress granted him $10,000, "for benefits accruing to the public service for the use of the principle of the gauge and sliding lathe, of which he was the inventor."



JOHN WILKINSON'S BORING MILL, 1800.

In this machine was first utilized the guide principle for machine-tools in boring steam-engine cylinders and cannons.

Parliament's Embargo on British Machinery

A new industrial era was opened by the invention of textile machinery and the steam-engine. The age of power, the age of the factory, had dawned. There was a growing demand for machinery that could be driven by the steam-engine, a demand that could not be met by the old boring tools and lathes. Englishmen, like John Wilkinson, Joseph Bramah, and Henry Maudslay, were in a sense the creatures of industrial circumstances. They were great inventors, great mechanics, but the character of the times dictated the character of their inventions.

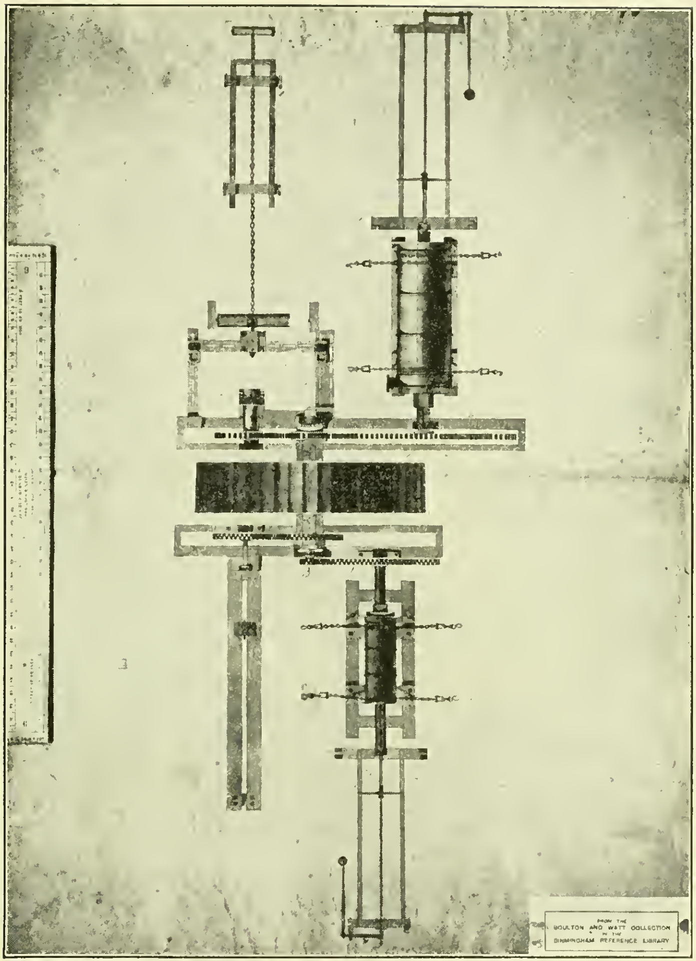
And so it was in America. David Wilkinson and many who followed him were also creatures of circumstances, but of circumstances that were not the natural outgrowth of remarkable inventions. The British Parliament provided the stimulus that men like David Wilkinson needed. They would have been willing enough to buy their tools from England, but England would not have it so. When the American colonists began to turn their attention to the development of their iron mines, England, fearing that she might lose her commanding position, prohibited the building of furnaces, rolling-mills, slitting-mills, and forges in America and opposed manufacturing of all kinds. This attitude of the mother country toward her colonies was one of the causes of the Revolution. After the war, when England could no longer dictate what might and might not be done in America, Parliament foolishly passed a law prohibiting any mechanics or skilled workmen from leaving the shores of England, hoping to prevent other nations and particularly America from learning her trade secrets and acquiring her skill in manufacture. It

JOHN WILKINSON.

THOMAS BLANCHARD.

John Wilkinson, the great eighteenth-century ironmaster, made it possible for Watt to build his steam-engines. It was Wilkinson who introduced the modern boring-mill. He ordered one of the first Watt engines for his foundry, first applied steam-power to forging, supplied the castings for an iron bridge, launched the first iron barge, and devised the modern method of drawing lead pipe.

Thomas Blanchard manifested a strong mechanical bent even as a boy. He invented a machine for making tacks, the profile lathe for manufacturing gun-stocks, and many other special machines used in making of guns and other articles.



Courtesy of the South Kensington Museum, London.

DRAWING OF THE FIRST STEAM-CYLINDER BORING MACHINE.

This drawing, copied from the original in the Boulton and Watt collection of Birmingham, represents the cylinder boring-mill which was invented by John Wilkinson in 1775, and on which all James Watt's steam-engine cylinders were bored between 1775 and 1795. It was the first boring machine that could bore a true cylinder. The earliest cast-iron Newcomen engine cylinders were bored on a cannon-mill by a rotating cutter-head fixed on the end of an overhanging bar, driven by a water-wheel or horse. Wilkinson's invention consisted in fixing the cylinder in a cradle and passing through it a long, stiff, hollow boring-bar, mounted in bearing at each end. A sliding cutter-head was mounted on the bar, and was traversed along it, by means of a long rod passing down inside the bar.

was because of this law that Samuel Slater (whose work in the textile industry is described in another chapter) had to disguise himself when leaving his native land for America. Slater was not only an all-around mechanic but a man who had a thorough knowledge of textile machinery. Slater had not dared to bring any drawings with him, but he carried in his head the details of Arkwright's spinning machinery, and, trusting to his memory alone, he designed and built, with his own hands, America's first carding and spinning machinery. He came to be known as "the father of the American cotton industry," and it was this industry that gave the machine-tool development its early start in America.

To build the machinery demanded by the budding American textile industry called for skilled mechanics, and as these could not be imported from abroad they had to be developed at home. Besides that, the scarcity of mechanics skilled in the use of hand-tools acted as a spur to the invention of machine-tools, and the Parliamentary embargo upon mechanics, instead of assuring England's monopoly of manufacturing, had the very opposite effect. America was forced to build its own machinery and develop its own tool builders. As a result, before long, "Yankee genius" came to be a by-word the world over, and, in time, American machinery began to find its way into English markets.

Eli Whitney and the Interchangeable-Parts System

We are accustomed to think of Eli Whitney only in connection with the cotton-gin, forgetting that he was one of the pioneers in the building of machine-tools and that he established what became known in England as the "American system of manufacture." Whitney's father, who was a farmer, had a workshop where farm implements were repaired. The shop was fairly well equipped with tools, and young Eli learned how to use them with remarkable skill.

The story of how Eli Whitney went down South after graduating from Yale University, to serve as a tutor in a rich Southern planter's family; how he chanced to learn of the difficulty the planters experienced there of separating cotton-fibre from the tenacious seed, how he invented a machine in which the cotton-seeds were held back by a grating while a set of circular saws reached in between the bars and pulled the fibre off the seeds—all this and more about cotton is told under "Cotton: from Plantation to Loom," in this book. What concerns us most at the moment is that the cotton-gin came just after Slater had established the first cotton-spinning mill in America, and thus an industry was started which was largely responsible for the development of machine-tools in America.

We can pass over the trouble that Whitney had in maintaining his patent rights in the cotton-gin, and pick up his history again at the point where, discouraged over his fight with persistent infringers and despairing of the outcome of his legal battles, he tried his hand at an entirely new venture. Possibly it was these very battles that turned his thoughts from the peaceful cotton-fields to the field of war. At any rate, in 1798 he obtained a contract from the United States Government to manufacture 15,000 muskets. Whitney had no experience in making guns, but he was sure that he could make them successfully and was bold enough to try, even though failure meant a heavy money penalty. But the interesting thing about this contract was that Whitney undertook to manufacture these muskets in an entirely new way.

There is a big difference between *building* a thing and *manufacturing* it. We build yachts and houses, but we *manufacture* automobiles and sewing-machines. No two yachts are exactly alike. They are built to order, and, even where the same plans are used, there are slight differences. The parts must be trimmed, sawed, planed, filed, or drilled as they are put together. Sewing-machines, on the other hand, are turned out by the thousands, all exactly alike. The parts are made in large quantities. Wheels, shafts, levers, pins, plates are all gauged with such precision that they do not vary in important measurements by one or two ten-thousandth parts of an inch, so that when it comes to assembling the machine no filing or scraping is required. Any wheel out of ten thousand will fit perfectly on any one of ten thousand shafts. The work of manufacturing the machine is divided into hundreds of different tasks. One mechanic will do nothing but turn out foot-plates, another will do nothing but turn out studs. This is what we mean by manufacturing in these days. "Quantity production" is the designation used in many industries.

In Whitney's time no such system was known, because handwork was not sufficiently accurate and such few machine-tools as were in use did not operate with the necessary precision. Besides that, there were not many standard articles that had to be turned out in large enough quantities to make such a system pay. Even muskets which should have been of standard size and were needed by the tens of thousands were "built" rather than "manufactured." Trained gunsmiths who had acquired their skill by years of labor in the shop, built the entire musket from barrel to flint-lock, filing, grinding, and drilling the parts to fit as they went along. Consequently, there were no two muskets exactly alike. Hence, if any part of a musket was injured or broken in service it had to go back to the machine-shop, where a skilled gunsmith forged a new piece and shaped it to take the place of the damaged part. Such a thing as having on hand a quantity of stock parts which could be slipped into place without filing or fitting was something unheard of, and in time of war gunsmiths could not begin to keep pace with the damage done on the field of battle. Thousands of broken muskets could not be fired for lack of ready repair parts. At the time of the War of 1812, the British Government had over 200,000 muskets either partly finished or awaiting repairs.

When Whitney obtained his contract from the government there was an unfortunate shortage of skilled mechanics in this country, owing to the objectionable policy of the British Parliament; and since it took years to train an all-around mechanic, Whitney had to depend upon machines. By perfecting his machines he believed that he could avoid the slight differences that invariably shcw themselves in hand-work, and make the parts with watch-like precision. He planned to have his men specialize on different parts of the gun and make these parts so accurately that they would be interchangeable and would not require an experienced gunsmith to fit them together into a finished musket.

Whitney built a mill at a spot near New Haven, now known as Whitneyville. The mill was located by a stream from which he obtained the power to drive his machinery. For nearly two years not a musket was turned out. Those who visited the shop found him busy building machinery instead of guns. He was organizing his system and building "machines for rolling, floating, boring, grinding, and polishing." Whitney outlined his plan to some English and French ordnance officers, explaining the advantages of having interchangeable parts in stock in time of war. They laughed at him. A Frenchman had tried to do the same thing fifteen years previously, but his plan had not met with success. As time went by and the government officials watched Whitney build his equipment without turning out a single musket, they began to grow uneasy. Unruffled by criticism and with his accustomed determination, the inventor kept steadily at work. According to his contract he must begin to make deliveries inside of two years, but the time was nearly up and still not a single musket had come out of his shop.

Then one day Whitney turned up at the office of the Secretary of War with an assortment of miscellaneous pieces which he arranged in piles. Each pile consisted of ten pieces, all the pieces in a pile exactly alike. Then to the astonishment of every one present he picked out a piece at random from each pile, fitted the pieces together and produced a complete and perfectly working musket. Again he repeated the performance and handed out a second perfect musket. Whitney kept on until all the pieces had been used up and he had handed out ten complete muskets for inspection.

The fame of this exploit spread over the civilized world. But gunmakers of Europe were slow to adopt what they called the "American system." It was difficult for them to get out of the rut in which they and their forefathers had been travelling. In this country, however, Whitney's system was tried in other lines of manufacture with great success.

How Chauncey Jerome Fooled the British Customs

Forty years after Whitney showed the way, a Connecticut Yankee, Chauncey Jerome, hit upon the idea of making brass clocks with interchangeable parts. Before that, clocks were largely made of wood, and the cheapest movements cost five dollars, even when made by machinery; hand-made clock movements brought as much as fifty dollars. But Jerome, by using the interchangeable system of manufacture, turned out one-day brass clocks that cost less than fifty cents each. To produce them at any such price he had to make them in large quantities, and soon the markets were flooded with Jerome's cheap time-pieces.

They were peddled all over New England and the neighboring States, and Jerome began to wonder where he was going to dispose of the ticking stream that poured out of his factory. Then it occurred to him that England ought to offer a good market for his wares. He made arrangements with a British dealer and sent over a shipment of clocks in 1842. The British Government placed a duty on time-pieces in those days, and when Jerome's cheap clocks arrived the custom's authorities thought he had put a low price on them merely to reduce the amount of duty he would have to pay. They had an ingenious way of punishing any one who undervalued his goods, which consisted in buying the goods at the invoice price. Much to Jerome's surprise a letter came to him from the British Custom-house informing him that his clocks had been confiscated and enclosing a draft for the full invoice valuation of the goods. But the punishment sat very lightly on Jerome's shoulders. He was just as willing to sell to the British Government as to any one else, particularly as he did not have to wait for his money, and did not have to pay any agent's fee. He sent over a larger shipment of clocks and awaited results. Sure enough, in due course a second draft came back from the British Government. Jerome roared with laughter. The next time he sent over a whole ship-load of clocks. This was too much for the British Customs authorities. It dawned on them that the Yankee clockmaker could really make cheap clocks, and they let the shipment in at his invoice price without any further trouble.

Whitney Invents the Jig

Whitney was so hard put to it for skilled workmen that he had to invent machines that would serve as human arms and fingers. One of his most important devices, found in every machine-shop, rejoices in the frivolous name of the "jig." Suppose a plate is to be drilled with ten holes which must register exactly with ten holes in another part. It would be a tedious matter to measure them off and lay out their positions with any great degree of precision. Only an experienced mechanic could be trusted to do the work, and Whitney had all too few such mechanics. If ten thousand such pieces were to be drilled the work would take an eternity, and even if the same man laid out the positions of the holes in each case, there would be certain slight variations in the different pieces, because it is impossible for a man to avoid slight errors.

A jig makes errors impossible. A box is made into which the plates are fitted. Over the box is a lid or frame in which holes are drilled by a skilled workman at exactly the required spacing. After that *no* further skill is required. One after the other the plates are fitted into the box and drilled through the holes in the lid without stopping for measurement, and in all the pieces the holes must be spaced exactly alike. It was in this way that Whitney obtained machine-like precision, even though he had to do largely without machines and had scarcely any trained mechanics. Whether he invented the jig or not is a disputed question, but he was certainly one of the earliest users of it. To-day we cannot get along without the jig. It is a holder for the piece of work and at the same time a guide for the tools that are to be used on it. It helps us properly to set up a piece of work in a machine.

Whitney and the Milling-Machine

One would suppose that the inventor who gave us the cotton-gin and who founded the "American system" of manufacture had done about enough for one man; but there was one other invention of Whitney's which is of the utmost importance in machine-work. Most of the standard machine-tools had been invented either before or at about the time that Whitney turned his thoughts to gun-manufacture. In all machine-tools either the work is fed to the tool or the tool to the work. In a lathe the work is revolved against the tool. In the planer the work is fastened to a table and slides against the tool. The boring-mill is a cross between a lathe and a planer, the tool being held as in a planer and the work fastened to a table, but in such a way that it revolves against the tool as in a lathe.

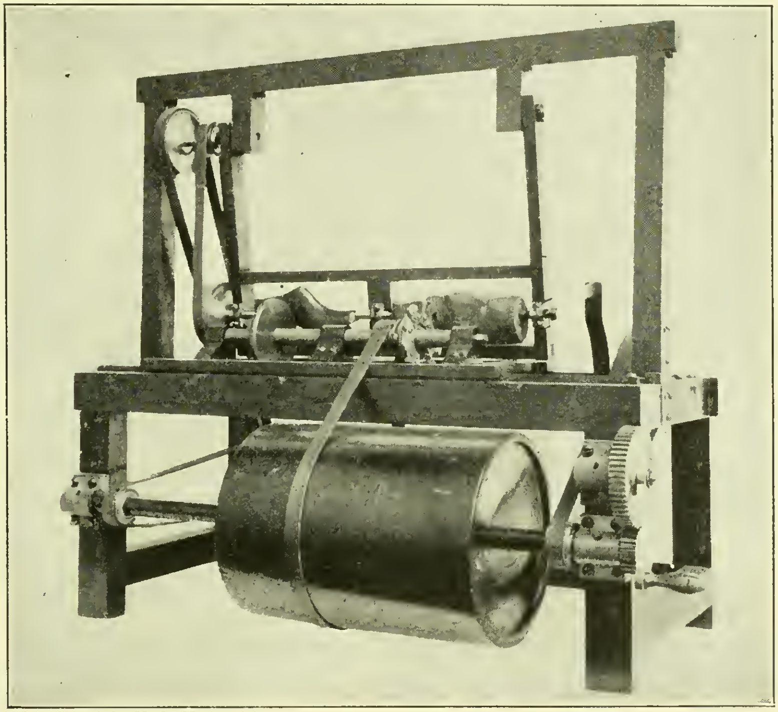
Moreover, the work revolves on a vertical axis instead of a horizontal axis. In a shaper we have the reverse of a planer—the work stands still, while the tool moves back and forth over it. In none of these machines does the tool rotate. But when we come to the drill we find the tool turning and feeding itself into the work while the latter remains stationary.

Now it remained for Whitney to invent a milling-machine in which the tool rotates while the work is fed against it. To-day no machine-shop is complete without milling-machines. Of course they have been vastly improved. If Eli Whitney could visit a modern busy machine-shop and see a battery of "universal millers" at work, he would probably not recognize in these marvellous machines the grandchildren of the simple little milling-machine which he built about 1818. Whitney's original milling-machine may be seen in the Mason Laboratory at Yale University.

Blanchard's Gun-Stock Lathe

The making of muskets, pistols, rifles, and revolvers played a very important part in the history of American machine-tools. This is perfectly natural when we consider that firearms were really the first machines that had to be built with great precision and in large quantities. One of the men who helped materially in the manufacture of muskets was Thomas Blanchard. People who knew him as a boy never thought he would amount to much because he stammered badly and was very timid, but he had a mechanical turn of mind and was always tinkering at something. When he was but eighteen years old he began working on a machine that would make tacks. It took him six years to perfect his invention, but then he had a machine that would turn out two hundred tacks per minute. He sold his patent for $5,000, which was considered a very handsome price, and continued to devote his inventive genius to various problems and produced many labor-saving devices.

One day he overheard a couple of workmen in the Springfield Armory talking about his inventions and complaining that they were robbing mechanics of their jobs. One of them said: "Well, I don't care, he can't take away my job. He can't invent a machine that will turn out gun-stocks." Blanchard took that as a challenge. Shortly after he build a "gun-stocking" lathe. Instead of a fixed tool he used a rotary cutter. The roughed-out wooden block was mounted to turn in a swinging frame which also carried a finished stock as a pattern. As the pattern turned against a fixed wheel it moved the wooden block in and out against the cutter, varying the depth of cut so as to turn out an exact duplicate of the gun-stock. That was the first "profile lathe," as we call it, and it was the forerunner of many ingenious wood-working machine-tools. The original machine, built in 1818, is still on exhibition in the Springfield Armory.



Courtesy of the U. S. National Museum.

BLANCHARD'S PROFILE LATHE.

Original form of the Blanchard profile lathe for turning gun-stocks or shoe-lasts. It is preserved in the United States National Museum. Instead of the customary fixed tool Blanchard used a rotary cutter. The rough-hewn wood block was mounted to turn in a swinging frame, which also carried a finished gun-stock or shoe-last as pattern to be followed. As the pattern turned against a fixed wheel it moved the wooden block in and out against the cutter, varying the depth of cut so as to turn out exact duplicates of the gun-stock, shoe-last, or other eccentric form.

Another leading figure in the history of American machine-tools was Richard S. Lawrence. When he was only nine years old, his father's death forced him to give up schooling and work on a farm. At the age of fifteen he found a job in a woodworking-shop. There was a gun-shop in the basement of the building, and here young Lawrence spent all his spare hours until he became an expert gunmaker.

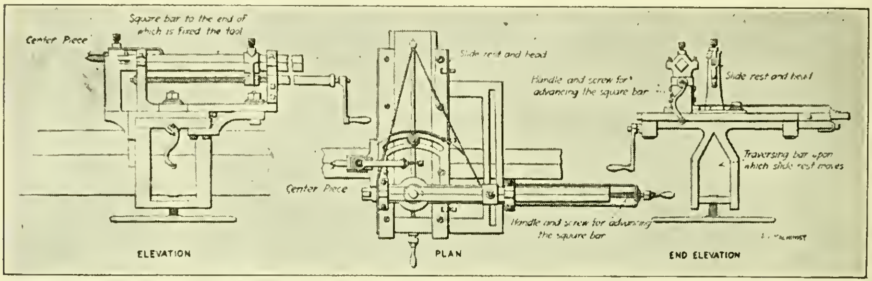
He was twenty-one years of age when an incident occurred that gave him a real start in life. He was visiting a Doctor Story in Windsor. The doctor had a rifle that he highly prized but which at the time was sadly in need of repairs. Lawrence offered to repair the gun and fit it with a peep-sight. The doctor was very reluctant to give his permission, but he was so greatly interested in the peep-sight, which was something he had heard of but had never seen, that he finally consented. The next day Lawrence took the gun all apart, cleaned it thoroughly, leaded out the barrel, forged a peep-sight, and fitted it to the gun. The doctor on his return that night was enthusiastic in his praise of the job. Most of the next day Lawrence spent in trying out the gun and adjusting the sights. When the doctor returned from his daily visits he went out to witness the shooting qualities of the gun. He paced off twelve rods from a maple-tree in which a three-quarter-inch auger-hole had been bored for drawing off sap. This was to be the target. Lawrence lay down on the ground, took careful aim, and fired. The doctor, who was tending target, told him he had missed. Again Lawrence fired with the same result. The doctor became irritated and declared that his rifle was spoiled. When Lawrence offered to make the gun all right he would not consent to any further tampering with his rifle. As the gun was loaded Lawrence said he would take one more shot. After he pulled the trigger he went up to the tree to examine it for himself, and to the great astonishment of the doctor he dug out the three bullets from the auger-hole. Doctor Story had never heard of such accurate marksmanship, and he was delighted with the peep-sight. He insisted that Lawrence go down with him to show off his peep-sight to N. Kendall & Co. at Windsor Prison, where they were making guns. They employed a number of freemen as well as prisoners, and here Lawrence obtained a two-years' job at $100 per year and board. In six months he had risen to the position of foreman of one of the shops, and as such acted as a turnkey and had a section of the prisoners to lock up.

Six years later (1844) Lawrence formed a partnership with his former employer, Kendall, and another man, S. E. Robbins, and started in to make rifles for the government. They had a contract to finish 10,000 rifles in three years' time. It was a notorious fact that gun contracts were never finished on time, but Lawrence determined that this was to be a grand exception. They had nothing to start with, no machinery, and not even a building in which to do the work. However, Lawrence started in with a vim, and much to the astonishment of the War Department the contract was completed within a year and a half. It was this concern which, in 1857, exhibited a set of rifles built on the interchangeable system at the Exposition in London. British ordnance officers were greatly interested in the exhibit and sent a commission to investigate the "American system" of manufacture. Although they had learned of Whitney's work half a century before, they had not really awakened to the importance of this method of manufacture. In a few years' time the "American system" was installed not only in England but in the leading gun-factories of Europe.

The Invention of the Turret-Lathe

It was from the works of Robbins and Lawrence that there came, in 1854, the most important improvement in lathes since the day when Maudslay and David Wilkinson invented the slide-rest. Up to that time lathes were fitted with a single tool, but Robbins and Lawrence put out a lathe which was fitted with a revolving tool-holder or "turret" in which a number of tools were fitted. These were set so that after one tool completed its work the turret could be turned to bring the next tool into operation. And so, without taking time to change tools and set them, a whole series of operations could be performed.

There were two men in the plant to whom credit for the turret-lathe belongs—Henry D. Stone and Frederick W. Howe, though it is quite probable that Lawrence himself had much to do with developing this machine. Of course, when any really important invention is brought out, men who claim to be prior inventors turn up. As a matter of fact, a lathe with a turret was built by Stephen Fitch in 1845, but the Robbins and Lawrence machine was the first to be manufactured and put on the market. This was the forerunner of those marvellous automatic screw-machines that seem to work with human intelligence, bringing one tool after another into play until the piece of work is completed, and then feeding forth another piece of rough stock to be operated upon. There is no machine in our shops that turns out so much and so great a variety of work as the automatic screw-machine.



By courtesy of the American Machinist.

DRAWING OF THE BRAMAH–MAUDSLAY SLIDE–LATHE OF 1795, PREPARED BY PROFESSOR JOSEPH W. ROE.

Who invented the slide-lathe it is impossible to determine with absolute certainty. It has been attributed to both Bramah and Maudslay. Probably it was a joint invention of the two, for it came out of Bramah's shop, where Maudslay was employed.

In the first turret-lathes the turret had to be turned by hand; then came the machine which took care of itself, automatically bringing the tools into play as needed. The man who did most to make the turret-lathe automatic was Christopher M. Spencer, and it is interesting to note that he also was a crack shot with the rifle and made his start as a gunmaker. Just before the Civil War broke out he obtained a patent on a repeating rifle, and he supplied the Federal armies with 200,000 of the type. At the close of the war he invented a machine for turning out spools for sewing-machines, and then was fired with the ambitious scheme of building a machine that would make machine screws automatically. Of course he had to use a turret-lathe for this work, but he fitted the lathe with cams, to feed each tool into the work, withdraw it after it had finished its cut, and turn the turret to present the next tool to the work. A cam ought to be familiar to any one who has ever driven an automobile. The cams of an automobile are on a shaft, and they automatically lift the engine valves at the right time.

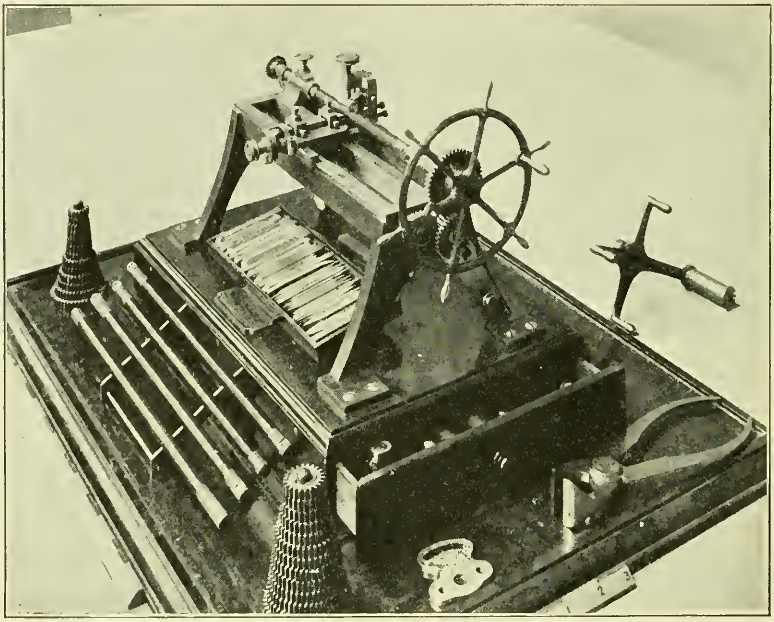
The most important improvement in Spencer's machine was the use of these cams, which he built in an ingenious way. Of course, for each job a special form of cam would be required; so Spencer made his cams in the form of a plain cylinder on which he fastened strips of metal that were adjustable for different settings. Spencer applied for a patent on his machine, but unfortunately his patent attorney did not understand or appreciate the importance of these adjustable cams and did not cover them in his claims, so that Spencer failed to get patent protection on the most important part of his invention.

Single-Spindle and Multiple-Spindle Lathes

We cannot go on detailing all the improvements in "automatics" down to the present day, nor mention all the inventors who played a part in their development. The most important steps were the provision of a hollow spindle through which the stock is automatically fed to the tools, and the multiple-spindle lathe which will be explained presently. In the single-spindle machine, the bar of steel, out of which the pieces are to be made, is placed in the hollow spindle and is seized by what is called a "chuck," with a portion of the stock projecting from the face-plate. The tools that are to work on the end of the piece are mounted in the turret, while those that work on the side of the piece are mounted in cross slides working from opposite sides of the piece. One after another the tools come into play until the piece is completed; then one of the side tools cuts it off the stock and it drops into a hopper. At the same instant the jaws of the chuck open and the stock bar or rod is moved forward to present a fresh length for the tools to operate upon.

Except for setting the tools in the first place and seeing that there is plenty of lubricant flowing over them, the machine requires practically no attention and will keep on turning out finished pieces all day long, if it is kept supplied with stock to work upon. One man can therefore take care of a number of machines.

This would seem to be perfection, but mechanical engineers were not content. The machine was not doing as much work as it should because, while one of the tools carried by the turret was busy, all the others had to stand idle until their turn came. This led to the invention of the multiple-spindle lathe. In such a lathe, four hollow spindles are geared together so that they all turn at the same time. Four bars of stock are fed through these spindles, and the turret, with its four tools, is mounted on a horizontal shaft, so that each tool is opposite a spindle. All the tools are working simultaneously, but each is doing its own task. One may be facing, another drilling, the third reaming, and the fourth counter-sinking. At the same time the side tools

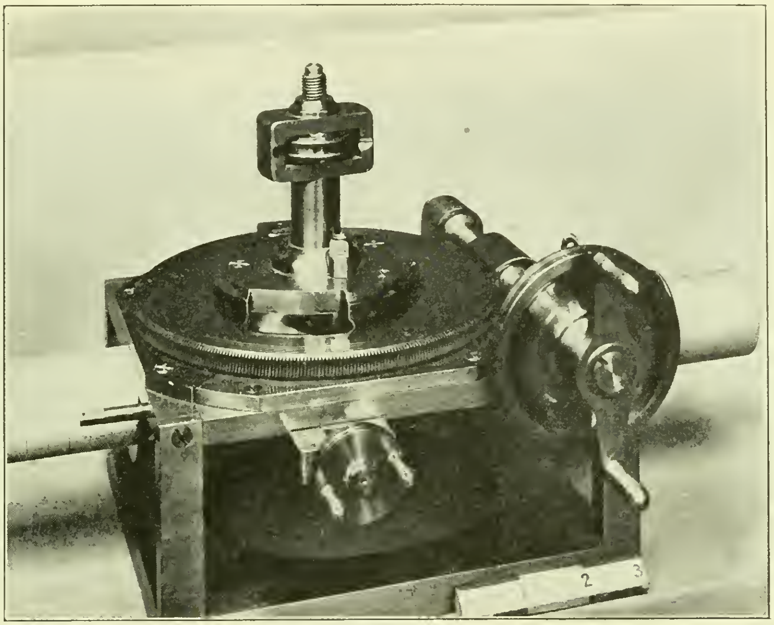

Courtesy of the South Kensington Museum, London.

ORIGINAL MAUDSLAY SCREW-CUTTING MACHINE.

This is a small example of the original screw-cutting apparatus invented by Henry Maudslay, about the year 1800, and preserved in the South Kensington Museum, London. A mechanical tool-holder or a slide-rest is combined with a power-driven screw-feed, the result being a screw-cutting lathe.

are forming, knurling, or thread-rolling, finishing, and finally severing the pieces one after the other. The output of such a machine is four times that of the single-spindle lathe.

There have been countless improvements in the automatic lathe until it stands to-day the most nearly automatic tool in the machine-shop, and its perfection, with that of the milling-machine, has placed American machine-work well in advance of the whole world. A pen-picture of these modern "automatics" has been drawn by the editor of this volume in an article from which the following has been abstracted:

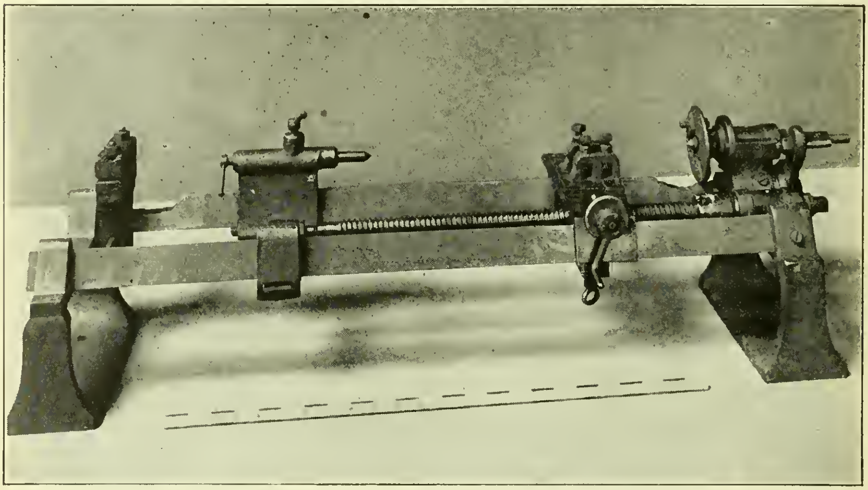


Courtesy of the South Kensington Museum, London.

MAUDSLAY'S MACHINE FOR PRODUCING SCREW-THREADS OF ANY DESIRED PITCH.

This appliance was made by Henry Maudslay, about 1800, for the purpose of producing screw-threads of any desired pitch. He had tried to obtain an accurate thread by winding steel-tape around a cylindrical bar, and by other means, but the method introduced in this machine consists in the use of a chisel-edge secured at the calculated angle with the axis of the bar to be screwed and free to travel without turning along the revolving bar under the action of the inclined edge. Cylinders of hard wood and soft steel were employed, and from the best of the screws thus obtained copies were produced in steel for use as standard screws, which were subsequently still further improved by various methods.

"Extraordinarily human are these automatics. . . . Would you like to see one in action? If you were to work on a piece of steel, you would first mark off the length of material that you want. A bolt machine does that. Then it presents the marked bar to a cutting tool. The first thing that the tool does is to *feel* the bar. 'Oh,' it says, 'you're too thick,' and so it proceeds to peel off the outside by just the right amount.

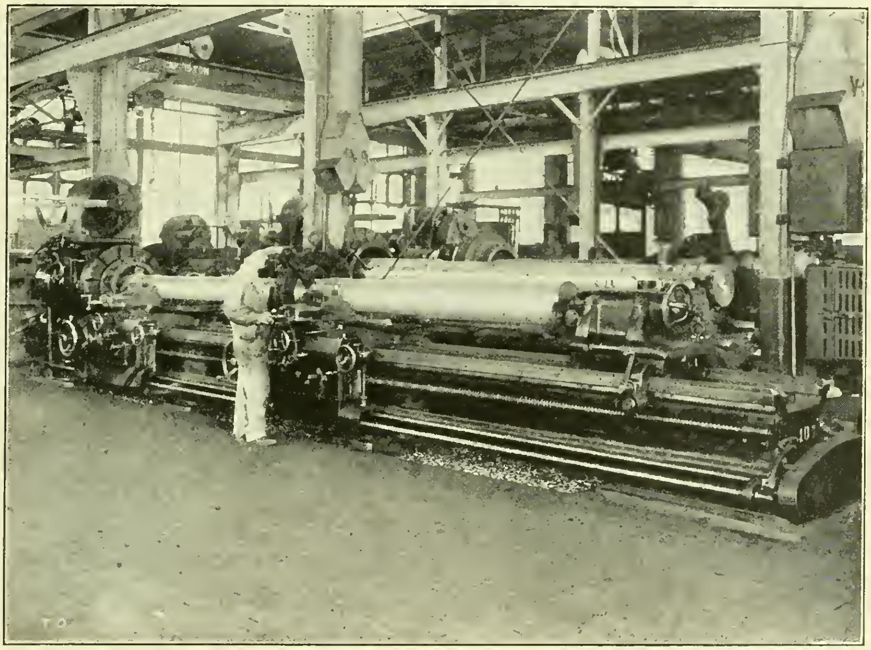


Courtesy of the South Kensington Museum, London.

MAUDSLAY'S THREAD-CUTTING LATHE.

This lathe was constructed at the end of the nineteenth century, and is believed to be the first workshop machine in which Henry Maudslay combined a leading screw and change-wheel for producing screw-threads.

Then that peeler backs off all by itself, and the bar is revolved and brought in line with a second tool. Now that tool's business is to cut a groove in the bolt and nothing else. So it gouges out the groove. 'That will do for you,' says the groover, and backs away; whereupon the bar is turned by a bloodless steel arm into line with a third tool. What does that do? It comes out and bores a hole in the end of the bolt. While it does so the first three tools attack fresh bars of steel. When the borer mechanically decides that the hole is deep enough it withdraws itself. And so the bar is presented to tool after tool. Finally the last cutter is reached. It notices, as it were, that the bolt is about finished, and so it proceeds to cut the bar off. Just as the bolt is ready to fall, metal fingers reach out and clutch it. 'You're not done yet,' says the machine. 'You need a hole for a pin.' And the fingers carry the bolt to a little drill, which bores a transverse hole for the pin. The job is done. The machine knows it and drops the finished bolt into the basket."



THIRTY-SIX-INCH LATHE-TURNING PROPELLOR-SHAFTS AT THE TACONY ORDNANCE WORKS.

The grinding-machine is another tool that was strictly an American invention. In order to finish the needles and foot-bars of a certain type of sewing-machine, Joseph R. Brown hit upon the scheme of using an emery-wheel on a lathe in place of the ordinary tool. With this he was able to finish the pieces to an exact measurement after they had been hardened.

This machine was put on the market in 1865. Out of it grew the universal grinder, which plays an important part in the machine-shops of to-day. Brown himself perfected a universal grinder, which was exhibited at the Centennial Exposition in Philadelphia, but he died just before the machine was put on the market in the summer of 1876.

Joseph Brown's Universal Miller

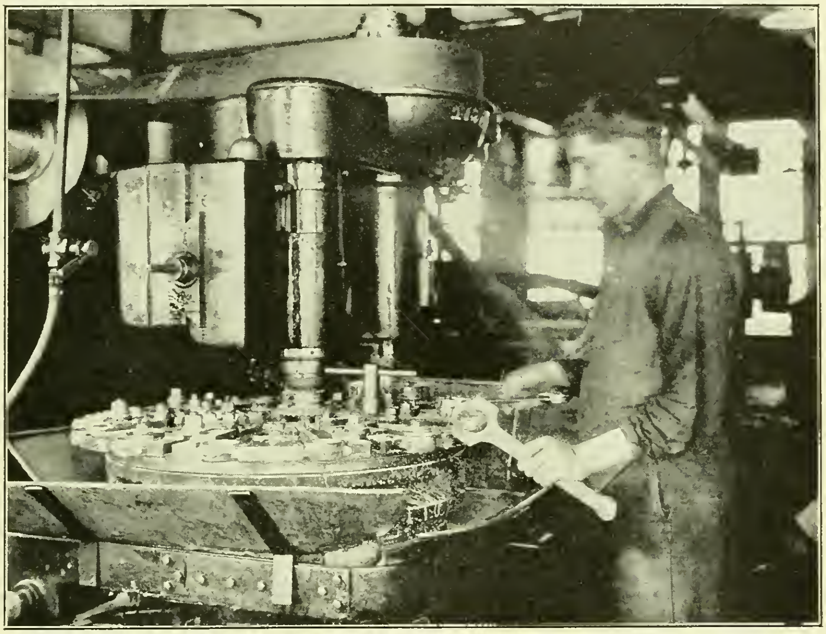
Brown was also a pioneer in other types of machine-tools. The machines that he was manufacturing called for very careful and accurate work, and it was in his shop that the modern micrometer was developed, with which it is possible to measure down to the thousandth part of an inch. In Eli Whitney's day certain parts of a gun were made with such accuracy that they varied by less than the thickness of two sheets of paper, or say six one-thousandths of an inch. Brown in his sewing-machine worked to one one-thousandth of an inch. To-day, on certain classes of work, the parts are gauged to one ten-thousandth of an inch, and it is common practice to work to half a thousandth of an inch.

It was Brown who invented the universal milling-machine; that is, one in which the work could be revolved and fed crosswise and longitudinally. Frederick W. Howe suggested the machine. Howe saw some men making twist drills by the slow method of filing spiral grooves in a fine steel rod. It occurred to him that the work could be done more accurately and speedily by machine; so he discussed the matter with Brown, who was beginning to use twist drills in the manufacture of sewing-machines. Acting on Howe's hint he brought out the first universal milling-machine in 1862.

Brown also invented the first machine for cutting gears. We cannot attempt to describe all the developments in gear-cutting machinery that followed. The automatic machines for cutting bevel-gears are too complicated to be explained in this brief chapter, particularly those which cut bevel-gears with spiral teeth.

As was stated in the early part of this chapter, it was the textile industry and England's effort to keep the secrets of machine-work to herself that first spurred Americans to develop their own line of machine-tools; then it was the large government orders for firearms and the lack of skilled mechanics that brought about the interchangeable system of manufacture;

after that the manufacture of clocks and watches and of sewing-machines did much to stimulate the invention of new machines and put us ahead of all other nations in machine-work. But the greatest stimulus of all came with the beginning of the present century, when America took hold of the automobile in earnest. It was not long before we outdistanced European engineers. We paid our workmen much higher wages than they did on the other side of the Atlantic, but because of our wonderful automatic machinery we could turn out automobiles of such high quality and so cheaply that they could be sold in Europe at a lower price than European manufacturers could afford to make them. The "American system" of manufacture is now carried out to the smallest details. Special machines are built to cut down expense and turn out the various parts in large quantities. Machines are fitted with gangs of tools that work simultaneously. There are drills with many spindles all



Courtesy of the Packard Motor Co.

BECKER CONTINUOUS MILLING-MACHINE, MILLING ALL FOUR FALLS OF AUTOMOBILE CONNECTING-RODS AT ONE OPERATION.

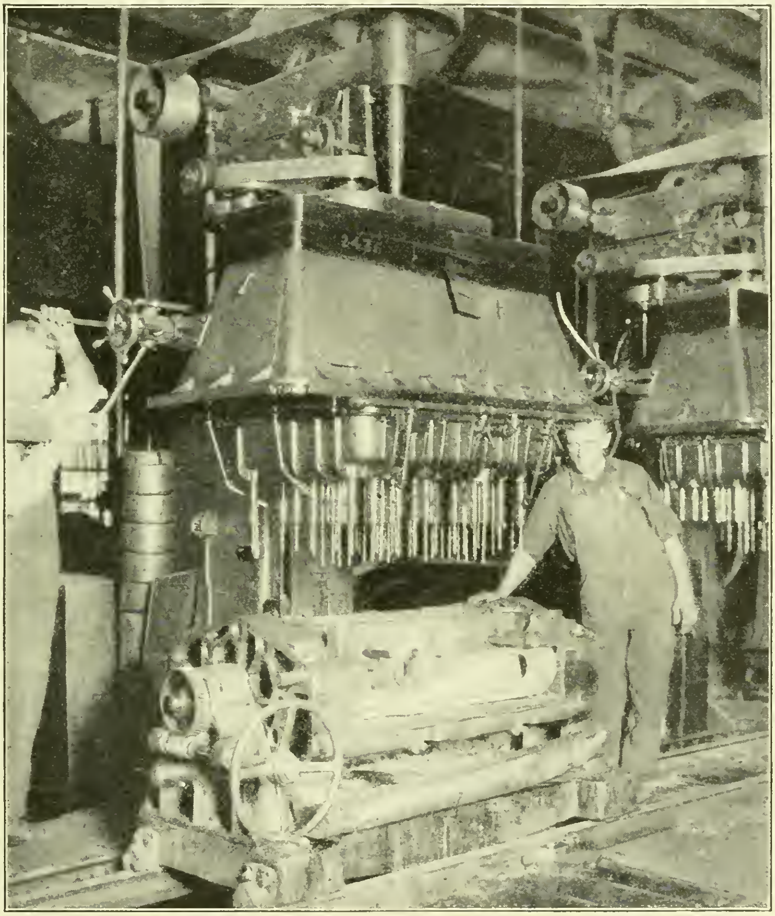
working at the same time, so that all the holes in a piece of work may be properly spaced and drilled in a single operation. Machines are set in rows so that as soon as one machine has completed its task the work passes on to the next machine in line; there is a steady procession to the assembly-room, where the parts are put together and the finished machine turned out.

Taylor's Revolutionary Methods

But the story of American machine-tools is not complete without an account of the work of Frederick W. Taylor. In fact, Taylor caused a veritable revolution in the industry. It was at the Paris Exposition in 1900 that European engineers first came in touch with his work. There they saw American machine-tools working so fast and taking such deep cuts that the chips and shavings which were turned off were at blue heat and the tools that did the cutting were red hot. Despite this heat the tools kept their temper and did not lose their cutting edge. This astonishing exhibit was the culmination of twenty years of experiment in the hands of a man of persistent and unflagging zeal.

Taylor was the father of what is called "efficiency engineering" or "scientific management." When he entered the Bethlehem Steel Works in 1880 he was distressed at the inefficiency of the workmen at that plant. It seemed to him that they did not begin to turn out as much work as they should; so he undertook to speed them up. But the men did not take kindly to his suggestions. Who was he to tell them how much work they could turn out? What did this young man know about the output of a machine?

Taylor realized that before he could make any progress he must study machine-tools and find out just what they were capable of doing. Strangely enough this matter had not been thoroughly studied before. No one could tell him what was the best cutting speed for different tools and how deep a cut they should make. To be sure, there were certain standards that had been handed down from one mechanic to another, but Taylor was not satisfied that these were the very best. He was a man of the type that had to try things out for himself. He was not content with the mere "say so" of another. Unless a statement was proved by searching tests he would not accept it. So he began to experiment with different machine-tools, trying various speeds and depths of cut, and various shapes of tools. It has been estimated that in the course of his experiments he converted 800,000 pounds of steel into chips and shavings. The experiment lasted twenty-six years and cost over $200,000.



Courtesy of the Packard Motor Co.

A MODERN MULTIPLE DRILL.

Machines of this type drill as many as eighty-one holes at one operation in a modern automobile factory; without them the modern cheap automobile would be an impossibility.

The results of this searching investigation were revolutionary. He found that the established practice was all wrong. Mechanics had shown a preference for a fine cut at high speed, but Taylor proved that a heavy, coarse cut at low speed was more efficient. It had been supposed that a tool with a diamond-shaped point was to be preferred to a round-nosed tool, but Taylor's research proved the contrary. All the old traditions were questioned and in many cases proved fallacious. He even questioned the advantage of pouring oil on the tools and tried water instead. The best tool steel of the day was known as "self-hardening steel," and he was warned by the manufacturers that he must not use water on it. But Taylor would not accept their word for it. In place of oil he played a solution of kitchen soda on the cutting tools, and to his great delight found that he could increase the speed of cutting by over thirty per cent. Then he began investigating various alloys of steel. Associated with him in this work was Maunsel White, and together they hit upon an alloy of chromium and tungsten, which showed a 300 per cent. improvement over the self-hardened steel. Later vanadium was added and still better results were obtained.

Needless to say, Taylor's researches had a revolutionary effect on the industry. Machines had to be redesigned to run at higher speeds and the output of the machine-shops was doubled and even trebled. His discoveries, coming just at the time when the automobile industry was beginning to get its stride, gave American machine-tools another impetus, which sent them far ahead of European rivals.

Like textile machinery, shoe-making machinery, type-casting machinery, electric lamps, and many other contrivances that play an ever-increasing part in our daily lives, machine-tools are no longer invented by Wilkinsons, Bramahs, Maudslays, and Whitneys. Great companies maintain staffs of hired inventors—men who design the most remarkable machines for specific purposes and do nothing else year in and year out. To them we owe the wonderful multiple-drill presses which bore eighty-seven holes at once in an automobile part, the machines that pare off the tops of a score of cylinders at once as if the steel were so much butter, the devices for reaming out several cylinders at a time—devices that would make Watt stare if he could but see them—and machines that do everything that lies within the power of the human hand. They are really automatons, these machines, for they simply mimic human motions. Each of them does the work of a score, even of a hundred men. They are characteristically American in the sense that they were invented to solve a distinctly American problem—the problem of producing vast quantities of metal articles cheaply in the face of high labor costs.

CHAPTER II

PUTTING AIR TO WORK

BEFORE the simplest forms of life came into existence, air had been assisting in the architecture of this planet for countless centuries. For millions of years it had ceaselessly lashed the sea. Air-driven breakers, moving with the irresistible might of an invincible host, since time immemorial had battled with the towering rocks and sifting sands of the seashore. They carved our coast-lines, even as a sculptor shapes his form of clay. If you wish to see a mighty monument to the work of moving air, visit the Garden of the Gods in Colorado. There you will find a vast area studded with tall columns of red sandstone, carved into fantastic shapes by air-driven sand.

The work of moving air has been of constant service to mankind. Even in this age of steam, ships are still driven by the wind, and in Holland grain is still ground by the windmill. What but air wafts inland the sea-born clouds that drop their moisture in gentle rains or fierce storms, thus watering the earth and feeding brook and river, pond and lake? Even the small boy owes something to moving air that bears his kite aloft.

The work of air is exhibited in nature, but the industrial applications of it are still young. And they are many. A vigorous youth, skilful as a magician and mighty as a giant, has leaped forth to lighten the world's burdens and perform a multitude of useful tasks. We wonder how we did so long without him.

To many men at various times and places belongs the credit of harnessing the air to perform the world's work. But, as always, certain giant figures tower above the mass. And such a giant was Benjamin Franklin Sturtevant.

The son of a Maine farmer, born toward the middle of the nineteenth century, and apprenticed to a shoemaker, Sturtevant had the vision to see a new way of pegging shoes and the genius to make his dream come true. This dream had nothing to do with air, but it paved the way to a new world and to vast achievement.

Into this youthful cobbler's brain came the idea of a machine to peg shoes for him. First he had to invent a machine that would rapidly and skilfully convert logs of wood into pegs. "Impossible," he was told. But Sturtevant did it. Very shortly this farmer's lad, with no previous mechanical training, had constructed a model to illustrate his idea. After months of patient labor he overcame every obstacle. His machine was perfected. It could take a barked log eighteen inches long, strip it into ribbons, much as a tape is unwound from a bobbin, and cut these ribbons into pegs, which could be driven into the sole of the shoe. It was an epoch-making invention, the first step toward placing shoe-manufacture upon a machine basis.

How Sturtevant Removed the Dust from His Buffing-Machine

The small country village of Skowhegan, Maine, offered no opportunity to the young inventor. So he went to Boston. He arrived with seventy-five cents in his pocket, a model, a patent, and a head full of ideas.

His first task was to introduce his pegging-machine into the shoe-factories of New England, as well as a buffer for smoothing leather. But very soon the workmen began to complain of the dust that the buffer threw into the air. To many men this would have been a mere trifle. Not so with Benjamin Sturtevant. If the dust bothered the men, it must be removed. Immediately he invented a simple suction-fan, which drew away the obnoxious dust as fast as it flew from the buffing-wheel. Then and there were the vacuum-cleaner and a whole host of dust-removers born.

With this simple device Sturtevant had put air to work. He had opened a vast new field for the expansion of his genius. An ordinary man would have been satisfied with the accomplishment of his immediate purpose. But Sturtevant saw the tremendous possibilities in his new invention. Were there not innumerable other industries, both in Europe and America, that suffered from dust or noxious gases? The application of scientific principles to the problem of ventilation was wholly unknown.

Here was an opportunity wide as the world, and Sturtevant knew it.

So clearly did Sturtevant glimpse the future of this new field of achievement that he gave up entirely his pegging-machine business and determined to devote all his energies to the development of fans and blowers. The possibilities of putting air to work seemed endless. And indeed they were.

SAND-BLASTING SHEETS OF METAL MOTOR-CAR PARTS.

Helmets are worn by workmen to protect them from sand particles.

Sturtevant was not an engineer. He had never studied in a technical school. In fact, there were no such schools in America at that time. Yet he mastered the engineering problem of putting air to work. His first accomplishment was the invention of mechanical dust-removing devices. No laws requiring the removal of dust in factories were written on the statute-books at that time. The public was indifferent.

Nowhere was any attention paid to the normal requirement that each worker in a factory should be supplied with 3,000 cubic feet of fresh air each hour. Little heed was paid to the ravages of tuberculosis brought about by the breathing of dust-laden air. The so-called "dusty trades" were content to remain dusty. That a worker in a cement plant breathes one pound of dust in five years, or the feeder of a wool-breaker in a carpet mill one pound in seven years, even if known, caused no alarm.

But these facts were of the utmost significance to Sturtevant. In a little shop in Sudbury Street, Boston, he began his business. At that time his sixteen workmen supplied practically all the fans that the world could use. Beginning with a little exhaust fan, which, placed close to a buffing-wheel, sucked away every particle of dust from his pegging-machine, Sturtevant proceeded to invent new types.

New Uses for Air

A fan or blower consists essentially of a rotating shaft, upon which are mounted curved vanes, the whole being enclosed in a tight-fitting case and connected with an outlet pipe. On one side is produced suction, on the other a draft. Suction or draft may be produced on either side at will simply by changing the direction of rotation.

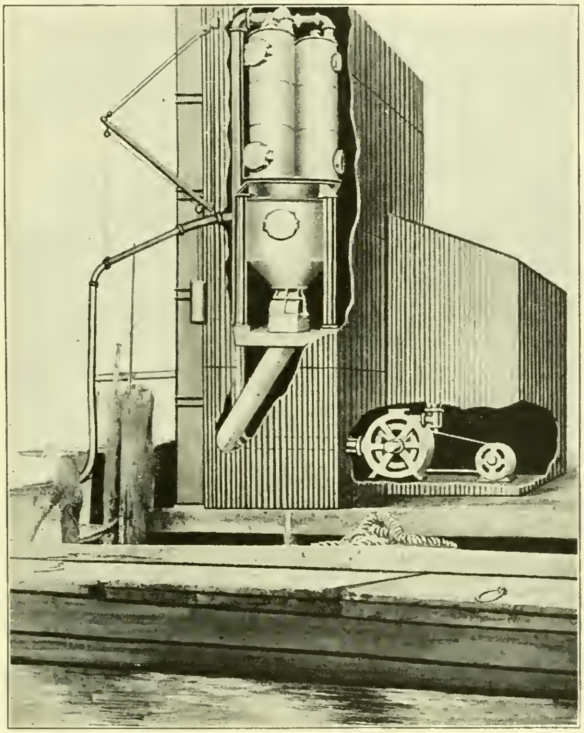
It must not be supposed that any one standard type of machine met all requirements. Each new plant had its own special needs, and it was in meeting these special needs that the genius of Sturtevant found full play. Each new set of conditions received his careful study. Sometimes fans or blowers alone answered. At other times water sprays and special devices had to be combined with the regular equipment. But Sturtevant was never baffled. He had made war on dust, and dust was always vanquished.

One of his earliest machines devours the shavings that rise in clouds from the planing-mills. Sometimes these are carried a mile or more in the dust-pipes and fed directly to the furnace fires. This is true in a coal-breaker, where the fuel dust that otherwise fills the air is conveyed straight to the boilers. Similarly, these dust systems draw off the noxious gases that poison the air and endanger the lives of the workers in chemical industries. In machine-shops the fine metal chips, which, like two-edged swords, cut the delicate membranes of the lungs and carry death in their wake, have been banished. But the most remarkable machine of all is a fan that pulls sparks out of smoke. It is installed in a lumber-mill located in the midst of a forest. The hot gases are drawn through fans and blown into large centrifugal separators. These whirl out the burning cinders into a receptacle and allow only the gases to escape at the top.

UNLOADING VERY FINE FERTILIZERS BY AIR FROM A BOX-CAR AT THE RATE OF TEN TO TWELVE TONS PER HOUR.

Soon Sturtevant found that the uses of air are almost numberless. He next turned his attention to the transporting of light material on the wings of the wind. Formerly only a symbol of magic power, this is now a reality.

All sorts of light materials such as wool, cotton, hemp, flax, hair, jute, rags, shavings, grain, coffee, wood pulp, and dozens more, may be borne with magic ease and swiftness in air conveyers. Carried from department to department, up or down, shunted hither and thither, like water in a pipe, these materials are in very truth conveyed on wings of air. Suction-fans connected with these conveyer systems frequently pull their loads along at the rate of a mile a minute. Huge suction-spouts, dipping into the hold of a ship, lift grain a distance of forty or fifty feet, and discharge it at the rate of 200 tons an hour into the storage-bins. At one Canadian port, grain is lifted ninety feet and carried 700 feet. In the same manner, coal is astonishingly sucked from barges, and practically any material, if not too bulky, may be air-conveyed if desired.



SECTIONAL VIEW THROUGH PLANT OF PIEDMONT-MOUNT AIRY GUANO COMPANY.

This plant unloads phosphate rock at the rate of thirty tons per hour through a four-inch air-hose.

Not only will air convey these materials, but it will pick out the dirt at the same time. Grain, coffee, and other products are frequently mixed with dirt and gravel. But the air current may be so nicely adjusted that the heavy foreign matter will fall and only the lighter good material will be carried on. For example, air separates the popped from the unpopped corn in a fritter factory.

Supplying Fresh Air by Fans

When Sturtevant began applying scientific principles to the problem of ventilation, the health value of fresh air was but vaguely understood. Although men would not drink dirty water, they were content to breathe hot, humid, germ-laden air. The desirability of supplying an abundance of fresh air to factory, home, and public assembly-hall was wholly unappreciated.

Good ventilation is much more than a matter of supplying oxygen in proper quantity. It cannot be obtained by opening a window or starting a desk fan. One creates a draft, and the other stirs up dead air, dust, and microbes. Ventilation depends upon four factors: pure air, the amount of moisture present, temperature, and movement of the air.

To control these factors was a problem for the engineer. Until Sturtevant took it up, no one had attempted its solution. Few recognized its existence. Air that is too moist or too dry, too hot or too cold, dust or germ laden, breeds disease. Our steam-heated homes, frequently dryer than the Desert of Sahara, result in physical weakness, drowsiness, and mental sluggishness.

But modern ventilating systems have changed all this. The fans give to the air a gentle movement and drive it through a rain-chamber. Here the air is washed free of dust and, according to the temperature of the spray, moisture is added to or subtracted from it as required. It is then heated over steam-pipes and returned to those who breathe it as clean as the breezes after a summer shower. Thus has ventilation been reduced to a real science. Such systems may give to air any desired temperature or degree of humidity. The sign so often seen outside a public amusement hall, "Twenty degrees cooler inside," is frequently no catch-phrase. A Sacramento restaurant is kept at a uniform temperature of eighty-four degrees when the temperature outside is 102 in the shade.

Dwellings, factories, schools, libraries, churches, hospitals hotels, and theatres, everywhere, may now enjoy pure, health-giving air without stint, thanks to the ventilating engineer. One illustration will show the health dividends which such systems pay. By the introduction of efficient ventilating systems, statistics prove that death-rates have been reduced in children's hospitals from fifty to five per cent.; in wards in general hospitals, from forty-four to thirteen per cent.; and in army hospitals from twenty-five to six per cent.

Making Weather and Climate to Order

The weather is the subject of more discussion, praise, and abuse than any other topic of conversation. To control the weather day after day to suit our fancy or convenience has always been regarded as a Utopian dream. Yet Sturtevant and other ventilating engineers have made this dream come true. Climate may be made to order—hot, humid, cold, or dry. If the candy-maker requires a mild climate in his factory it can be given him. Instead of closing his plant in the hot, sultry months of July and August, as he once did, he may adopt the slogan, "business as usual." The production of artificial climate has enabled large storage-plants to keep fruits and vegetables for months with very slight loss.

England became a great cotton-spinning country because the humid English climate is the best natural climate for textile spinning and weaving. Now, since the engineer has harnessed the weather, textile mills may be located even in the midst of a desert. Indoor weather may be manufactured anywhere, and making it has become a great aid to modern industry.

Have you not noticed how on a cold, crisp winter day your hair crackles and stands on end as you brush it? This is due to tiny electric charges generated on hair and brush. The same effect is observed in textile mills as the cotton, silk, and wool fibres pass through the spinning-machines. It formerly caused no end of annoyance, because some fibres are attracted to each other and others repelled from each other. Simply to humidify the air of the factory does not solve the problem. If steam is blown into a room, the atmosphere will become unbearably sultry; if water is sprayed in, the moisture will condense on machines and fabrics. By supplying air, carrying just the right amount of moisture, these annoying electrical effects are avoided. The modern ventilating engineer installs a system that provides a constant ideal climate suited to any given industrial purpose.

Many other industries require special climates. The manufacturer of photographic materials, gelatine, glue, paper, tobacco, foodstuffs, rubber, explosives, and many more, each must have his particular climate. Formerly an utter impossibility, this is now an accomplished fact of modern industry. It is one of the immensely practical results of putting air to work.

Many moist materials need drying. Asbestos, sugar-beets, bricks, soap, fibres, paper, lumber, tobacco, and yarn are a few of the many that require seasoning at some stage of their manufacture. Simply to apply heat is not sufficient. A special kind of air treatment is required. Thus, although previously ignored, a new problem presents itself to the modern engineer.

Lumber is one of the best examples of the need of seasoning. Wood for pianos, furniture, airplanes, unless dried, will split in time. Kilns are, of course, necessary, but the old-style kiln spoiled much valuable wood. The wood was unequally dried, and therefore it cracked and warped. It was not dried according to nature's process. Engineers who came after Sturtevant studied the process, and discovered that the temperatures were too high and the volumes of air too low. Ordinarily it takes two years to dry the wood used in airplane construction. Two years in time of war was unthinkable in a national crisis. The necessities of war prodded the engineers into activity. They devised a process of circulating the drying air in larger volumes and at lower temperatures in a kiln. The wood was seasoned progressively, and wood for airplanes was dried, not in two years, but in two weeks.

The difficulties encountered by the paper manufacturer in drying his product have been removed by the application of the same principles. And there are many more examples.

Making Air Save Fuel and Power

As you have fanned or blown the dying embers of your campfire into a ruddy glow, you have applied in a primitive way the principles of mechanical draft. To burn, fuel must have oxygen, and its only source of oxygen is the air. Why is it that large factories have such huge, tall chimneys? Principally to produce a draft for the furnace fires. The difference in pressure, or weight, between the cold, heavy air outside and the hot, light gases inside, forces the air through the fires and up the chimney. But there is a better way. The chimney disfigures the landscape. It will not draw well when the wind is not right. Besides a chimney is expensive. For much less than half its cost the engineer who knows how to put air to work will install a blowing system that will do all that the chimney does, and more.

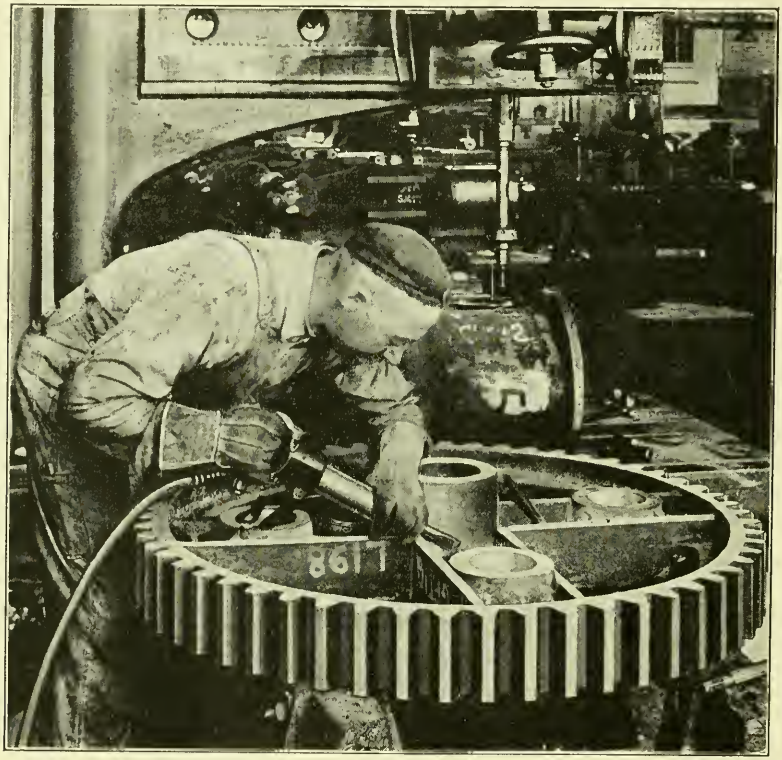
More than sixty years ago Sturtevant began to apply science to the production of draft. His suction-fan simply pushed the hot gases up a short stack, thus creating a partial vacuum in the furnace behind it; into this vacuum the air from the outside rushed to feed the fire. It seems easy, but the world had plodded on for centuries without making application of this simple principle. Sometimes a "forced draft" is employed. A blower is placed under the furnace grate, and air is sucked from the outside and blown into the fire.

And what did these systems do? They made the manufacturer independent of wind and weather. They made possible a furnace fire of any desired temperature. They increased fuel and power efficiency. Hot gases, forced through a system of water-pipes at the outlet of the furnace, were robbed of their heat, and at the same time a bountiful supply of hot water was provided for factory purposes. This same system, too, extracted the soot from the furnace gases, and thereby eliminated the smoke nuisance.

The first blast-furnace—on the principle of a hand bellows—consisted of a hole in the ground into which were alternately thrown lumps of iron ore and charcoal. By vigorous work, two men squatting over this crude furnace would produce a dozen pounds of metal in a day. Contrast with this the blast-furnace, ninety feet high, that swallows every day 800 tons of ore, 400 tons of coke, and 100 tons of limestone, yielding some 400 tons of molten pig iron every twenty-four hours. This process hangs on a blast of air.

Without the forced draft, the Bessemer process, which revolutionized the metallurgy of iron, and ushered in the Age of Steel, would have been impossible. Forced draft is employed in the extraction of many other metals, such as copper, zinc, and lead. The continuous supply of fresh air, indispensable to the health of the miners who go down into the depths of the earth to bring back the stores of fuel and precious metals, also comes from huge fans.

In the foregoing paragraphs we have described only a few of the great variety of uses to which "low-pressure air" is put.



CHIPPING BY COMPRESSED AIR.

There are many more, but enough have been cited to show the immense importance of this vast, new field of invention, in which Benjamin Franklin Sturtevant was the pioneer.

Westinghouse and the Air-Brake

When a rapidly moving railroad train is quickly but surely brought to rest, gently as a spent golf-ball rolling across the green, do you ever stop to think of the debt you owe to compressed air? The wonderful air-brake is the accomplishment of George Westinghouse, a pioneer in many fields of invention.

Westinghouse, like many other boys, disliked school and liked to play. His father wished him to come into the shop after school hours and learn to use tools. This was too much for any healthy play-loving boy. He had to play at work if he were to stay at the bench for any length of time. If he were allotted any particular piece of work, his mind soon wandered away to some miniature engine or water-wheel of his own contriving. His father denounced these contrivances as "trumpery," and frequently sent them to the scrap-heap. He did not understand the boy and had great doubts of his amounting to anything. At length, one of the men took pity on young Westinghouse and fitted up a den in the loft of the shop, where the boy spent many happy hours. Here, with his own hands, he built a small rotary steam-engine with which he ran a boat on the Erie Canal.

One Saturday morning the young inventor was led to a pile of pipe and given instructions to cut it into pieces of a certain length. His father was going away and told him that this job would take all his spare time while he was gone. While listening to instructions, Westinghouse had been thinking out a plan of action. Before noon he had rigged up a combination of tools, which, when attached to a power machine, automatically fed the pipe and cut it into the proper lengths. Here for the first time he displayed his wonderful genius for contriving a mechanism to meet perfectly any need that might arise.

When the Civil War broke out Westinghouse enlisted for thirty days. At the end of that time he tried to recruit a company so as to obtain a lieutenant's commission. Unsuccessful in this, he enlisted again as a private. After two years of service, he passed an examination which won for him an appointment as acting third assistant engineer in the navy. He finished his fighting career on the ships *Muscoota* and the *Stars and Stripes*, returning to Schenectady in the spring of 1865.

The autumn of that year was spent as a student in Union College, located in his home town. For languages and theoretical mathematics he had little inclination. Being more interested in a number of machines he was trying to invent than in his college work, he frequently absented himself from class. Upon the advice of the president, his father withdrew him at

Christmas time, and his college career came to an end. For lack of a better job, he went to work again in his father's shop at two dollars a day.

One day he was returning from Albany, when the two rear cars on the train running just ahead of his jumped the track. He spent two hours watching the wrecking crew slowly and painfully lifting the cars back onto the rails, and to a friend he remarked: "That was a poorly handled job."

While watching the work there was born in his mind the idea of a car replacer. It was to consist of a pair of rails, which might be clamped to the track and run off at an angle like the frog of a switch. By hitching the engine to the cars they might be pulled back upon the track in a few minutes. His friend suggested that he invent such a device and sell it to the railroads.

Before he went to sleep that night, Westinghouse had the device fully thought out, and the next morning he made drawings and a model. These he carried to his father, but failed to interest him. He then applied to a number of the business men of the town, and found two who were willing to risk $5,000 each on the venture. He quickly patented his invention and immediately began to manufacture and sell it. Soon he had his car replacer in use on a large number of railroads.

The Beginning of the Air-Brake

One day, as Westinghouse was travelling from Schenectady to Troy, his train stopped suddenly. With several other passengers he went ahead to learn the cause of the delay. Two battered locomotives told the story of a head-on collision. The track at that point was perfectly straight for some distance, the road-bed smooth, and it seemed to Westinghouse that the collision could have been avoided. Upon inquiry he found that the engineers had seen each other and had made every effort to stop, but the brakes would not act quickly enough.

Here was a great opportunity for the inventor. Suppose, thought Westinghouse, that instead of blowing the whistle and waiting for the trainmen to set the brakes, the engineer could set them himself? Would not that put an end to such accidents? But how could this thing be done? His first idea was a brake-chain extending the whole length of the train that could be drawn taut by some device under the control of the engineer. But he soon discovered that a system similar to this was in operation on the Burlington Railroad, and he realized that this clumsy device would not solve the problem. Something better must be invented.

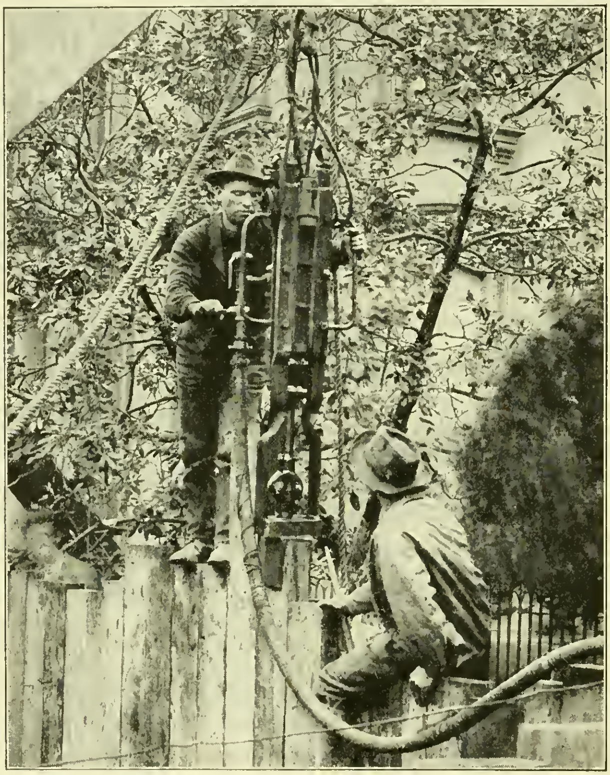
He next conceived of brakes operated by a cylinder and piston placed under each car and supplied with steam from the engine. But he decided that the condensation of steam in the pipes and cylinders, especially in cold weather, would make the success of this scheme impossible. Haunting him every moment of his waking hours, the problem baffled him; but he would not give up.

How Westinghouse Solved His Problem

One noon-hour as he sat in his father's shop, a young woman approached and asked him to subscribe for a magazine. Westinghouse was not interested, but seeing the look of disappointment upon her face, he reconsidered. Pulling out a two-dollar bill from his pocket he paid for a three-months' subscription. In looking over the specimen magazine exhibited to him, his eye was caught by an article on the Mont Cenis Tunnel, which was then being bored in Switzerland. He specified that his subscription must begin with this number.

A seemingly trivial incident this, and yet it solved Westinghouse's problem of the brake and changed his whole future career. When the magazine came he immediately turned to the article on the tunnel. In it he learned that compressed air was being used to operate a rock-drill, located at a distance of 3,000 feet from the air-compressor. Westinghouse threw down the magazine. Here was the very power needed to operate his brake. Air! It would not condense. It would not freeze. It could be transmitted great distances without loss. Very quickly he designed his brake system and made application for a patent.

About this time Westinghouse took over the entire charge of his car-replacer business, and went to Pittsburgh, where he hoped he might get the parts made more cheaply. He arranged with a firm to manufacture them and allow him to act as salesman. At every opportunity, and particularly on the occasion of his visits to railroad officials, he talked about his air-brake. It was always the same old story. Men were interested, but the "scheme was visionary," "impractical," "it would never work," and so on. He did succeed, however, in interesting a young man of Pittsburgh, named Baggaley, who had some means, and together they built a working model. This was in the autumn of 1868, when Westinghouse was not quite twenty-two.



COMPRESSED-AIR DRILL USED AS A PILE-DRIVER.

Westinghouse wanted some railroad to place a train of cars at his disposal for a public demonstration. But Robert Pitcairn, local superintendent of the Pennsylvania Railroad, who had become enthusiastic over the new brake, could not induce the officials above him to bear the expense of a demonstration. A similar rebuff came from the officials of all other railroads.

Eventually, W. W. Card, of the Panhandle Railroad, became convinced of the remarkable superiority of Westinghouse's invention. He persuaded his company to furnish a train of cars, provided Westinghouse would equip it at his own expense and reimburse the company for any damage to the locomotive or cars. Weary of delay Westinghouse accepted the offer.

The day of the trial arrived, and a train consisting of a locomotive, tender, and four coaches was on hand. An air-pump driven by a small steam-engine was mounted on the locomotive, and air was compressed to sixty or seventy pounds per square inch. A pipe leading from the reservoir to a valve mechanism near the engineer's seat passed beneath the train to the brake-cylinders, one for the tender and one for each car. The piston of each brake-cylinder was connected to the ordinary hand-brake gear. Flexible hose connections were provided between the cars. To set the brakes, the engineer turned the valve so as to admit air to the pipe-line and brake-cylinders. The admission of air thrust out the pistons and set the brakes. To release the brakes, the engineer turned the valve so as to cut off connection with the main reservoir, and at the same time open the train pipe and cylinders to the outside atmosphere.

Just before the train started Westinghouse shook hands with the engineer. In that hand-clasp a fifty-dollar bill passed, the last dollar the young inventor had in the world. The train pulled out. Suddenly there came a jolt. With a jar and grating that sent the passengers sliding from their seats with bruised shins and battered hats, the train was brought to rest. A drayman had blundered upon a crossing scarcely two blocks ahead of the approaching train. In trying to whip up his horses, the driver was thrown across one of the rails. There was no time to lose. Immediately the engineer reached for the brake-valve and gave it a mighty twist. The air rushed from the main reservoirs into the line and cylinders, driving out the pistons and setting the brakes with irresistible force. Just four feet in front of the drayman and his rig the train came to a stop. The disgruntled railroad officials and their invited guests tumbled out to learn the cause of their shaking up. A more dramatic conversion of scepticism into enthusiastic approval of an invention could hardly be imagined. But most delighted of all was Westinghouse. The trial trip was continued and at every point the brakes worked without a flaw. It was a great triumph, the dawning of a new day in railroading.

The First Air-Brake Factory

Westinghouse's patent was issued in April, 1869, when he was not yet twenty-three years old. He immediately abandoned his car-replacer business and, with the assistance of his friend Baggaley, he rented an old foundry in Pittsburgh to begin the manufacture of his brake. The Pennsylvania Railroad now provided a train and asked for a demonstration. This was as successful as the other, and with this same train he was permitted to make demonstrations in Philadelphia, Chicago, and St. Louis.

Westinghouse now bounded along to success. A company composed of some of the most prominent railroad men of the country, with Westinghouse as president, was organized in July, 1869. All of the more important railroads of the country began rapidly to install his brake. With this business prosperity came financial success. Westinghouse went to England in the following year, and after a hard battle was largely successful in introducing his brake there and on the Continent. By the fall of 1881 his brake was in use on 6,599 locomotives and 30,080 cars in this and other countries.

Westinghouse immediately began to improve on his first model, which, compared with his later inventions, was crude. In case a train should break in two, his first mechanism made no provision for setting the brakes. To avoid this difficulty he brought out the automatic brake. In this system each car carried an auxiliary cylinder of compressed air, and the brakes were applied not by an increase, but by a reduction of air-pressure in the train-pipe. Decrease of pressure from a ruptured hose connection, or any other cause, intentional or accidental, would stop the train. The device that accomplished this was known as the "triple valve," and in its early form and subsequent development it represents one of the very highest examples of scientific invention.

At first the air-brake was used only on passenger-trains, but by 1888 Westinghouse had perfected his system so that it would handle the longest freight-train with the utmost ease and safety. In a series of demonstrations in three successive years, at Burlington, Iowa, he convinced the railroad world of the vast superiority of his all-air system. He continued to improve it almost down to the time of his death, in 1914.

USING COMPRESSED AIR.

(Left) Grinding. (Right) Driving screws and other fastenings into wood.

Other Westinghouse Applications of Air

Although not the first to invent air-operated signalling systems, Westinghouse was the first to improve and introduce them extensively into this country. The purpose of signals is not really to stop trains, but rather to keep them moving. Every one is familiar with the block system, by which only one train is permitted within a certain space, called a block, at any time. To depend solely upon operators along the line to set these signals is to rely upon too uncertain a factor. Therefore so-called "interlocking" systems are employed.

By this system switches and signals are so interlocked that they *must* move in a certain order; it is mechanically impossible to move them in any other. If a blindfolded man moved the switches at random, he might stop traffic, but he could not cause a collision. Frequently several hundred switch-levers are assembled in a single machine. These switches were formerly operated by hand, and it required much man-power to move them. As the result of a series of brilliant inventions, Westinghouse harnessed the air to do this work. By means of electromagnetic valves he turned on and off the air that operated the switches. Air-compressors, cylinders, and switches could be located at long distances from the central station which controlled them. The mere pressing of an electric button set them in motion.

It would seem that his inventions in the field of compressed air would have required the labors of a lifetime. As a matter of fact they taxed only partially this wonderful man's genius for invention. He was equally brilliant in other fields, notably in the introduction of the alternating current—a story told in the chapter on "The Rise of Electricity." His was a glorious career of magnificent achievement, equalled by few and surpassed by none of his fellow countrymen.

How the Rock-Drill Helped Tunnelling

For more than half a century compressed air has been at work liberating fuel and ores, uncovering precious metals, boring through the mountains, tunnelling beneath the rivers, levelling the sea bottom, and removing rock wherever it has obstructed the progress of men. The machine chiefly responsible for this is the highly efficient compressed air-drill. It is a splendid triumph of modern invention, and one of the most striking examples of putting air to work.

The history of the rock-drill has been told in "The Story of Metal-Mining" elsewhere in this volume, and we shall review it only briefly in this connection. Before air had been put to work, and the rock-drill invented, the railroads followed the stream valleys. They could not penetrate the hills and mountains. The Hoosac Tunnel on the Boston and Albany Railroad, four and three-quarter miles in length, was the first tunnel constructed in this country. It was begun before the invention of the rock-drill, and so slow was its progress that Oliver Wendell Holmes wrote of it:

"When the first locomotive wheel
Rolls through the Hoosac tunnel bore,
Then order your ascension robe."

The compressed-air drill was put to work in 1867, and the tunnel speedily completed. Before that year all drilling had been done by hand; one man held a chisel, occasionally turning it slightly, while two other men struck it alternately with sledges. Into these drilled holes powder was put for blasting, then as now.

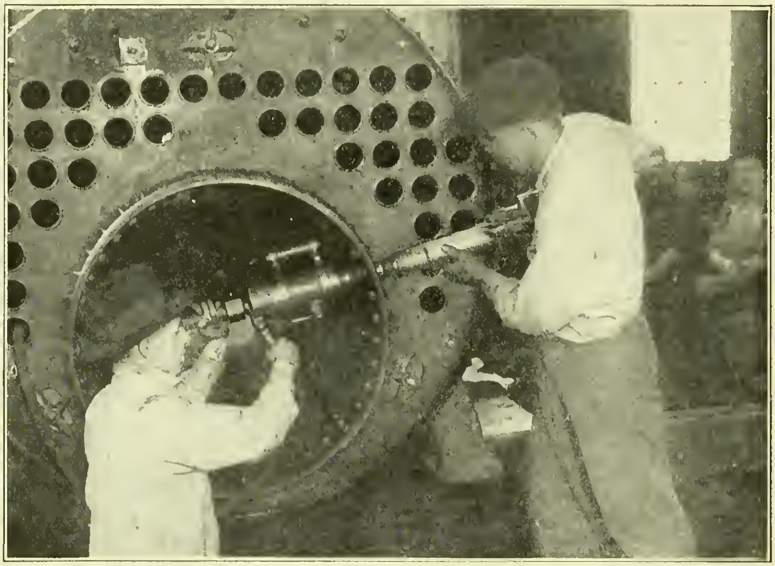
In 1849, J. J. Couch, of Philadelphia, invented a power-drill which he and J. W. Fowle, of Boston, perfected. The patent rights were purchased in 1866 by Charles Burleigh. This was the drill used on the Hoosac Tunnel, and also on the Sutro Tunnel, to tap the Comstock Lode, at Virginia City, Nevada.

One day, in 1871, Simon Ingersoll, an ingenious mechanic who had just come to New York, was riding in a horse-car and showing a model of an invention to a fellow passenger. The latter's companion, John D. Minor, a prominent contractor who was interested in inventing a rock-drill, asked: "Why don't you invent something worth while?" As a result of this chance acquaintance, Minor agreed to finance the work, and Ingersoll to build a drill. It worked for only a short time, when the fronthead broke. Ingersoll carried it to the shop of Sergeant and Cullingworth for repairs. Sergeant, who had a genius for invention himself, made several suggestions for improving the drill. Ingersoll and Sergeant could not agree. Therefore Sergeant, having become much interested in the new invention, very soon persuaded a friend, J. F. de Navarro, to buy Ingersoll out. Immediately they began improvements.

About this time A. C. Rand and George Githens, who had a shop at Port Henry, New York, invented the Rand "Little Giant" drill. For many years these two groups of inventors, working independently, were the principal factors in developing this new phase of putting air to work. Finally they joined forces and formed a company, whose machines are known wherever compressed-air tools are used.

Many other inventors have contributed to the perfection of the rock-drill. Chief among these was John George Leyner, the story of whose work has been told in the chapter on "Coal." The world-wide famous "jackhammer," essentially a product of his inventive genius, is a small portable one-man drill, which removes twice as much rock in the time formerly taken by two men using the older type.

The earliest drills were operated by steam. Indeed, their construction was very similar to that of a steam-engine. There was the cylinder with piston, or hammer, driven to and fro by steam or air admitted through the two-port-slide-valve device. The reciprocating piston dealt heavy blows at a very rapid rate, often 600 per minute, upon the head of a steel chisel-bit, held against the rock and automatically turned. Although vast improvements and numerous refinements have since been made, the principle remains the same to-day.



COMPRESSED-AIR COMBINATION JAM-RIVETER AND HOLDER-ON AT WORK ON A STEAM-BOILER.

As air rapidly displaced steam as the motive power of the rock-drill, air-compressors became essential. It fell to John Hickey, a young Irish machinist of the Sergeant shop, to develop this important type of machine. He has supervised the designing and construction of more than 1,800 compressors. On June 2, 1920, he celebrated a half-century of faithful service in the fascinating field of putting air to work.

Nowhere has compressed air displayed such vast resources of power and endless variety of applications as in tunnelling. It has led the highways of travel and traffic through the mountains and beneath the rivers. With it man has successfully pitted his puny strength against the mightiest of nature's barriers. The St. Gothard, Mont Cenis, and Simplon Tunnels in Europe, the subways of London and New York, the Catskill aqueducts, the Cascade, Silverbow, and Snow Shoe Tunnels in this country, and many more are magnificent monuments to the magic power of compressed air.

But boring beneath the rivers in the subway construction of New York and London is probably the most baffling problem that compressed air has been called upon to solve.

The First Hudson Tube

The first Hudson Tube was begun in 1874 and not completed for thirty years. Colonel DeWitt C. Haskin was the engineer in charge. His method of attack was simplicity itself. Beginning back some distance from the river, he blasted away the intervening rock and began to burrow through the soft earth beneath the river-bed. To keep out the water he used compressed air. Across the mouth of the tunnel he built a wall, and in this wall he built an air-lock. An air-lock is simply a small room with a door opening on one side into the outside world, and a door on the other opening into the tunnel. Air-compressors maintain inside the tunnel a pressure of about twenty-five to thirty pounds per square inch, which is sufficient to keep back the water, all the while trying to force its way in. Hence air-pressure is constantly struggling against water-pressure.

To enter the tunnel the men must pass through the lock. They close the door behind them. Air is turned on. At first the pressure is normal. It is then gradually increased until it is equal to the pressure in the tunnel. The door leading into the tunnel is now opened, and they pass on. In leaving the tunnel the procedure is reversed. Hours must sometimes elapse before the pressure is reduced to normal in the lock and the men permitted to leave. High pressure has charged their blood with gas. If they were to emerge suddenly into the outer world, the result would be similar to that which follows when a bottle of charged water is opened. Their blood would bubble, and they would suffer agonies.

As fast as Colonel Haskin removed the soft earth, he followed it with an arched wall of solid masonry. But his undertaking was too dangerous. Between the workmen and the Atlantic Ocean was only a wall of mud and a barrier of compressed air. The air-pressure being greater at the top of the tunnel than the opposing water-pressure above, blowouts frequently occurred at weak spots in the roof. On such occasions quick work was required to keep out the sea and prevent a flood. In one instance, Captain John Anderson, the superintendent, with great heroism thrust himself into the gap and stopped the water until his men could repair the leak. On one other occasion, as the men tried to escape, the door of the air-lock became jammed, and twenty perished.

After having completed 2,000 feet and spent a fortune, Colonel Haskin was compelled to abandon the project. It was not resumed until 1902, when William G. McAdoo, as president of the New York and New Jersey Railroad Company, pushed it to completion.

The Tunnel Shield

As early as 1824 Sir Marc Isambard Brunel, a famous English engineer, had invented a "shield" designed to overcome the very difficulties that Colonel Haskin encountered. With it Brunel ran the first tunnel beneath the Thames. A shield is simply a short steel cylinder which is pushed forward by mechanical means as the work progresses. This huge boring-machine, without which river tunnelling would have been impossible, was reinvented and vastly improved, about 1869, by the English engineer, J. H. Greathead, and independently somewhat later by Alfred E. Beach, a former editor of the *Scientific American*.

With his shield, Beach drove a short tunnel under Broadway, New York, from Warren Street to Murray Street. By means of a blower, he propelled a car through the completed tunnel, and by reversing the direction of rotation sucked it back.

As typical of the modern shield let us examine that used in driving the East River subway tubes. They were the most massive shields ever built. Each shield weighed 185 tons. It was simply a short cylinder made up of steel plates riveted together, the whole slightly larger than the tunnel lining. Its height was 23.5 feet, and its length 18 feet. The front consisted of a sharp cutting-edge, behind which were two vertical partitions and two horizontal floors, which made nine pockets or rooms in all, each higher than a man's head. Between the two vertical partitions were air-locks, to permit workmen to go through to the tunnel heading, and through which to withdraw the excavated earth.

Equally distant around the back circumference of the shield were fourteen hydraulic jacks, somewhat similar to an ordinary jackscrew, and operated by compressed-air motors. These jacks exerted a pressure of 6,000 pounds per square inch, or a total for fourteen of 2,111 tons. The jacks thrust the cutting-edge of the shield forward into the soft earth as far as possible. Then workmen from the various pockets of the shield passed through the air-locks to the tunnel heading and removed the earth. The excavated material was passed to the back of the shield through special air-locks, and then carried to the main entrance lock and out of the tunnel. The greatest advance made by a shield in the East River tunnelling was four feet in an eight-hour shift.

Behind the shield came the "erector," a travelling platform which put in place the tunnel lining of circular steel plates. The erector carried an extensible arm, capable of moving about the circumference of the tunnel and operated by an hydraulic piston. The piston was driven by a compressed-air motor. This moving arm picked up the steel plates and riveted them into the tunnel lining. The space between the tunnel lining and the soft earth was filled in with cement, brought from the tunnel mouth by a pneumatic conveyer and squirted into place by a blast of air.

These shields may be driven with remarkable accuracy. They go straight to the destination calculated by the engineer. They may be steered at any angle, up, down, or sidewise. Had Colonel Haskin employed a modern shield, his undertaking would have been quickly and easily completed.

Digging the Hole for a Skyscraper's Foundation

Somewhat similar is the process followed in laying the foundations of skyscrapers, and of bridge piers. Again men must work at great depths, sometimes upon the river bottom. To do this they must make use of the diving-bell invented about the beginning of the eighteenth century by the great astronomer, Edmund Halley. The diving-bell is a bell-shaped iron box, open at the bottom and having a platform projecting part way out from its sides, about two-thirds the way down. In its modern form a flexible heavy-walled hose connects it with an air-compressor and reservoir at the surface. The interior is electrically lighted.

When the sea bottom is to be prepared for the support of any engineering structure, men with the necessary tools take their places on the platform. A huge crane picks up the bell and slowly lowers it to the bottom. At the same time sufficient air is forced in to prevent the water from creeping up higher than the edge of the bell. A telephone provides constant communication between the men in the bell and the operators at the surface. The air forced into the bell and constantly bubbling out from beneath its lower edge, not only excludes the water, but affords the men a constant supply of fresh air to breathe. With compressed air and other tools the work of levelling is done, and the bell is then slowly hoisted back to the surface.

Diving-bells are not used so much now as formerly. This work is largely done by divers. But the foundations of river and harbor structures rest upon a modified form of diving-bell known as a "caisson," which is nothing but an immense iron box open at the bottom, and divided into two compartments by a horizontal floor about half-way down. The lower compartment is connected with the surface by a vertical shaft having an air-lock at the top. The upper compartment is filled with concrete to give it weight and stability.

A crane lowers the caisson to the exact spot upon which the particular foundation is to rest, compressed air being employed to exclude the water. Through the air-lock workmen descend to the sea bottom. As they remove the dirt, the caisson sinks deeper and deeper until finally it rests on rock bottom. When this occurs and the bottom has been properly levelled, the men ascend and the whole interior is filled with concrete. The caisson then becomes an almost indestructible foundation, capable of supporting any weight, however great. In this same manner the foundations of skyscrapers are also laid.

HOW ORNAMENTAL GLASS SHADES ARE BLOWN BY SHEER LUNG-POWER.

Although bottles are now mechanically blown, many glass objects are still produced in this way. Chiefly because glass "freezes" quickly, and because it is difficult to control the temperature of the molten batch.

The Knights of the Sea Bottom

From early times compressed air has enabled men to explore the sea bottom within certain depths, bring back its sunken treasure, and disclose something of its mystery. The diver and crude forms of diving apparatus are mentioned even in the writings of the Greeks and Romans. The first accurate description of a diving-dress dates from 1721. To enable a man to leave his diving-bell and walk upon the sea bottom, Halley devised a leather suit. Later, in the same century, Kleingert, of Breslau, invented a diving-dress suitable for depths of twenty feet. It consisted of tin-plate armor and leather breeches. The development of the modern diving equipment began in 1828 with the inventions of August Siebe, in England. His first device was an open helmet dress consisting of a copper helmet and breastplate with canvas jacket. The air, passed down to the diver, escaped at the lower edge of the jacket; but he had to remain in an upright position, otherwise water would have filled his suit and drowned him.

A modern diving-dress consists of a heavy water-proof garment, into which the diver gets, feet first. The "neck-hole" and wrists are strengthened by heavy bands of the best rubber. A corselet of heavy plate brass is curved to fit the shoulders, chest, and back. The rubber collar fits snugly over the edge of the corselet and is bolted securely to it. The helmet, made of copper, coated with tin, is tightly screwed to the corselet. In the front and at each side of the helmet are small glass windows. At the back is an air inlet-valve to which is connected the rubber tube leading to the air supply above. Ducts carry the air to the front of the helmet and blow it in flat jets across the window. The inlet-valve permits the air to enter, but will not allow it to return. Through another duct the foul air passes to the outlet-valve at the side of the helmet.

The diver must at all times adjust the air pressure in his suit to that of the water pressure outside. This he does by controlling the intake and outlet of air. Sometimes a telephone is placed inside the helmet and connected with the surface by wires passing up the life-line. The life-line is the rope attached to the helmet by which his comrades on the surface regulate the diver's ascent and descent. The diver wears boots weighing sixteen pounds each, and carries lead weights of twenty and twenty-five pounds, respectively, on his chest and back. These are necessary to counteract the buoyancy of his dress and to enable him to sink.

In 1880 an Englishman named Fleuss invented a self-contained diving-suit. It has attached to it no life-line or air-pipe. In a copper cylinder fastened to his back the diver carries a supply of compressed oxygen, which is mixed with air from another cylinder and admitted for breathing. From an attending boat the diver slides down the life-line to the sea bottom and then makes his way to any desired point. When he wishes to rise he returns to the life-line.

By means of electric or specially devised oil lamps, the diver is able to see dimly the objects about him. Probably the greatest depth to which a diver ever descended occurred during the raising of the American submarine F–4; he went down over 300 feet, but this is far beyond what is usually considered safe practice.

It is in salvaging wrecked ships that the diver and his efficient ally, compressed air, find their greatest field of usefulness. In the autumn of 1913 the *Royal George*, in a heavy fog foundered upon the rocks of the St. Lawrence, tearing a hole in her bottom and admitting water to her hold. W. W. Wotherspoon, a salvage expert from New York, was called to the scene. He immediately sealed the hatches and fitted them with air-locks. Compressed air was then turned on and blew the water out of the very hole by which it had poured in. Divers then entered the hold, and with plank and clay closed the wounds. Thus buoyed up, the ship floated free and into deep water. As winter was approaching and the St. Lawrence would soon freeze over, Wotherspoon made temporary repairs on the spot, and the *Royal George* proceeded to England.

The *Gut Heil* was sunk in the Mississippi in 1912, and remained at the bottom of the river for five years. Hundreds of tons of mud had drifted into her hold. With compressed-air siphons this mud was removed, and with compressed air she was raised. This ship is now valued at a million dollars.

One of the greatest salvage feats in history occurred in the autumn of 1918. The *St. Paul*, about to sail for England with troops and munitions, foundered, not on a rocky coast, but in the quiet waters of New York Harbor. When being warped into her berth, she keeled heavily to one side, water entered her hold, and she very quickly settled to the bottom. In rolling over, she smashed her smoke-stacks, broke her masts, dumped some of her cargo, and settled in fourteen feet of mud. Here was a problem. Divers immediately removed a quantity of rapid-fire guns, much needed in anti U-boat warfare, and compressed air was used to blow away the mud that buried them.

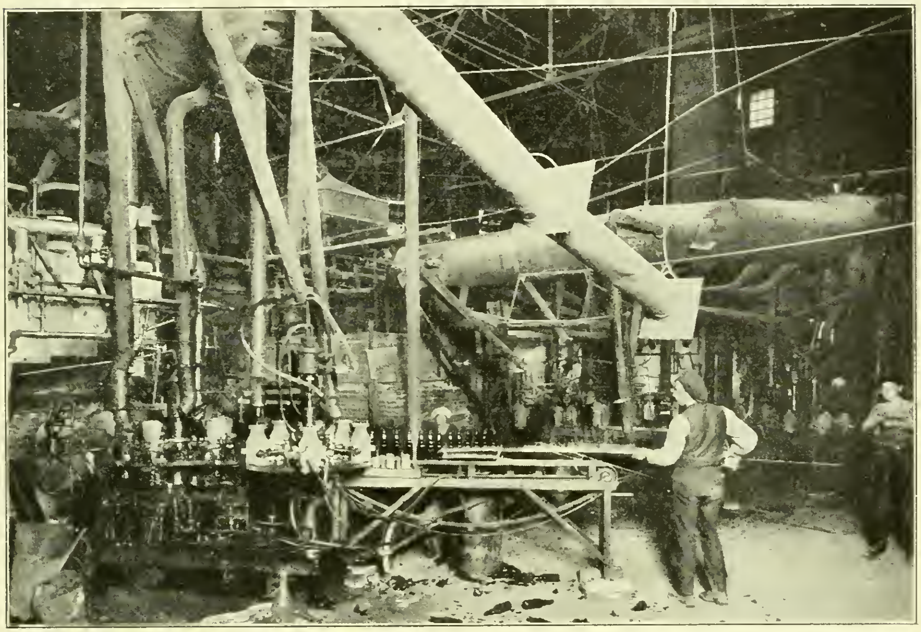
Ralph E. Chapman and Captain I. M. Tooker, salvage experts of New York, supervised the work. Divers entered the hold and, by means of an oxyacetylene torch, cut holes under water in the steel where required, and also sealed several hundred openings. Large pontoons, immense steel cylinders, were placed on either side of the ship. The pontoons were sunk by admitting water, and steel hawsers were fastened from them to the ship. By pumping out the water these giant buoys gained thousands of pounds of lifting power which, together with several tugs, righted the ship. Coffer-dams were then built, that is, the hull of the ship was extended upward to the surface by a tight-water construction. A vast array of pumps soon emptied her of water and she floated free.

The most perilous work which the diver finds to do is in recovering treasure from ships sunk in comparatively deep water. There are many instances on record. The famous English diver, Alexander Lambert, recovered a half million dollars of Spanish gold from the mail steamer *Alphonso XII*, sunk in 160 feet of water. At this depth the pressure upon the diver's body exceeded eighty-five pounds per square inch.

PNEUMATIC DESPATCH-TUBES

We are familiar with the pneumatic despatch-tubes, so widely used in department stores, and also for the rapid distribution of mail in a big city. This use of air dates back more than two centuries. The records of the British patent office, between 1835 and 1855 show great activity in this field of invention. One of the first patents granted in the United States was issued to Alfred Beach about fifty years ago. Indeed, his tunnel beneath Broadway was really a pneumatic tube. In the early eighties the Western Union Telegraph Company developed a pneumatic system for carrying telegrams between branch stations and the main office. In this same manner the despatches of the daily press were supplied to the newspapers of New York.

Out of patience with the slow and unsatisfactory message service, the City Press Association of Chicago, in 1893, established the most elaborate system in the world. It contains fifteen miles of pneumatic pipe-lines. A Philadelphia system was built with 250 stations, 20 miles of tubes, and a power plant of 150 horse-power capacity. Large packages may be carried in these tubes. Boston formerly maintained such a delivery system between its shopping section and outlying residence districts.



THE BOTTLE-BLOWING MACHINE, THE INVENTION OF MICHAEL OWENS, OF TOLEDO, OHIO.

Compressed air is applied in this machine to the blowing of bottles. The glass is gathered at the end of a blowing-iron; the blowing-iron is removed with the blown vessel attached. Each machine has a table which carries a number of moulds opened and closed by compressed air. As a blowing-iron is connected with an air-jet the sections of the mould close upon the molten glass, the compressed air blowing out the glass to fill the mould.

The tubes in a department store are about two and one-fourth inches in diameter. By means of compressed air, or suction, the brass carrier-cylinders are whisked to and fro between the various counters and the cashier's desk at velocities of from 1,000 to 2,500 feet per minute. By means of suction-fan or blower, pressures of from six to twelve ounces are maintained behind the despatch-cylinders. About four feet from the end of the "line" a valve is placed. This is opened by the pressure of the carrier and immediately closed by a spring after its passage. The end of the tube is curved downward and the carrier drops to the desk by gravity.

Other Uses of Compressed Air

The uses for compressed air are legion; we could not exhaust them. Compressed air guides the torpedo on its mission of destruction and death. It pounds the rivets into the structural-steel work of the world at the rate of a thousand blows a minute. In war it operates the mortars that drop grenades into the enemy trenches. It aerates the water we drink and frees it of bacteria and organic matter. Compressed air sprays the farmer's orchards and growing crops. The air-brush paints your automobile. Compressed air raises water and petroleum from the depths of the earth. It operates the railroad-gate that prevents you from speeding to death in front of an approaching train. It blows the pipe-organ of your church. Pneumatic hoists lift heavy burdens in our mills and shops. Compressed air blows our window glass and bottles. It blows the germs and dust from Pullman seats and bedding. It cleans boiler-flues and inaccessible parts of machinery. It has shortened the process of dressing stone. By placing perforated pipes parallel with an exposed coast-line, and blowing air through the water, Philip Brashear has invented a breakwater that keeps out the inroads of the sea. In a word air, in its manifold uses, has become the servant of the world.

CHAPTER III

MAKING CLOTHES BY MACHINE

"BODY of me! I have driven the needle under my nail! Let these be noble stitches! They have a grandeur and majesty about them that do cause these small and stingy ones of the tailor man to seem mighty paltry and plebeian!"

That bluff and hearty soldier of fortune, Miles Hendon, utters the words in Mark Twain's *Prince and Pauper*, a story of England in the sixteenth century, while fuming over his task of trying to make a second-hand suit of clothes fit the little son of the British king. He had saved the boys from a band of ruffians who, not knowing that the lad had changed clothes with a young beggar, were treating him like the crazy ragamuffin he seemed to be. If there had been any sewing-machines in those days, Hendon might have picked up in the shops a cheap brand-new suit which would have fitted the Prince well, and have spared himself a good deal of trouble and not a few needle-pricks.

So great a part does the sewing-machine play in our everyday life, that it is difficult to imagine how the world ever got along without it. Probably soldiers and sailors, with their need for ready-to-wear uniforms, deserve the credit for bringing into existence the cutting and sewing of clothes by machinery. The wants of war had to be appeased first, and this spurred inventors both in this country and abroad to design contrivances that could put clothes together far more quickly than the nimblest of fingers. Then the sewing-machine became the tireless servant in the home and in a thousand ways added to the comfort of every one. Millions of its tiny stitches are in our clothes, our shoes, and our hats.

Before the coming of the sewing-machine, men, women, and girls—and sometimes boys—bent their backs and strained their eyes sewing by hand. There is an old saying that it takes nine tailors to make a man, which was first uttered, no doubt, by some one who noticed that sewing in the old way made men round-shouldered and bow-legged. The tailors whom Miles Hendon derided sat cross-legged on a bench all day long: even when some kindly inventor built a legless chair for them, they were no better off.

Saving the human race from drudgery is too often a thankless task; almost every device which has lessened labor has been opposed by the very men and women it ultimately helped. Most men are so inclined to let well enough alone, so content with what is, that the inventor has had to fight his way through poverty and heart-breaking toil and in hundreds of cases has gone to his death without even a glimpse of the success that should have been his. Even when he succeeds in converting the public belief toward his invention it then seems so simple of understanding that the world is likely to say: "Why, anybody could have done that. It's as easy as falling off a log!"

It is indeed strange that men did not try to build machines that would take the place of fingers in the making of clothes long before they did. Perhaps the bad luck and misfortune of so many former inventors had something to do with it. In fact, the unfortunate experiences of so many men who had tried to bring the sewing-machine into use is a conclusive proof that the inventor who eventually won the day was a plucky man.

Who first thought of putting wheels and bobbins and gears to the tasks of plain and fancy sewing? It is likely that the first attempt to make a machine that would knit suggested one that would sew. The Reverend William Lee, who lived in England about the time that Miles Hendon is thought to have lived there, studied the motions of his wife's knitting-needle, and he invented a machine late in the sixteenth century which took the place of the shining needles and the nimble fingers. When Queen Elizabeth heard that the minister had applied for a patent, she refused even to consider his plea. She said that if she granted it many thousands of her liege subjects who made stockings and hose would be forced out of work; so she would have none of it. Gloriana, as Kipling calls her, could not be crossed when she made up her mind; persons who did that lost their heads. Parson Lee got the promise of some aid from the King of France, but on the death of that monarch he found himself with little hope and no means.

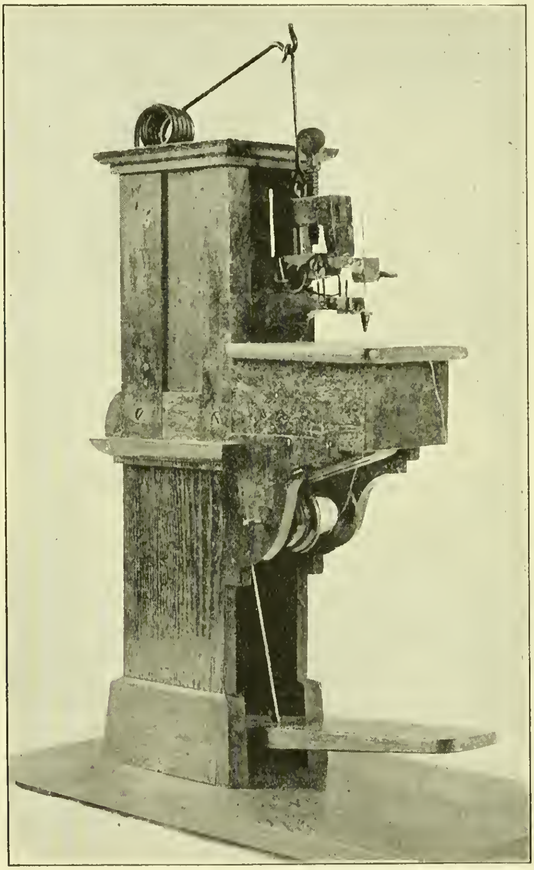
In spite of all this, Lee did manage to start a small factory, but he had to abandon it, owing to the objections of the working classes, and he died bankrupt and broken-hearted. For many years to come, stockings and hose continued to be cut out of cloth and sewed up by hand. Inventors had to build their machines secretly and wait year after year for the permission to introduce them.

So far as is known, the first sewing-machine patented in England was one in 1790, an invention by Thomas Saint. It made a plain crochet stitch, similar to that made by hand, and crude drawings of it may be seen in the British Patent Office. Probably a few of his machines were sold, but for the most part they were regarded as mechanical toys and classed with such oddities as tomatoes and potatoes, long objects of curiosity and distrust. And yet, at least sixty years before the hum of the sewing-machine reached the public ear, Thomas Saint, to whom success was denied, had given the world a great labor-saving invention.

Genius under the Goad of War

The military bugle was calling more and more men in Europe at the beginning of the nineteenth century, and this meant that thousands of soldiers needed garments of the same pattern, uniforms which had to be made more quickly than human hands could fashion them. Napoleon's success in sending his men over the Alps was due largely to the efficient way in which they were outfitted, down to every button and every gaiter strap. Europe, even in times of peace, was increasing its standing armies, and the nations were like armed camps. Hence genius, urged on by the exigencies of war, began the invention of machines for the rapid making of uniforms.

The first important step in making the sewing-machine a part of the life of the world was taken in 1830 when Bartholomey Thimmonier obtained a patent for such a device in Paris. He worked in a small way until 1841; then he improved his machine so far that it was possible for the French Government to make army uniforms by the thousands. Then the storm broke. The tailors rose up and complained that the new invention would take the bread out of their mouths. They called on the laboring classes to help them. Soon a mob broke into the factory where the machines were used, tore them out, and burned them. As the original machines were made of wood, the flames made short work of them.



SEWING-MACHINE MADE BY THIMMONNIER IN 1825.

Thimmonier was not so easily discouraged. Determining to make his invention a success, he started all over again. But his life was far from a pleasant one. Wherever he went, he was threatened by the people.

When his second lot of machines, which he had in good running order in a factory in 1848, were burned by another mob, the inventor felt that he was to be cruelly denied success. He made a final effort to get on his feet, and indeed even took out a patent on his machine in the United States in 1850, but his spirit was broken and he never regained his old courage. He died in bitter poverty.

Although other inventors soon surpassed it, the machine of Thimmonier had many good points. It carried a needle on a horizontal arm. The cloth, as it was sewed, was pressed forward by a device to receive the thread. His machine made two hundred stitches a minute, which meant it sewed fourteen times faster than was possible by hand. Since it automatically drew the cloth toward the needle, it was certainly a motion-saver.

ELIAS HOWE.

ISAAC MERRITT SINGER.

Elias Howe, of whom this is a rare photograph, was apprenticed to Ari Davis, an instrument-maker, when he first conceived the idea of a sewing-machine. After years of hardship in the United States and England he eventually succeeded in introducing his machine. When he petitioned Congress for an extension of his patent in 1860, he estimated that his invention was worth $150,000,000. Up to that date he had received $1,185,000.

Isaac Merritt Singer was the most resourceful and energetic of the sewing-machine pioneers. He was the first to sell machines in lavishly decorated show-rooms. Among other devices Singer introduced the treadle.

On this side of the Atlantic, not only the War of 1812 and later the Mexican War created a demand for uniforms, but the

American merchant marine was also storming the shops for ready-to-wear clothes. In the old town of New Bedford, Massachusetts, the centre of a whaling industry, very profitable before the discovery of petroleum, the sailors from the whalers wanted new clothes the minute they got ashore from their long voyages. They could not get out of their tar-stained, blubber-soaked breeches soon enough; therefore they went to the shops and asked the merchants to "hand me down a suit of clothes." The same situation obtained in New London, in Old Salem, in Boston and in the big city of New York.

George Opdyke, later mayor of New York, who became a well-known banker, had started, in 1831, says a government report, the first clothing factory in the United States. When the men from all the Seven Seas came to him with their "Shiver my timbers! Let's have some duds in a jiffy!" he was always ready for them. The Thimmonier machine for sewing was only being developed at that time, and all the work in the Opdyke ready-to-wear plant, was done by hand, by as skilful and rapid cutters and tailors as could be had at the highest wages then paid. It was really not until the middle of the nineteenth century that the sewing-machine was first felt as a factor in the ready-made clothing industry both in the United States and in Europe.

Although he has never received due credit for his work, the brunt of the battle for the introduction of the sewing-machine on this side of the ocean was borne by the American inventor, Walter Hunt, of New York. Hunt, careless and easy-going, kept so little in the way of exact notes that the actual date at which he began to invent his model is not known. Between 1832 and 1834, however, he built and sold a few workable sewing-machines of his own design. Jack-of-all-Trades, busy with many other things, a typical visionary inventor, Hunt did not even take the trouble of patenting his device. Had he used more common sense to guide his fine talents, he would have reaped the rewards which went later to Elias Howe, Jr.; for when he finally made up his mind to do something, years after Howe had obtained a patent, Hunt found that he was too late. His machine was of the lock-stitch variety; that is, it made a stitch consisting of two threads twisted together in such a way that they could not be ravelled out as easily as could the simple stitches of the earlier machines. Hunt's great contributions were the lock-stitch and the eye-pointed needle. Without the eye-pointed needle, Howe would never have developed his successful sewing-machine.

The introduction of the eye-pointed needle enabled inventors to depart from the erroneous idea that a machine must imitate exactly the motions of the human hands and fingers which it is endeavoring to aid; in fact, it led to the machines of the present day.

Elias Howe and His Start

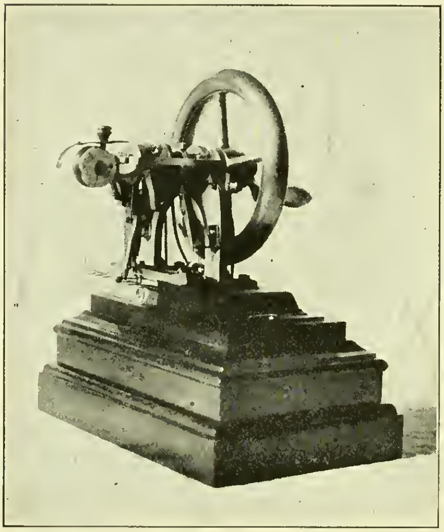
Bleak New England farms do not as a rule raise bumper crops, but they certainly seem to produce inventors who have the necessary iron will implanted in them to stick to their work until it is done and get the full value of it. It did not take the New Englanders long, after they had rid themselves of hostile Indians, to find that they must use all their ingenuity to wrest a living out of their rock-strewn acres.

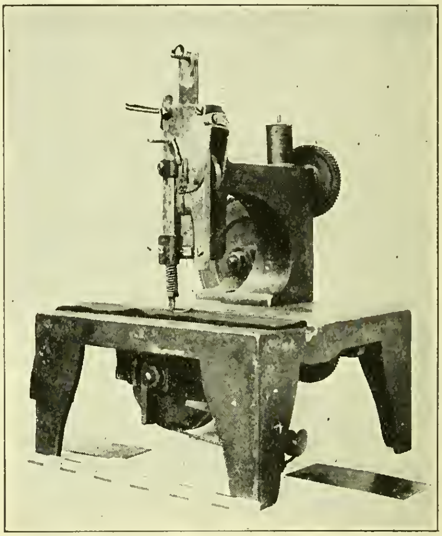
The father of Elias Howe, Jr., owned one of these barren farms near Spencer, Massachusetts, and there in 1819 the inventor of the sewing-machine was born. The elder Howe eked out his income by running a small grist-mill; he also manufactured cards for the growing cotton industry of New England. Among the earliest recollections of the long-haired, high-cheek-boned, and puny Elias Howe was that of bending over a bench and putting bits of wire on the wooden forms which made up the comblike contrivance known as a card, with which the fibres of the cotton were pulled.

He was not much of a success at that, and at the age of six he was bound out to a neighboring farmer. Children were leased in those hard days for their board and keep, and they came into a way of living not much better than that of "Orphant Annie." Doing the odd chores of the place, such as watering the horses and milking the cows, did not appeal to the lad, and he went back to his father's home for a while. Then, against the wishes of the family, he went to Lowell, Massachusetts. There he got employment in a machine-shop where cotton-spinning machinery was made and repaired. Losing his job in

1837, on account of the financial panic which was then sweeping the country, he decided to find a place in Boston.

There he came in contact with Ari Davis, a maker of mariners' instruments and scientific apparatus, and a rough hewer of men's destinies. Howe was eighteen years old at this time and his meeting with Davis meant much to him. He learned to develop his ideas and how to get at the root of the difficulty without wasting too much time. It is also likely that Howe, without knowing it, picked up many of the mannerisms of Davis. Many inventors are off in their ways, but Davis was queer even for an inventor. He was often asked to make apparatus for the professors of Harvard University, and he could turn out a model of the solar system or rig up an air-pump and





(Left) MODEL OF HOWE'S SEWING-MACHINE IN THE UNITED STATES NATIONAL MUSEUM.

Before Howe patented this machine Walter Hunt, about 1832–1834, had invented the eye-pointed needle and the double thread or lock-stitch, both of which Howe later re-invented and patented (1846).

(Right) ORIGINAL SINGER SEWING-MACHINE IN THE SOUTH KENSINGTON MUSEUM, LONDON.

This machine was patented in 1851.

keep up two or three conversations at the same time. Inventors often went to Ari Davis to ask his advice about models they had made, which were good enough in their way except that they would not work. Sometimes he helped them, and sometimes he shouted at them in anger, for he was one of the noisiest men in Boston. His clothes, too, were characteristically loud and unusual, for Davis prided himself on wearing the most outlandish, voluminous, and gaily colored garments.

Young Howe chanced one day to hear the shrill voice of his employer airing opinions for the benefit of an inventor of a knitting-machine, who had been brought to the dirty, topsy-turvy little shop by a capitalist. The man with the money thought that the machine might be developed, if it would only work, and wished to retain Davis as a consulting expert.

"Why are you wasting your time over a knitting-machine?" shrieked Davis. "Take my advice, try something that will pay. Make a sewing-machine."

"It can't be done," was the reply.

"Can't be done?" Davis bellowed. "Don't tell me that. Why—I can make a sewing-machine myself."

"If you do," interrupted the capitalist, "I can make an independent fortune for you."

Davis, like most men of many words, was short on performance, and he never did invent a sewing-machine. In fact, he probably thought no more of the suggestion; but the keen-witted boy of eighteen who was standing by his side could not forget that sentence, "I can make a sewing-machine myself," and the promise of the capitalist. And from that moment began the career of Elias Howe.

The Struggle for the Goal

Howe married when he was twenty years old, just when his work on the sewing-machine was beginning. All too frequently young Howes came into this world, to share the haps and the mishaps of their father's lot. The inventor's health was often so poor that he had to stop work for days at a time and sit about the house with a wet bandage on his head, trying to get over his numerous headaches. Things went so badly that Mrs. Howe took in sewing, and while the inventor saw before him the vision of the machine that would release her precious fingers from toil, he was forced to realize that his idea was, as yet, merely a dream, and that what his wife was doing was the grim reality.

It is not unlikely that in those dark days there came to him the words of Thomas Hood's "The Song of the Shirt," a poem only recently written in his day, and widely read:

> "With fingers weary and worn,
>   With eyelids heavy and red,
> A woman sat in unwomanly rags,
>   Plying her needle and thread.
> Stitch! Stitch! Stitch!
>   In poverty, hunger and dirt,
> And still with a voice of dolorous pitch,
>   She sang 'The Song of the Shirt.'"

But Elias Howe, grim prophet of an age of power, possessed a heart of steel. Year after year he worked on at his trade of machinist, earning just enough to enable him to get food for his family, while he spent all his spare time in perfecting his invention.

Tinkering away in his small home shop, he must have presented a strange sight. Working away at his model, his long and shaggy hair falling in waves from his puckered forehead, his clothes shabby, his form became bent by close attention to his yet unrewarded toil. Despite the complaints of his family and the chidings of his friends, who thought he was a poor lunatic and an idle dreamer, he persevered.

Like some of his fellow workers, Howe at first fell into the mistake of trying to follow too exactly the motions of the human hand and arm in sewing. The truth is that a machine which mimics such motions must always analyze those motions and then create or restore them in the finished work. The binder which is part of a reaping-machine, for instance, seems to be doing just what the human hand does in tying a knot in the twine that holds together a sheaf of wheat; but in reality it is doing that magic task with the equivalent of three fingers. The early inventors of the airplanes believed that the so-called wings really had to flop up and down, as do the wings of a bird; but they discovered that the canvas wings need only be supports and the propellers would do the work of sending the flying craft through the air. For many years Howe had been working out in his mind a great principle without having had the benefit of the successes and failures of other inventors, for he knew little or nothing about their work.

The Dream That Brought Fortune

In continuing to imitate the motions of his wife's all too busy needle, Howe made the needles of his early failures with a hole in the middle of the shank. His brain was busy with the invention day and night and even when he slept. One night he dreamed, so the story goes, that he was captured by a tribe of savages who took him a prisoner before their king.

"Elias Howe," roared the monarch, "I command you on pain of death to finish this machine at once."

Cold sweat poured down his brow, his hands shook with fear, his knees quaked. Try as he would, the inventor could not get the missing figure in the problem over which he had worked so long. All this was so real to him that he cried aloud. In the vision he saw himself surrounded by dark-skinned and painted warriors, who formed a hollow square about him and led him to the place of execution. Suddenly he noticed that near the heads of the spears which his guards carried, there were eye-shaped holes! He had solved the secret! What he needed was a needle with an eye near the point! He awoke from his dream, sprang out of bed, and at once made a whittled model of the eye-pointed needle, with which he brought his experiments to a successful close. As we have seen, Hunt had invented the eye-pointed needle, wide-awake in broad daylight and not in a dream. Much was made of this in patent suits in which Howe was later involved, but poor Hunt never took the trouble to patent his great idea.

Scant as were his funds, Howe did a great deal in the months which followed his vision. Most of the work was done in the attic of a factory for splitting palm-leaves which his father had started at Cambridge. When this building burned down, Howe was for days in the depths of despair until he thought of his old schoolmate, George Fisher, who had received a small inheritance. Like many another man who has had a windfall of good fortune, Fisher was willing to let some easily gained money go in backing what he considered at most a very risky venture. He lent $500 to Howe and entered into one of the strangest partnerships in the history of invention. For an interest in the invention Fisher was to take Howe and his numerous family into his house, there to feed and lodge them, and also give the attic of the dwelling over to the inventor for a workshop.

In building the second machine, Howe spent all the money advanced by Fisher. The machine was ready in May, 1845, but was not patented until the following September. Howe rested a little on his oars then, for he believed that at the age of twenty-six he had won his long pull against the tide. He set up his machine in a public hall in Boston, and after much cajoling he induced a tailor to operate it for about three times the usual wage. Howe's reception by the regular garment-makers was similar to that suffered by the unfortunate Thimmonier. A gaping crowd went to see the "new-fangled contraption," but when Howe tried to get the big clothing establishments to use the machine he found out exactly where he stood; the howl of the tailors echoed to the Bunker Hill Monument.

A Prophet without Honor in His Own Country

Confronted at every turn with disappointments and rejections and feeling that his own country was against him, Howe permitted his brother, Amasa B. Howe—who had had some business success down South—to take a model of his machine over to England. From there, after many rebuffs, appeared a little ray of sunshine. William Thomas, a manufacturer of umbrellas, corsets, and leather goods, employing several hundred workmen, all of whom stitched by hand, became interested in the new machine. He saw its possibilities in the manufacturing business.

"This," said the manufacturer, after he had seen the machine demonstrated, "is the beginning of a tremendous enterprise. And the man who has carried it thus far is the man to carry it farther."

On the strength of these encouraging words, Elias Howe gathered together his goods and chattels and, with his family, crossed the ocean. His father had lent him $1,000 for expenses, and prospects appeared bright.

But poor Howe's troubles were not over yet. William Thomas certainly bought a machine of him for 250 pounds—about $1,250 dollars—and with it he acquired the entire rights of the new sewing-machine for Great Britain. Howe was retained by the Thomas establishment at a salary of fifteen dollars a week, and this kept him from begging his bread. He was to adapt his invention for the sewing of heavy leather, used in travelling bags and other articles, in the making of which the English have always excelled. But after eight months or so, a quarrel arose and amicable relations between employer and inventor came to an end. Poor Howe was again without a job.

He took this ill turn with good grace, and started to build another machine. His funds ran so low, however, that he was obliged to take his family to cheaper lodgings. Things went from bad to worse. At last Howe, glad enough to accept the charity of a captain of a Yankee packet-ship, sent his family back to America. To do this, he borrowed enough money for their current expenses and pawned his model and his patent papers. After he had saved himself from imprisonment for the non-payment of his bills by taking the "Poor Debtors' Oath," the inventor returned to the United States some months later in a sailing vessel, paying his way by cooking for the steerage passengers. When he reached New York he heard that his wife was seriously ill, but he could not go to her until he had received a loan from his father for his travelling expenses to Boston. His wife survived only a few days after his return.

Howe Wins His First Patent Victory

During his absence the fame of his machine and its acceptance in England had reached his own country. The scoffers began to realize that there was something in his device after all. Indeed, several American firms had already begun to sell sewing-machines, which were like his in design. This looked like the end of all his hopes, but Howe roused himself and went after the manufacturers for infringement. Fisher, his former partner, having lost all belief in the invention, had sold his half interest in the American rights to George W. Bliss, a man of wealth. He it was who now advanced the money for the heavy legal expenses necessary to protect the patent. The rights of Howe were not fully established in the courts until 1854, and the fight for them was one of the longest in the history of American patent law. Many thousands of pages of testimony were taken which are in themselves a record of sewing-machine invention. With the proceeds of one or two successful suits, Howe was able to provide himself still further with the sinews of war. He was a rather gaunt and fierce figure in those days, for the death of a wife who missed sharing his good fortune had added to his firm resolve to get all that he could for the product of his brains. His patent was declared basic, and the courts gave him judgment for a twenty-five-dollar royalty on every sewing-machine built that infringed his patent. It was success at last. But Howe must have been haunted by the vision of the death-bed of one who shared all his sorrows and none of his joys.

During the life of his patent, fourteen years, Howe's income often reached $4,000 a week. He held that his rights were really worth as much as $150,000,000, and when, in 1860, he petitioned Congress for a further extension, he stated that up to that date he had received only $1,185,000. Although Howe had invented, demonstrated, and sold his machines, he never had a factory of his own. The one at Bridgeport, Connecticut, popularly believed to be owned by him, belonged to his brother, Amasa Howe. It was the centre of many lawsuits, brought by other inventors who declared that, although the machines built there were nominally made on the Howe principles, their own ideas had also been embodied in them.

Elias Howe again showed his mettle in the Civil War. He enlisted as a private soldier in a Connecticut regiment which he organized. Elected colonel by the men, he refused a commission and served in the ranks, although placing his means at the regiment's disposal. Once he advanced the money for the entire pay-roll, taking his own $13.60 with his comrades when the cash was paid. He died in Brooklyn in 1867, only two years after the struggle between the North and South had come to a close.

The excitement caused by the many suits of Howe against his competitors stimulated the invention of sewing-machines of all kinds, and there are now more than a thousand patents for such devices in our national archives.

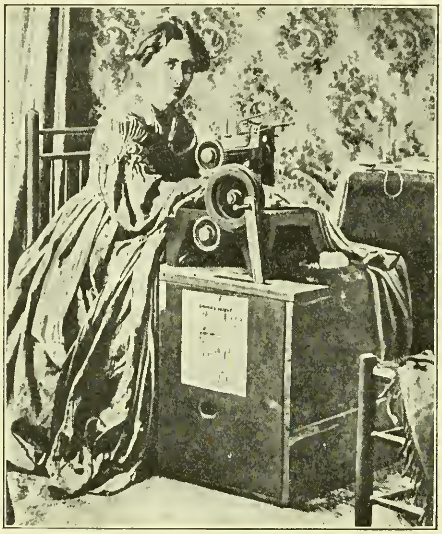
SINGER, PRINCE OF PROMOTERS

Among the inventors and the promoters of the sewing-machine, the name of Isaac Merritt Singer stands out conspicuously. His energy, force, initiative, and fine executive ability did more than any other agency to make the sewing-machine a boon to every household and a mighty factor in industry. By trade a mechanic, he made important improvements in sewing-machines, but his good fortune lay in the fact that he was one of the best salesmen of his time. He had been a theatrical manager at one stage of a picturesque career and his experience as a showman probably stood him in good stead in bringing the sewing-machine before the American public.

Singer was the pioneer in the use of lavishly decorated show-rooms. Even to this day, there are relics of the carved walnut furniture and the gilded ornaments which the sewing-machine makers used in attracting the women-folk to their establishments. These rooms were carpeted richly, and pretty young women sat before mirrors, operating the "greatest invention of the age," a sewing-machine that would make "three hundred stitches a minute." Consequently nearly every good housewife soon wanted to own a machine, and the Singer got a very good proportion of the business.

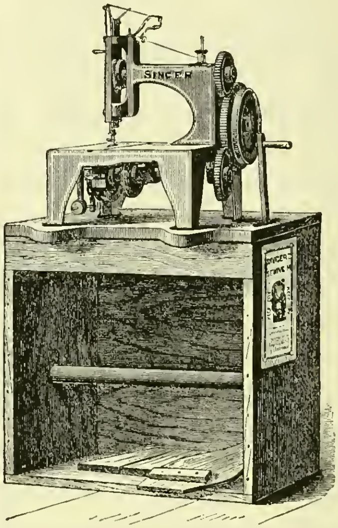
Singer, who proved to be the drum-major of a new industry, started life in Oswego, New York, as a cabinet-maker and mechanic. He became interested in a wood-carving machine and went to Boston to perfect it, after the manner of many inventors of that time who found help from experts of the Ari Davis type. In fact, Boston was then the hub of this humming new industry of making sewing-machines and power-machines of all kinds. He thought he could produce a machine for sewing clothes, and did it with forty dollars which he borrowed from a friend to pay for the materials. His machine was perfect as far as the top of the seam was concerned; but to his dismay, when he was using it at a demonstration, he found that on the other side were many hanging threads. He thought that he had failed, but soon a new inspiration struck him.

"It's tension," said Singer; "just tension; that's all that it needs." Correcting that defect, in 1855 he had a machine ready for the market. For a while he manufactured his machine in a small way in Boston, then moved to New York, where he opened up a large factory in Centre Street. Elias Howe came demanding his toll about that time, and there was a lively battle between these strong-willed and resourceful sewing-machine pioneers. The Singer Company maintained that it had a right to operate because the neglect of Walter Hunt in patenting his machine had opened up the use of the eye-pointed needle and other devices to all the world. The courts decided otherwise, and the Singer interests paid $15,000 in back royalties and



(Left) SINGER SEWING-MACHINE OF 1851.

In some respects Singer's machine suggested that of Thimmonnier. Thus it had a presser-foot, the device by which the cloth is firmly held down. The old Howe machine got its power from a wheel turned by hand, whereas Singer introduced the treadle. Singer also introduced the trim cabinet which now distinguishes the American machine.



(Right) ONE OF THE FIRST SINGER SEWING-MACHINES.

These were set up on the packing-cases in which they were shipped.

obtained a license from Howe. This sum helped Howe considerably in carrying on his fight against other alleged infringers.

But the efficient sales force of the Singer interests were soon spreading the "great American sewing-machine" to all parts of the earth. Owing to a quarrel with one of his associates, Singer withdrew from the company and went to England to live. There, at Torquay, he occupied an oddly built house which was one of the show places of the neighborhood.

Many improvements have been made on his original machine. It was marked, however, by an up-and-down motion of the needle, driven by a rotary shaft concealed in an iron casing. The rough rim of a wheel, coming up through a slot in the table, easily carried the material toward the sewing mechanism. In some respects it suggested the forgotten machine of Thimmonier, particularly in the device called a presser-foot, that firmly held down the work. The old Howe machine got its power from a wheel at the side turned by hand, whereas Singer introduced a treadle by which even a slight drive with the feet would keep the machine in motion. The first Singer machines were packed in awkward-looking boxes, on which they were set when operated, the treadle being in the case. These boxes were later superseded by inlaid and varnished cabinets, or by the trim standards and supports of iron which now distinguish the American sewing-machine everywhere.

From a mechanical point of view, much credit belongs to Allen Benjamin Wilson, who invented a sewing-machine, even in the height of the craze over that device, without ever having seen one of any type. He used a double-pointed shuttle in combination with the needle, which made a stitch with each forward and backward movement of the shuttle, instead of one at each throw of the shuttle, as in the Howe machine. His first patent was granted in 1856 and from that date he led a busy inventor's life. He obtained a patent for a rotating hook a year later which made a lock-stitch of unusual holding power. Another twelve months and we hear of him introducing a method of feeding the thread by four motions, a method which was later adopted in practically all sewing-machines in popular use. The hook seized the loop of the thread in the needle when it had gone down to the lowest point, opened it, and carried it around the bobbin, so that the thread was then passed through the loop of the stitch.

Wilson formed a partnership with Nathaniel Wheeler, a very able manufacturer, and the Wheeler & Wilson machine was made for many years in Bridgeport, Connecticut, in a factory which before the Civil War was considered one of the largest establishments of its kind in the world. The machine had a vogue for many years and was in much demand by the women of the United States. Its model also proved of much value to the manufacturing trades, and some types of it for factory use have made three thousand stitches to the minute.

A Picture Inspires a Virginia Planter

Sewing-machines were being invented by people who had little or no mechanical experience to guide them. It has been shown that Wilson, the cabinetmaker, had never seen a sewing-machine until he decided to make one. Now came James E. Gibbs, a Virginia planter, who saw a picture of a sewing-machine in the *Scientific American*, together with a brief description of it. The mechanism was not visible in the engraving, for the working parts were largely hidden in the cast-iron casings. Gibbs fell to wondering how the thing worked and just how the needle stitched the cloth. To satisfy himself he made a rough machine of his own—the first model of which is still in existence—in which he thought he had shown just how those sewing-machines do their work. It did not occur to him until later that he had a revolving-hook, and therefore a machine of his own. His device needed the eye-pointed needle and the four-motion feed to make it a practical success, and this he found out later when he had to pay royalties to Howe and Wilson.

Such was the origin of one of the finest machines for certain purposes which the world has ever seen. It is marked by the peculiar and gracefully curved "G"-shaped head, which is represented in the trade-mark. Gibbs went to New York, where he formed a partnership with a man named Willcox, who had a large machine-shop. This was the origin of the noted Willcox and Gibbs machine. When the Civil War broke out, Gibbs returned to his native Virginia, where for four years he made gunpowder for the Confederate Army. When the war was over he went back to New York, where he found that his Northern partner had conserved his interests during all that period, and the two men resumed their business relations without making any reference to "the late unpleasantness."

The Willcox & Gibbs machine has for many years been made by Messrs. Brown & Sharpe, fine tool and instrument makers of Providence, Rhode Island. With the introduction of a new lock-stitch, the Willcox & Gibbs machine is now extensively used in the making of fine underwear, for which it is desirable to have the seam lie snug and flat.

Among the many good machines that spread the fame of American ingenuity around the world, was the old Grover, with its double-chain action, now long since disappeared from the market. To mention the names of all the machines which have contributed to the success of the wholesale manufacture of clothing would be to pile up a towering record.

With so much talent devoted to the perfecting of the sewing devices, it is not at all astonishing that ready-made clothing makers were soon utilizing every labor-saving device they could find. There was some opposition to the successive steps by the labor-unions, of course, but this was eventually overcome.

Again the Goad of War

The ready-to-wear clothing industry developed as the introduction of power machines hastened production. But it was not placed on its present firm foundation until the demands for uniforms made by the Civil War spurred inventive genius to the utmost and necessitated large-scale methods of handling the output of the woollen-mills. In order to meet the needs of the army, large buildings for the making of uniforms were erected in various parts of the country, and the clothing-makers responded with great ability to the requirements of the quartermaster-general. When the war was over, many persons feared that these big structures would have to be torn down, but the change into civilian clothes on the part of so many discharged soldiers kept up the old forces and taxed the capacity of the war plants. The development of the West, and the tide of immigrants from Europe, all eager to put aside their peasant costumes and appear in smart American clothes, still further increased the orders for ready-to-wear garments.

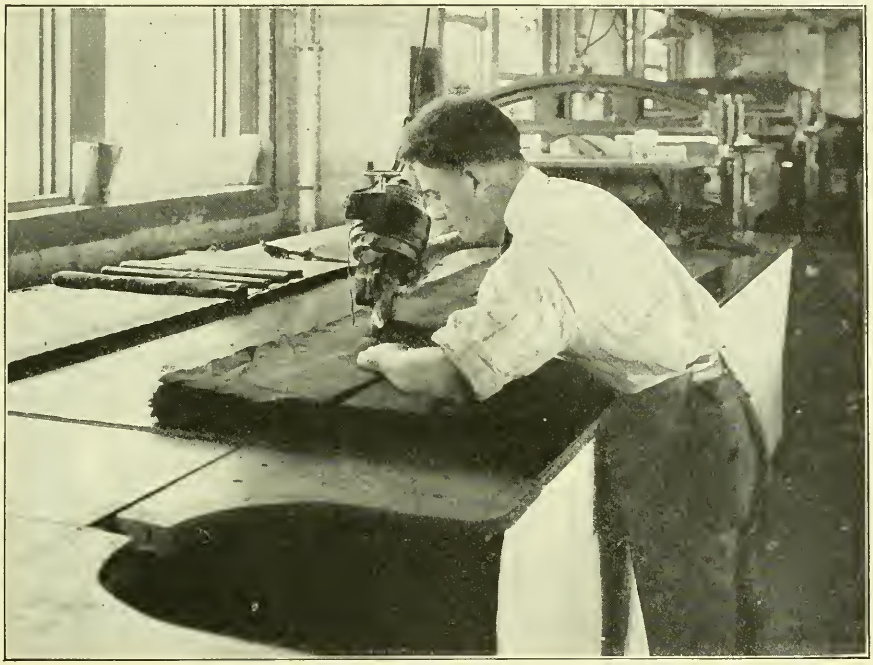
The machines used in the leading clothing factories are built into long tables and are driven by electric current which sends their needles flying at the rate of from three to four thousand stitches a minute. As the average stitch is about one-eighth of an inch in length, machines of this power can reel off readily forty-five feet of seam a minute.

Cutting Cloth with Electric Knives

It was soon evident that garments could not be cut fast enough to keep pace with four thousand stitches a minute on a machine operated by one man or woman. In the early days of the ready-made-clothing industry, a very strong and clever cutter could use his shears on three plies or thicknesses of cloth at a time. Workers of this class were known by their calloused thumbs and first fingers of their right hands.

George P. Eastman, a foreman in a clothing factory in Toronto, invented in 1897 a reciprocating or straight-knife machine of unusual excellence. He had been in the clothing business as cutter and foreman for many years, and had become dissatisfied with the appliances which were then on the market as substitutes for the shears. The round-blade machine then in use he thought unsuitable, for in going around a curve in the design laid out of the cloth, he noted that the machine did not cut all the pieces precisely the same, and that the variation was still more marked in going about an angle. The Eastman Machine Company, of Buffalo, was organized for the marketing of his inventions, as Eastman had no capital of his own. He later sold his holdings for a large amount and retired to his old home in Canada. The device of Eastman, which has undergone many improvements in the last twenty-four years, is widely used.

Some unknown genius in England then invented the short knife, which could be employed in cutting out four or five plies. Later came a gang-saw arrangement, much like the heavy vertical blade in the old-time sawmills. The cloth was shoved up against this moving saw by hand, and the cutters, in order to keep their hands whole, wore fingers of tin a little longer than their own digits. Later came the round or buzz-saw, which whirled around as it projected half-way above the top of a table. The cutters got up to ten or twelve thicknesses of cloth in this way, but without a guard the saws were dangerous. Also, since the position of the layers of cloth had to be continually shifted, the method was neither satisfactory nor speedy.



CUTTING CLOTH WITH AN ELECTRIC MACHINE.

As many as 120 layers of cloth are cut at one operation. Electrical cloth-cutters of this type have blades which rotate at a speed of forty-eight miles an hour.

A distinct advance was made in cloth-cutters in 1872, when two mechanics, Albion and Wurth, established a small factory on Staten Island, New York.

There they made a steam-driven machine of heavy build, consisting of mechanisms for operating a reciprocating, vertical knife. The blade, so adjusted, and rising and falling at a high speed, reminded one of the action of the earlier sewing-machines. Another arrangement, the Fenno cutting device, was also worked by steam, but had a circular rotary knife rigged to a long arm. Both cutters were heavy and could not be run over the cloth as are the machines of the present day.

A Cincinnati cutter, a man named Bloch, devised a round-blade machine operated by electricity, and as it weighed only thirty-five pounds it was better adapted to the needs of the industry. From 1892, the year of the Bloch patent, the development of the mechanical cloth-cutting machine was rapid. The Eastman Company of Buffalo, in 1897, introduced a vertical-blade machine driven by electricity, and seven years later they brought out a rotary device. In all these cloth-cutters, a small motor above the blade supplied power and speed. A machine perfected by H. Maimin, a veteran in the business, has in some types a four-inch circular blade which develops a speed of 4,000 revolutions to the minute. While the machine is laid over the cloth, this little round knife is travelling at the rate of 12½ inches (3.1416 times its diameter) per revolution, which is four-fifths of a mile a minute or forty-eight miles an hour.

The advantage of these high-power cutting machines is not merely that they can cut twenty, thirty, forty, and even as high as 120 thicknesses of cloth, but also that they enable one marking out of the pattern to do for all the thicknesses in the pile. This reduces expenses. The laying out of the pattern so as to get the value of all the cloth possible is a fine art, and one man may save ten per cent. more cloth than another.

Sometimes this economy is blocked by unions which insist that only so many piles may be laid down. There have never been any riots over the introduction of the cutting-machine, but for all that its coming into the industry has been opposed by labor rules and regulations at every step. There were in the city of New York twenty years ago about 200 mechanical cloth-cutters of six or seven different types in use, and every one of them was attacked. It was feared that men would be thrown out of employment right and left, especially as the worker with clear head and steady nerves could operate a machine without ever having served an apprenticeship at the shears. There are now, according to a careful estimate, 6,000 machines in use in the metropolis, but the number of operatives in the clothing industry is still increasing.

There is hardly a step now in the ready-made clothing business which does not have some kind of a special machine. There is a machine, for instance, employed for stitching the stiffening in the lapels of coats, another that presses into the form of the body the lining of overcoats. Once the clothes take shape and are duly basted together, the lightning-like sewing-machines make quick work of them.

One of the most tedious operations in clothing-making is the putting in of the buttonholes. The customs tailors made them by hand, but in most ready-to-wear garments they are the work of machines. Many attempts to fashion buttonholes by machinery were made as soon as the clothing business was established on a wholesale plan. The best-known of the pioneers in this line was John Reece, of Boston, who in the early eighties produced a machine which would cut and work buttonholes at the same time. He had to work many a year after his device was mechanically perfect before he could market it; but it is now used for all kinds of fabrics, from the flimsy shirtwaist to the heaviest overcoat. Only an expert can detect the difference between the work of the Reece buttonhole-machine and that of the most skilful journeyman tailor. Another type of this machine is used in sewing on shoe-buttons, and the makers show with a glow of pride a photograph of a pair of shoes worn by President Harding at his inauguration, the buttonholes of which were made and worked by their contrivance.

The Dislocated Shoulder That Gave Fortune

The appearance of a suit of clothes largely depends upon the way it is pressed, and the maker of even the cheapest ready-made garments cannot afford to neglect that feature of his trade. The hardest article of men's apparel to make is a coat, and it is also difficult to press so as to catch the eye of the customer. Painstaking workmen will often take a whole day to press eight or ten coats with the big iron, known as the "goose." More speed is attained with the use of the gas-irons, which have flaming vapor inside of them and are fed by means of a rubber tube. All these are heavy and awkward tools, and had it not been for the fact that a certain boy apprentice in a small tailor and dyeing shop at Syracuse, New York, dislocated his shoulder, the pressing of suits might still be a slow and laborious business.

After his accident, Adon J. Hoffman was unable for a time to use his arms, so he invented a clothes-pressing machine which he could operate with his feet. Instead of wielding the heavy iron, he applied steam-pressure, which he controlled with a foot-lever. A man with a broken shoulder can handle this press alone, for all that he has to do is to lay the garment between two pads and turn on steam-pressure. Hoffman felt so sure that he had something worth while in the first model he made, that he mortgaged his earnings for six months in advance to get the materials for his experiments. But the dyeing and dry-cleaning business not being very good at that time, he went to the State of Washington for a few months to regain his health. He finally drifted back to his home town of Syracuse, bringing back with him his machine, on which he had made some improvements. Eventually he set it up in a little tailor-shop which he opened just opposite the Yates Hotel.

Sitting in the window of that comfortable old hostelry one stormy day was a man who had been caught in the rain. His coat was humpy, his trousers baggy, and he had no other suit with him. As he gazed across the street, he saw in a window opposite the sign:

CLOTHES PRESSED WHILE YOU WAIT

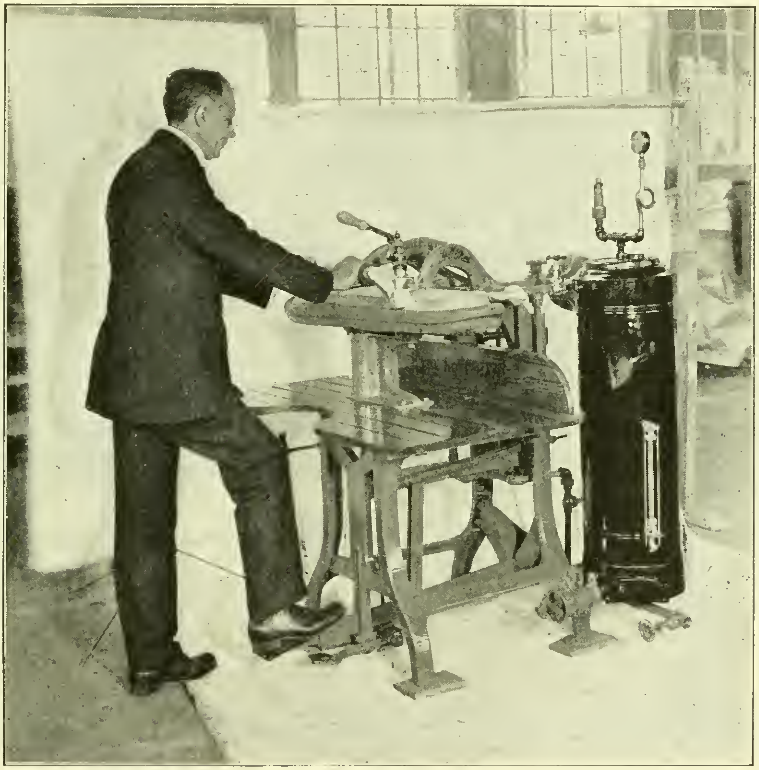
It was just what he needed. Over he went and the young clothes-presser gave him a bath-robe to put on temporarily and told him to make himself comfortable behind the curtain which partitioned the little store. Presently the patron heard a queer bumping and the hiss of live steam. Rushing out into the store he saw young Hoffman putting his coat into a strange contraption, the jaws of which snapped like those of an alligator.

"Hold on!" he shouted. "What are you doing with my coat, young man? Where is your iron?"

"Don't need it," answered Hoffman. "There are your trousers, already pressed. Put them on."

Theodore D. Palmer, for that was the customer's name, was extremely interested and asked to have the principles of the new contrivance explained to him.

"Have you patented this thing?" he inquired when he had heard the young man's story.



THE HOFFMAN CLOTHES-PRESSING MACHINE.

The man at the machine is the inventor. More than 100,000 of these machines are now in use.

"No, sir. To promote this, I need $15,000, and I haven't a red cent to my name."

Palmer had some money left from the wreck of an ill-starred tanning enterprise. He saw that here was an invention that should make a great deal of money for the promoters. Within a few days a stock company was formed to build and sell machines; young Hoffman went on the road as chief salesman and demonstrator and Palmer remained in Syracuse to manage the factory.

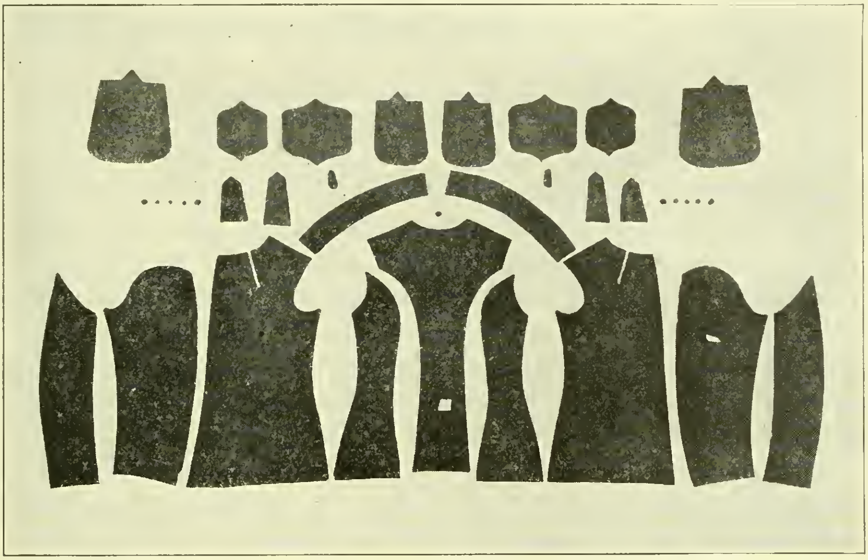
During the first year 100 of the new machines were sold, and by 1908 the business was on a good basis and had been reorganized on a larger scale. An office was opened in Wall Street, New York city, and the stock put on the market. Five years later 30,000 machines had been sold and branches of the company, then known as the T. D. Palmer Company, were established in all parts of the world. There are now said to be 100,000 of the machines in use, and the corporation, known as the United States Hoffman Machinery Company, Inc., has a huge factory in Syracuse. In that city Adon J. Hoffman built himself a fine house, and became a rich man.

Any one watching one of the Hoffman presses at work in a large clothing factory is taken aback with the magical way in which it irons and dries out the clothes. When the suit goes into the jaws of the press, a heavy pressure of steam penetrates and moistens it. Then the steam is turned off, and the surplus steam or moisture lingering in the garment is drawn off through the lower flange by a pipe connecting with a chamber in which a vacuum has been created.

The various steps of clothing manufacture, ending with the pressing of the final product, are about as complex, if not more so, in the making of clothes for women. Even swifter sewing-machines are used on some of the light fabrics, and machines of more refinement and finish are employed in the pressing and ironing operations.

The mission of the knitting-machine seems dedicated to women's wear. It is a machine that has undergone many changes since the vain efforts of the Reverend William Lee, in 1589, and it has now become a dependable mechanism without which there would be no reasonably priced stockings and sweaters and such comforts. However, the simplest form of framework knitting, devised by Lee, remains with only slight alterations to this present year of grace. The rib-work design of Strut made possible those openwork lace hosiery designs which are in such demand by fashion. Dawson, by the invention of his wheel, permitted the threads to be laid in any direction and in any course.

It was the good fortune of another clergyman, Isaac W. Lamb, of Michigan, to compensate for the failure of William Lee, for, in 1863, he patented one of the most important of the knitting-machines ever devised. Isaac Lamb, son of a pioneer minister, showed his mechanical ability at the age of twelve by constructing whip-lashes, and later he invented a machine for braiding the leather thongs in four strands. From this simple contrivance he progressed to a complicated knitting-machine that could knit both flat and tubular work. Lamb organized a company and improved the machine so that it could produce thirty different kinds of knitted goods and could be worked at the rate of 4,000 knots a minute. After making a fortune and receiving many medals from foreign governments, Lamb was ordained as a Baptist clergyman and spent the remainder of his life preaching in Michigan.



COMPONENT PARTS OF A WOOLLEN SERVICE COAT WORN BY OFFICERS OF THE UNITED STATES ARMY DURING THE GREAT WAR.

How the Clothing Industry Grew

Considering its small beginnings, the manufacture of ready-to-wear clothing has made remarkable progress, and it furnishes one of the most notable examples of the value of power applied to machinery. A Department of Commerce report made in 1916, after a long study of the men's factory-made clothing industry, shows that in 1849 the average number of wage-earners employed a year was 96,531. The labor-saving machines, such as the sewing-machines, did not get even a slight hold on the industry until 1850. In 1909, sixty years later, after scores of labor-saving devices had been brought into the business, there were 191,183 operatives.

Again the urge of war swept over the ready-to-wear garment industry in 1914, and especially when in 1917 the United States entered the European conflict. To meet the requirements of millions of men, both here and overseas, the inventors were put on their mettle to devise machines that would speed up production to the limit of human strength and ingenuity. Many improvements in existing machines were made at that time. New types of powerful sewing-machines, swifter machines for stitching, buttonholing, blind buttonholing, seaming, seam-closing, fronting, pressing, and labelling, and later for pressing came into being as though born of the needs of the hour.

As an example of what clothing soldiers in the trenches need, we append a list.

Slicker and overcoat, every five months.
Blanket, flannel shirt, and breeches, every two months.
Coats, every seventy-nine days.
Shoes and puttees, every fifty-one days.
Drawers and undershirts, every thirty-four days.
Woollen socks, every twenty-three days.

These figures from the office of the quartermaster-general show that war depends upon the clothes-maker, as well as upon the victualler, to keep its armies in the field.

The value of the output in the men's ready-made-clothing industry in 1919 was $1,186,707,000, as compared with the $458,211,000 of 1914. Prices were high at that period and are coming down, and the Engineering Council, in a recent report, has estimated the value of the clothes made for men in the year 1921 at $600,000,000.

One of the wonders of the clothing industry is the wide variety of garments which it furnishes ready-made. A large manufacturer, for instance, may put out twenty-nine kinds of sack suits, with fourteen special variations, and the choice of 1,100 varieties of cloth, to say nothing of three styles of linings — thus making possible some 278,000 different combinations. This, of course, adds greatly to the cost of clothing, for if garments were all of standardized makes, such as is the case in military uniforms, the cost of covering the human frame neatly would be scaled down to the lowest rates.

CHAPTER IV

HOW SHOES ARE MADE BY MACHINES

IN all civilized ages but ours the cobbler with his hog's bristles waxed to thread, his lapstone, knee-clamp, hammer, pincers, awl, knives, paste-horn, and blacking-pot has made boots and shoes with tools practically unchanged. Shoemakers' tools taken from the ruins of Roman villages and even from more ancient tombs differ little from those in use when the United States army shoe of 1860 was made. But, suddenly, sewing-machines run first by hand and treadle, and then by horse-power or by steam, began stitching first the shoe-uppers, then uppers to the soles. By another year many Northern shoemakers enlisted and let the machines do it. So far as the public knew, it all came about like the lifting of a theatre curtain, but the stage-setting meant a glum century of experiments, and we must go to Europe for the beginning of it.

Thomas Saint, a London cabinetmaker living in the parish of St. Sepulchre, invented in 1790 the first known leather sewing-machine, unless we class as sewing-machines certain devices for embroidering gloves. The Saint machine was designed to sew "shoes, boots, spatterdashes, clogs, and other articles." The needle used had a notch near the point, but no eye; this notch pushed the thread through a hole made by an awl on the previous stroke of an overhanging arm and formed a loop with the bent point of the needle. This loop was carried over a former loop, leaving a chain of loops on the under side, and seems to have been the prototype of the stitch perfected by Willcox and Gibbs years later in America. These and other interesting things about the sewing-machine needle can be found in the chapter on "Making Clothes by Machine." Saint had the key to great possibilities in the shoe-machinery line, but he was unable to open the door.

Brunel and His Nailed Shoes

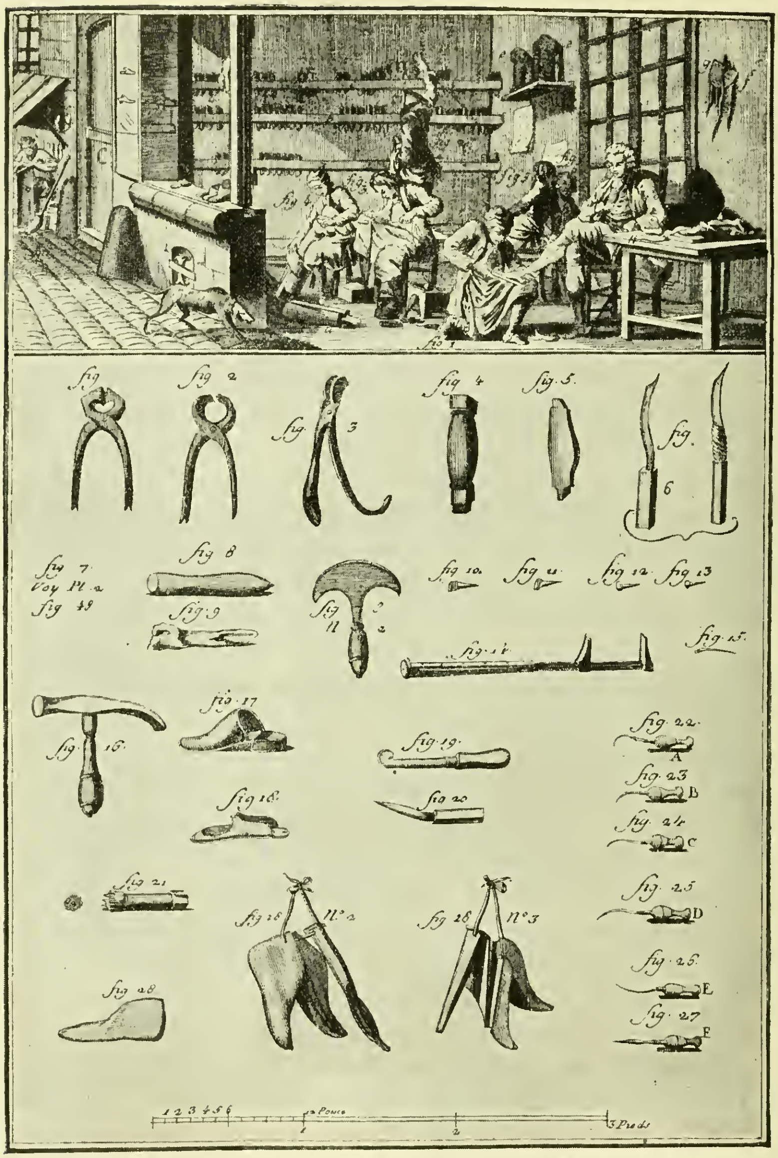
Twenty years later, 1810, an inventor in England made and ran a range of sixteen machines that turned out shoes with soles nailed to the uppers. He brought it within reach of the English public and the English public did not care for it.

On a day in January, 1809, a Frenchman was standing on the wharf at Portsmouth, England. He had escaped the terrors of the French Revolution by boarding a packet bound for America, where he was naturalized as a citizen in 1796, and, after a short career as civil engineer and architect, had settled in London. He watched in evident pain the landing of wounded soldiers from troopships fresh from Spain, where Napoleon was overrunning the Peninsula. Their feet were shoeless and bound about with filthy rags. He knew this misery came from dishonest army shoe contractors, who had put clay between two thin outer soles to give them the proper weight and had blacked them to give them the proper appearance. His indignation resulted in his making an emergency shoe, nailed, and its leather cut and finished by machinery.

The name of this man was Marc Isambard Brunel; he was afterward knighted for building a tunnel under the Thames River. His son was architect of the *Great Eastern* steamship.

Within a year after the disgraceful scene on Portsmouth dock Brunel designed and built upon the banks of the Thames a chain of machines producing nailed army shoes, the soles also studded with fine nails. Twenty-four one-legged soldiers from Chelsea Hospital soon learned to operate the machines. The sole was cut on a cast-iron frame and the upper was stretched over a cast-iron last and securely clamped. The driving of the nails through the outer sole, upper leather, and inner sole was done by the up-and-down stroke of a rod carrying on its end an awl and hammer, the iron last revolving in a way to bring the rim of the sole to the base of the falling rod.

A trial consignment of shoes for the Thirteenth British Regiment established the superiority of the Brunel type over the army shoe. He was given orders by the government, and his factory turned out 400 pairs a day. But when Napoleon escaped from Elba in March, 1815, followed by more fighting, about



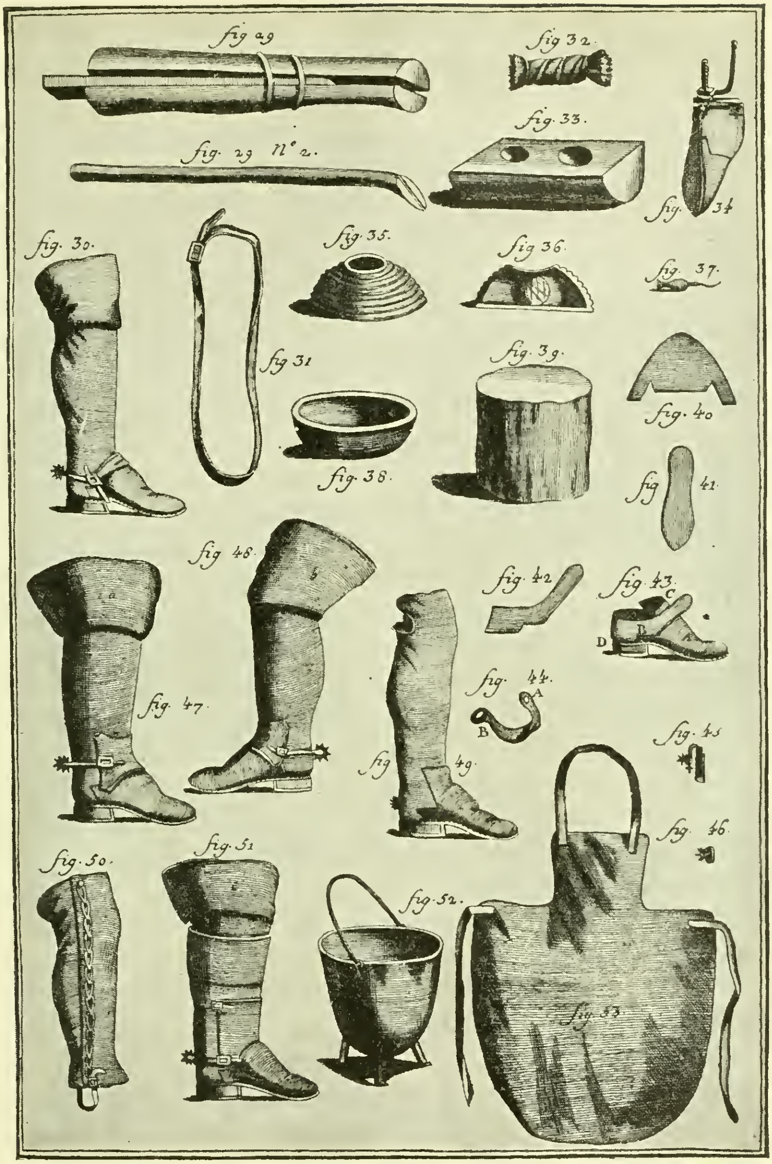
From the "Encyclopédie ou Dictionnaire Raisonné des Sciences, des Arts et des Métiers, par une Société de Gens de Lettres. 1789."

AT THE TOP—AN EIGHTEENTH-CENTURY COBBLER'S SHOP.

Fig. 1. Workman measuring a foot.
Fig. 2. Workman looking for the last he needs.
Fig. 3. Workman stitching a sole.
Fig. 4. Workman putting a boot over a last.
Figs. 5 and 6. Two journeymen.
Fig. 7. *a*, *b*, *c*, rows of different lasts.
d, boot lasts.
e, ready-made boots.
f, measuring-tapes.
g, vamp pattern.
h, table laden with various tools.

LOWER PART OF PICTURE—TOOLS OF THE EIGHTEENTH-CENTURY COBBLER.

Fig. 1. Pincers.
Fig. 2. Cutting nippers.
Fig. 3. British type of lasting pincers.
Fig. 4. Rand-forming tool.
Fig. 5. Boxwood polishing-tool.
Fig. 6. Shoemaker's knives.
Fig. 7. Boot transferred to Fig. 48 on page 407.
Fig. 8. (No. 1), Boxwood rubbing stick.
Fig. 8. (No. 2), Cropping-knife.
Fig. 9. Scratch bone.
Fig. 10. Three-flange hob-nail.
Fig. 11. Two-flange hob-nail.
Fig. 12. Lasting-stick.
Fig. 13. Wire tack.
Fig. 14. Shoe-measuring stick.
Fig. 15. Square-shank sewing-needle.
Fig. 16. Hammer.
Fig. 17. Man's overshoe.
Fig. 18. Woman's overshoe.
Fig. 19. English type of seam-setting tool.
Fig. 20. Spreading-tool.
Fig. 21. Star stamp.
Figs. 22, 23, 24, 25, 26, 27, *A*, *B*, *C*, *D*, *E*, *F*, British type of awl.
Fig. 28. (No. 1), Last.
Fig. 28. (No. 2), Expansible form.
Fig. 28. (No. 3), Another type of expansible form.



From the " Encyclopédie ou Dictionnaire Raisonné des Sciences, des Arts et des Métiers, par une Société de Gens de Lettres. 1789."

Fig. a9.	A boot-tree.
Fig. 29, No. 2.	A trimming-stick.
Fig. 30.	A military jack-boot.
Fig. 31.	Shoemaker's strap stump.
Fig. 32.	Bunch of bristles.
Fig. 33.	Moulding-block.
Fig. 34.	Shoe-stretcher.
Fig. 35.	Thread-holder.
Fig. 36.	Interior of thread-holder.
Fig. 37.	Curved sewing-awl.
Fig. 38.	Wax cup.
Fig. 39.	Cutting-block.
Fig. 40.	A vamp.
Fig. 41.	A sole.
Fig. 42.	A foxing or quarter with strap.
Fig. 43.	Low shoe. *A.* Vamp. *B.* Quarter. *C.* Strap. *D.* Heel.
Fig. 44.	Adjustable spur-holder.
Fig. 45.	Removable spur.
Fig. 46.	Cockcomb spur.
Fig. 47.	Jack-boot (dragoon.)
Fig. 48.	Jack-boot.
Fig. 49.	Officer boot (infantry.)
Fig. 50.	Loop-laced garter or legging.
Fig. 51.	Postilion boot.
Fig. 52.	Kettle for tempering leather.

30,000 pairs of Brunel army shoes remained undistributed in the government stores. Brunel stored his surplus and protested. Lord Palmerston, newly installed in the war office, dropped in at the Brunel shoe factory and learned that the inventor's losses of over $15,000 were caused by the failure of the government to keep its word. The minister turned to Lord Rosslyn and remarked: "We must take this from Mr. Brunel." Waterloo and a second peace overtook Brunel, who became disgusted with broken promises, and he was elbowed into the bureau of claims with still further losses. A contractor's lobby and the hostility of shoemakers' guilds must share the responsibility for a part of this shabby treatment. When later he made for the public shoes, water-boots, half-boots, fashionable shoes, and Wellington boots, Brunel continued to lose, although he sold a common walking shoe for $1.20 when leather was about forty-seven cents a pound. Brunel then went out of the shoe-machinery business. American shoe-pegging machines appeared some twenty years later, but the next machine gang that completed a nailed shoe was put on the market by Colonel McKay over fifty years after Brunel's successful invention and business failure in nailed shoes.

A strange fatality kept England out of the industries built upon the machine-stitching of leather until America gave the hint. This seems all the more remarkable from the fact that an English machinist, Thomas Archbold, of Leicester, while making improvements in machine-stitching for a glove manufacturer named Edward Newton, applied the principle of the eye-pointed needle in 1841. Three years later James Gibbons, a Nottingham merchant, an old hand at lace-making, invented a curved eye-pointed needle, which was the central thought of the Howe needle used in connection with a shuttle. If Gibbons had only lifted his eyes from lace to leather and cloth, he might have seen a Canaan of future factories clothing and shoeing the world by means of machinery.

Early American Improvements

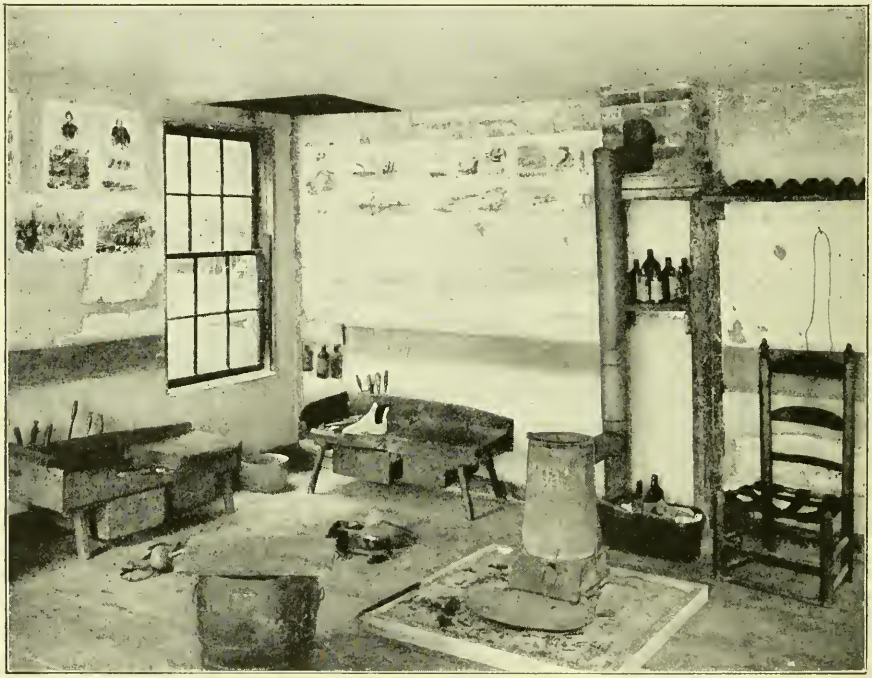
Devices multiplied in America for fleshing, hairing, and breaking hides, as well as splitting, rolling, cutting, and crimping leather. One can turn over the pages for 200 years from the landing of the Pilgrims without finding any novelty in mechanical shoe construction that survived the man who devised it. In the thirties of the nineteenth century Parker's leather-splitting machine and Preston's device for pegging shoe-soles had some vogue. In 1845, Gilmore's rolling-machine for hardening sole-leather proved to be a labor-saver, as it could do in a minute or two what formerly required half an hour's pounding of hammer on lap-stone. From 1812 to 1833, the date of Samuel Preston's shoe-pegger, there were eleven patents taken out for attaching soles by means of pegs. The Preston contrivance was awkward enough to handle, but cobblers used it as late as the Civil War.

Anticipating for the moment the story of this symptom of shoe machinery, no great advance was made in pegging machines until B. F. Sturtevant perfected the "peg strip" under the patronage of Elmer Townsend, a Boston auctioneer. The peg strip is a thin ribbon of wood cut across the grain, and wide enough to split into peg lengths. Sturtevant's contribution was a method of compressing the peg strip between hot rollers, so that the moisture was withdrawn from the wood and the peg reduced in size. When driven into the sole it absorbed the moisture of the leather and expanded, making a secure fastening. Sturtevant and associated inventors demonstrated the feasibility of a machine-pegger, which retired all others from the market. By the Sturtevant method the pegging was done upon the shoe-last. Years later John F. Davey introduced a horn-pegging device, something on the principle of the Blake rotary horn in sewing. Sidney W. Winslow and his experts united the virtues of the Sturtevant and Davey machines, and this was later refined by the United Shoe Machinery Company. Pegs can now be split and driven at the rate of 350 per minute. Seventy-five years ago many farmers' boys made pin-money by whittling shoe-pegs during their winter evenings. A whole pegged shoe can now be made in the time a boy could whittle a handful of pegs.

How the Sewing-Machine Influenced Shoemaking

The real story of the machine-made shoe begins with the Howe eye-pointed curved needle operating with an under shuttle. It was this invention that inspired a whole generation of inventors working on the two specialties of cloth and leather stitching.

In a larger way invention had hit a high-water mark in the forties. In the year 1844 Goodyear the elder had hardened rubber by the use of sulphur; Howe had invented the sewing-machine; and the news of the nomination of Polk for President, sent from Baltimore to Washington over the Morse "magnetic telegraph," constituted the first public despatch over the only telegraph line in the country.



INTERIOR OF THE OLD WINSLOW SHOP.

Typical shop of the period in which boots were sewed by means of hogs' bristles waxed to thread, and the lap-stone, hammer, pincers, knife, paste-horn, rubbing-stick, and blacking-pot were their only implements the shoemakers knew.

Howe's invention of the domestic sewing-machine was almost immediately applied to the machine-sewing of leather by the boot-and-shoe trade, and this branch of the art had so advanced by the time of King Edward VII of England that he fell into the habit of sending regular orders for shoes to Lynn, for himself and his royal family. India produced the kid pelts, Massachusetts tanned the leather and made the shoes on a chain of cutting, sewing, and finishing machines, and all his Majesty had to do was to wear and enjoy them. Beau Brummel thought it a good act to employ separate makers for his right boot and his left; but American machinery did better, for King Edward and the world by putting the old hand-tooled boot and shoe out of commission. The leather stitchers of the Singer factories are now equipped for sixty machine operations, of which about one-third are used in sewing uppers for boots and shoes, an important business in itself.

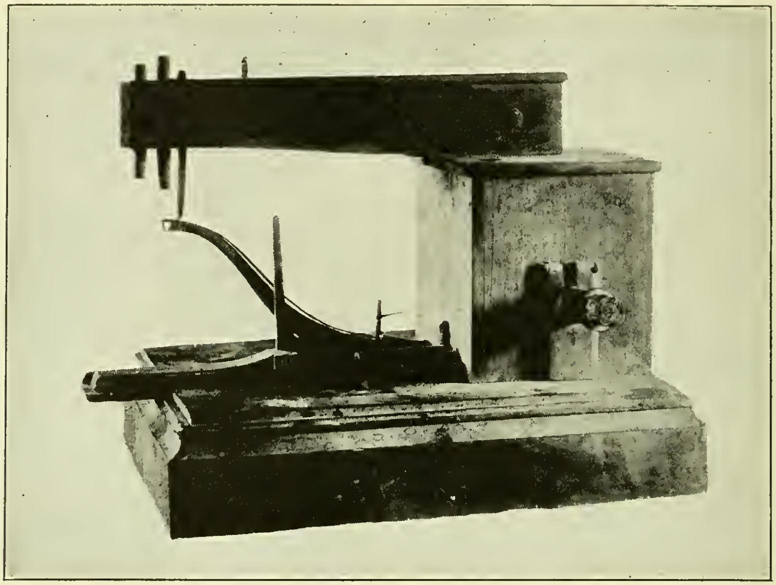
The work of bottoming and finishing the shoe led to the founding of another immense industry. Three men of notable personal gifts are identified with the history of bringing one hundred and more operations under machine control in order to bottom boots and shoes. The first is Gordon McKay, who, after making an emergency army shoe in 1861 with stitched soles, gave most of his attention to metallic fastenings of soles. The second is Charles Goodyear, Jr., who began by promoting the invention of machines for stitching "turned" shoes, and won distinction by developing machines for stitching together the inner sole, upper, welt, and outer sole, without permitting the needle to pierce the upper surface of the insole. And, finally, Sidney W. Winslow speeded the invention of machinery for lasting shoes, and made the master-stroke that brought all three into one company in 1899.

These three men cannot be called inventors. They had the gift of forecasting new methods of manufacture, the patience to hunt up machine experts, the art of interesting capital, and the ability to market their machines when made. Few men have created and perfected a more difficult business.

We have now to deal with a forty years' wandering in the wilderness of invention, ending in 1899, when the three groups of shoe-machinery interests joined in forming the United Shoe Machinery Company.

Gordon McKay Meets Lyman Blake

About three years before the breaking out of the Civil War a mechanic, once the manager of a large machine-shop in Lowell, Massachusetts, watched intently a cobbler operating a machine for sewing soles to uppers in a little room on Tremont Row, Boston. The cobbler invented it and had given an option of purchase to some Lynn shoe manufacturers for $50,000. The mechanic, a Scotchman, offered the cobbler $70,000, in case the Lynn men did not buy, $8,000 to be paid in cash and $62,000 out of the earnings of the machine. The moment the option expired the Scotchman handed $8,000 to the patentee. The Lynn men appeared with their $50,000 immediately afterward. It took a seven years' lawsuit to establish the Scotchman's right to the cobbler's patent.



THE ORIGINAL BLAKE MACHINE.

This was invented shortly before the outbreak of the Civil War. Blake lasted the shoe in the old way. Then he withdrew the last or wooden model of the foot over which the upper had been fitted to admit a stationary horn bearing a thread and looping device that wound the thread around and into the barb of an eyeless hooked needle. Thus a lock-stitch was formed, and a seam closed which held together the outer sole, the upper, and the insole. It was this machine which Gordon McKay bought.

Gordon McKay was the purchaser and Lyman R. Blake the inventor. The Blake leather-stitcher, put into shape under McKay's eye and refined later by United Shoe Machinery experts, is still doing service in shoemaking.

In 1857 cobbler Blake conducted a contract-stitching room at South Abington, Massachusetts, for sewing the tops of boots. A sweep pulled by an old horse furnished the power to machinery that could stitch three thicknesses of leather. Both the Singer and Howe machines of that date could do it easily. Blake was somewhat of a character in Abington. At one time he wanted to make wheels to be attached to boots, a generation before roller-skate days. People smiled. Now he wanted to sew soles with the needle used by the machine to sew three thicknesses of leather. "Not with the firm's money," replied his partners, who would not meet the expenses of experiments. A local wheelwright, however, and a brother-in-law machinist, a few dollars of his own, and hard work after hours to complete wooden models for the wheelwright to make casting moulds, comprised the equipment that produced the original model of the world-known sewing-machine, patented first in 1858, and later by McKay and Blake, and by McKay and Mathies, another brother-in-law of Blake.

Blake lasted the shoe in the old way, that is, he fitted the uppers snugly over a wooden model of the foot and temporarily fastened on the sole. Then he withdrew the wooden model or last to admit a stationary horn bearing a thread and looping device or whirl which wound the thread around and into the barb of an eyeless, hooked needle, forming a lock-stitch and closing a seam that held together the outer sole, the upper, and the insole. As the stationary horn could sew only the sides, leaving the toe and heel to be nailed, Mathies devised a rotary horn with complete success.

McKay kept his Scotch eye on stock dividends as well as public service, and at first undervalued the inventor's part of it. Blake took his $8,000 cash and, on account of his lungs, went to Staunton, Virginia, where he opened a shoe-store. McKay wrote him several times to return, as his experts "thus far have fallen down on the job completely." The gathering war clouds and a private tip of warning as to the danger of a Northern man's remaining in business in the South settled it; and Blake with his family rode on the last train out of Richmond bound for Washington in the spring of 1861. The Confederates seized his stock of goods and his money.

THE CIVIL WAR GIVES McKAY HIS CHANCE

The government needed shoes for the army, and the hand method of making them took time. Blake soon began to adapt the machine to army-shoe sewing, working with others under great pressure. For McKay, the war could not have come at a more fitting time. The manufacturers did not fancy the notion of offending their hand operatives by introducing labor-saving machines; nor did they care to increase their capital to invest in them; but a government order for 25,000 pairs of shoes or "bootees," as these brogans were called, put the shoe manufacturers in a more serious frame of mind and scored for McKay the first of a brilliant series of successes in making shoes by machinery.

To meet government specifications, Mathies channelled a track for the seam on the sole. After sewing in this channel the machine left it and continued the seam round and round toward the centre on the flat surface to strengthen the sole. Blake trained operatives to sew shoes for the Massachusetts Light Artillery Company, and he set up machines in many shoe factories with orders to hasten the work on army shoes.

The New England shoe-manufacturers were substantial people and co-operated in the war work. Seth Bryant, of Joppa Village, East Bridgewater, had been so disgusted at a pair of frail, ill-sewed shoes made in France and worn by a member of Washington's special guard, that he had made army shoes a study. When the call of 1861 came he carried to Gordon McKay a sample of shoes having two rows of seams about the soles stitched with large hemp thread. He was soon running McKay machines practically after his Joppa sample. Generally, however, the quilted bottom shoe prevailed. All these army shoes were "straights," that is, they were not rights and lefts.

Scattered through New England, and in shoe and leather districts of the country, small cobblers' shops or shops containing teams of five cobblers made shoes on a division-of-labor basis. The urgency of the government for soldiers' foot-wear became so great that these teams were increased to six, and there sprang up factories large enough for several teams, all making "fade-aways," which were pegged shoes with imitation seam-marks made by a wheel. They were called "fudge welts," and a six-handed team working from seven in the morning until nine at night could turn out fifteen pairs a day. Asa How, a shoemaker of Rowley, Massachusetts, in recalling those exciting days says:

"And so in that little old shop in Rowley we six cordwainers made fudge army shoes for Uncle Sam during the last six months of 1861 through '62 and '63. And then, early in '64, as Uncle Sam could now get McKay sewed shoes a plenty, five of our number, including myself, enlisted."

In some factories the old-fashioned shoemaker with a "fudge welt" on his last worked beside the operator of the McKay machine. A Haverhill shoemaker received his first McKay machine in 1862 and, as it had no channelling attachment, a local gunmaker fixed up for him a tool for bevelling, which served until the McKay channelling-machine appeared. In the first rush to supply the army, many pegged shoes were made and accepted by the government; but the McKay stitcher gained in favor as the machines came into use from the factories overworked to produce them.

Mayor Peter Neal, of Lynn, Massachusetts, a Quaker, took occasion at the White House to explain to the President that the McKay machine could sew around the sole of a shoe in thirty seconds. Mr. Lincoln remarked: "Friend Neal, go home and buy real estate. The day of little country shops is coming to an end. Shoes will be made in big factories in cities."

The early McKay machine continued to be worked over by experts, and it soon turned out 600 pairs a day, though part of the finishing had to be done by hand. The United Shoe Machinery Company continued to simplify the machine until it stitched 1,260 pairs a day.

The Development of Shoe-Making after the Civil War

When McKay lost the government as a customer on the return of peace, he lost the cream of his new business, as he had been forced to rent out his machines, dividing equally with the manufacturer the saving in labor cost. He picked up the notion of selling royalty stamps to be put on each pair of shoes made by his machines from a doctor next door to him on Tremont Street, who charged a royalty on the manufacture of a health shoe of his invention.

When the Blake patent expired in 1872, his application for an extension raised a storm of protests, particularly among Western shoe-manufacturers. When McKay undertook to explain to the trade at a meeting in Cincinnati why the extension should in justice be granted to him, the feeling became so intense that he rode out of the city in a cab rather than run the risk of being mobbed. After the extension factory men, even in the East, took the small stock premium offered them as an inducement to buy the McKay royalty stamps as a joke. But when the McKay stock had climbed in the market from five to seventy dollars, it proved the best joke of that and many seasons, for it laid the foundation of scores of private fortunes in New England. An Albany, New York, shoe-manufacturer with æsthetic tastes, pasted these gilded premium shares on his office walls, and the next tenant first painted and then wall-papered over them. Years later the shoe-manufacturer who owned the stock was unsuccessful in excavating and recovering his precious wall pictures. The joke was on him.

In 1863 English shoe-manufacturers paid Blake's expenses to cross the Atlantic and demonstrate the McKay machine. He had a happier time of it than did Elias Howe, for the McKay people knew something about doing business.

In Blake's plea for an extension in 1872 he estimated that 200,000,000 pairs of shoes had been sewn on his machines, at a saving of eighteen cents a pair over the cobbled product. When the extension had been granted, the McKay company renewed the contract with Blake. Unfortunately, consumption fastened upon him and he died in 1883, in Newton, Massachusetts, only forty-eight. Blake's talents were recognized both here and abroad; but as much cannot be said about his brother-in-law, Robert H. Mathies, the inventor of the rotary horn still in service as a McKay machine feature. His revenue never went above the mechanic's wage, and, desperately concluding that it never would, he took his own life.

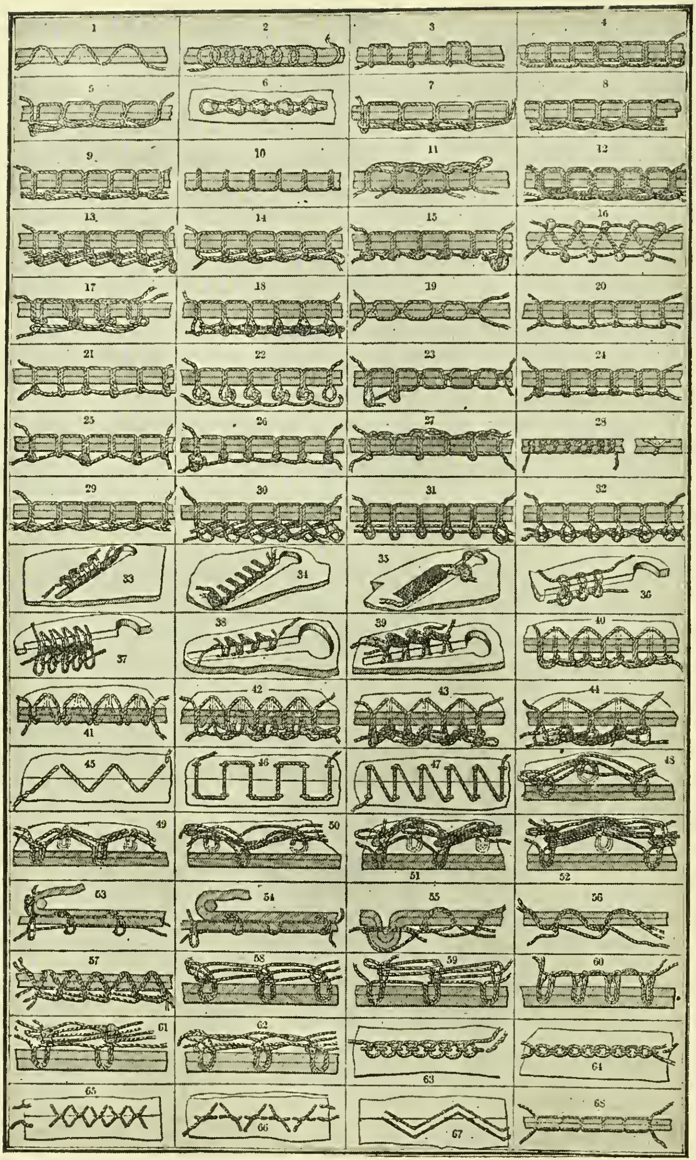
Gordon McKay's metallic-fastening interests centred in Winchester, Massachusetts, but for twenty years he lived in Cambridge, Massachusetts, and enjoyed the society of the college community and the distinction that public service brings. Most of the revenue from the four million dollars willed by him to Harvard University for the department of mechanical science will be left to increase until it reaches about twenty-two million dollars. It is a coincidence worth noting that Cambridge is identified with the troublous beginnings of machine-sewing of boots and shoes. Here Howe built his first model; here Singer made his first experiments, and here McKay lived in the days of his prosperity and planned a school of mechanical science that will remain a permanent memorial to him.

After the fall of Richmond, McKay took up the problem of nailing shoe-soles. He hired inventors, bought inventions, and gradually made metallic fastenings a success for the stouter grades of boots and shoes.

John Mundell, a Philadelphia shoe-manufacturer, exhibited at the Centennial of 1876 a French machine which rotated a wire with screw-threads into the sole, then cut off the section left in the leather. The War Department adopted the type which was built on a last cut to the shape of the foot; but the nails proved a conductor of cold, leaving a dot of frost on the stockings. Later the government adopted the Goodyear sewed welt shoe for the army and navy.

About the time that Mundell was exhibiting the French wire-nailing invention, Louis Goddu, a French-Canadian shoemaker, turned his attention to the subject. His first screw-machine held the coil of wire in a revolving kettle suspended from the ceiling, with pressure enough from its weight to worm the screw-cut wire into the leather. McKay bought it, as he did other devices for attaching soles by nails or screws. A thin slip-sole inserted in the shoe protected the foot from the cold nails. McKay's name is identified with the introduction of the first shoes, either stitched or nailed by machine, that came into general use.

Before footwear reached anything like a fixed standard, there were many stages of refinement for grace and comfort for machinery to accomplish. Men of learning tell us that the human



From Knight's "Mechanical Dictionary."

SEWING–MACHINE STITCHES.

(SEE OPPOSITE PAGE FOR EXPLANATION.)

SIXTY-EIGHT STITCHES AS REPRESENTED IN THE ILLUSTRATION ON THE OPPOSITE PAGE.

SINGLE THREADS.

No.

1. The ordinary running-stitch used in basting.
2. The back-stitch.
3. The fast stitch.
4. Chain-stitch.
5. Coiled-loop chain-stitch.

No.

6. Knitted-loop chain-stitch.
7. Knotted-loop chain-stitch.
8. Loop enchained by second alternate stitch.
9. Each loop locks and enchains alternate loops.
10. Staple stitch for waxed threads.

TWO THREADS.

11. Double-needle chain-stitch.
12. Double-thread chain-stitch, two threads, one needle.
13. Double loop-stitch. Grover & Baker.
14. Chain with interlocking thread.
15. Under thread through its own loop.
16. Two needles penetrate fabric from opposite sides.
17. Two needles working from the same side of the fabric.
18. Doubly interlocking loop.
19. Lock-stitch: Singer, Wheeler & Wilson. Weed, Wilson, Howe, Domestic, Florence.
20. Coil in needle-thread.
21. Double coil in needle-thread.
22. Coil in shuttle-thread.
23. Double coil in shuttle-thread.
24. Knot-stitch, every stitch knotted.
25. Knot-stitch, every other stitch knotted.
26. Knot-stitch (different knot).
27. Shuttle-thread drawn up to form embroidery.
28. Wire-lock; thread locked by wire.

THREE THREADS

29. Two-shuttle, each locking alternate loops.
30. Double-loop with interlocking third thread.
31. Two-shuttle, threads locking each loop.
32. Two-shuttle, threads intertwining and locking each loop.

DOUBLE-HOLE STITCH.

33. Single thread, loop of needle-thread drawn up over the edge and locked by needle at its next descent.
34. Two threads. Bights of needle-thread, above and below, extend to the edge of the fabric, and are locked by shuttle-thread.
35. Two threads. Needle penetrates back from edge, its loop passed to, and interlocked by, the needle at its next descent over the edge, and this second needle-loop locked by shuttle-thread.
36. Shuttle-thread drawn up over the edge of the fabric to the line of the needle-thread.
37. Needle-loop through the fabric locked by needle loop over the edge, and the second loop locked by second thread.
38. Third thread laid under the stitch at the edge of the fabric.

FANCY STITCHES.

40–47. Various of above described stitches made zigzag.

48–52. Single-faced or straw-braid, zigzag or herring-bone stitches.

53–62. Single-faced or straw-braid stitches.

63–67. Embroidering stitches.

68. Saddler's stitch.

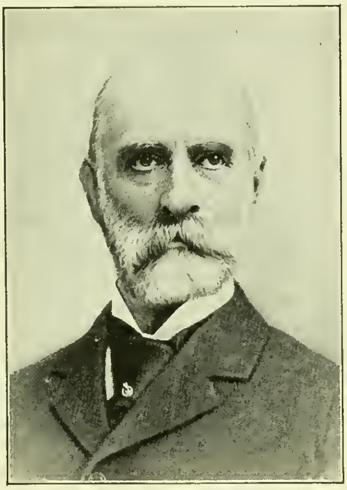
foot is the largest and most tender of any in the animal kingdom in proportion to size of body, because it was the last to come down from the tree-tops. The artificial protection of the foot has kept it tender, and it is the glory of machinery that this protection has been done gracefully. A cobbler is credited with the saying: "As a man walks, so he is, and the shoe tells the tale." The modern shoe cannot climb a tree, but it is more a part of a foot than the cobbled straights of past ages. Fashionable people at first poked fun at the "crooked shoes," as rights and lefts were called. The McKay army shoes were straights; so were the shoes of fashion down to about the time of the Civil War; and women's shoes continued straight till well into the eighties.

Charles Goodyear and the Welt Shoe

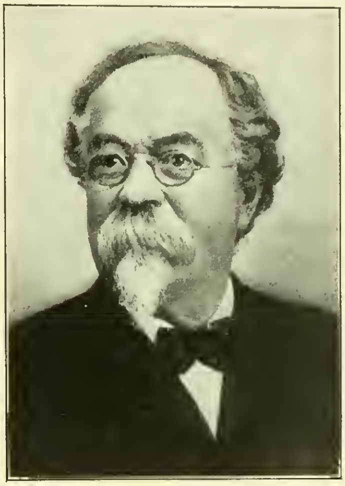
Style in the modern shoe of comfort is associated with the name of Charles Goodyear, Jr., who after years of toil and trouble added a rare touch of refinement in adroit machine motions and a novelty of design that pleased the eye and eased the foot. Like Elias Howe, young Goodyear grew up in a family where invention was the prevailing thought and where poverty became almost an invited guest as the constant search for new ideas went on.

Charles Goodyear was born in Germantown in 1833, near Philadelphia, where his father invented and manufactured domestic hardware and finally gained fame in hardening rubber. Shortly before the death of his father, young Goodyear tried his hand at making shoe-machinery and at the opening of the Civil War he was president of the American Shoe-tip Company. His vision went straight to a complete machine-made shoe, and it was his good-fortune to run across Auguste Destouy, a French machinist, in 1864, who had invented a machine for stitching light "turned" shoes. Three years later Goodyear engaged as superintendent a German named Christian Dancel, who for the next twenty-five years improved not only the "turn" machine but made many inventions down to 1892, when he perfected a curved-needle machine for sewing welts with a lock-stitch while the shoe was on the last. This exploit alone stamped Dancel as a master.

James Hanan, the Brooklyn shoe-manufacturer, brought Goodyear and Destouy together in a little shop on Church Street, New York city, where the Frenchman was working on a sewing-machine for "turns," Hanan being his patron. The old-time shoemaker sewed women's shoes "inside out" and then turned them. If he could turn them without starting the seams, he was classed as an expert workman. The Destouy machine for "turns" had two stitch movements. On one side was a curved awl and a curved needle, the awl, by advancing the leather, acting as a feed. On the other side of the machine a needle, straight and forked, operated in sewing harnesses, the thread being pushed through the hole made by the awl. It could thus do both light and heavy leather stitching. Goodyear bought Destouy's invention, but James Hanan, as well as his son, John H., never broke away from the Goodyear group. David Mills, an English machinist, improved the Destouy stitch



GORDON McKAY.

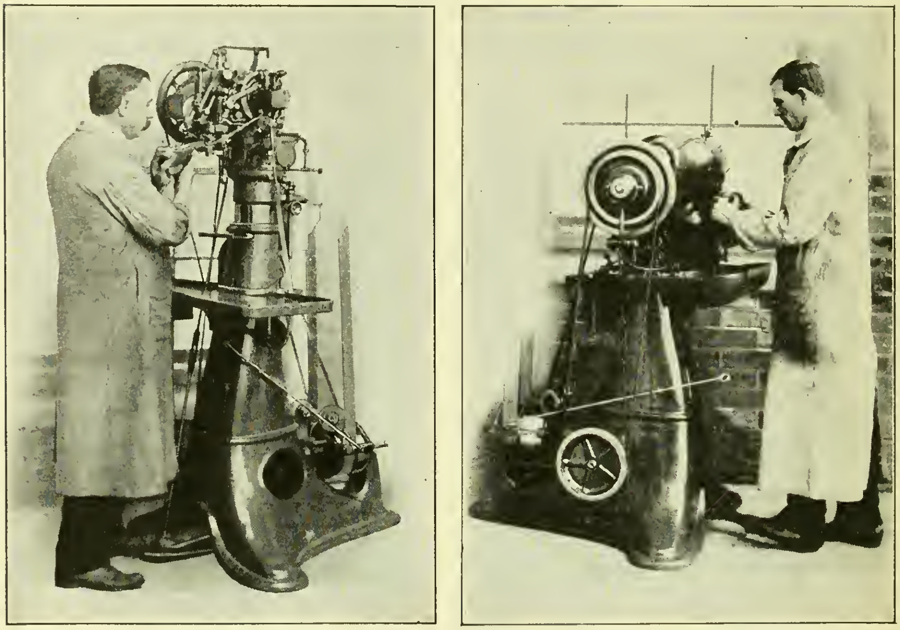


LOUIS GODDU.

Gordon McKay was the founder of the sole-machinery industry. His chance came with the Civil War with an order for 2,500 "bootees," to be worn by soldiers, and to be made on Blake machines. In his will he left $4,000,000 to Harvard University for the department of mechanical science.

Louis Goddu (1837–1919) was a French-Canadian who was one of the most prolific inventors of tacking and nailing machinery. At the time of his death over 300 patents had been issued in his name.

by giving greater rigidity to the needle, but it was years later before the "take-up" or setting of the stitch was so perfected as



TWO ESSENTIAL MACHINES IN THE GOODYEAR WELT SYSTEM.

(Left) The welt of a shoe is a narrow strip of prepared leather, which is sewn along the edge of a shoe, beginning where the heel is placed and ending at the same spot on the opposite edge. This welt is sewn from inside the lip of the insole, so that the needle passes through the lip, upper, and welt, uniting all three securely and allowing the welt to protrude. The welt was once sewn entirely by hand, so that each stitch had to be drawn by main strength. It is impossible for a cobbler to draw stitches all day long with the same tension. The work is now done by the Goodyear welt machine, which has been the leading factor in revolutionizing shoemaking. Its stitches are all of equal length and are measured automatically. The strong linen waxed thread is drawn evenly and tightly.

(Right) The Goodyear outsole rapid lock-stitch machine is a rotary-shuttle machine forming a lock-stitch which sews the outsole to the welt. The stitch is fine, and extends from the channel which was cut for it to the upper side of the welt, where it shows even after the shoe has been finished. The thoroughly waxed thread holds the outsole securely in place, even after the connecting stitches have been worn off. It is able to sew even in the narrow shank, where a straight needle could not possibly place its stitch.

to resist the beating-out process to get an even thickness to the sole.

While the Goodyear company, with its factory in New York city, had worked out the turn-machine problem in making ladies' shoes, the marketing of "turns" moved slowly; and during a season of depression when he seriously thought of abandoning the enterprise, he turned, as Howe had done, to Europe. His uncle organized an English company, and Goodyear himself went to London in 1870. He returned the following year and began anew by organizing his business as the Goodyear Boot and Shoe Machinery Company. It was then that Dancel did his most brilliant work for the company. By adding a welt guide he produced, in 1874, a machine that could sew welts as well as turns. The promoter, with the true spirit of leadership, insisted that the ambition of his corps of experts should be the making a perfect welt shoe as though it were made by hand. His instructions were to avoid penetrating the inside of the insole so as not to interfere with the stocking.

The welt is a narrow strip or ribbon of firm leather placed about the rim of the shoe in a way to permit one edge to be stitched to the upper and insole, the other edge being stitched to the outer sole. Shoemakers as far back as the fifteenth century used the welt on high-grade boots and shoes, and the American shoemakers became expert in making them, though the extra expense prevented their common use. Machinery popularized the welt in this country.

Dancel, after some years, during which he made an unsuccessful attempt to run a shop of his own, delivered to the company a great machine. It could lock-stitch the outer sole with a curved needle while the shoe was on the last. The Goodyears bought it in 1885. The final act in this drama of invention was a curved-needle machine that sewed welts upon the shoe with a chain-stitch when the shoe was on the last, the welt, upper, and insole being caught by one stroke of the needle.

Goodyear and McKay Join Interests

As the Goodyear and McKay groups of inventors continually overlapped each other, their work drove the two companies into courts of law. It was war between them from 1876 to 1880, but in that year the Goodyear and McKay Association was formed. The McKay company turned over its patent rights in turn-shoe machinery of its own invention to the new company, while the Goodyears assigned its rights in welt and turn machines. This left the McKay group free to push its machines for making the heavier grades of boots and shoes, including its metallic fastenings for bottoming shoes. After an experience of fifteen years, the McKay interests were sold to the Goodyear shareholders. This tendency toward consolidating under one management the various factories making machinery for different operations, proved to be the salvation of the shoe industry.

CHARLES GOODYEAR.

CHRISTIAN DANCEL.

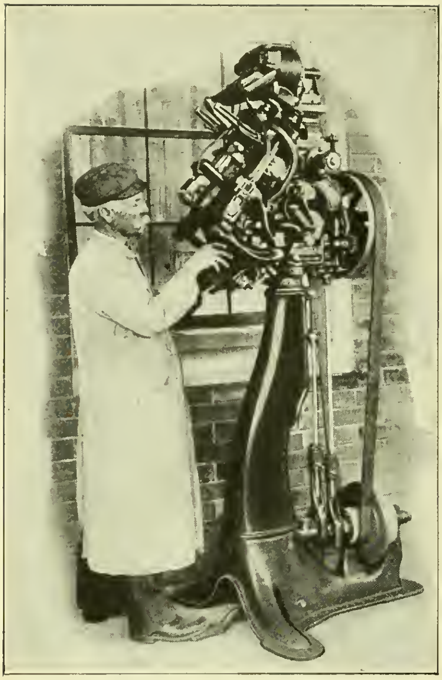
Charles Goodyear was the son of the discoverer of the process of vulcanizing rubber. He became one of the foremost figures in the shoe-machinery industry by successfully organizing and introducing the machines for making shoes according to the Goodyear welt system.

Christian Dancel (1847–1897) was engaged by Goodyear as superintendent. Dancel was the foremost sewing-machine expert of his time, and improved not only the "turn" machine, but made many inventions down to 1892, when he perfected the curved-needle machine for sewing welts with a lock-stitch while the shoe was on the last. His solution of the stitch-forming problem made the Goodyear welt system a success.

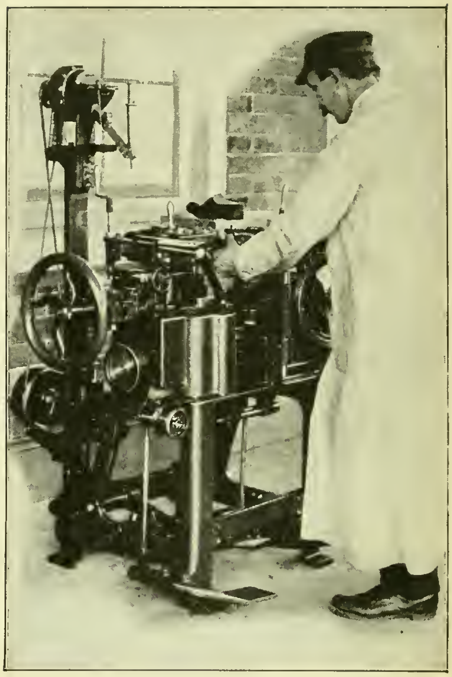
Howe and Singer had been twice saved from financial straits by two strangers, Colonel Bliss and Lawyer Clark. Charles Goodyear, in the darkest hour of his career, found his savior in Jonathan Munyon. The latter, a director of the Bay State Shoe and Leather Company of Brooklyn, New York, and Worcester, Massachusetts, was informed that some Goodyear directors, holding certain stock and rights in foreign patents as security for loans to Goodyear, were acting as though they planned to take from the inventor the whole business by demanding prompt payment. Munyon rescued Goodyear by raising the money and recovering the security. The consolidation with the McKay interests followed. Munyon had a genius for putting goods on the market, and both the turn and welt business flourished under his management. When Goodyear retired in 1888 Munyon succeeded him as president.

S. V. A. Hunter, who had served as treasurer and manager, was sent to England, where Charles Goodyear and his uncle had introduced the twin machines. He gave a dinner at Northampton, the company's headquarters, to the leading shoe-manufacturers of that district. They accepted the dinner, but not the American machine; indeed, Manfield & Sons, shoe-manufacturers and dealers, declined a $1,500 offer for window space in one or two of their shops, for the purpose of demonstrating Goodyear machines. They contended that the popular prejudice against welt machines would injure them. This prejudice sprang mainly from the labor element and was by no means confined to England. Some dealers here and abroad were not above palming off the Goodyear for "genuine hand-welt" shoes; while, on the other hand, labor-union shoemakers were even known to cut open the seams to show their Goodyear origin.

The last word on Goodyear welts had not been spoken when the promoter retired from active business, for the United Shoe Machinery experts had not yet added the finishing touches. Before the union of the three shoe-machinery groups, a McKay machine could stitch a pair of ladies' shoes in thirteen minutes, using forty-two machines with fifty-seven different machine operations. After the starting of the United Shoe Machinery Company it became possible in building a shoe of extreme fashion—a Polish Goodyear welt shoe with perforated vamps, foxings, and outside panel, eyelet, and stays—to perform as many as 210 operations. Of these 174 could be performed on 155 different machines and the rest by hand. But the average Goodyear welt shoe of business is the product of a string of from about twenty-five to forty machines.



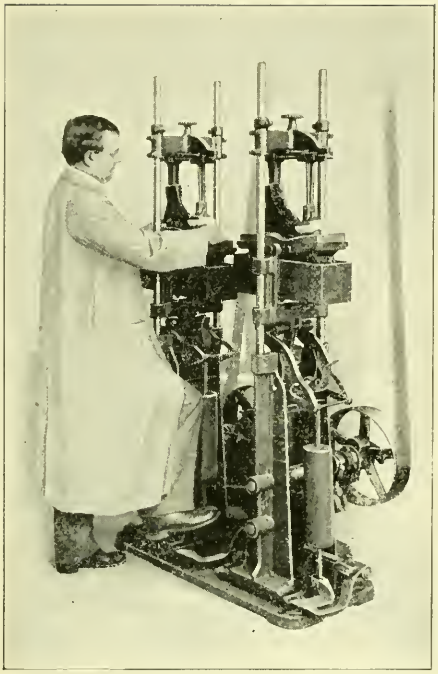
IT COST $900,000 TO PERFECT THIS PULLING-OVER MACHINE.



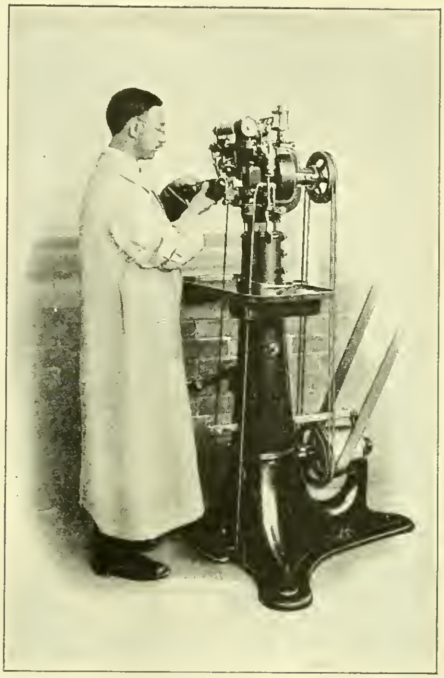
THE WELT SIDE-LASTER.

(Left) It was once thought to be absolutely impossible to fit an upper to the last satisfactorily by machine. A corps of inventors attacked this problem, and after spending over $900,000, solved it by producing this "pulling-over" machine. Pincers grasp the leather at different points on each side of the toe, and the operator, standing in a position from which he can see when the upper is exactly centred, presses a foot-lever. The pincers then close and draw the leather securely against the wood of the last. At this point the machine halts. By moving different levers the workman is able to adjust the shoe-upper exactly, so that each part of it lies in the correct position. When this important operation is completed the operator again presses a foot-lever, the pincers move toward each other, drawing the leather securely against the last, and at the same time three tacks are automatically driven on each side, and one at the toe to hold the upper securely in position. These tacks are driven only partly so that they can later be removed.

(Right) Lasting is one of the most difficult operations in shoe-making, and one of the most important. Upon it depends comfort. The welt side-lasting machine invented by Matzeliger performs this work in an almost human way. It is wonderful to see how evenly and tightly it draws the leather around the last. At each pull of the pincers a small tack, driven automatically part way in, holds the edge of the upper exactly in place, so that in the finished shoe every part of the upper has been stretched in all directions equally.



THE GOODYEAR SOLE-LAYING MACHINE.



THE GOODYEAR ROUNDING AND CHANNELLING MACHINE.

(Left) In the Goodyear sole-laying machine is a rubber pad or mould which conforms with the curve in the sole of the shoe. After the shoe has been jacked in position over the rubber mould, the outsole having been previously coated with rubber cement is placed against the bottom of the shoe, the operator presses a foot-lever, causing the machine to force the shoe down into the mould, so that every portion of the outsole is pressed against the bottom of the shoe and welt. The shoe is allowed to remain in position for a length of time for the cement to set. The operation is duplicated on another part of the machine, one shoe being left under pressure while another is being prepared.

(Right) The sole and welt of a shoe are trimmed so that they will protrude a uniform distance from the edge of the shoe. This work is performed on the Goodyear rounding and channelling machine, which gauges the distance exactly from the edge of the last. The operator is able to change the width of the edge at will. By the use of this remarkable machine the operator is also able to make the sole conform exactly to all other soles of similar size and design. Simultaneously with the rounding operation the machine cuts a little channel or slit along the edge of the sole, in much the same manner as the work was done on the insole. This portion of the work was formerly a very difficult and costly operation by hand, but seems simplicity itself when done by this machine.

Systematizing the Making of Shoes

To understand how the mass of machine problems became reduced to a system, one must first realize what trouble the experts had in substituting metal for human fingers in pulling over the upper on a last and in bottoming a shoe. We can best get at the heart of this story by following the acts of Winslow and his experts forming the third of the great shoe-machinery groups.

Sidney W. Winslow, leader of the third group, was born at Brewster, Massachusetts, in 1854, five years before McKay bought Blake's patent, which really started the shoe-machinery game. Young Winslow learned his trade in his father's shoe factory at Salem. The father, a Cape Cod cobbler and sea captain, had abandoned the work-bench for machine-sewing, and the son had a good chance to witness both the glories and the shadows of the new day that broke over the shoe industry.

The old shoemakers had no more use for machinery than for artillery in their shops. The call to arms in 1861 put patriotism ahead of shop and factory jealousies, and McKay machines multiplied without much opposition from organized labor. But peace between the North and South started rumblings of discontent in the factories. Clashes between operatives and their employers extending over a long series of years did not disturb young Winslow's faith in the new order of things. The neighboring city of Lynn was the last to give in. The Lynn shoemakers boasted of the strongest organization of shoe-workers in the land—the Lynn Lasters' Union—and there the closing battles of that period were fought. In recalling this chapter of shoe history a local paper in 1889 said:

"Finally in a series of pitched battles, which drove many Lynn manufacturers out of the city or out of business, the Lasters' Union was at last forced to yield to machinery, and crippled by its expenditures and loss of members, viewed with sullen hatred machines introduced in almost every factory, and the union men forced to work them or give place to non-union men who were provided to take their places by the machinery companies. To-day there is no opposition manifested and amiable relations prevail between the Lasters' Union and the great machinery combine. Preference is given to union lasters in working the machines, and hand lasters, many of them middle-aged or old men, are learning to run the machines."

This was in 1889, when Winslow was thirty-five years old. He had just invested in a lasting company owning a lasting-machine destined to complete the series of machines required for shoemaking. The story of it dated back nine years when an attempt to introduce it roused the "aristocracy," as the lasters were called in the factories.

Matzeliger Invents the Lasting-Machine

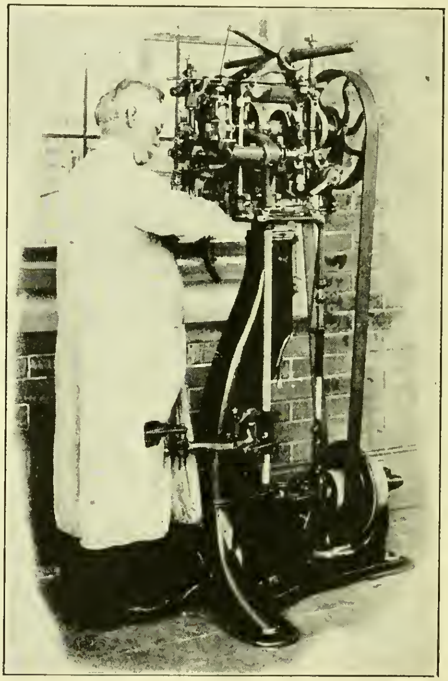
In the shoe factory of Harney Brothers, at Lynn, in 1878, there was an alien mechanic who knew more about machinery than the English language. He operated a McKay stitcher for turn-shoes and a burnishing-machine; he was brown in complexion with crinkly hair and an interesting if not comely face. His father, born in Holland, had been sent to Dutch Guiana, South America, to superintend government work, and had married a native woman. Their son, Jan Earnst Matzeliger, had been well trained under his father's eye as a machinist and had come to the States to seek his fortune.

Such was the Harney Brothers' alien operative. He found shop conditions unsettled by the introduction of machinery. Not being a shoemaker, he had no use for those who hated machines. He particularly resented the boast of the lasters that no inventor could substitute iron for human fingers in lasting a shoe. This he disputed in broken English and the jeers of the operatives added to the natural loneliness of his position. When he did invent a process of machine-lasting, the shoemakers called it a "niggerhead," and "niggerhead" it has remained in the shoe-factory world until this day. It was the pioneer invention of still another branch of the shoe-machinery industry.

Matzeliger started out to last a McKay shoe by some device patterned to imitate the motions of the hand laster. He took a room for night work over the West Lynn Mission; he became a Congregationalist, and a possible easement in rent may suggest why he went there. Unmarried, delicate in health, cut off from companionship by hostile factory mates, he stuck to his work for six or eight months, and in September, 1880, a model made out of cigar boxes and other odds and ends satisfied him that he had hit the right principle. Then he made a real machine that pleated the leather around the toe, for which he refused a $1,500 offer. Not being a practical shoemaker, he avoided mistakes in his third laster, a plan of which he forwarded to Washington with his application for a patent. The department could not understand it, but his claim seemed so attractive that an expert was sent to Lynn to make a personal examination, and a patent was issued to him. The Consolidated Hand-Method-Lasting-Machine Company was formed by Lynn men with little capital; a fourth machine was completed by Matzeliger. Wins-

JAN EARNST MATZELIGER

Jan Matzeliger (1857–1889), a poor half-breed son of a Dutch engineer and a native black woman of Guiana, invented a laster, which derisive shoemakers called "niggerhead." He left all his money to churches in Lynn.



(Right) It is particularly difficult to last the toe and heel of a shoe. This work is done by a lasting-machine. A series of wipers for toe and heel draw the leather simultaneously from all directions. There can be no wrinkles at the toe or heel of shoes on which the machines are properly used. After the leather has been brought smoothly around it is held securely in place by the surplus leather crimpled in at this point. The surplus leather crimpled in at the heel is forced smoothly down against the insole, and held there by tacks driven by a very ingenious hand-tool, in which there is a constantly-renewed supply of tacks.

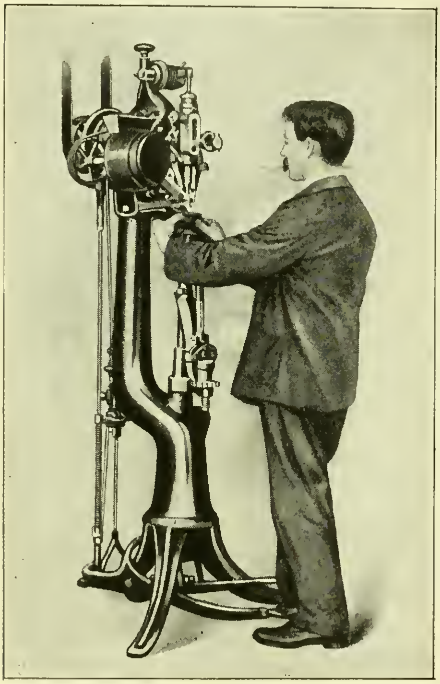
low bought some of the stock, and he employed experts to take up the inventor's task, whose life was ebbing. Matzeliger lingered until 1889, when he died.

To complete at this point the story of this martyr to a useful science, let us anticipate a scene in the North Congregational Church at Lynn on a December Sunday, 1904. To this society Matzeliger had left a block of the stock of the Consolidated Hand-Method-Lasting-Machine Company. This was exchanged for United Shoe Machinery stock at the organization of this company in 1899. The Matzeliger shares had more than doubled in price by 1904, enabling the church to pay its mortgaged debt. On that December Sunday the members solemnly rededicated the church. On the pulpit platform stood an easel with a crayon portrait of Jan Earnst Matzeliger, surrounded by church dignitaries. The minister and a venerable deacon burned the cancelled mortgages in an urn. Thus, this messenger from a foreign land, who had solved in principle the final problem in making shoes by machinery, but was not spared to work out the many details involved, was remembered as a benefactor and honored as a master.

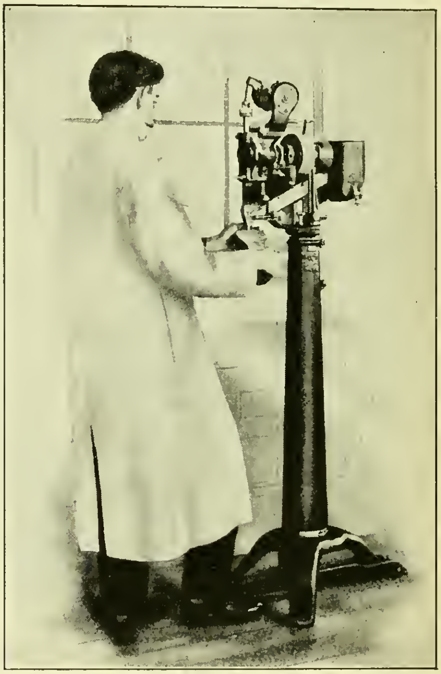
In the process of lasting, the old-time shoemaker would pull the leather of the upper down at the toe with pincers and twist the surplus into small pleats; "pull and twist" they called it. This was a detail left by Matzeliger for others to perfect. When Winslow gained control of the Consolidated Lasting Company, every effort was made to develop a "puller-over" in the machine-shop at Beverly. Not until 1904 could they make a machine ready for the shoe factory, and even then constant changes went on for seven or eight years. The story would fill a volume. No less than 2,600 changes were made by the old lasting company and by the United Shoe Machinery Company, at a cost of nearly a million and a half dollars. The daily output of the shoemaker of the past rarely exceeded sixty pairs of shoes a day. This machine, however, running as one in a chain of machines will "pull over" from 700 to 1,000 pairs a day, according to the type of shoe.

This exploit is one of the most brilliant in shoe-machinery history. Watching five iron fingers carefully adjusting the upper to the leather while at the right instant another contrivance tacks it ready for welting and soling, one would think that the operator touching the machine now and then with his fingers had given to the dynamo running it the magic power of thought.

In spite of the long list of brilliant inventions in machine shoemaking, the business from the angle of shoe-factory owner was distressing. Three large centres of the industry, each making some machines that the others produced, each sending out a separate set of agents, made the life of the manufacturer mis-



THE LOOSE NAILING-MACHINE.



THE INSOLE TACKING-MACHINE.

(Left) The rounding operation simply includes that portion of the shoe to which the welt has been sewn, and leaves the heel-seat without attention. This is first nailed to the shoe on the loose nailing-machine (here shown), in which small brass nails, driven automatically, fasten this portion of the sole leather securely. It is then trimmed by another machine to conform to the shape of the heel. This machine is capable of driving nails at the rate of 350 per minute.

(Right) The insole tacking-machine drives tacks which temporarily hold the insole to the bottom of the last. This last, which is made of wood, is of the utmost importance, for upon its form depends the shape of the shoe.

erable. If he picked from each group, his factory would be a meeting-place for three sets of machine repairers with separate if not hostile purposes.

Winslow Organizes the Shoe-Machinery Industry

As the business stood in the last decade of the nineteenth century, all was confusion and waste of energy. To bring order to it, a leader was necessary. Charles Goodyear had died and Gordon McKay, nearly eighty years of age, was enjoying at Newport the retirement he had earned. There remained Sidney W. Winslow, whose inventors were well on their way to a perfect system of machine-lasting, without which the new art of shoemaking could not be completed. From the time he was foreman in his father's stitching-room to his ownership of the Matzeliger laster he had been a student of shoe-machine construction. He had business vision, and the faculty of attracting about him men who could do things. He realized that teamwork would save the industry. This became so self-evident that the three groups came together in February, 1899, as the United Shoe Machinery Company, with Winslow as president, and all the interests properly represented in the board of directors. The resultant factory built at Beverly, whence as a boy Winslow rode to school every morning with his father on his way to the Salem factory, is now the largest and best-equipped in any land.

With the pick of the experts, an experimental division was established and the task of selecting and improving the best devices for making a shoe was pushed forward at a cost, at times, of $450,000 a year. No less than 125,000 different kinds of machine parts are now kept in stock, from which about 450 distinct shoemaking machines may be assembled.

If one watchman were to make the complete round of all the beats of the factory force of watchmen, he would travel six miles through the sixteen buildings with a floor space of over twenty-four acres. A much more extended journey might be taken by the observing visitor who starts with the experimental department, with its forty-three designing-rooms, proceeds through the various process-rooms, where the machine parts are made, and finishes at the museum containing nearly 2,000 machines and hundreds of attachments all discarded for better things.

Shoe machinery solved the army-shoe problem in 1861; a shoe-machinery system solved the army-shoe problem when during the World War the American Expeditionary Forces arrived overseas only to find that they must wear heavier footwear.

The growth of the boot-and-shoe industry, made possible by substituting machines for hand labor, has been amazing. In this country alone there were about 1,400 factories in 1919, which produced 330,644,202 pairs of shoes, valued at over five hundred millions of dollars. This makes an average of about three pairs to a person, if all were worn in this country. Teams of six shoemakers in 1861, we have learned, turned out fifteen pairs of army shoes a day. At this rate of production over 450,000 old-time shoemakers working every day in the year would be needed to shoe the American people, even if they made only the cheap army brogan of sixty years ago.

INDEX

INDEX

* indicates illustration
† refers to caption under illustration

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