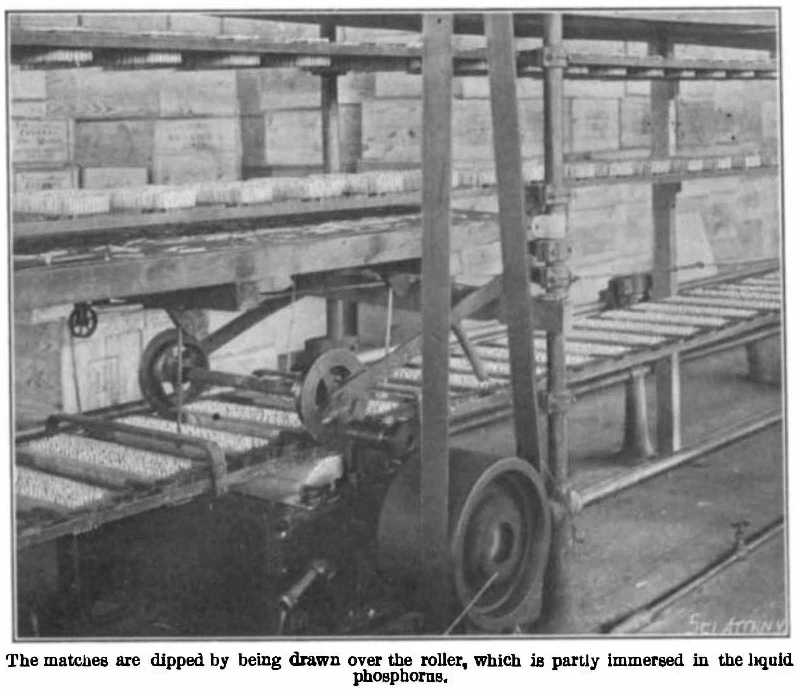
THE MANUFACTURE OF MATCHES.

The match-making industry affords a striking instance of the great economy in time and labor which has been accomplished, particularly of late years, by the development of labor-saving machinery. Of the many articles that are necessary to the comfort of our domestic life, there are few that are produced and sold so cheaply as the common, tipped match. Were it not for the very ingenious machinery which has been specially devised for their manufacture it would be impossible to produce matches in such enormous numbers, and place them on the market at the astonishingly low price which prevails at the present time. The rapidity of manufacture may be judged from the fact that the machine shown in the accompanying illustrations, which is in operation in the factory of the Federal Match Company, Paterson, N. J., is turning out 18,000,000 matches per day of 20 working hours. The process of match-making, as carried out at the works of this company, may be broadly divided into the manufacture of the splints and the dipping of the splints in phosphorus to produce the finished matches. Although the present article is devoted more particularly to the match-making machine, we will trace the whole process from the rough lumber to the finished match as packed ready for the market.

MANUFACTURE OF SPLINTS.—The raw material for the manufacture of "splints," as the diminutive sticks of wood which carry the igniting material are called, usually consists of a special grade of sawn lumber, the wood being chosen for the straightness of its grain and its freedom from notches. This lumber costs from $26 to as high as $50 per 1,000, board measure. In cutting the splints it is necessary that the grain should run parallel with the splint, otherwise the latter will snap in two when the match is struck. The impossibility of securing sawn lumber in which the grain is everywhere parallel with the board results in a considerable percentage of waste. To avoid this waste and to render it possible to use a cheaper grade of lumber, the Federal Match Company manufacture their splints from white-pine cordwood. The rough lumber, as soon as it is delivered at the works, is peeled, split, and stacked to dry. The split wood is then sawn crosswise of the grain into 2-inch lengths, and the splints are cut from these blocks in the specially-designed planing machine shown in the accompanying illustration. The planing tool of this machine consists of a double row of circular knives superimposed above one another, there being 32 of these little knives in each row. As the knife makes 250 strokes per minute, the capacity of each machine, allowing for time lost in picking up a fresh block, is nearly a million splints per hour. The splints are first dried by hot air, and then gathered up by boys and placed in the hopper of a cleaning machine, where all slivers or broken fragments are separated out. The cleaner consists of a hopper which delivers the matches onto the upper end of a sloping oscillating table, whose surface contains a number of parallel grooves, running in the direction of the oscillation. At intervals of a few inches transverse slots are cut entirely through the table. The match splints travel down the table and fall into a receptacle below, while the slivers and broken fragments fall through the slots. From the cleaning machine the splints are taken to a straightening machine, where they are shaken down until they arrange themselves side by side in long parallel rows, just as cordwood is arranged and stacked by the wood-cutter. The machine is then stopped and the slats drawn away, leaving the matches straightened out ready for further handling. They are picked up and put in "holders," little boxes 4 inches deep, 2 inches wide, and 15 inches in length. These holders are carried to the large match-making machine which forms the chief subject of our illustrations.

The splints are cut by a reciprocating knife from the two-inch blocks of cordwood.

PREPARING THE SPLINTS



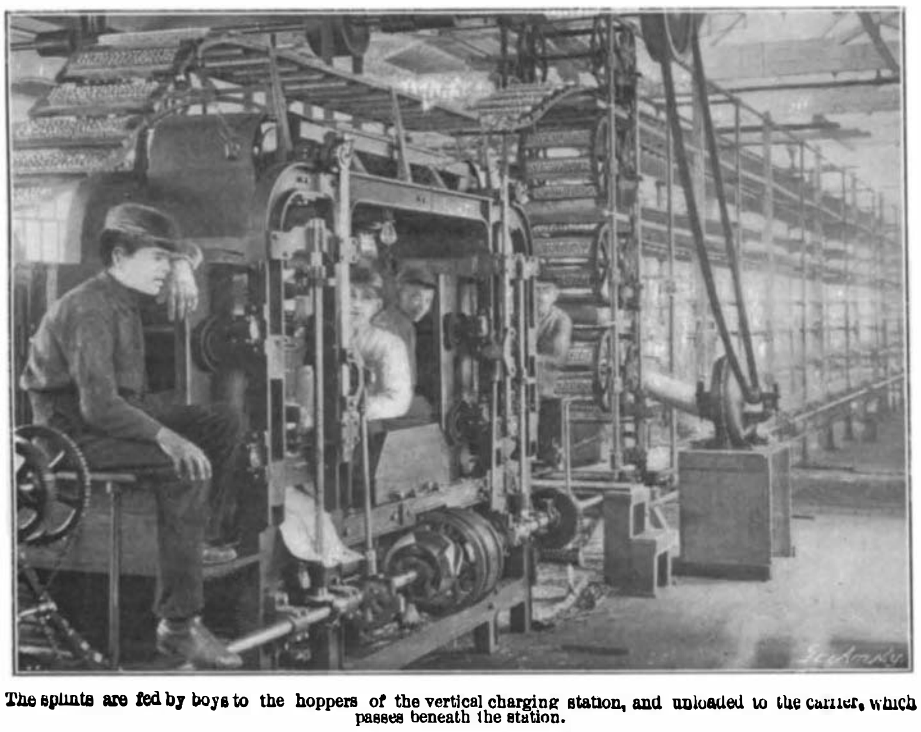
The matches are dipped by being drawn over the roller, which is partly immersed in the liquid phosphorus.

THE PHOSPHORUS BATH.

THE MATCH-MAKING MACHINE.—The very interesting match-making machine shown in our illustration finishes the match in one continuous operation; dipping it in paraffine wax, tipping it with phosphorus, drying it out, and delivering it ready for shipment, the whole operation taking just 32 minutes, and the matches being turned out at the rate of 18,000,000 per day of 20 hours. Generally speaking, this machine may be described as an endless belt, 600 feet in length, known as the carrier, which extends up and down the length of the room, passing at each turn over end-sprockets. The belt travels with an intermittent motion at the rate of 9 inches a stroke and 30 strokes a minute. Each link of the belt consists of a set of transverse slats, known as a "block," and in each block are placed 400 splints. After the splints have been inserted no further handling is necessary, each block being successively dipped in wax, dried, tipped with phosphorus and again dried, and finally delivered as finished matches ready for packing.

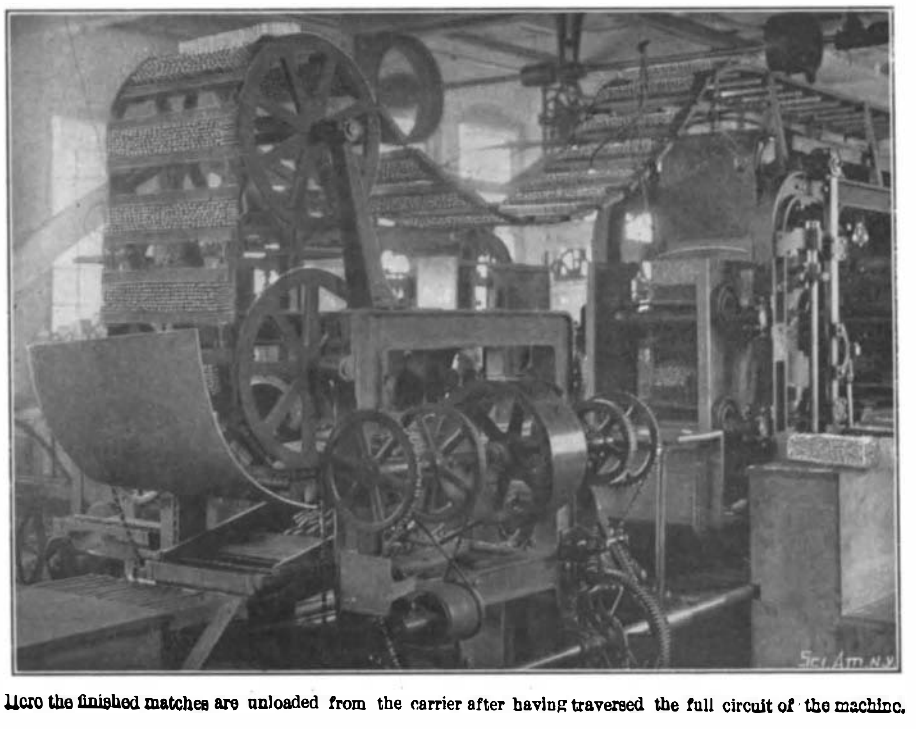
The special improvement in the machine under consideration, as distinguished from all others, lies in the great rapidity with which the splints can be charged into the endless carrier. In the ordinary type, the splints are fed a few at a time from a single hopper located at the charging station, a single row of matches being fed at each forward movement. In the machine herewith illustrated the hopper is replaced by a vertical loop, called the charging station, which is arranged above the endless carrier and has an intermittent motion corresponding in speed and frequency with the movements of the carrier. In the vertical sides of this charging station are eight assembling stations, each of which performs functions corresponding to those of the single hopper in the old type of match-making machine, by charging in this case a row of 50 splints into special perforated brass holders. Each of these holders has a capacity of 8 rows of splints; and by the time a holder has made the circuit of the eight charging stations and passed entirely around the loop, it is loaded with its full quota of 400 splints. The loaded holder is now automatically brought into position over the carrier, and its load discharged directly into the frame or "block" beneath it, 400 splints being delivered at each intermittent stroke of the machine. It will thus be seen that, by the provision of a separate multiple-unit charging station in place of the single hopper, the capacity has been increased 10-fold.

Each frame is made up of 9 parallel slats of wood, which extend across the full width of the carrier. As each frame is successively brought forward beneath the brass plates the load of 400 splints is pushed down from the plates into the frames. The slats are then closed up tightly, and the splints locked in, by means of a circular cam. The position of the matches will be seen clearly in the various illustrations. The endless carrier, as we have said, has an intermittent motion in one direction, and the insertion of the matches in the block is accomplished at the moment the carrier is stopped—the cam opening the frames, the matches being transferred from the brass holder, and the slats closed up and locked before the carrier makes its next advance. The frames, with the matches in place, next travel over a steam-heated drying table, at the end of which a beater strikes a blow upon each frame and levels the matches out evenly, ready for their passage over the phosphorus roller. The lower ends of the splints then travel through a bath of melted paraf-



The splints are fed by boys to the hoppers of the vertical charging station, and unloaded to the carrier, which passes beneath the station.

THE CHARGING STATION.



Here the finished matches are unloaded from the carrier after having traversed the full circuit of the machine.

THE DISCHARGING STATION.

fine wax, the paraffine being necessary to make the splint burn easily after the match is struck. The matches next travel over a roller, the lower part of which is immersed in a steam-heated bath of melted phosphorus. As each frame, with its 400 matches, travels across the upper portion of this roller the proper amount of phosphorus is deposited. By the time the matches have traveled in the carrier through the whole circuit of the machine the composition has become thoroughly dried out. The matches are ultimately brought back to the receiving station end of the system, where the circular cam descends between the slats and releases the matches, and they are pushed out of the carrier frame automatically by means of a discharger comb which descends from above the slats for this purpose. The matches are then carried down over an inclined, oscillating table, where they are automatically arranged in parallel piles for convenience of handling. They are then gathered up and taken to the packing tables, where they are put into match boxes of various sizes, and packed in boxes and in crates for shipment.

In closing, it may be mentioned that only 5 boys are required for operating this machine. This may be compared with the older match-making machines for which the services of 25 men were necessary.

Our Coal Exports.

Coal exportations from the United States during the fiscal year just ended, as shown by the Treasury Bureau of Statistics, amounted to $22,317,459, against $19,502,813 in the fiscal year 1900, $13,661,028 in 1899, $11,008,643 in 1897, $10,646,062 in 1896, and $8,391,026 in 1891. Thus the value of coal exportations from the United States has doubled since 1897 and nearly trebled in the decade. These figures relate to values. Measured by quantity the increase has been even greater, the exports in 1901 being 7,676,149 tons, against 2,399,039 tons in 1891, thus making the total exports of 1901 in quantity more than three times as much as in 1891.

The United States now stands third in the list of coal-exporting countries of the world. The coal-export figures of the principal countries of the world in 1899 show that while Belgium slightly exceeded the United States in the total number of tons exported, her imports were more than one-half as great as her exports, making her net exportation of coal much less than that of the United States. The figures of coal exports during 1900 recently published by the British government, a copy of which has just reached the Bureau of Statistics, show that the coal exports of the three principal coal-exporting countries—the United States, Germany, and the United Kingdom—in 1900 were: United States, 7,558,000 tons; Germany, 18,055,000 tons; and United Kingdom, 58,405,000. Thus, while the growth of the coal exports from the United States shows a large percentage of increase, these figures of the exportation of coal from Germany and the United Kingdom show that the field occupied by those countries is still much larger than that which the United States now supplies.

In growth of both exports and production, however, the United States had made much more rapid advance than any other country. The total quantity of coal produced in the United Kingdom was, in 1886, 157,518,000 tons; in 1900, 225,181,000 tons; while in the United States the production was, in 1886, 100,664,000, and in 1900, 245,422,000. Thus the United Kingdom since 1886 has increased her production but about 50 per cent, while the United States has increased hers nearly 150 per cent.

The cost of coal has meantime increased much more rapidly in the United Kingdom than in the United States. The value of the 157,000,000 tons of coal mined in the United Kingdom in 1886 is put by the statement of the British government above referred to at £38,000,000 sterling, and of the 225,000,000 tons mined in 1900, is put at £121,000,000 sterling. Thus, while the quantity mined in the United Kingdom has increased but 50 per cent from 1886 to 1900, the value has meantime increased over 200 per cent. On the other hand, the value of the 100,000,000 tons of coal mined in the United States in 1886 was, according to the same authority, £32,000,000 sterling, and that of the 245,000,000 tons mined in 1900, £67,000,000 sterling. Thus, in the United States, while the quantity increased about 150 per cent, the value of the coal mined increased but a little over 100 per cent.

The relative increase in the cost of coal in the United Kingdom and the United States is shown in an even more striking form in the statement of the British government above referred to by a table which gives the price per ton of coal in the United Kingdom and the United States in 1888 and 1900, respectively. It shows that the price in the United Kingdom advanced from 5 shillings per ton to 10s. 9d., from 1888 to 1900, while in the United States it fell from 6s. to 5s. 5½d. per ton in the same time. Another table in the same statement shows the relative value per ton of coal produced taken at the pit's mouth in the United States, United Kingdom, Germany, France, and Belgium, in 1899, to be as follows:

Country.	Value per ton. Shillings	Pence.
France	9	12
Belgium	9	11
Germany	7	9
United Kingdom	7	7
United States	4	8½

DISTRIBUTION OF COMBINED ELECTRICAL ENERGY.

BY ALTON D. ADAMS.

After electrical energy from scattered water powers and steam plants has been combined and reduced to a common voltage at a main switchboard it is ready to be transformed and converted for any desired purpose. Alternating lines to local transformers, that supply private consumers for 110-volt incandescent lamps, go directly from the main switchboard at about 2,000 volts. These same lines may feed other local transformers that deliver current at 500 volts for induction motors. Such motors are also often supplied by circuits from 500-volt transformers in the sub-station.

Other transformers in the sub-station, of the constant-current type, change constant pressure energy from the board to current at variable pressure for series alternating arcs. To supply direct current energy is drawn from the main switchboard by transformers, which in this case feed alternating motors or rotary converters. If series lines for direct-current arc lamps are to be operated, current from the transformers, at probably 500 volts, will drive alternating motors connected mechanically to the usual types of arc dynamos. A 220-volt, 3-wire, direct-current system is supplied from rotary converters of this pressure, fed by transformers connected with the main switchboard. Street railway and stationary motors requiring 500 volts, direct current, are supplied from still other rotary converters, driven by alternating current from transformers, fed as before. If storage batteries form a part of either the 220 or 500-volt direct system, they draw their charging energy from the same converters that supply the lamps and motors. A variation from the methods of direct-current production just outlined is sometimes made by the use of alternating motors to drive one or more lines of shafting, to which generators for the several sorts of direct current desired are mechanically connected. This plan is easily resorted to where a steam plant in the city served is necessary to supplement the combined water powers during a portion of the time. If the steam station has connected to its main shaft three-phase alternating generators, as well as the dynamos necessary for direct-current service, at times when the water power is sufficient to carry the entire load, these 3-phase generators may draw energy from the main alternating switchboard and, operating as motors, drive their connected shaft and with it the several direct-current dynamos.

Thus far only that sub-station where the energy from various water powers is received and combined has been mentioned, but there may be others. The pressure of about 2,000 volts, adopted for distribution from the main switchboard, is high enough to give a substantial advantage over the 220 and 500 volts necessary on some of the direct-current circuits, in the cost of conductors where a considerable distribution area is to be covered. For this reason minor substations are established at convenient points in the area of distribution, each containing one or more transformers and rotary converters, yielding direct current at 220 or 500 volts, and also in some cases storage batteries, to increase the capacity at periods of maximum load and to steady the pressure. Other minor sub-stations may contain simply transformers, for series lines of alternating arc lamps, or for 500-volt alternating motors, all fed from the 2,000-volt switchboard at the combining sub-station. The methods employed to gather up the energy of scattered waterfalls, transmit it to a common center, combine it for general use, and distribute it over the area of urban service in the forms desired by consumers, have now been outlined. Example of actual accomplishment along these lines may not be uninteresting.

Among the cities of New England numerous instances may be found where the combination of energy from distant water powers for electrical distribution has been carried out to some extent, but two places, Manchester, N. H., and Hartford, Conn., present the most complete examples of the above methods.

At Manchester electrical energy from four separate water powers and two steam plants is received, transformed, combined and then distributed at a single substation. One of the water powers is 3 miles, one 6 miles, one 10 miles and one 14 miles from this substation. The larger steam plant is less than 200 feet from the sub-station, and the smaller one is three miles away, in the same building with the nearest water power plant. At this nearest water power the electric generators have a combined capacity of 1,090 kilowatts and are operated in varying proportions by steam and water, according to the amount of the latter available. Current is generated at 2,000 volts, alternating by these machines, and then raised by transformers to 6,600 volts for transmission to the substation. The water power six miles away drives a single alternator of 1,200 kilowatts capacity, at 10,000 volts, and this energy goes direct to the transmission line without the intervention of transformers. Ten miles from the sub-station the water power drives generators of 600 kilowatts total capacity, at 1,000 volts, and the current is raised to 10,000 volts for transmission. At the greatest of these water powers, 14 miles from the sub-station, the alternating generators now being installed have a combined output of 2,600 kilowatts at 12,000 volts, and are connected directly to the transmission line. The steam plant, close to the sub-station in Manchester, operates alternating generators having a total capacity of 1,250 kilowatts, and dynamos with a direct-current capacity of 1,300 kilowatts, from a single main shaft. These alternating generators, when steam-driven, deliver current at 2,000 volts to the main switchboard in the substation, where it is combined with energy from the other steam plant and the four water powers. The direct-current machines have their own distribution boards in the steam-generating station.

At times when the energy from water powers is sufficient the main shaft in the steam station just described is driven by the alternating machines acting as motors and drawing energy from the switchboard in the sub-station. This practice puts the entire load onto the water powers, and converts the steam-generating plant into a sub-station for direct-current distribution. All of the energy delivered at the switchboard in the sub-station is at 2,000 volts, 3-phase, suitable for general distribution to transformers on the premises of consumers for the operation of arc and incandescent lamps and motors. The plans here adopted for the combination of energy from distant water powers make it possible to distribute in the city of Manchester more than 5,400 kilowatts, or 7,200 horse power for direct and alternating electrical service from these sources alone.

At Hartford a separate department of the steam-driven station receives 2,700 kilowatts of electrical energy from two water powers, and there combines it with 2,500 kilowatts from local generators. The two water-power plants are distant, one between 10 and 11, the other between 11 and 12 miles from the Hartford station. At one water power are located generators of 1,200, and at the other of 1,500 kilowatts total capacity, in each case at 500 volts. Transformers are employed at both plants to raise the voltage to 10,000, at which it is delivered to the transmission line and received in the main station at Hartford. Transformers at this receiving station reduce the pressure to 2,400 volts and deliver the energy to the main switchboard. The local steam-driven generators also deliver alternating current at 2,400 volts to this same board in combination with that from the water powers for general use. In this same station other transformers reduce the pressure of a part of the alternating energy from 2,400 volts, for 220-volt rotary converters of 800 kilowatts total capacity, that feed a direct-current, 3-wire system of distribution. At the principal sub-stations, also in the city, but some distance from the steam station, are located other 220-volt rotary converters and their transformers, fed from the main 2,400-volt switchboard. These converters also supply the 3-wire system and charge a large storage battery in the same station, which is used to increase the rate of output and to steady the pressure. At the steam station, and also at two small substations, are located constant-current transformers, which operate alternating arc lamps on series lines for street lighting. These last transformers are also fed by the 2,400-volt system. This system is 2-phase at 60 cycles, and in addition to the transformers for rotary converters and arc lamps supplies those for local incandescent service.

Depth of the Atmosphere Surrounding the Earth.

The Belgian Royal Meteorological Observatory has published the estimates made by various mathematicians and physicists regarding the depth of the atmosphere surrounding the earth. The calculations of the various savants upon this subject are widely divergent. Biot estimated that the depth was only about 40 miles; Bravais, 70 miles; Mann, 81 miles; Callandrau, 100 miles; Schiaparelli, 125 miles; Marie Davy, 187; while Ritter stated that it reached to a height of 216 miles. In Great Britain, during the early part of the last century, the depth of the atmosphere was generally accepted as being 47 miles, but the fact that meteors became incandescent at a much greater altitude incontrovertibly proved that this calculation was fallacious. Sir Robert Ball states that meteors have been observed at a celsitude of more than 200 miles, and since they only become incandescent when they come into contact with the air, the calculation of Ritter appears to be the most correct.