AMERICAN MILL METHODS—A POPULAR DESCRIPTION OF HOW FLOUR IS MADE AT THE PRESENT TIME.

By LOUIS H. GIBSON.

WOMAN was probably the first miller. It was the woman of the primitive people who did most of the manual labor. The first miller was not a specialist. She did not pose as a miller, but as she sat mashing the grain on a rock, she probably had a baby or two in her arms, and three or four trotting around her. She told them to keep their fingers away or they would get them pounded, just as little boys and girls who run around the mills in these days are warned against getting caught in the machinery. The primitive mill had its catastrophes in the shape of mashed fingers. The serious character of the accidents of to-day are in keeping with the progress of the art. It took a great mill, a large and complicated establishment, to explode and kill a large number of people and destroy many thousands of dollars' worth of property.

The physical examination of wheat shows the grains or berries to be of different qualities, varying from each other only slightly in form, which is generally an irregularly oblong oval, having a deep groove extending from end to end, which gives to a cross section a surface bounded by three right angles. At one end of the berry is the brush, or vegetable hairs. At the opposite extreme, under an irregularly curved surface layer of bran, technically called the shield, is the embryo or germ.

If a blade of a sharp knife be passed through the wheat berry midway between the two ends, there will be presented a section which, under the microscope, will show an exterior envelope of several layers, an interior envelope consisting of cells and their contents of gluten and phosphate, constituting the most nutritious portion of the berry, and a mass of white, consisting of loose cellular tissue, supporting a vast body of starch granules, clusters of cells of albuminoid matter extending to the heart of the berry. If a grain of wheat be moistened with water and rubbed between the folds of a rough cloth, the outer covering may be readily detached. This is composed of two layers. The inner coat of the bran proper is made of transverse tubes which, from their arrangement side by side, suggest the convenient name of cigar coat. The third is the seed skin. In it are the granules which make the coloring matter, which determine whether the wheat is red or yellow, or, by their absence, leave it white. In the inner membrane, the comb coat, are set the gluten sacs, containing the cells affording the gluten and phosphates. It is necessary to go through this tiresome description in order to make the subsequent matter clearer.

Before considering the reduction of the wheat, I will say something about the way in which it is cleaned. The process consists in the removal of all foreign material from the mass of grain and the fibrous and fuzzy exterior from the grain itself. The foreign impurities consist of dust, sand, chaff, straw, etc. There are numerous seeds, chit, wild onions, corn and other foreign grains and seeds. Then there are the blasted kernels of wheat, rust, and ergot (smut). In some parts of the country there is trouble from small bits of clay getting mixed with the wheat, and there are always pieces of metal, such as nails, screws, wire, etc. The cleaning of the wheat involves the removal of all these foreign impurities, and as well the removal of the attached impurities so far as that is possible. In order to make a separation of any kind, there must be a distinction as to form, size, specific gravity, general structure, or magnetic affinity. The wheat in passing over a screen passes through openings which are adapted to its form.

These screens are made of zinc in light sheets, and are perforated in forms consistent with the various separations which they are to make. They are attached to sieve frames. By means of these screens, chaff, straw, oats and particles of sticks are separated from the wheat by taking advantage of the elongated form of these impurities.

The wheat passes through the screen openings, which are abundantly large for their passage, but as the screen is inclined, each berry must be tipped in order to enter the hole. Each hole in the screen which makes these separations is of such diameter that when the wheat grain, sliding forward, carries its center of gravity beyond the support of the upper edge of the hole, it drops through. The oats, grain, and other similarly formed substances, being longer than the wheat grain, will for this reason extend over the lower margin of the hole before the weight of the lower end is sufficient to cause it to dip and fall through. Thus it passes over the end of the screen and goes off as impurities.

The separation as to cockle and other round seeds is made in another way. One device is a cylinder of partially perforated or indented metal. The cylinder is kept in slow revolution. Within this cylinder is a trough which is given a slow, shaking motion and is inclined at an angle of about ten degrees. The indentations in the outer cylinder are of such a depth as to allow the small seeds to rest in them until the cylinder has revolved sufficiently to allow the small seeds to fall back, not into the cylinder itself, but into the vibrating trough within, the movement and slant of which is sufficient to conduct these impurities into a separate spout. The form of the wheat berry does not allow it to become embedded in the perforations or indentations of the cylinder sufficiently to carry it so as to fall into the trough.

Separations as to the size of the impurities are made by passing the grain over perforated screens, which allow the impurities which are larger than the wheat to pass over the screen, and the wheat to pass through the openings. From thence the wheat passes to other screens which are smaller than the wheat itself, and through which the smaller impurities pass. Thus exact separations are made.

Another condition to be taken advantage of in cleaning wheat is the variation in specific gravity, which is the ratio of weight of bodies of equal volume to one another, when taken in connection with a standard. Bits of chaff, straw, and dust are of less specific gravity than wheat. That is, the same volume of such articles weighs less than the wheat grains themselves. The separation on account of specific gravity is made by passing the entire volume of wheat to be cleaned

through currents of air, so as to remove all particles of less specific gravity than the wheat itself. Aside from dust and chaff, various seeds, and especially screenings and other impurities, which are of the same general form and size as wheat, are removed through a difference in weight. The bulk of what is called screenings is not removed by screening, but because of the difference in specific gravity of the so-called screenings and the wheat.

Separations in the cleaning of wheat are also made by means of the difference in the general structure of the wheat and the impurities. For instance, often there is smut, or ergot, and other frail substances which are of the same size and specific gravity as the wheat. Hence they cannot be removed, either by the screens of the separators, or by the air currents which recognize the difference in specific gravity. It so happens that the smut is a frail, brittle substance, which is readily broken by friction which will not disturb the wheat.

If the grain containing particles of this kind is passed into a perforated cylindrical jacket in which there are revolving arms, or beaters, or iron disks, or brushes running together, the smut is broken in pieces, and by means of an air current is drawn out through the perforated cylinder. This changes the gravity and size of the substances, and admits of a distinct separation. With bits of clay and dry earth, the particles being of the same size, form, and specific gravity as the wheat, and not being readily broken, it remains to take other measures to make a separation than those above stated.

In practice it has been found that it is necessary to moisten the entire body of wheat, which process has the effect of softening the particles of earth, and admits of their disintegration by the same machines which make the separation of the smut and other frail substances. The clay is not frail, but is made so by being moistened.

Aside from the removal of the foreign impurities, there are also the impurities which are attached to the grain, the vegetable fiber and hairs which are a natural part of the growth of the wheat. Such impurities are removed by the scouring machines, which are constructed with the various friction devices inside of a perforated cylindrical jacket. This jacket is about the size of an ordinary barrel, is made of light steel, with perforations in it in the form of narrow slots. The friction devices may be in the form of the revolving arms of beaters, as mentioned, or a cylindrical brush which comes in contact with the jacket, or disks made up of stone or iron, or brushes which come closely in contact with one another. These revolving surfaces may be arranged vertically or horizontally. Their principle of operation is the same. The wheat, as it passes through the jacket, is rubbed or scoured in a way to remove the attached impurities mentioned. The current of air drawn by fans into the jacket and outward through the perforations has the effect of removing the attached impurities.

The other foreign substances which remain to be separated from the wheat, and which cannot be removed according to any of the general principles named, are the metallic substances, nails, screws, bits of wire and metal in all shapes and forms. Such particles, if they should get into the mill with the wheat, would injure the machinery to a greater or less degree, according to its delicacy. To make separations of this kind, magnets are arranged so as to temporarily interrupt the passage of the wheat through the various parts of the mill, at which times all metallic substances are attached to and retained by these magnets, from which they may be readily removed.

The arrangement of the machines used in the process of wheat cleaning is various. First may be the magnetic separator, then the separator proper, which is arranged with a suction fan to make separations as to specific gravity, as well as to make the separation as to the differences in form and size of certain of the impurities which the wheat contains. After this separator comes the cockle machine, as it is called, or the round seed separator. Following this are the scouring machines, of which there are usually two different kinds of varying severity, and through which the wheat passes successively. Next comes the last metallic separation by the magnets, and finally the passage of the wheat by means of conveyors and elevators to the stock bins over the reduction machinery.

During the last twelve or fifteen years, the process of milling has been entirely revolutionized. There is no more resemblance between a modern mill and one of the past than there is between a flour mill and a saw mill at this time. According to the old millstone method, after the wheat was cleaned it was ground by millstones. These were made very rough and sharp, so that they would pulverize the grain and rub most of the flour from the bran. In this severe effort the bran was pulverized to a great extent, and the flour affected thereby. The germ was rasped into fine pieces and went into the flour, to its great detriment, as did also the fibrous interior of the grain.

The middlings idea changed all this. It cared for the wheat in a gentle way. It disturbed the bran as little as possible, and neither this nor the germ found its way, in any serious proportion, into the high grade flour. The fibrous interior of the wheat was to a certain extent rendered removable in middlings milling. It remains to tell what middlings milling is. First, it may be said that middlings are particles of wheat. If we should take a knife and cut wheat into small pieces, and detach the interior portion from the bran, we would have middlings. Or if we should in any other way break the wheat without making it into flour, we would make middlings. Middlings are made because when the wheat is in this form it can be still further cleaned, or purified, as it is called when we clean middlings. Middlings purification is nothing more or less than a wheat-cleaning process, and is carried forward according to some of the same general principles. The wheat is broken into pieces, so as to detach and liberate certain of the impurities which cannot be detached while the kernels are whole.

This is the essence and logic of the middlings idea. Middlings were always made on millstones, even before their value was understood. They were made incidentally, and not intentionally, before the recognition of the value of the middlings idea. In 1836, Oliver Evans, the pioneer in milling literature, said: "Although we may grind in the best manner we possibly can, so as to make any reasonable dispatch, there will appear in the

bolting a species of coarse meal called middlings." The miller was never able to arrange his burrs so that he could avoid the production of middlings. It was in the effort to do something with this unavoidable product that the milling system was revolutionized. We have had mutterings of the middlings idea in this country ever since 1860.

The first account we have of absolute milling for middlings was at Northfield, Minn., in 1866. This was done by grinding high, by raising the millstones higher than was usual, by avoiding an effort to clean the bran. No general effort was made, however, to make middlings in this country until the purifier was developed. The purifier is a machine which separates the impurities which are detached from the middlings during the process of their production. At first these purifiers were made to handle only the middlings that were made incidentally. The miller took the middlings that were otherwise sold as feed, and ran them over these machines. Having value only as feed, as little as possible of this kind of stock was produced. However, the purifier developed the fact that from the middlings the best flour could be made. The reasons were, as has been previously stated, that the wheat particles could be made cleaner by the aid of the purifier than was possible by the other machinery of the mill. Hence every effort was made to increase the production of this kind of stock. The miller reduced the speed of his burrs, grinding much slower than ever before. He ground higher, that is, with stones farther apart, all for the purpose of producing these pieces of broken wheat called middlings, and as he produced more middlings he had to have more purifiers. All previous ideas of burr grinding were set aside, and the miller only thought to do something to his burrs to make them produce more middlings. This led to endless changes and experiments, and constituted "new process" milling.

To repeat: Middlings purification is simply a species of wheat cleaning, and the wheat is broken into middlings for the purpose of further cleaning or purification. The thorough purification of middlings makes pure flour possible. Pure flour is patent flour. As wheat cannot be purified in its original form, other means were adopted. Purification is now the sum and substance of modern milling. Reduction is a detail, and in so far as a system of reduction aids in the purification of a stock, it is a good system. Modern milling is a wheat-cleaning and wheat-reducing process. If it were possible to make it all middlings, it would be possible to make nearly all of the wheat into patent flour.

As the purification of middlings means the removal of certain impurities, the basis of the separation must be considered. These impurities are the vegetable hairs, the bran which is attached to the middlings, and that which is free in the middlings, the germ with its coatings and surroundings, and the interior cellular coatings. According to the present method, the basis of purification is size, specific gravity and general structure. Thus it will be seen that the same general conditions apply to the separation of impurities from middlings as from wheat. Differences in size, specific gravity, and structure are the conditions which make the purification of middlings possible. They suggest the construction of purifying devices. The separation as to size is accomplished by the means of bolting cloth, and as to specific gravity by air currents which allow the heavier particles to pursue one course and the lighter ones another. As to the structure, the separations are made by means of reduction machines, which allow the impurities to remain intact. For example: The smooth rolls may be mentioned as making a germ separation. These rolls are simply two dressed chilled iron cylinders, running together in a way to crush anything which comes between them. Stock which contains germ, when run between smooth iron rolls, is smashed or broken. The middlings portion is broken and the germ is flattened. The middlings are made smaller and the germ larger. Thus, by passing the body of the reduced stock over a reel, it may be clothed so as to allow the middlings to pass through the cloth and the flattened germ to pass over it and thus separate it from the better stock. The separation as to size and specific gravity as ordinarily made, as every miller knows, is on a vibrating sieve machine, with a current of air up through the sieve. The current is caused by a rapidly revolving fan which is placed over the sieve. The lighter impurities go in the direction of the air currents, and the purer stock through the cloth. There is a class of impurities which is larger and heavier than the good middlings which pass over the tail of the cloth and thus are separated from the pure middlings. The sieve motion in itself has a tendency to aid in the work of purification, being calculated to make all of the light impurities come to the top and the pure middlings stock, which is heavier, cling closer to the cloth and pass through it in due time. The motion of the sieve has the quality of bringing all the light particles to the top, and they float to the place where the suction from the fan is heavy enough to lift them from the cloth and blow them into the dust collectors which are placed over the machines. If not, this stock floats over the end or tail of the sieve.

There is another type of purifier called an aspirator. It is something like a wide spout, into which the middlings are allowed to fall, and as they pass downward through it, the course of the stock is interrupted by slats at the same time that there is a suction or blast of air through the middlings. This has the quality of drawing out light material. In any case it is usual to grade the middlings into different sizes. By grading is meant the separation of the different sized middlings so that each class may have a purifier or number of purifiers to itself. This is done so that the suction of air may be adjusted to suit the different qualities of impurities which may be in each grade of middlings. If one were to put all sizes of middlings, coarse and fine alike, on a single purifier, it would be found that either the middlings would not be well purified, or that they would be wastefully purified.

Where there is a wide range of sizes of middlings to be handled, it will be found that there are impurities which belong to the coarse middlings which are heavier than the lighter middlings. Hence a suction of air which would be intended to remove the impurities from the heavy middlings would draw out the fine middlings as well, and thus cause great waste; or, if the current of air were adjusted so that it would not do this, it would not effect any good in the purification of the coarse middlings in the case. Thus it is that middlings should be

graded into different sizes, so that the suction may be adjusted to purify the middlings and yet not do it wastefully. Material which is lighter or of less specific gravity than good middlings may be removed by currents of air as here stated. The impurities which are larger than good middlings will pass over the end of the sieve and thus, theoretically, the material which goes through the cloth is middlings purified of everything but the germ. Practically this is not true. The middlings have to be handled a number of times in order to make a separation which is satisfactory.

The first purifier made in this country was in 1868, and was used in a mill owned by the Lacroixs at Faribault, Minn. It was described by Rodney Mason, the patent attorney, as a box with a sieve on top of it, and a current of air passing up through the cloth. This is practically what an ordinary sieve purifier is to-day, excepting that the sieve is inclosed by the box. The Lacroix purifier herementioned had a blast from below, whereas it is common at this time to have a suction fan above. Theoretically the result is the same—the air passes upward through the cloth. In the purification of middlings I have described how the separation as to size and specific gravity is made. It frequently happens that there are impurities attached to the middlings, pieces of bran and fiber. These can only be removed by the process known as sizing, that is breaking them lightly between smooth iron rolls, then taking out the dust by passing the middlings through a reel, and finally grading them again, after which they may be run on to purifiers and repurified. This sizing, dusting and repurification idea is sometimes continued a number of times, until the middlings all become very fine. During this process all of the germ is entirely separated from the middlings, and by the operation of sizing and repurification, all of the bits of bran and fiber which were attached to the middlings are removed. The sizing has the quality of changing not only the relative size of the middlings and impurities, but at the same time the relative gravity. The middlings are made smaller and the branny particles remain the same size as previous to reduction. Hence they are relatively larger, and thus easily removed from the stock.

I have dealt at length with the middlings and their purification for the reason that it is the middlings idea that led to the milling revolutions. I have delayed speaking of the reduction of the wheat because the method of reduction, as compared with the middlings idea, is a mere detail. Reduction of wheat is for the purpose of producing middlings that they may be purified. If wheat could be thoroughly purified without making middlings, then there would be no need for the purifiers. Then reduction would become the sum and substance of milling. But as wheat cannot be thoroughly purified, except in the form of middlings, the middlings idea is dominant. After the introduction of the purifier, after the importance of the middlings idea was thoroughly understood, every miller gave his attention to increasing the proportion of middlings from the wheat. This was the "new process" milling. The millers did all that could be done in the way of producing middlings by millstones, and were not satisfied.

The first roller mill built in this country was a hundred barrel experimental mill, built in one end of the Washburn "C" mill, at Minneapolis, in the winter of 1878-79. It was called an experimental mill, whereas there was no experiment about it. As early as 1875 the roller flour of Buda-Pesth, Hungary, had achieved a worldwide reputation, and was generally appreciated outside of that country. The rollers were machines that would make more middlings than burrs would. That was the sole reason for their adoption by the American millers. The middlings are made on corrugated rolls, or those with small corrugations or grooves cut into them. The number varies as the breaks advance. That is, the corrugations for the first breaking of the wheat are coarser than the others. From four to eight corrugations to the inch are used on the first break, and on the last break twenty-four corrugations to the inch is common. On the intermediate breaks, intermediate corrugations between the coarsest and the finest are used. With the introduction of rolls for reducing wheat came "gradual reduction milling," a term which means just what it says. The reduction is gradual. The first reduction is intended to merely split the wheat, after which it is sent to a short reel clothed with wire cloth of 18 to 20 meshes to the inch, through which the middlings and dust pass. Over the end or tail of thereel pass the broken particles of wheat, which are spouted to the second reduction, where the wheat is broken a little more, and the operation of scalping on the wire-covered reel is repeated, and so on ordinarily to the sixth time.

Middlings are usually made during the first five reductions. The sixth or last reduction is exclusively a bran-cleaning process, and makes only flour. The flour of the first break is very poor, and for that reason the product of the first break scalping reel is sent into a separate reel by itself, for the purpose of separating the middlings from the flour. The middlings from this break are sent in with the other middlings to be graded and purified. The product of the scalping reels of the second, third, fourth, and usually the fifth break is sent to a reel by itself, to separate the middlings from the flour stock. These middlings, together with the first break middlings, are sent into a grader, which is usually a reel covered with different numbers of cloth, according to the size of the middlings, and thence the middlings are sent to the various purifiers. The flour stock which is separated from the middlings which come from the scalpers as stated is sent into other reels to be rebolted. The flour product of the second, third, fourth, and fifth break is called bakers' or clear flour.

There is a material made by the break rolls and other rolls which is too fine for middlings and too coarse for flour. It is called dust middlings. It is so fine that it cannot be purified without great waste. It is reduced on smooth rolls and sent to reels by itself, and the flour is separated from the stock which may pass over the end or tail of the reel.

The stock which passes over the tails of the purifiers and the tails or ends of the reels is called tailings. It in turn is reduced on smooth rolls, and the flour bolted out on reels in the usual way, and the tailings from the tailings reel is again reduced and again bolted. This latter product is usually low grade flour. The tailings from the purifiers is frequently reduced by itself. It is of a higher grade than the other tailings.

There are various types of reels. The scalping reel is usually a short reel intended to separate the coarser

from the fine material, which process is usual and frequent in the various stages of modern milling. However, a scalping reel may be any kind of a reel, or of any length. Flouring reels are mentioned in milling literature. They are the reels which rebolt the flour after the flour stock has been scalped or separated from the coarser stock. Such reels are usually clothed with what is known as Nos. 12 and 14 cloth, which are the usual flour numbers, though sometimes numbers a little finer than these, and occasionally numbers a little coarser, are used. Sometimes all of these numbers are used in one mill, that is, the coarser and the finer, as well as the ones mentioned specifically. There are different types of reels. The ordinary six-sided reel, which is 32 in. in diameter, is formed by passing wooden arms through a shaft and securing wooden ribs at the end in a way to form supports for the bolting cloth which passes around the reel. The centrifugal reel is usually a short reel of cylindrical form, with internal wings which revolve much faster than the cloth, or outer cylinder. These wings throw the stock against the cloth and thus operate with great capacity. This is the principle upon which all centrifugal reels are constructed, though the details are various.

The Morse elevator bolt stands alone; it has no imitators. It is made up of an inclined sieve or screen of bolting cloth, on one side of a frame, with a wide elevator at the other side. This elevator continuously elevates the stock and throws it against the screen. The flour passes through the cloth and the other stock gradually works down toward the other end of the screen to be rebolted or reduced by smooth rolls. Another class of reels is sometimes called the inter-elevator type. The Jonathan mills reel is the pioneer and is representative of this class. It is a cylindrical reel, covered with bolting cloth, and has an interior cylinder of wood of a form closely resembling coarse corrugations of say 3 or 4 in. each. They are close to the cloth, and thus keep the material which is in the reel from thrashing around and being handled in a severe manner.

ELECTRIC TRANSMISSION OF ENERGY.

There are various combinations and arrangements of rolls, reels, and purifiers. There is the centrifugal system, which derives its name largely from the extended use of centrifugal reels. Prominently before the milling public at this time is the short system of milling. It has to do largely with the reductions. Instead of making the five or six reductions which are usual in a gradual reduction mill, only three or four are used. There are two divisions in the general short system idea. One class discards the middlings idea, and attempts to make flour only with the break rolls. The other still retains the middlings idea. The short system idea is prominently in use only in the winter wheat section at this time.

There is a naturalness in the construction of mills which in itself makes them wonderfully picturesque in their interiors. The long lines of rolls have a military air. The grinding floor view indicates this. The purifiers, with dust collector on the top, the spouts and pulleys and conveyors and all make a splendid picture. People are in the habit of raving over the picturesque qualities of old mills. They are admired more as dilapidations than anything else. I am constrained to believe that while few people have thought of it, nothing can be more beautiful and picturesque in a constructive way than the interior of a modern flour mill. The play of light and shade among the spouts, the perspective of the long lines of machines, the uniform movements of the shafting and pulleys, the military precision of the elevator legs, the rude strength of the posts and girders, the whipping of the lighterbelts as they pass over the pulleys, and the ponderous movements of the main drive and heavier belts, the thunder of the gearing, the musical hum of the fan—all contribute to the wonderful combination—a combination which is not appreciated for the reason that few people think of it as anything more than a money-making or a money-losing device.

The popular character of the title of this article might suggest that it was gotten up in the "every man his own miller" spirit. The easiest way to get around this is by saying that it is not so. It was the purpose

to write something about modern milling which will partake of the spirit of the times, and possibly interest or instruct those who are not immediately associated with milling facts, but who are more or less interested through indirect connection with the milling business. It may be of interest to the millers because of the primer method of the exposition of the ideas herein contained.—*Northwestern Miller.*

ELECTRIC TRANSMISSION OF ENERGY.

A COMMITTEE was appointed, under the presidency of Professor Amsler, of Schaffhausen, the well known inventor of the planimeter, and the following gentlemen were members: Professor Weber, of the Zurich Polytechnic School, and his two assistants; Professor Hagenbach Bischoff, of Basle; Professor Veith, who occupies the chair of machine construction at the Zurich Polytechnic School; Herr Keller, engineer to Messrs. Escherwyss, of Zurich; Herr Lang, a manufacturer of Derendingen; and Herr E. Burgin, of Basle, the inventor of the Burgin dynamo. This committee have just issued their official report on the trials made on the 11th and 12th of October last with the plant as actually installed. Before quoting the results of these trials, it will be well to briefly refer to the general arrangement of this installation.

At Kriegstetten there is a water power available, representing about forty actual horse power, and the problem was to carry as much of this power as possible to a mill in Solothurn, the distance being $4\frac{3}{4}$ miles as the crow flies; but, allowing for deviations, the length of each circuit may be taken as about five miles. There are at Kriegstetten two generating dynamos, and at Solothurn two motors coupled up on the three-wire system, as shown in the illustration below. Each dynamo weighs 3 tons 12 cwt., and has a Gramme armature 20 in. diam. and 14 in. long, the normal speed being 700 revolutions per minute. Referring to the diagram of connections, G¹ and G² are the generators

at Kriegstetten, and M¹ and M² are the motors at Solothurn. R¹ and R² are electro-magnetic switches which automatically come into action and short-circuit the exciting coils in case of the current rising beyond a certain limit. This provision was introduced in order to guard against the destruction of the generator in case a short circuit should take place somewhere in the line.

The current from each generator passes through an ammeter and then to a plug board, to which is also connected the balancing wire joining the negative brush of G² with the positive brush of G¹. The balancing wire is then carried direct to the middle one of the three lightning arresters, L, and then to the middle wire of the line, while each of the outside wires is led through a liquid switch, S¹ S², then to lightning arrester, and to the line. Each lightning arrester consists of a circular metal disk, the edge of which is provided with projecting teeth, and situated in a concentric metal ring, the internal circumference of which is also provided with teeth, but not touching the teeth of the disk. All the disks are connected with a common earth wire and two earth plates, E E. Should a flash of lightning strike the line, the current will leap across the intervening space between the teeth of the ring and those of the disk, and will thus be led to earth without passing through the machinery. The same provision against lightning is made at the motor station. The switches, S¹ S², are of peculiar construction, and consist of a vessel containing a conducting liquid and a perforated metal ball dipping into it. When the current is to be switched off, the handle is turned so as to raise the ball out of the liquid; but the circuit is not immediately interrupted, since the liquid within the balls issues in fine streams out of the perforations, and so maintains the connection for a short time after switching off. As the liquid in the ball gets exhausted, and the streams become thinner, the resistance of the liquid connection is gradually increased to infinity, and thus causes the current to gradually diminish to zero. The line wires are supported on Johnson & Philips' patent fluid insulators, and the average