ELECTRIC POWER IN FACTORIES AND MILLS.

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INTRODUCTION.

The application of electric power distribution to the operation of factories and mills, including the driving of the various machines and other apparatus, is the latest and one of the most important problems toward which attention is now being directed, the question being one of extreme prominence both from an economical as well as from an engineering standpoint.

In comparing two or more different systems of power distribution, the fundamental basis of comparison is generally that of dollars and cents. This is certainly correct, as far as it goes, but unless a very decided difference be found between the costs of running under the various systems, it may be found that other factors enter; factors which cannot be estimated in dollars and cents, namely, questions of desirability and convenience. Without considering any tests whatever, there are several exceedingly advantageous points in the use of motors in factories which are almost self-evident, such as:

1. Clear and unobstructed passages and head room, the latter facilitating the use of travelling cranes.
2. Ease of shifting the tools from place to place, possibly necessitating the placing of a starting box and the putting up of a little extra wire, as compared with the inconvenience and trouble of setting up and adjusting a line of shafting, hangers, belts, etc.
3. The economy due to the ability to run a single tool without necessarily starting the whole factory or at least a complete section.
4. The running expense is entirely stopped when the tool is shut down.
5. The absence of the drip of oil from overhead shafting.
6. The tools may be placed at any desired points

almost regardless of the distance. 7. It is not necessary to arrange the tools parallel as in the mechanical system. 8. A wider range of speed is possible. 9. Less damage caused by a fuse blowing, than by a belt slipping off in case of accident or excessive load.

Considerations like the above have great weight in deciding a question such as that under discussion, and there is no doubt whatever that in most cases they rise to such prominence that they warrant a complete change from the old system to the new, even though there is no gain in economy or increased output. In most cases, however, it has been conclusively shown that considerable saving and increase in production is obtained, one test showing a very considerable percentage of increase in the output. The partial, if not the complete, displacement of the old method by the new is only a question of time, and it was the appreciation of this fact that induced the authors to undertake the determination of the power actually required to run the various tools and machines as used in ordinary practice.

HISTORICAL NOTES.

The general use of electric motors in factories is comparatively recent, hence the history of the subject is necessarily short, although Froment, about 1850, used an electric motor to drive tools in his workshop. About five years ago motors were in operation in the works of the Thomson-Houston company at Lynn, the Crocker-Wheeler company and the C. and C. company. Shortly afterward the great German works of the Siemens and Halske company and the Allgemeine Elektrizitäts Gesellschaft began using motors to operate sections of their factories. From that time to the present, the use of motors has extended rapidly, until now they have been adopted in many factories all over this country and to a less extent abroad.

PRACTICAL TESTS.

In the tests which follow, the power required to drive the tools was obtained by placing an ammeter in the circuit of the motors running the various machines and groups of machines, and taking readings every few seconds, the frequency of the readings depending upon the nature of the tool and the work it was doing. The potential was practically constant at 110 volts, not varying more than one or two per cent. The first tests were made at the factory of the Crocker-Wheeler Electric Co., at Ampère, N. J., and the machines tested and the results obtained were as follows:

1. *Large Boring Machine*.—This machine was driven by a $1\frac{1}{2}$ H. P. motor, speed 1,200 R. P. M., mounted directly on the frame of the tool, the reduction in speed being obtained by the use of gearing. During this test, which lasted three hours, the machine was used for turning down a commutator for a 100 H. P. dynamo. The average current drawn was 8.3 amperes, representing 1.23 H. P. at 110 volts. Before the run was finished, the speed of the tool was increased by changing the combination of gears, and during this time the power required was 1.43 H. P. When the machine was started from rest, the rush of current was considerable, the average being 17.75 amperes, representing 2.6 H. P. It will be seen that this motor is well suited to the machine, the average load being very close to the rated power of the motor.

2. *Drill Press*.—A drill press was run by a 1 H. P. motor, speed 545 R. P. M., mounted on a shelf at top of press and belted down to countershaft at bottom, and thence up again to main shaft of machine, thus securing a reduction of the speed. This machine was boring the faces of the cast-steel pole-pieces of a 10 H. P. motor, two cutting tools being used. The test lasted 4 hours and 40 minutes and during this time the pole-pieces for three motors were bored. The first run covered 1 hour and 10 minutes and the average current was 2.92 amperes, representing .43 H. P. It required 15 minutes to replace the completed pole-piece by another one. This second piece required 2 hours and 32 minutes to finish, and the average amperes were 2.82 or .41 H. P. This time it required 17 minutes to replace the piece, and then the machine ran only 23 minutes until closing time. The current for this short run was 2.81 amperes, representing .41 H. P. The total length of time the machine was running was 4 hours and 5 minutes. Therefore power was supplied to the motor 86 per cent. of the time of the test.

3. *Drill Press*.—This machine was similar to the one preceding, but the work was different; namely drilling half inch holes in cast-iron bearings. The average current was 2.86 amperes, which represents .42 H. P.

4. *Drill Press*.—This tool was the same as the other two and the work consisted in boring the inside of cast-iron bearings. The average in this case was 1.9 amperes or .28 H. P. It will be noticed that in the case of these three machines a motor of one-half H. P. would be of ample size to do the work.

5. *Punch Press*.—This was a small punch run by a one H. P. motor mounted on the base of the machine and belted to its heavy fly-wheel. The speed of the motor was 700 R. P. M. This tool was punching slots in sheet iron disks for a 10 H. P. armature, there being 28 slots in each disk. The motor was turned off every time a disk was replaced, but it did not come to a dead stop as the inertia of the fly-wheel was so great. Readings were taken every five seconds and the time of turning on and off the current was noted. The test lasted 57 minutes, during which time the current was turned on for 35 minutes and 45 seconds, or 62.7 per cent of the time. The average current was 4.86 amperes, equivalent to .71 H. P. The rush of current at starting varied from 7 to 15 amperes, depending upon the haste of the workman in turning on the starting box.

6. *Gang Drill*.—This tool was driven by a one H. P. motor, 1,000 R. P. M., mounted with vertical shaft in frame of the machine and belted directly to the three drill spindles. The material drilled was cast-iron, and the sizes of the holes were $\frac{1}{4}$ in. and $\frac{3}{8}$ in. The average of the readings taken was 4.75 amperes or .7 H. P. When the drills were running free the motor took 3.5 amperes. Thus the power required to overcome friction was 74 per cent. of the power used while drilling.

7. *Group of two machines, one lathe and one milling machine*.—This group was driven by a three H. P. motor, belted to a short line shaft, from which belts ran to the countershafts above the two machines. The average current was 10.04 amperes, the power being 1.48 H. P. In this test, special attention was paid as to which machine happened to be running free, cutting, etc., with the results given in the following table.

Class of Machines and Work.	Amperes.	H. P.
Milling Machine Running Free—Lathe at Rest.....	5.67	.836
Lathe " " —Miller " "	7.36	1.085
Both running free	10.	1.47
Milling Machine Cutting—Lathe run free.....	10.33	1.52
Lathe Cutting—Milling Tool running free.....	14.42	2.12
Both tools cutting.....	15.4	2.28
Cutting rate increased on the lathe.....	17.8	2.61

8. *Group of Six Machines, Consisting of 1 Milling Machine (Small) 2 Lathes (10 or 12 Inch Swing), 1 Grindstone, 1 Drill Press and 1 Small Punch Press*.—The last named tool was not run at all during the test, and the grindstone ran continuously. This group was run by a one H. P. motor, belted to the usual

ceiling line shaft. The average current required to drive these machines was 5.86 amperes, representing .86 H. P. Thus this motor ran at about its most economical load.

9. *Group of Seven Machines, 1 Planer, (Small) 1 Grindstone, 4 Lathes, 1 Hand Turning Lathe.*—A three H. P. motor was used to drive this group, being belted to a line shaft, the same as the previous groups. The current was 13.36 amperes or 1.97 H. P. When the entire group was in use 2.65 H. P. were required.

10. *Group of 7 Lathes and 1 Grindstone Driven by a 3 H. P. Motor.*—The average current was 9.92 amperes and the power required was therefore 1.46 H. P. The power used by the motor when different numbers of lathes were running is shown by the following table:

Number of Lathes Running.	Amperes.	H. P.
One	7.76	1.14
Two	9.16	1.35
Three	10.69	1.58
Four	12.23	1.8

Thus in a group like this, it only takes 63 per cent more power to drive four lathes than it does to run one, the reason being the fact that it probably takes about one horse power to drive the countershafts.

11. *Group of Two Machines, a Large Punch Press and a Large Planer.*—The motor for running this group was placed on the floor, and drove a short line shaft on the ceiling by the usual form of belt. The rated capacity of this motor was $7\frac{1}{2}$ H. P., and its speed was 1350 R. P. M. The punch press did not run during the test. With the planer idle and the motor driving the shafting and belting alone, the current was 15.5 amperes, which represent 2.3 H. P. While the planer was at work the motor required 33.1 amperes or 4.87 H. P. As the loss from friction in the shafting is nearly constant under the variation of load, the power required to overcome this friction was 47 per cent. of the total power used. When the bed of the planer reversed from its slow cutting stroke to the comparatively rapid return stroke, the current increased to 52 amperes, showing an expenditure of 7.6 H. P. for a few seconds. This tool was planing the frame of a 90 K. W. multipolar dynamo, the material being cast-iron.

12. This group was a very large one, consisting of 20 machines ;

8 lathes, 4 milling machines, 3 planers and shapers, 2 grindstones, 1 vertical shaft grinding machine, and 3 small tools. The motor in this case was rated at 10 H. P. at 750 R. P. M. A Thomson recording wattmeter was placed in the circuit of this motor for one afternoon. At the end of this time the wattmeter showed a total of 17,854 watt-hours used, and as the time was five hours, the average power was 3,571 watts or 4.78 H. P. The average number of machines running was 13, most of the lathes being in use the greater part of the time. An ammeter was inserted in the circuit of the motor for a few minutes, and it was noted that the work was very steady, the current not varying more than 3 or 4 amperes at any time.

13. A group of five machines run by a 3 H. P. motor was next tested. Of these five machines, one was a lathe with 17 inches swing and 8 feet bed, one was a slotter, and the other three were lathes of 12 or 14 inches swing. The average amperes were 7 and the power 1.03 H. P.

14. The last tool tested at this factory was a large new engine lathe, which had just been set up, of 50-inch swing. This tool was driven by a 3 H. P. motor mounted on an iron bracket built in the base of the machine. The motion of the motor shaft is transmitted to the tool by gears, thus doing away with all belts. The work done was turning a $5\frac{1}{2}$ -inch steel shaft for a 200 K. W. dynamo, facing the ends etc., the cut being very light, as the work was only preliminary. The average current consumption was 11.4 amperes. Hence the average power was 1.68 H. P.

The following tests were made in the erecting shop of the De La Vergne Refrigerating Machine Company, at Port Morris, N. Y.

1. *Planer.* A large planer, 120 inches between posts, by 108 inches high, by 22 feet bed was driven by a C. and C. motor of 15 H. P. The voltage employed was supposed to be 220, but due to an incorrect station voltmeter the actual potential only averaged 190 volts on the morning of this test. The average current was found to be 20.08 amperes which at 190 volts represents 5.11 H. P. At the reversal from the cutting to the back stroke, the current increased to 85 amperes, equivalent to 21.65 H. P. The power required during the cutting stroke was 4.76 H. P., while on the return stroke the average was 5.73 H. P.

2. *Drill Press.* A drill press driven by a 5 H. P. C. and C. motor was tested in the afternoon. The potential was raised be-

fore this test, so that the average was 215 volts. The power required when drilling variously sized holes is shown in the following table :

Size of Drill.	Amperes.	H. P.
Running Free.	3.	.865
$\frac{7}{8}$ in.	4.07	1.23
$\frac{21}{32}$ in.	4.37	1.26
$\frac{31}{32}$ in.	4.6	1.33

3. *Corliss Cylinder Boring Machine.* This tool was driven by a 10 H. P. C. and C. motor and was boring the brass boxes, $6\frac{3}{4}$ in. diameter, of the main shaft bearing of a large ice machine. The average current was 14.47 amperes, representing 4.17 H. P. at 215 volts.

In order to place the results in a more convenient form the following table of average powers was compiled.

TESTS AT THE CROCKER-WHEELER FACTORY.

No. of Test.	Size of Motor.	Number of tools driven by motor.	Average Amperes.	Average horse power.	Remarks.
1	1.5 H. P.	1 boring machine.	8.3	1.23	
2	1. "	1 drill press.	2.85	.42	} Less than $\frac{1}{2}$ full load of motor.
3	1. "	1 " "	2.86	.42	
4	1. "	1 " "	1.9	.28	
5	1. "	1 punch press.	4.86	.71	
6	1. "	1 gang drill.	4.75	.7	} Drilling $\frac{1}{4}$ in. and $\frac{3}{8}$ in. holes.
7	3. "	2 machines.	10.04	1.48	
8	1. "	6 " "	5.86	.86	} All small machines.
9	3. "	7 " "	13.36	1.97	
10	3. "	8 " "	9.92	1.46	
11	7.5 "	2 " "	33.1	4.87	} Required 2.3 H. P. to run shafting only.
12	10. "	20 " "	4.78	4.78	
13	3. "	5 " "	7.0	1.03	} Light cut taken by tool.
14	3. "	1 engine lathe.	11.4	1.68	

TESTS AT THE DE LA VERGNE WORKS.

1	15. H. P.	1 planer.	20.08	5.11	} Planer 10 ft. x 9 ft. x 22 ft. Voltage 190. $\frac{7}{8}$ in. drill. Voltage 215. Voltage 215.
2	5. "	1 drill press.	4.07	1.23	
3	10. "	1 boring tool.	14.47	4.17	

The results obtained in these tests show that the power required to drive machine tools has been considerably overestimated, for it will be noted that with a large majority of the tools tested, the motor was not more than one-half loaded, and in

these cases it was seldom that the load equalled the full power of the motor, even for an instant. In the case of the large planer, although the motor was overloaded 50 per cent. upon reversal of the bed, the average load was only one-third of the rated full load. With this machine, however, when the piece of work is very short, necessitating more rapid reversals, the average load will be much nearer the most economical output of the motor.

The question of running machine tools by individual motors or grouping a number of machines together and driving them by one motor, does not seem to allow of a general solution. It would not be advisable, for example, to use the individual system where there are a number of small tools, each one of which requires only a small fraction of a horse-power. On the other hand if we have a large tool that requires considerable power, it would seem to be far more economical to run it by a single motor, using as little belting and shafting as possible.

Many of the manufacturers of machinery are now supplying boring mills, punching presses, drill presses and other machine tools arranged to be driven by electric motors. In most cases all that is necessary is a shelf or bracket on the tool to support the motor, and a gear wheel in place of the main pulley, unless a belt connection is preferable. A press or other tool having a large fly-wheel may be driven very conveniently by cutting teeth on the edge of the wheel which gear with a pinion on the motor shaft.

ELECTRIC POWER IN THE NEW ENGLAND COTTON MILLS.

The introduction of the electric system of distribution of power in the cotton industries of New England is now fairly begun. Although there are no large mills driven entirely by this system, a number of them have an electric plant and certain sections of the mill are driven by motors. An electric plant was installed four or five years ago in the works of the Silver Spring Bleaching and Dyeing Co., at Providence, R. I., but it was intended chiefly for lighting. But motors were placed in the carpenter and repair shops, and several other places, until at present there are about 100 H. P. of motors installed in eight units. The generating plant consists of three 100 H. P. U. S. dynamos belted together from a countershaft which is driven by a Corliss engine. Two of the machines are 110-volt dynamos which are used for lighting and running most of the motors at present. The third machine which has just been installed is a 500-volt Westinghouse power

generator of the same type as the lighting machines. There is only one machine at present connected to the 500-volt circuit, a 30 H. P. motor which drives a centrifugal pump supplying a storage reservoir with water for use in the bleacheries. The electric plant in this mill is not of much importance yet, but its chances for development are very bright since there are a number of machines now run by individual steam engines. These could be most advantageously replaced by electric motors as they are in some cases a great distance from the boilers, involving large losses from condensation.

A visit was made to the works of the Dunnell Manufacturing Company, at Pawtucket, R. I., where a very fine electric plant has very recently been installed to drive the calico printing machines. The problem of running this class of machinery by electric motors has been a very difficult one to solve, for the motor must be capable of running at a number of different speeds, and running constantly at any given speed with a variable load. In this case it has been solved by the use of a modification of the Leonard system of motor regulation. The outfit for each printing machine consists of a motor and a dynamo of the same size, the field rheostat of the dynamo being placed alongside the printing machine. The speed of the motor is thus changed by varying the voltage of the particular dynamo which supplies it with current.

The dynamo room contains eleven dynamos of the new moderate speed, four-pole type, made by the General Electric Company. They are run by a Corliss engine through a system of belting and ceiling countershafting. Six of these are 20 k. w. machines and four are 25 k. w. The eleventh dynamo is a similar 20 k. w. machine used for exciting the fields of the other dynamos. The normal potential is 250 volts, and is lowered in any particular dynamo when slower speed of the motor connected to that circuit is desired. This plant has been completed but a short time, and it was not possible to obtain any accurate figures showing the power used by the motors under various conditions of speed and load. Formerly the machines were run by individual engines and much difficulty was experienced in starting them, as the pressure of the printing rolls against the cloth is so great. With electric motors this difficulty is overcome, as the motors will stand a very heavy overload for a short time, and the starting torque is very great. The great advantage of the electric system as here used, is not so much in the saving of power as in the convenience to the workmen, and hence the increased production.

The saving of power, however, is quite considerable as in the old system steam was piped several hundred feet to the small individual engines, which were necessarily inefficient under the best conditions, and added to this the engines were run part of the time with partly closed throttle, still further decreasing the efficiency. With the present system, the attendant at the machine may quickly vary the speed to any required extent by turning the rheostat near the machine.

Although this plant has been in operation only a short time, it is claimed by those in control that the production is materially increased. In a paper by Mr. S. B. Paine in *Power*, June, 1895 he states that the increase in the production amounted to more than 25 per cent., and that the quantity of "seconds" (inferior product) was also considerably reduced.

This is very important, as the men in charge of printing machines are skilled workmen of the higher order, and a small saving in wages for a given production is of more value than a considerable saving of power.

A visit to Baltic and Taftville was also made to see the practical working of the well-known power transmission plant between these places. At Taftville, where the Ponemah mills are located, there is not sufficient water power to drive all the machinery, so an electric plant was installed at Baltic, $4\frac{1}{2}$ miles up the river where a dam had been built, giving an available head of 34 feet. The wheels are horizontal balanced turbines, two of them being rated at 800 H. P. each, while the third one is rated at 300 H. P. The wheels are belted to a long line shaft, which is in turn belted to the dynamos. The generators, of which there are two, are placed in a separate room. They are of the three-phase General Electric type and are capable of supplying 250 k. w. at 2,400 volts. They have ten poles and run at 600 R. P. M., giving a frequency of 50 cycles per second. The field is excited by a 3 k. w. bipolar dynamo belted from the generator shaft. The power is transmitted to Taftville by a very well constructed pole line. The motors are located in the basement of the Ponemah mill near the engines which they replace. They are belted to pulleys which are connected to their respective shafts by friction clutches in order to enable the motors to be started without load, as they are of the synchronous type. The motors are identical with the dynamos except in having an induction winding of heavy bars sunk in the pole-pieces, to cause them to be self-starting. In starting the

motors, the switch in the induction circuit is closed and then the line is connected to the armature, causing it to start as an induction motor, without a very great torque, however. When the motor has nearly reached full speed, the field is excited and it will speed up until it falls into step and then the induction switch is opened. This method of starting has two advantages: first, no auxiliary motor is needed; second, no device is required to tell when the motor is in synchronism with the generator.

One of these motors drives 1,200 looms requiring an expenditure of about 155 H. P. The other drives 500 looms and also the railway generators for the Norwich Electric Railway Co. The introduction of this plant has enabled the company to concentrate all its power for use in one mill, tending to decrease the cost of production, diminishing transportation charges and avoiding the use of any coal for steam power.

CONCLUSIONS.

First Cost.—Practically the only objection which can be urged against the electric system is the fact that the first cost of installation is greater than with ordinary belting and shafting, but even this is questionable, since the authors know of cases in which the estimated total cost of installing the necessary belting and shafting was actually greater than the equivalent electric motor outfit. The electric system would be cheaper for example in the case of very long or scattered buildings or those containing many stories or rooms, in any of which cases the belting and shafting required would be very complicated and expensive. The use of belting and shafting requires a much stronger and more expensive roof or ceiling than the electric system.

Saving of Power.—It might seem that the electric system would actually consume more power than the ordinary plan since it involves two transformations of energy. In most cases, however, if the power has to be distributed to a number of machines, particularly if they are located at any distance from the engine, the loss of power is less with electric transmission. This is explained by the high efficiency of the dynamo and motor, compared with the low efficiency of belt transmission as ordinarily practiced, involving as it often does very imperfect alignment and lubrication of the shafting. Perhaps the greatest saving, however, of the electric system is due to the fact that the consumption of energy entirely ceases when the tool stops. This

stoppage in the case of the busiest tools, amounts to at least 25 per cent. of the nominal working hours throughout the year, and with large or special tools which are not used so steadily, the stoppage is often as high as 50 to 75 per cent., since there are many whole days when they are not used at all.

Idleness due to strikes as well as to slack times must also be considered, and would usually amount to quite a large percentage in ten years for example. This assumes, of course, that a portion of the shop is running, which is usually the case even under such conditions. In short, with the mechanical system there is an enormous amount of shafting, idle pulleys and belting which run for long periods of time doing little or no useful work, but consuming considerable power.

Wherever electric motors can be substituted for a number of small engines scattered about, the saving in power is very great not only because of the low efficiency of small steam engines, but also by the avoidance of condensation in long steam pipes.

Increased Output.—This is, perhaps, the most important advantage gained by the electric system, since after all the cost of power is a very small item, being, according to Mr. Richmond,¹ only about 1 per cent. of the wages paid in average machine shop practice.

This increased output is secured by the greater convenience and promptness in starting and stopping as well as in regulating the speed of the machinery. The workman can, for example, temporarily increase the speed when the conditions are favorable, thereby saving considerable time.

Flexibility. The great convenience of moving the tools and placing them in any desired position is another special advantage of the new system. The great adaptability of this system is particularly well shown in the case of a factory which was almost completely destroyed by fire, nevertheless a few uninjured tools in a remote end of the building were operated successfully by means of electric motors within two days after the fire.

Speed Regulation.—The ordinary type of motor used in factories is the plain shunt wound machine, fed with constant potential current. The motor is started and varied in speed by means of a rheostat in the armature circuit. This simple arrangement answers very well in most cases, but for variable speed between

1. *Engineering Magazine*, January, 1895.

wide limits, a series wound motor controlled by a rheostat as in electric railway practice may be preferable. In other cases some special method of regulation such as the Leonard system, or the "boost and retard" plan may be adopted.

In concluding, the authors wish to express their sincerest thanks to the various companies for the courtesy shown by them and for the kind assistance which they rendered during the tests.

Comparison between Useful and Total Power Consumed in a Factory,
Observations taken every Fifteen Minutes.

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DISCUSSION.

THE PRESIDENT :—I think that Dr. Crocker's apology for presenting exact data is not necessary, as that is precisely what we want. Opinions are valuable, more or less, according to the persons they come from. Exact data is always valuable, and in a new departure of this kind it is especially useful to us, and the data given here is certainly of great value to any one who is connected with machine work. The paper is open for discussion.

DR. C. E. EMERY :—This paper is of great value. Without question the electric motor should play an important part in shop transmission. The extreme view originally expressed that a motor should be applied to every tool, is modified by the illustrations here presented, though unquestionably there are many tools which should be thus driven independently. For tools that are used occasionally it is wasteful to keep a belt running, particularly in an out-of-the-way corner where a long line of shafting must also be kept in motion. An electric motor is desirable in such case as well as to operate tools which are at times used during the night. There are also many tools of which the speed is required to be changed frequently, which can be most economically and most satisfactorily operated by an electric motor. There are, however, advantages in having some of the tools grouped together, for the reason stated in the paper, that the power required for the group is much less than the sum of the powers required to operate each separately. Properly arranged groups therefore require a less number of motors, and motors of less aggregate power, and moreover the larger motors are proportionably cheaper so that a considerable saving of interest is secured to balance the comparatively small losses due to running short countershafts. These considerations are not arguments against the desirability of using independent motors on certain tools, but show the necessity in this, as well as in all branches of engineering work of considering the conditions for each particular case.

The electric method of transmission has become of great importance in the distribution of small powers in our large cities. In the lower part of New York it is very common to have warehouses and small shops in the same loft. With the old system long shafts were run underground and through various buildings with belts leading in all directions, and in many such shops the rattle of the machinery could be distinctly heard. Now, in many such places, small motors are substituted requiring little care, and