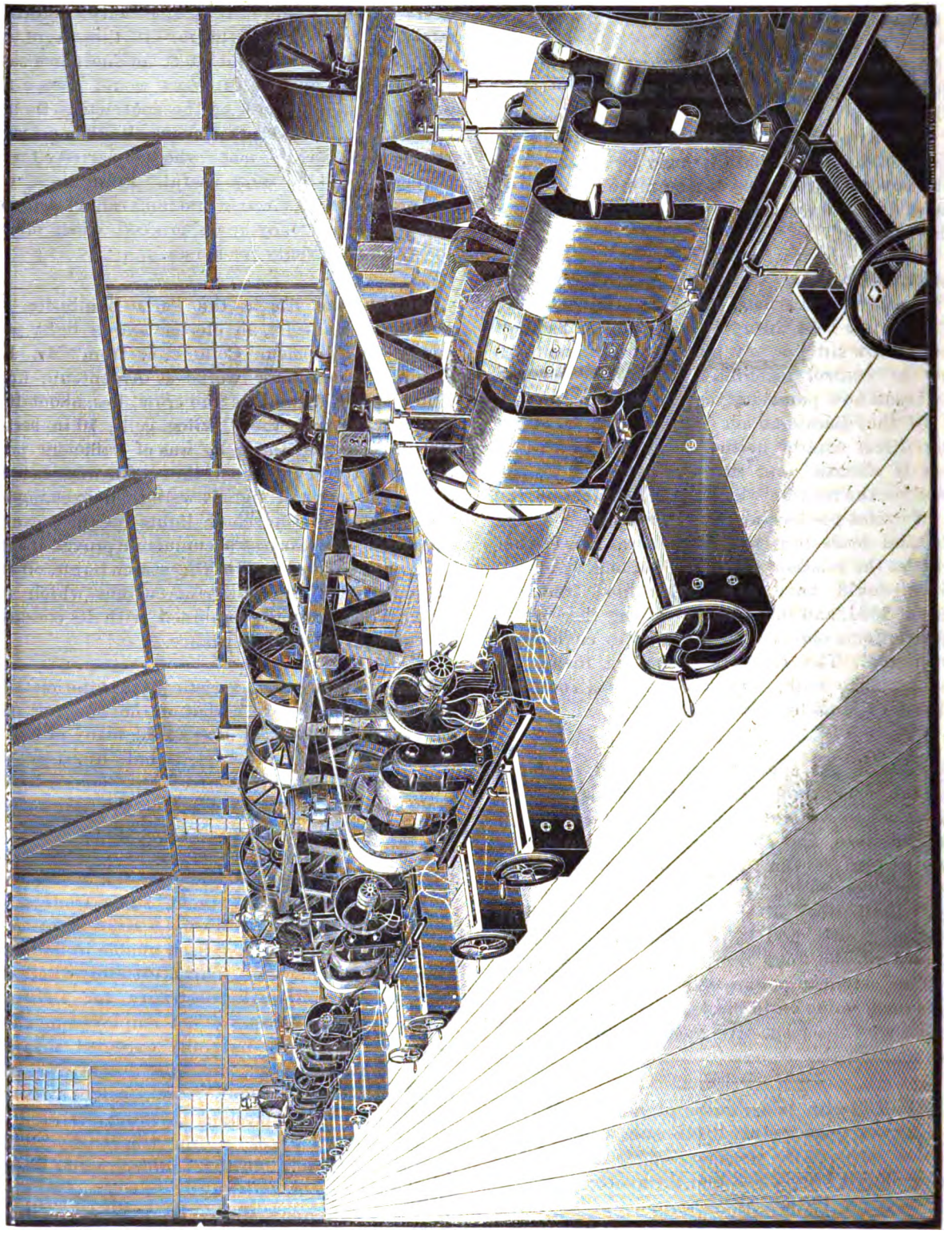
ELECTRICAL POWER TRANSMISSION AT VIRGINIA CITY, NEVADA.

THE LARGEST INSTALLATION IN THE WORLD SUCCESSFULLY CARRIED OUT BY THE BRUSH ELECTRIC COMPANY, CLEVELAND, U.S.A.

"MORE power, economical power," has been now for several years the imperative demand of the owners of mining properties on the celebrated Comstock lode at Virginia City, Nevada. The problem has been to work the enormous quantities of low grade ore at a profit. Large sums have been expended in carrying water from streams in the neighbouring Sierra Nevada mountains for a distance of some 30 miles, to be utilised at the mines and mills on the Comstock. But this supply of water is limited and fickle, and by no means meets the demand. Operations have frequently been suspended on this account, causing great loss to the mine owners and hardship to the labourers dependent upon the active working of the ores.

The best engineering talent has been called to work on this vital problem of power supply, and new arrangements have been made for increasing the amount of water, but vast powers now within reasonable range are still running to waste, which the use of electricity alone can conserve.



ELECTRIC MOTOR ROOM IN THE NEVADA STAMP MILL.

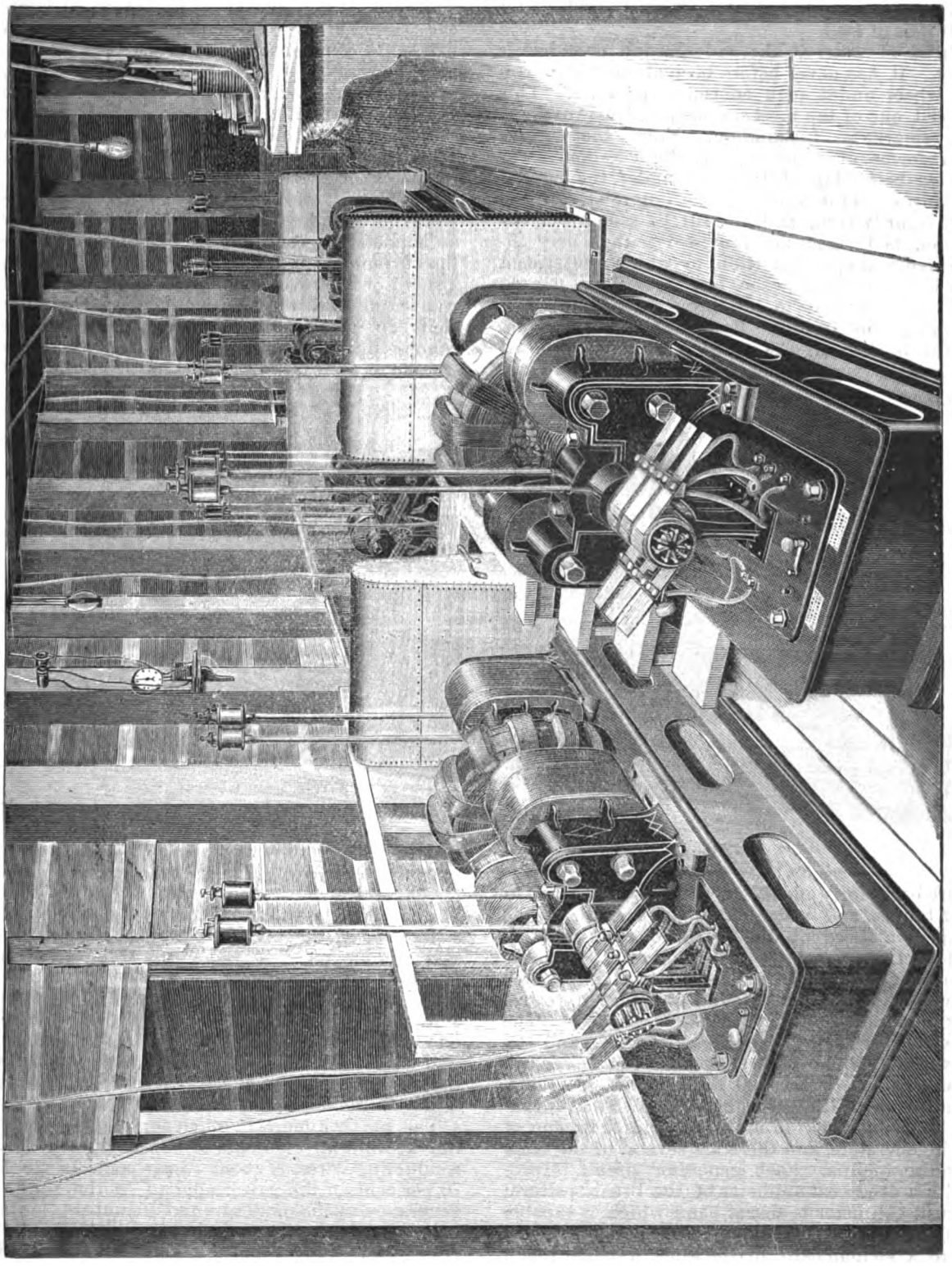
At the Stamp Mill of the Nevada Mill and Mining Company water power was obtained at the level of the mill from a reservoir on the side of the mountain. The mill contains 60 stamps, with their complement of pans, settlers, agitators, rock-breakers, &c. The water-power readily available was entirely inadequate for the operation of the mill.

The problem was submitted to the Brush Electric Company, of Cleveland, Ohio, through its agents, the

California Electric Light Company, of San Francisco. A solution was speedily offered, and the plans were accepted by the owners of the Nevada Mill and Chollar Mine. The shaft of the latter is close to the Stamp Mill. It was proposed to collect the waste water from the surface wheel at the mill, convey it in pipes to the shaft of the Chollar Mine, and thence down the shaft until a sufficient head should be obtained to produce the power required. The scheme was novel, and presented many difficulties. However, experts pronounced the plans feasible, and work was begun last winter.

At the 1,650 feet level of the Chollar Mine a subterranean chamber was excavated out of solid porphyry, for the reception of the dynamo-electric generators and waterwheels. This chamber is 50 feet in length by 25 feet in width and 12 feet in height, clear of all timbers. From the tank containing the waste surface water two wrought iron pipes are led to the subterranean chamber, one 10 and one 8 inches in diameter. At the bottom of the shaft a Y unites these two pipes into a single one 14 inches in diameter, out of which six 6-inch pipes run to the nozzles of the waterwheels provided to drive the large Brush dynamo-electric generators.

The underground electrical station is of the most interesting character, and is shown in our illustrations. The large Brush primary generators, of which there are six, are adapted to the conditions by a few mechanical changes from the standard pattern. They are mounted on a heavy cast-iron base, and are provided with an extended shaft and outer bearing. On the armature shaft, and between two bearings, the Pelton wheel is mounted and enclosed in a water-tight cover. The cut of the generator is made from a photograph taken at the Brush Electric Company's Works at Cleveland, before shipment, and shows a pulley on the armature



UNDERGROUND POWER STATION AT THE 1,650 FOOT LEVEL OF THE CHOLLAR MINE, VIRGINIA CITY.

shaft, arranged for testing runs at the factory. The waterwheel is attached to the armature shaft at the place occupied by this pulley, and an insulated coupling is provided for detaching this entire end of the shaft carrying the wheel, from the other end carrying the armature.

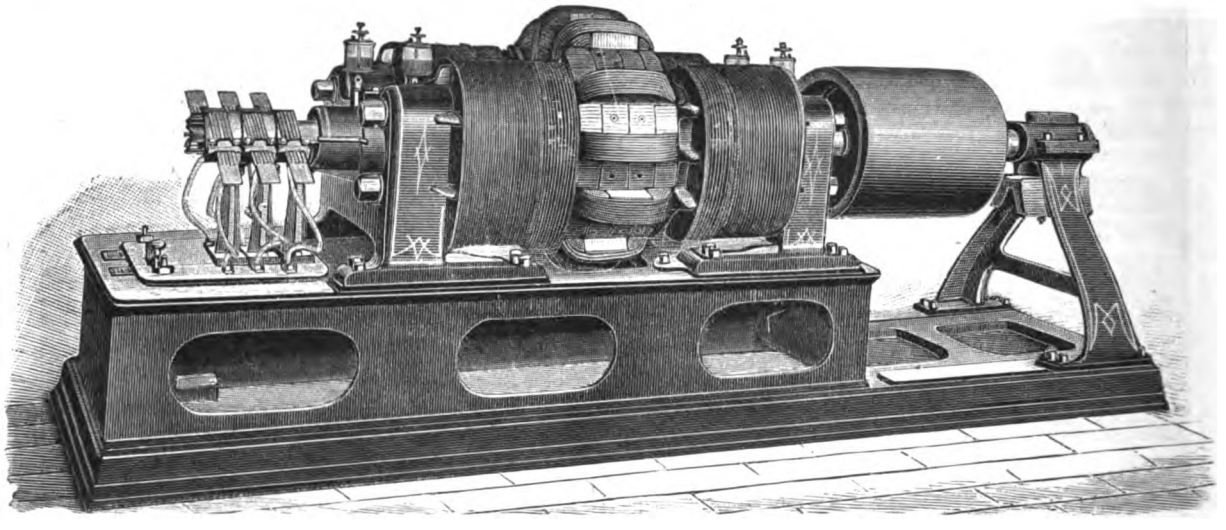
These Brush generators are each of 130 horse-power capacity, and are compound-wound for constant current. The electrical curve from the machines is almost ideally perfect, and they require no regulator whatever. The current remains of constant strength under all conditions of load.

The head of water at the underground chamber is 1,680 feet. It has never before been attempted to run a water-wheel under such enormous pressure. This was, indeed, one of the most serious problems involved in the remarkable installation. From the various excellent forms of water-wheels, the "Pelton" was selected as best adapted to work under the special circumstances. This wheel is the outgrowth of the old hurdy-gurdy form, and, as will be seen from the illustration, its buckets are provided with a very ingenious wedge-shaped partition, by which the stream of water is divided and sweeps out through the curved sides in such a way as to produce a reactionary effect in addition to the impact. By the peculiar construction of the buckets all the water is also thrown down and out of the way of the wheel. The six Pelton wheels are each forty inches in diameter, are made of phosphor bronze, and weigh 220 lbs. They drive the generators at a speed of 900 revolutions per minute. The compact arrangement of combined dynamo-generator and water-wheel makes it almost impossible for the visitor to the underground chamber to realise the enormous amount of power here at work. The machines are placed in parallel rows of three, and the swift revolving armatures are all that can be seen in motion as evidence of the 800 horse-power generated. The chamber is brilliantly lighted by 36 Swan incandescent lamps operated in multiple series from one of the Brush generators, and there are several of the same lamps in the incline. Each generator circuit is provided with a dead beat ammeter of the Brush pattern, and a Brush voltmeter is also at hand which is capable of measuring up to 3,000 volts. The generator circuits are led to a switchboard in the same dynamo room, where any generator can be thrown on to any one of the outgoing motor circuits.

Leaving this subterranean power station and ascending the Chollar shaft are the circuits of copper wire, one to each generator. At one point these circuit wires pass through a shower-bath of spray, but the insulation is so perfect that no leakage has yet developed. The wires issue from the mine shaft, and are carried above ground to the electric motor room at the Nevada Mill. The total length of each circuit is a little more than a mile.

The electric motor room is shown in one of the large illustrations. The six motors are of the regular Brush constant current type, each of 80 horse-power capacity, and are arranged in a single row parallel with the main driven shaft, to which they are all belted in the ordinary manner. The surface water-wheel is also connected to this same shaft. It will be noted that there is here a very novel and interesting feature. This surface wheel uses the water in the first instance and furnishes part of the power to drive the main shaft. The waste water after this primary use is carried down the Chollar shaft to the underground chamber, where it drives the dynamos which generate the electric current and energise the electric motors above ground, which, in turn, furnish additional power to the main shaft.

Each electric motor has its own independent circuit fed from one of the generators. The well known Brush centrifugal governor with which each motor is fitted, regulates the speed sensitively, and all or any number of the motors work perfectly in a battery together or with the waterweel. In the motor room there is also an ammeter for each electric motor to show at all times the current flowing in each circuit. The motors run at a speed of 850 revolutions per minute. Some difficulty was anticipated in operating the motors together on one shaft in the manner described, but none was encountered. The motors have not given a moment's trouble or annoyance of any kind from the start.



BRUSH DYNAMO-ELECTRIC GENERATOR, 130 HORSE-POWER.

Some idea of the economic value of this electric power plant to the mine owners may be got from a statement of the saving effected by it. The surface wheel alone requires 312 miner's inches of water to develop power sufficient to drive 40 of the 60 stamps with which the mill is equipped. Moreover, this amount of water is seldom available. Two of the electric motors, working in addition to the surface wheel, will perform the same service with but 72 miner's inches of water, thus effecting a saving of about 77 per cent.

The net commercial efficiency of the plant, taking into account all elements of loss, including that in the conducting wires, is about 70 per cent. In other words, 70 per cent. of the power applied to the shafts of the generators in the underground chambers, is delivered for work at the main line shaft in the mill.

The waste water from the 1,650 feet level of the Chollar mine is piped into the Sutro tunnel. It is now proposed to use this water a third time at a lower level for other work by means of a similar application of electrical machinery.

It was expected at the outset that many difficulties would be met in an installation of such novel and original character, which was also by far the largest ever attempted. The projectors, the Brush Electric Company, and their agents, the California Electric Light Company, who assumed charge of the details of the erection, were very greatly pleased to find that their fore-

thought had eliminated the troubles anticipated and predicted in almost all respects. Two purely technical difficulties were encountered when the plant was started experimentally, which caused some delay and anxiety. They were, first, the lack of any governing appliance for the water wheels, and second, the damage to the primary generators caused by the extreme heat and dampness in the underground station.

The Brush Electric Company in its original plans and specifications stipulated that the water wheel should be governed within reasonable limits, but this requirement was not met, and the first generator and motor started up experimentally, showed the necessity of this provision. The Brush Company was surprised to receive by the telegraph the first intimation that the makers of the water-wheels had wholly neglected such an important matter, but was fortunately able to close the breach at once. A water-wheel governor, invented and sketched out by Mr. W. B. Devereux, the prominent mining engineer, of Aspen, Colorado, had been placed in the hands of the company some time previously, and working drawings of it had been made at Cleveland. These were at once sent to California, the governors were quickly made, and this source of trouble was overcome. Mr. F. E. Smith, the electrical engineer in charge of the installation, made several modifications of the governor, after watching its performance, which proved of much value, and it has worked perfectly in practical service. We expect to be able to present our readers with illustrations of this water-wheel governor in a later issue.

The second difficulty was met with equal promptness, and likewise entirely overcome. The temperature of subterranean power chamber is about 72° F. The atmosphere is almost saturated with moisture—78 per. cent. Any piece of metal taken into it begins immediately to "sweat." The generators when placed in this chamber were soon covered and saturated with moisture, and began to show leaks, while the motors above ground were absolutely free from any trouble.

The Brush Company was at once notified of this unanticipated source of difficulty, and Mr. Brush speedily devised a method of insulation which would certainly and completely resist the moisture of the saturated atmosphere. Since its application the generators have worked admirably, and the entire plant is now at work regularly, performing its expected duty, and economising the power available, as stated above.

The achievement of the Brush Electric Company in connection with this plant on the Comstock is a very notable one, and of the greatest interest to mining engineers. The plant is by far the largest electrical power plant in the world. The company is making a speciality of powerful generators and motors for power transmission and distribution, and is taking large orders for them, not only in this country, but also for foreign shipments. The latest contract announced is one with the Calumet and Hecla Mining Company, for five of the large Brush generators of 130 H.P., and five of the 80 H.P. Brush motors. A power station will in this case be built above ground for the generators, and the motors will be used for driving pumps under ground. The plant goes to the great copper mine at Calumet, Michigan.

ON THE INFLUENCE OF GAS AND WATER PIPES IN DETERMINING THE DIRECTION OF A DISCHARGE OF LIGHTNING.*

By HENRY WILDE.

ALTHOUGH the invention of the lightning conductor is one of the noblest applications of science to the wants of man, and its utility has been established in all parts of the world by the experience of more than a century, yet a sufficient number of instances are recorded of damage done by lightning to buildings armed with conductors to produce in the minds of some an impression that the protective influence of lightning conductors is of but questionable value.

The destruction by fire of the beautiful church at Crumpsall, near Manchester, during a thunderstorm on the morning of the 4th instant, has induced me to bring before the Society, with a view to their being known as widely as possible, some facts connected with the electric discharge which have guided me for some years in the recommendation of means by which disasters of this kind may be averted.

For the proper consideration of this subject, it is necessary to make a distinction between the mechanical damage which is the direct effect of the lightning stroke, and the damage caused indirectly by the firing of inflammable materials which happen to be in the line of discharge.

Instances of mechanical injury to buildings not provided with conductors are still sufficiently numerous to illustrate the terrific force of the lightning stroke, and at the same time the ignorance and indifference which prevail in some quarters with respect to the means of averting such disasters; for wherever lofty buildings are furnished with conductors from the summit to the base and thence into the earth, damage of the mechanical kind is now happily unknown.

Even in those cases where lightning conductors have not extended continuously through the whole height of a building, or where the lower extremity of the conductor has, from any cause, terminated abruptly at the base of the building, the severity of the stroke has been greatly mitigated, the damage being limited in many cases to the loosening of a few stones or bricks.

The ever-extending introduction of gas and water pipes into the interior of buildings armed with lightning conductors has, however, greatly altered the character of the protection which they formerly afforded; and the conviction has been long forced upon me that, while buildings so armed are effectually protected from injury of the mechanical kind, they are more subject to damage by fire.

The proximity of lightning conductors to gas and water mains, as an element of danger, has not yet, so far as I know, engaged the attention of electricians; and it was first brought under my notice at Oldham in 1861, by witnessing the effects of a lightning discharge from the end of a length of iron wire rope, which had been fixed near to the top of a tall factory chimney, for the purpose of supporting a long length of telegraph wire. The chimney was provided with a copper lightning conductor terminating in the ground in the usual manner. In close proximity to the conductor and parallel with it the wire rope descended, from near the top of the chimney, for a distance of 100 feet, and was finally secured to an iron bolt inserted in the chimney about 10 feet from the ground. During a thunderstorm which occurred soon after the telegraph wire was fixed, the lightning descended the wire rope, and, instead of discharging itself upon the neighbouring lightning conductor, darted through the air for a distance of 16 feet to a gas meter in the cellar of an adjoining cotton warehouse, where it fused the lead pipe connections and ignited the gas. That the discharge had really passed between the end of the wire rope and the lead pipe connections was abundantly evident from the marks made on the chimney by the fusion and volatilisation at the end of the wire rope and by the fusion of the lead pipe. As the accident occurred in the daytime, the fire was soon detected and promptly extinguished.

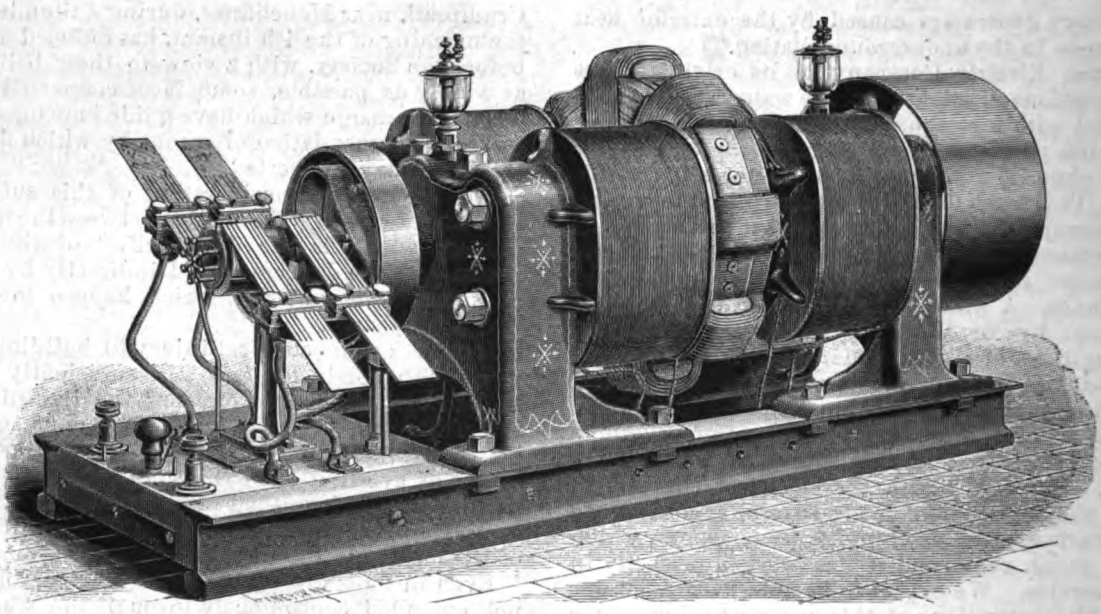
Another and equally instructive instance of the inductive influence of gas pipes in determining the direction of the lightning discharge occurred in the summer of 1863 at St. Paul's Church, Kersal Moor, during divine service. To the outside of the spire and tower of this church a copper lightning conductor was fixed, the lower extremity of which was extended under the soil for a distance of about 20 feet. The lightning descended this conductor, but, instead of passing into

* From the Proceedings of the Literary and Philosophical Society of Manchester, January 9th, 1872.

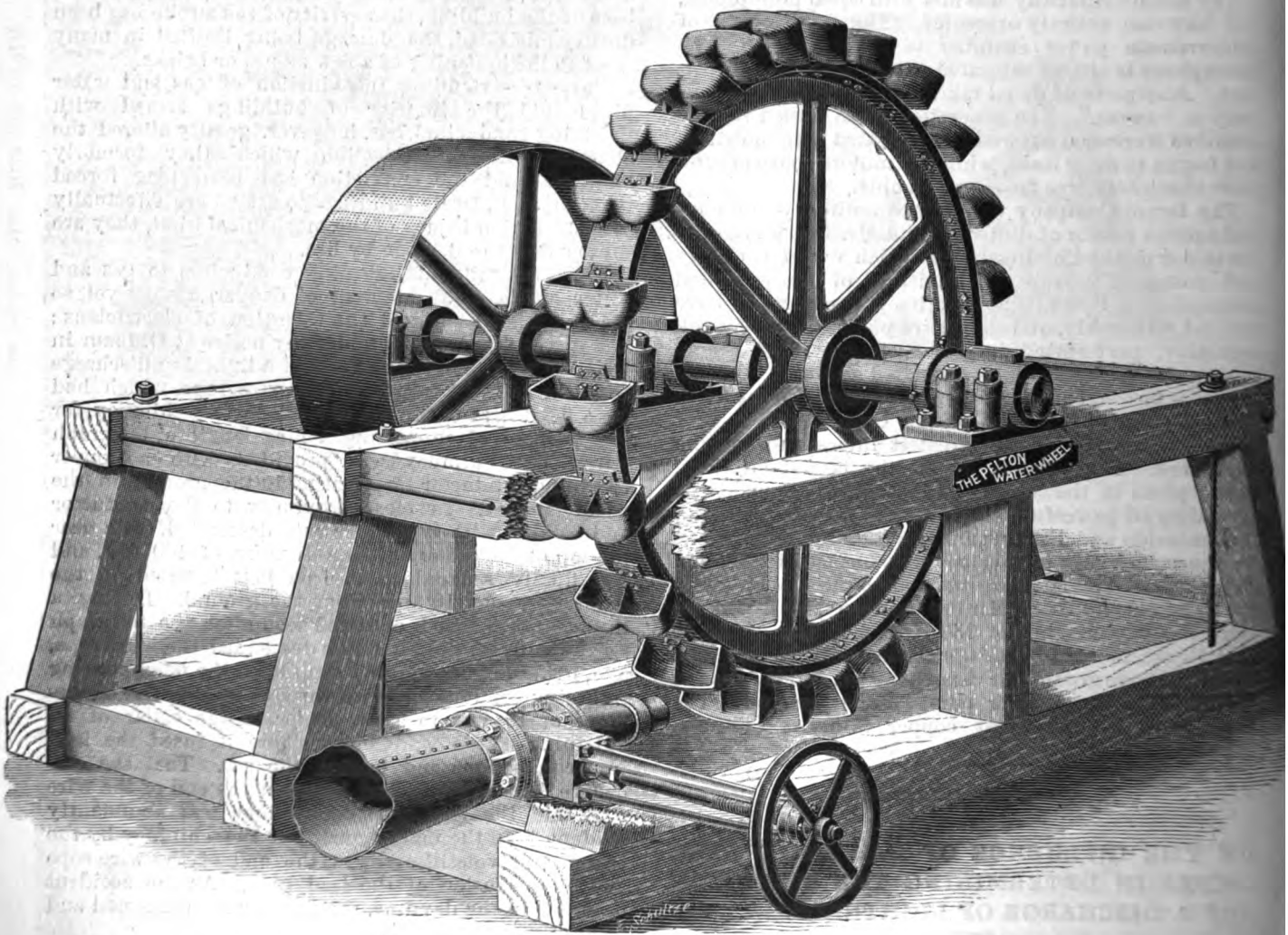
the earth by the path provided for it, struck through the side of the tower to a small gas pipe fixed to the inner wall. The point at which the lightning left the conductor was about 5 feet above the level of the ground, and the thickness of the wall pierced was about 4 feet; but beyond the fracture of one of the outer stones of the wall and the shattering of the plaster near the gas pipe, the building sustained no injury.

That the direction of the electric discharge had in this case been determined by the gas pipes which passed under the floor of the church was evident from the fact that the watches of several members of the congregation who were seated in the vicinity of the gas mains were so strongly magnetised as to be rendered unserviceable.

The church at Crumpsall is about a mile distant from that at Kersal Moor, and the ignition of the gas by lightning, which undoubtedly caused its destruction, is not so distinctly traceable as it is in other cases which have come under my observation, because the evidences of the passage of the electric discharge have been obliterated by the fire. From information, however,



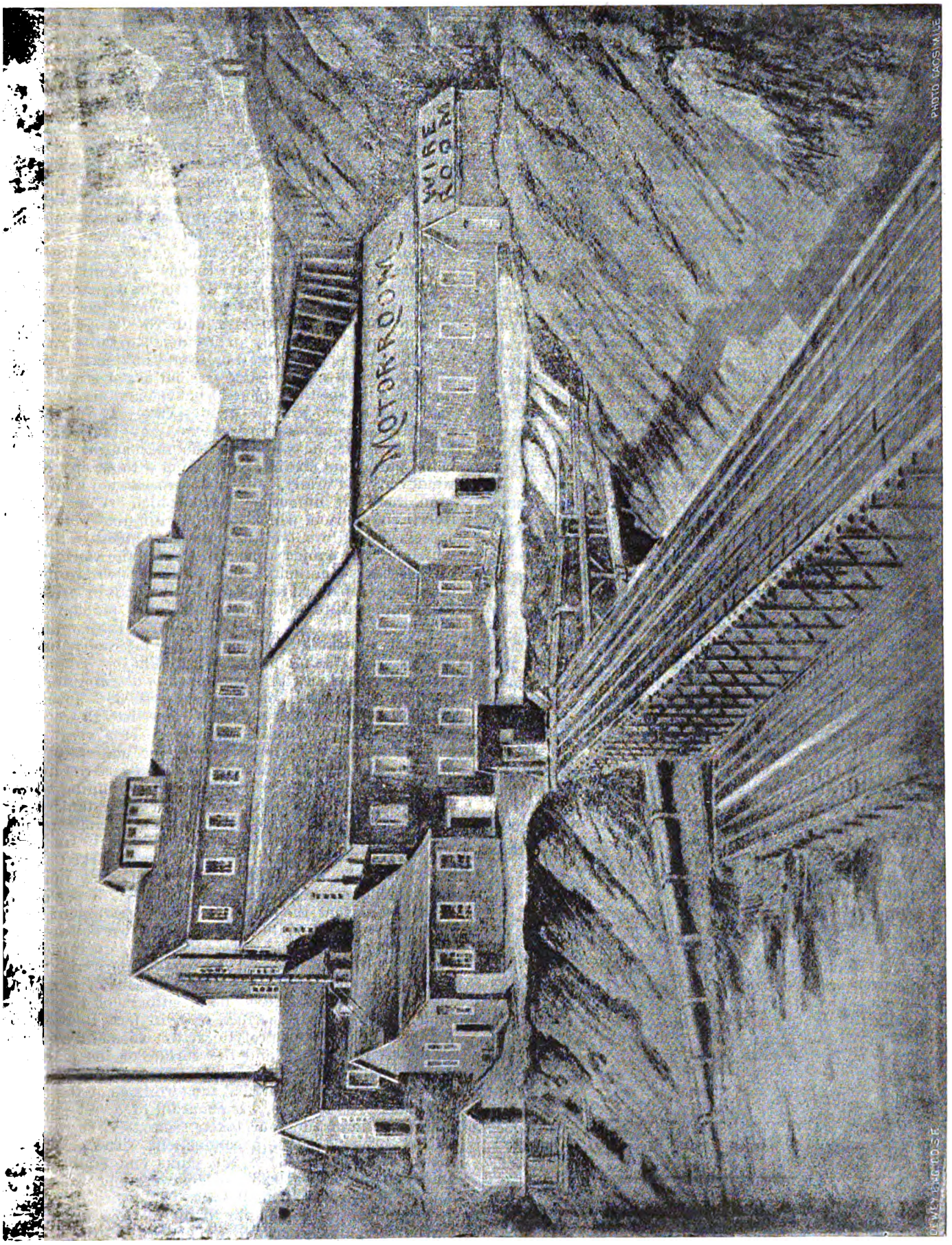
BRUSH AUTOMATIC ELECTRIC MOTOR, 1 TO 100 HORSE-POWER (See p. 678).



THE PELTON WATER-WHEEL (See p. 678).

communicated to me by the clerk in charge of the building, as to the arrangement of the gas pipes, the most probable course of the electric discharge was ultimately found.

drain as that in which the spout discharges itself. Immediately under the roof of the nave and against the wall a line of iron gas pipe extended parallel with the horizontal lead gutter which conveyed the water from



THE NEVADA STAMP MILL (See p. 676).

The church is provided with a copper lightning conductor, which descends outside the spire and tower as far as the level of the roof. The conductor then enters a large iron down spout, and is carried into the same

the roof to the iron spout in which the conductor was enclosed. This line of gas piping, though not in use for some time previous to the fire, was in contact with the pipes connected with the meter in the vestry, where

the fire originated, and was not more than 3 feet distant from the lead gutter on the roof. As no indications of the electric discharge having taken place through the masonry were found, as in the case of the church at Kersal Moor, it seems highly probable that the lightning left the conductor at the point where the latter entered the iron spout, and by traversing the space between the leaden gutter and the line of gas piping in the roof found a more easy path to the earth by the gas mains than was provided for it in the drain.

In my experiments on the electrical condition of the terrestrial globe* I have already directed attention to the powerful influence which lines of metal, extended in contact with moist ground, exercise in promoting the discharge of electric currents of comparatively low tension into the earth's substance, and also that the amount of the discharge from an electrometer into the earth increases conjointly with the tension of the current and the length of the conductor extended in contact with the earth. It is not, therefore, surprising that atmospheric electricity, of a tension sufficient to strike through a stratum of air several hundred yards thick, should find an easier path to the earth by leaping from a lightning conductor through a few feet of air or stone to a great system of gas and water mains, extending in large towns for miles, than by the short line of metal extended in the ground which forms the usual termination of a lighting conductor.

It deserves to be noticed that in the cases of lightning discharge which I have cited the lightning conductors acted efficiently in protecting the buildings from damage of a mechanical nature, the trifling injury to the church tower at Kersal Moor being directly attributable to the presence of the gas pipe in proximity to the conductor. Nor would there have been any danger from fire by the ignition of the gas if all the pipes used in the interior of the buildings had been made of iron or brass instead of lead; for all the cases of the ignition of gas by lightning which have come under my observation have been brought about by the fusion of lead pipes in the line of discharge. The substitution of brass and iron, wherever lead is used in the construction of gas apparatus, would, however, be attended with great inconvenience and expense, and moreover would not avert other dangers incident to the disruptive discharge from the conductor to the gas and water pipes within a building. I have therefore recommended that in all cases where lightning conductors are attached to buildings fitted up with gas and water pipes the lower extremity of the lightning conductor should be bound in good metallic contact with one or other of such pipes outside the building. By attending to this precaution the disruptive discharge between the lightning conductor and the gas and water pipes is prevented, and the fusible metal pipes in the interior of the building are placed out of the influence of the lightning discharge.

Objections have been raised by some corporations to the establishment of metallic connection between lightning conductors and gas mains on the ground that damage might arise from ignition and explosion. These objections are most irrational, as gas will not ignite and explode unless mixed with atmospheric air, and the passage of lightning along continuous metallic conductors will not ignite gas even when mixed with air. Moreover, in every case of the ignition of gas by lightning, the discharge is actually transmitted along the mains, such objections notwithstanding. A grave responsibility therefore rests upon those who, after introducing a source of danger into a building, raise obstacles to the adoption of measures for averting this danger.

ELMORE COPPER DEPOSITING PROCESS.

A good deal has been heard lately with regard to this process introduced by Messrs. Woodhouse and Rawson, limited, and notwithstanding that a large number of eminent men were contained in the prospectus issued with reference to the Elmore Company for working the patents in England, the results of the process were almost believed to be too good to be true.

Lately some trials have just been finished at the works of one of the principal manufacturing companies abroad at their own factory, which places the results of the Elmore process beyond dispute, and more than proves the statements made by the inventors. It is well known that the process consists of depositing copper upon a rotating mandril from a sulphate of copper solution, but the valuable portion of the invention relates to the mechanical working of the surface of the metal from one end of the mandril to the other by means of an agate burnisher having a few pounds pressure. By these simple means a very remarkable change takes place in the constitution of the metal, which is found to possess extraordinary strength coupled with remarkable malleability. These points are fully shown in the results of the tests given later on. The instruments used for arriving at the constants were a Carpentier ammeter and a Siemens potential galvanometer reading ·01 volts per degree, the dynamo being a one horse Gramme machine. Work was carried on continuously for 10 days, with the exception of a short stoppage caused by an accident to the dynamo, but no bad results in the tubes could be traced. After five days' working one tank was cut out of circuit, the mandril with the tube upon it removed and another one put in and started with the greatest ease. The attention necessary during the operations is of the slightest possible kind, the whole of the mechanical portion being purely automatic, and working without any hitch whatever. Naturally, as in most processes of a similar kind, there are numerous points which we are not at liberty to mention, which make the difference between success and failure, but these merely consist in details which are not subject to variation, and the working of the process is simplicity itself. Five tubes were made, these were separated from the iron mandrils by pressure being applied to the copper while the mandril was rotating in a lathe. The expansion of the copper is sufficient to enable the tube to slide off easily, but in regular work the method of expanding the copper by superheated steam will be employed as it is simpler and cheaper. The mean current used was 36·7 ampères, giving a current density of rather more than 15 ampères per square inch of cathode surface. This very high current density is no doubt possible on account of the use of the burnisher, and is more than twice the maximum found advisable in ordinary copper refining without the burnisher. The E.M.F. of each tank was taken separately at the terminals, the average being as nearly as possible 0·9 volt per tank. In connection with this point, it may be remarked that after about 36 hours the E.M.F. reaches its normal point, being at the commencement about 5 per cent. higher, and that the reading of the instrument was perfectly steady in spite of the well-known delicacy of the Siemens instrument. This fact is important in connection with the method of connection with the rotating mandril, which is made by means of a brush pressing on its surface. The steadiness of the voltmeter was practically perfect, and, in fact, there is to all appearance an electrolytic action constantly going on between the brush and the surface of the mandril which tends to keep the contact remarkably perfect. The total E.M.F. measured at the terminals of the four tanks, taken as a whole, was about 0·1 of a volt greater than the sum of the four taken separately, showing a remarkably small loss in connections. The electrical horse-power absorbed in the tanks and connections amounted to about 0·28 horse-power, and the total copper deposit was about 104 lbs.

A very careful calculation deduced from the mean current employed, showed a remarkably close agreement between the theoretical and actual quantity of copper deposited. The thickness of copper deposited was 0·14 inches, being as nearly as possible at the rate of one-eighth of an inch per week.

Exhaustive tests were made upon portions of the tubes made after their removal from the baths: the

* Philosophical Magazine, August, 1868.