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(*Paper No. 2633.*)

"The Electric Lighting of Danger Buildings."

By Charles Frewen Jenkin, B.A., Assoc. M. Inst. C.E.

The danger from ordinary electric lighting, carried out in accordance with such rules as those drawn up by the Phœnix Fire Office, will soon be able to be estimated from the statistics of the Fire Offices. It is probably very small, but is certainly not non-existent; and it must be remembered that for every fire of sufficient magnitude to come under the notice of a Fire Office, there must be many trifling cases of fire, overheating, and sparking, any one of which would be sufficient, in a dusty powder building, to cause a disastrous explosion.

These considerations show the necessity for taking much greater precautions in danger buildings than in others. At the same time, the danger arising from electric light varies immensely in different classes of buildings, all of which may come under the definition of "Danger Buildings" as given in the Explosives Act. Probably the most dangerous buildings are those used for some of the processes of gunpowder manufacture, such as granulating and pressing.

This Paper contains a description of the system of electric lighting, devised by the Author, adopted in some of the danger buildings of this class, at the Royal Gunpowder Factory, Waltham Abbey. At that factory, as is often the case, the powder buildings are spread over a considerable tract of low-lying ground, covered with trees, and intersected with numerous water-channels. The trees are valuable as screens in the cases of explosion, and the water furnishes both motive-power and safe means of transport. The buildings are light brick and wooden structures, partly surrounded, as a rule, by heavy traversers, designed to prevent an explosion from being communicated to the other buildings in their neighbourhood. Inside is the machinery. In "Dusty Buildings," when the machinery is at work the whole house is filled with a cloud of powder dust, which settles over everything, and, issuing from the doors and windows, covers the outside of the buildings and ground in the vicinity with a thin layer of explosive dust. In "Non-Dusty Buildings" there is comparatively little dust, though there is in most machine houses enough to cover the interior with a considerable sprinkling, but not enough to cause any appreciable quantity to settle outside the buildings. In both classes of buildings there is always a considerable quantity of powder undergoing the process of manufacture. The layer of powder-dust is sufficient to transmit ignition from any point within the limits of the "dusty area" where it may originate to the bulk of the powder in the building. The powder-dust, then, is the chief cause of the danger, since the least spark, or other cause of fire, occurring within the "dusty area" will cause an explosion of the whole of the powder in the building. The distinction between dusty and non-dusty houses has been long recognised, but having regard to the precautions necessary to make electric light safe, the Author slightly re-arranged the classification according to the following definitions.

Dusty Houses are those in which the operation carried on produces such an amount of dust that the outside of the buildings and the ground in the neighbourhood may become covered with a layer of dust sufficient to communicate any fire occurring within the dusty region to the interior of the building. The following buildings at the Royal Gunpowder Factory are classed as dusty houses:—dusting houses; granulating houses; breaking-down houses; press houses.

The neighbourhood of a dusty house, namely, the whole area over which explosive dust may collect in sufficient quantity to be dangerous, has been called the "danger area." (See Home Office "Memorandum on Electric Lighting of Factories and Magazines for Explosives," December 31, 1891.) The boundary of this area is necessarily indefinite. It depends on the rate at which dust escapes from the building, the nature of the ground, the climate, and particularly on the length of the longest spell of dry weather which may be expected. At Waltham, the Author having consulted with the men of longest experience in the factory, fixed the boundary of the danger area at 50 yards from the nearest part of the building.

Non-dusty houses are those where there is never a sufficient amount of dust to cover the exterior of the building or the ground in the neighbourhood. The following buildings at the Royal Gunpowder Factory are classed as non-dusty houses:—incorporating mills; moulding houses; stoves; magazines.

I. Dusty Houses.

If it were possible to keep all the electrical apparatus outside the "danger area," it would render the light perfectly safe. But it is clearly impracticable to light the interior of the building by lamps 50 yards from the nearest part of it. It is, however, possible to keep much of the apparatus outside this area, and to protect that part inside it in such a manner as to render it extremely safe.

The appliances which must be inside the "danger area" are, obviously, the lamp and the leads to it. Nothing else should be allowed inside the "danger area." And further, it is not necessary to take even the lamps inside the building, for sufficient light can quite well be obtained from lights outside the windows. Before describing the precautions which must be taken to make electric light safe, a brief list of the possible sources of danger is given:—

Sparks at any point within the "danger area" arising from:—(1) A broken wire; (2) Connection between positive and negative leads; (3) The blowing of a fuse; (4) The action of a lightning protector; (5) The opening of a switch; (6) The breakage of a lamp; (7) Lightning flash.

Heat.—(1) Of the lamp itself; (2) At the lamp-holder; (3) At any defective joint; (4) In the leads; (5) Owing to leakage or partial connection between positive and negative leads; (6) Owing to leakage to earth.

In order to avoid these dangers, the following precautions should be taken.

Sparks.—(1) The wires must be protected from breakage. If there are trees near, the wires must be taken underground, or they will be liable to be broken by falling branches; (2) The leads must be kept apart and well insulated, or else enclosed in a dust-proof case; (3, 4, 5) Fuses, lightning protectors, and switches must not be admitted inside the danger area; (6) The lamp must be protected; (7) Lightning protectors must be placed close outside the danger area, to prevent lightning being carried to the building by the wires.

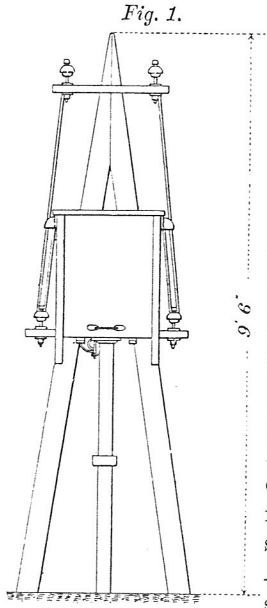
Heat.—(1) The lamp must be enclosed in an outer globe, of sufficient size to keep cool; (2) Suitable lamp-holders must be used, and they should be protected, like the lamp, from dust; (3) Joints in the wires should, if possible, be avoided; (4) The leads must be thoroughly protected by fuses; (5, 6) First-class insulation, suitable for the special conditions, should be used; great care must be taken in selecting the method of support for the wires.

With these conditions in view, the Author arranged the following system:—

The main leads, which are carried overhead, terminate at an

"A" post (*Fig. 1*), situated at least 50 yards from the building to be lighted, on which is fixed the switch-box, which contains all the fuses, switches, and lightning protectors used in connection with the building. The leads from this box, consisting of a pair of insulated wires to every lamp, are carried underground through iron pipes to the lamps. The lamps, which are all outside the buildings, are supported in front of the windows on lamp-posts of various forms, designed to suit the special circumstances of each case. The principle aimed at in the design of these is to provide a support for the lamp entirely independent of the building.

Fig. 1.

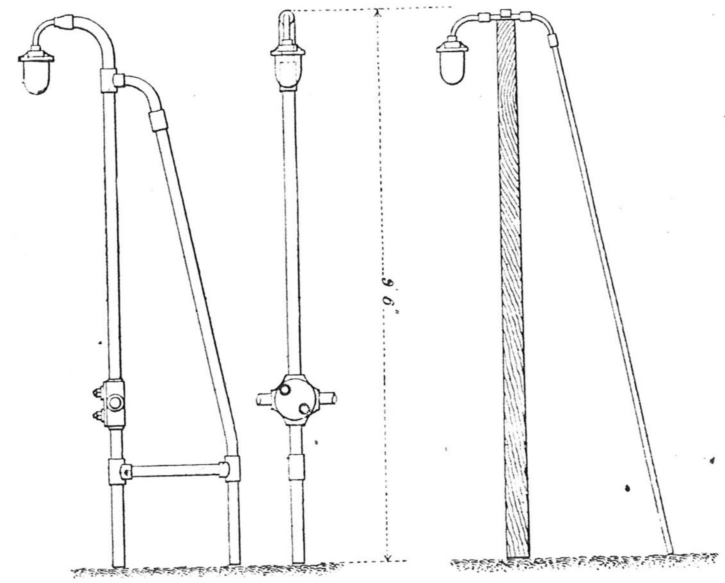


Figs. 2 show two forms of lamp-post. In all cases the wires are carried up to the lamp enclosed in an iron pipe, on the end of which the lamp is fixed. The pipe used is wrought-iron steam-pipe, with ordinary socket-joints, coated inside and out by Angus Smith's process. It starts at the switch-box, to which it is fastened by a flange, and runs underground to the building, where it branches, as required, to the various lamps. The size of the pipe is determined by the number of wires which it has to carry. The following Table shows the sizes which have been found most suitable for different numbers of lamps, each lamp having two wires.

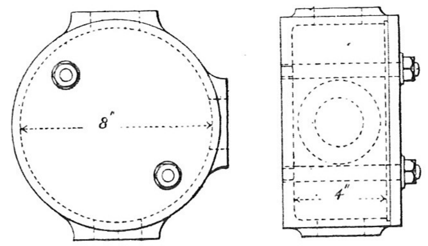
Lamps		Inches.
Lamps 1.	Inside diameter of pipe	1
,, 2.	,, ,, ...	$1\frac{1}{4}$
,, 3, 4.	,, ,, ...	$1\frac{1}{2}$
,, 5, 6.	,, ,, ...	$1\frac{3}{4}$
,, 7, 8.	,, ,, ...	2
,, 9, 10.	,, ,, ...	$2\frac{1}{4}$

Cast-iron "drawing-in boxes" (two patterns of which are shown in *Figs. 3* and *4*) are placed at all the angles of the larger pipes, and the same box is used wherever the branches leave the main pipe, except that a smaller box is sufficient at the junction of the branches leading to single lamps. Drawing-in boxes are not necessary at all the bends of these smallest branches; but where they are not used, running joints are provided on both sides of the bends. The insertion of these boxes at the bends and branching

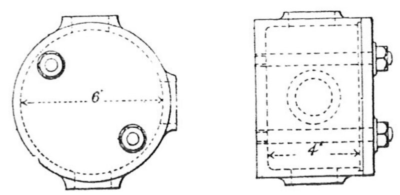
Figs. 2.



Figs. 3.



Figs. 4.



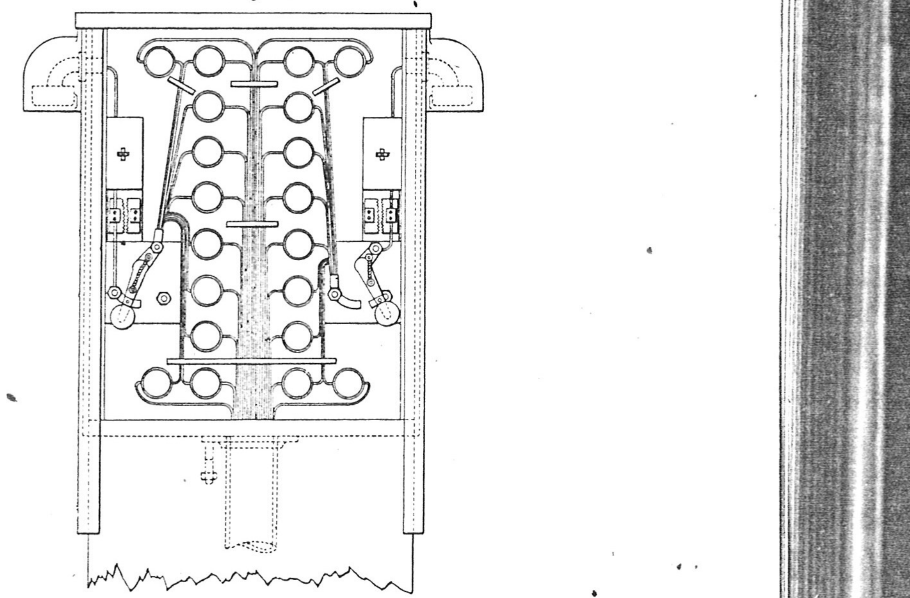
points greatly facilitates the drawing-in of the wires. No tees or elbows are allowed, on account of the sharp edges which are left inside these fittings. The sharp edges left on the insides of the pipes when they are cut are carefully removed before the pipes are fixed in their places. Those ends of the pipes which are screwed into the drawing-in boxes are belled out slightly so as not to catch the wires as they are drawn in. The joints are all made with red lead, including those round the lids of the drawing-in boxes.

The leads to the lamps are single No. 16 copper wires, insulated with vulcanised india-rubber and lead-covered, supplied by the India-rubber, Gutta-percha and Telegraphic Works Company, with a guaranteed insulation of 300 megohm miles. No joints are allowed in the leads; but as the wire is made in long lengths, this causes very little waste. The wires are drawn into the pipes, after they are completed, by means of soft spun-yarn ropes. The boxes, though small, give ample room to bend in the bight of the wires without kinks.

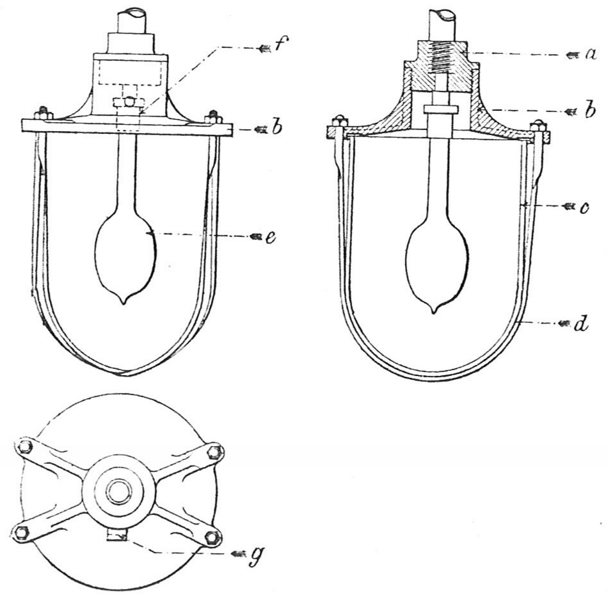
The switch-box is shown in *Fig. 5.* It is made of teak, of watertight construction, with either a wooden or a slate back on which the switches, &c., are fixed, and a sliding wooden front. The positive and negative leads enter the box through two Johnson and Phillips' fluid insulator "leading-in pipes," on opposite sides, and are joined to the two main fuses. The fuses are in turn connected through two lightning protectors to the two main switches. From the switches the leads divide and are joined to the two rows of single-lamp fuses. The lead-covered wires are connected to the other terminals of these fuses, and pass straight down into the iron pipe, the end of which is fixed to the bottom of the box. A wooden ring is fitted round the top end of the iron pipe to preserve the wires from getting cut, while they are being bent into position. The earth plates of the lightning protector are connected to the iron pipe.

The lamp (*Figs. 6*) is a modification of that invented by Colonel Watkin, in 1885. It consists of a cylindrical cast-iron piece *a*, tapped to screw on to the end of the iron pipe carrying the leads, and fitted with a nipple on to which the lamp-holder is screwed. The outside of the piece *a* is screwed, and fits into the cast-iron piece *b*, which forms a cover to the glass globe *c*, to which it is attached by the copper straps *d*. The joint between the glass and iron cover is made with an asbestos ring. A long-necked glow-lamp *e* is used, held in the holder *f*. The hole in the cover *b* is sufficiently large to allow the lamp *e* to pass easily through it. The globe is filled with water (with a small amount

Fig. 5.



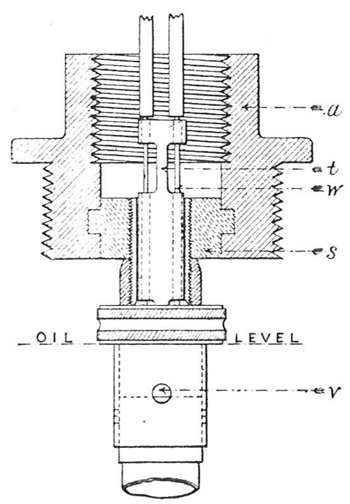
Figs. 6.



of glycerine to prevent its freezing), to within $\frac{3}{8}$ inch of the top. On the top of the water oil is poured up to the level of the filling-hole *g*, which is afterwards closed with a screw. A part of one side of the globe is silvered on the outside, and the rest of that half painted with white enamel.

The details of the method of attaching the lamp-holder, and leading in the wires, are shown in *Fig. 7*. The cast-iron piece *a* is recessed slightly near the bottom; and the nipple, which is tinned, is run in with sulphur *s*. Fitting loosely inside the nipple, and projecting above it, is the earthenware insulator *t*, which has two small holes formed in it, through which the bare wires *w* (the

Figs. 7.



insulation having been removed) are threaded. It rests at the bottom, on the insulator, in the lamp-holder. Two small holes, *v*, are drilled in the sides of the lamp-holder, level with the top of the lamp, to allow the oil to enter and circulate. The glow-lamp is kept cool, and dust is prevented from settling on it by the water. The oil greatly reduces evaporation, and prevents the condensation of water on the lamp-cap and interior of the holder. This point is of great importance, since, if the plaster of Paris in the lamp-cap gets wet, heat is rapidly generated, and the metal contacts corrode by electro-chemical action. The oil also serves as an insulator and cooling agent round the lamp-holder,

and prevents dust settling there. It likewise seals the asbestos joint. The object of the sulphur is to insulate the lamp-holder. The earthenware insulator is to preserve the insulation on the wires from the decaying action of the oil. The expansion of the water and oil with any air they may contain, and also the expansion of the air enclosed in the top of the lamp, cause the oil to rise slightly when the lamp is hot. This takes place without the oil coming in contact with the rubber insulation. The shape of the insulator is designed to prevent the creeping up of oil by capillary action.

The Author tried many sorts of oil, such as rosin oil, rape oil, heavy hydro-carbon oils, and paraffin wax; but failed to find any which entirely prevented evaporation of water at 140° Fahrenheit. A heavy hydro-carbon machinery-oil was found sufficiently good; and by the special construction of the lamp the condensation of any moisture which does evaporate through the oil cannot take place on the wires, contacts, or lamp-cap.

To replace a glow-lamp, all that is necessary is to unscrew the cap *b* off the plug *a*, and carefully lower the globe, full of water and oil. The lamp can then be changed, and the globe replaced. The joint round the top of the globe is never broken; and there is no risk of spilling oil and water.

The Author made a few experiments to find out what size of globe was necessary in order that no part of it should get too hot when the lamp it contained was run continuously. The maximum allowable temperature, recommended by H.M. Inspector of Explosives, in the "Memorandum on Electric Lighting of Factories and Magazines for Explosives," is 140° Fahrenheit. Four globes of different sizes (*Figs. 8* next page) were tested; the results were as follows:—

Globe A, containing 8 ounces of water, boiled in two hours.
„ B, containing 130 ounces, attained a maximum temperature of 156° Fahrenheit.
„ C, 200 ounces attained a maximum temperature of 132° Fahrenheit.
„ D, 192 ounces attained a maximum temperature of 131° Fahrenheit.

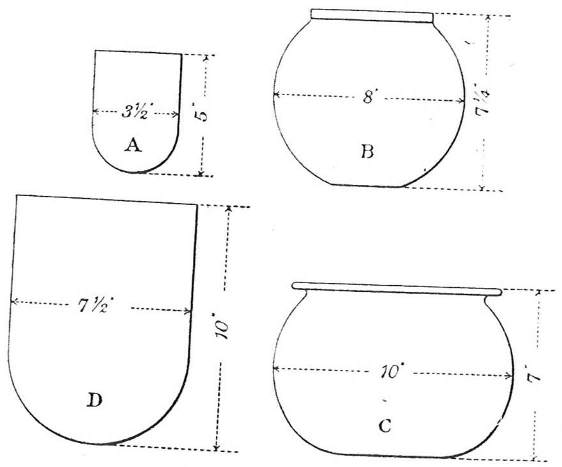
The glow-lamp in each case was absorbing 60 watts. The temperatures given are those of the surface layer of water in the globe; the temperature of the surrounding air being 60° Fahrenheit. Globe D is that adopted in the lamp above described.

A safety switching-off device is applied as follows: A weight is attached to the two main switches by a wire over a pulley so as to open the circuit. A pull-wire is run from the switches to some convenient point within reach from the building, by means of which the switches can be pulled on, raising the weight. In the event of any defect appearing in the lighting, the release of this wire will at once entirely disconnect the leads. If this wire, in course of time, breaks, the defect will show itself at once.

The Author believes that these arrangements fulfil all the conditions laid down. The following points may be specially noticed:—

The wires are entirely enclosed in dust-tight iron pipes the whole way from the switch-box to the lamps; that is, for the

Figs. 8.



whole distance traversed within the danger area. The iron pipe will not only keep out the dust, but tend, in case of any short circuit, to develop it rapidly, and so to blow the fuse.

There are no joints in any of the wires. The wires, being lead-covered, are well protected against wet and iron rust. The drawing in of the wires is easily and quickly accomplished.

The fuses are set to blow at four amperes, well within the safe carrying capacity of the wires, and far above the regular working current. Thus there is perfect protection, and yet the fuses will be quite cold in ordinary work. The main fuses are only intended to act if lightning short-circuited the dynamo. They are also very large for the normal current.

The lamp globe, already described, affords complete protection from the danger of the lamp itself.

II. Non-Dusty Houses.

In lighting non-dusty houses, many of the sources of danger before enumerated do not exist.

Sparks.—There is no danger from sparks if they are kept clear of the building.

Heat.—There is no danger from heat if it is kept clear of the building. The following precautions are therefore sufficient:—

Sparks.—The wires need only be protected from breakage, or short-circuiting, in the immediate vicinity of the building. The fuses, &c., need only be kept a few feet off the building. The lamp, which is necessarily very near the building, should be protected from breakage. A lightning protector should be fixed on the main leads at a little distance from the building.

Heat.—The same precautions, as in the case of dusty houses, are necessary, but only in the immediate vicinity of the building.

The following description gives the particulars of the method of lighting non-dusty houses:—The main leads which are carried overhead terminate, as before, at an "A" post, situated at any convenient point near the building, on which is fixed the switch-box, containing, in this case, only the two main switches, main fuses, and lightning protectors. The leads (insulated) from this box are carried overhead again on posts round the building, at about 6 feet from the outside wall. The same lamps are used, fixed, as before, on posts outside the building, in front of the windows. The connection between the leads and lamps is made as follows:—One of the supporting posts for the overhead leads is fixed opposite every lamp; each of these posts carries a cast-iron fuse-box, containing two single lamp fuses; from this box a 1-inch iron pipe runs overhead to the lamp, a distance of about 6 feet. Branch wires are attached to the overhead leads, and carried into the fuse-box, and connected to the fuses. From the fuses, two wires are carried in the iron pipe to the lamp. *Figs. 9* show this fuse-box, and *Fig. 10* shows the general arrangement (see next page). By this arrangement the leads are kept sufficiently far from the house to be safe, in case of their breaking, while the branches to the lamps, which necessarily approach the house more nearly, are completely enclosed, and also protected from mechanical injury. There is a fuse on every lamp, as before.

In conclusion, a few words may be said about some other classes of Danger Buildings. At Waltham Abbey there are, besides the powder factory, a gun-cotton factory, and a cordite factory. In

Figs. 9.

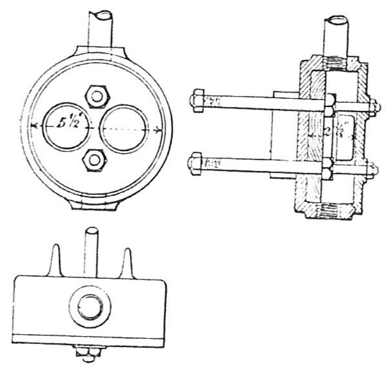
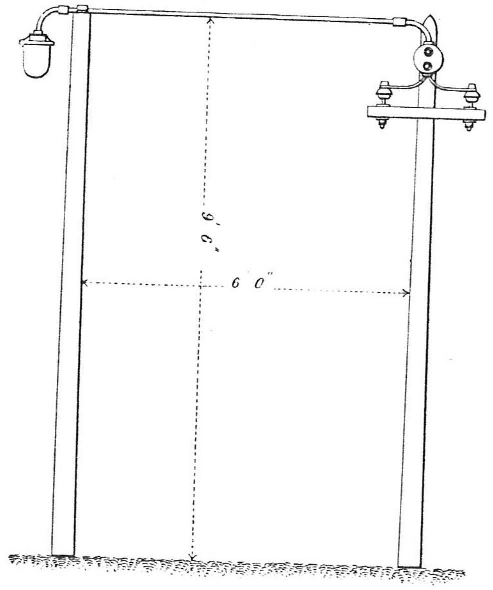


Fig. 10.



the gun-cotton factory, since there is no dust and hardly any gun-cotton in a sensitive state, no special precautions need be taken beyond those necessary in an ordinary house or factory, except

that the acid fumes should be specially guarded against. Such lamp-holders as Messrs. Woodhouse and Rawson's chemical holder may be used. In the cordite factory, as there is no dust, the lamps may be taken inside the houses, but should be protected by suitable globes. Also the leads should be entirely enclosed. The fuses, &c., should be outside the buildings. A modification of the first system described may be used, carrying the pipes inside the buildings. The dry gun-cotton buildings should be treated like dusty gunpowder-houses.

The illustrations have been reduced and engraved from the tracings which accompanied the Paper.
