ON THE ARTIFICIAL LIGHTING OF WORKSHOPS.

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In manufacturing districts the use of Artificial Light is of considerably greater importance for work of all descriptions than it can be elsewhere. Whether the work be fine or coarse, delicate or bold, a better light is needed than for work which does not come under the head of manufacture. In Lancashire the staple industries of engineering, machine-making, spinning, weaving, bleaching, and dyeing, are mainly established in certain centres; and with them is invariably associated in the surrounding district the great coal industry. Although Lancashire coal has a number of excellent qualities, yet it is one that makes the most smoke of any. A large portion of the manufacturing industries, great and small, date from a number of years back, when smoke-consuming and smoke-preventing apparatus had not yet been devised; and many of the factories are working at the present day under pretty much the same conditions as when they started. Hence the atmosphere in all manufacturing towns in Lancashire is heavily charged with unconsumed carbon, producing an excess of cloud and fog, which, while inducing an excess of rain, acts also as a screen against the rays of the sun, and thus does a double injury to the neighbouring agriculturist, the producer of the country's native wealth. A circle of thirty miles radius around Manchester is said to include a larger population than an equal circle around any other place in the world; and within this circle, about twelve miles north-west of Manchester, lies Bolton, the town with which the author is best acquainted, where all winds, except the west and north-west, bring the surcharged atmosphere from other manufacturing districts, producing at any season of the year, if the wind happens to be slight, a sky ranging from dull lead to dark brown. For four years in succession it has occurred at the writer's works, that on the 21st of June, the longest day, the gas in every room, amounting to nearly 7,500 jets, has had to be lighted by eleven o'clock in the morning, and has remained lighted until work ceased; and this has occurred also in other towns, and in weather that ought to have secured abundant sunshine. To such an extent does gloom prevail that in clear weather the effect of bright sunlight becomes even distressing to the eye-sight, simply from the rarity of the contrast.

Requirements for a well-lighted Workshop.—Firstly, the light, if artificial, should be sufficiently intense to give the power of clear and natural sight over any portion of the work. For enabling the work to be performed with ease, the light should evidently be arranged to produce as nearly as can be the effect of natural sunlight. The light of the sun is diffused by the atmosphere; and unless its entrance is limited in extent, such shadows as it may produce are only natural shadows, so natural that the eye has no difficulty in following detail in any visible part. In this respect therefore artificial light should as far as practicable imitate the best natural conditions.

Secondly, the light should be so diffused as to avoid casting shadows, or placing any one portion of the work in too great relief, as compared with the general tone of the whole. If the work were being done in front of a window which faced the sun, a certain portion of it would receive an undue amount of light, and give a false idea alike of size and distance, owing to the contrast of the overlighted and underlighted parts. This might be a natural light, but would nevertheless be improper.

Thirdly, the light should be of such a character as to have no tendency to injure the sight by a blinding glare. This remark applies either to a good gas-flame or to the electric glow-lamp, from both of which the light is fairly well diffused; the rays being all comparatively weak are easily diverted and thus distributed. But the effect of having either a bright gas-flame or the still brighter coil of glowing wire before the eyes is exceedingly fatiguing and destructive to the sight, and in combination with the dust of workshops makes it a wonder that ocular diseases are not more common than they are.

Fourthly, the light should be of such a character as to leave the atmosphere free from noxious emanations. Any kind of natural or electric light will fulfil this condition. The artificial light that most infringes it is gas, which varies much from town to town, and even in the same town from time to time; but it is generally so impure as to be deleterious to health and comfort in the products of its combustion, which is always more or less incomplete.

Fifthly, the light should not unduly raise the temperature of the room in which it is employed. If on a hot day a gas burner has to be lit for every person in a crowded workshop, as has to be done in certain manufactories, the combustion of so much gas affects the temperature greatly, and thereby produces lassitude among the workpeople, together with various ailments which are almost in proportion to the amount of gas consumed.

Sixthly, the light should be simple, and capable of easy control. The whole arrangement should be so contrived that nothing but the simplest knowledge and experience are required for turning the light on and off. This implies of course both a central control and also various points of sub-central control.

Seventhly, the cost should be kept within such limits as will render the light practicable at the present day for those who have to make their livelihood by their special trade in open competition with the rest of the world.

Electric Lighting by Inverted Arc-Lamps.—Some years ago, while engaged in visiting and examining certain mills on the Continent, the writer was much struck with a mode of lighting which he then saw for the first time. This consisted in the use of electric arc-lamps of from 1,600 to 2,000 candle-power, suspended in a white enamelled reflector at a certain distance below the whitewashed ceiling of the mill. The first he saw was of 2,000 candle-power, and thoroughly lighted a large room of about 40 feet square with light sufficient to see to pick up a pin off the floor. The walls of the room, as well as the ceiling, were whitewashed. The light had a sort of bluish tinge, and looked like bright moonlight, but with much greater illumination and entirely without shadows. This appeared so striking that he made a few experiments at once, and found that it was possible to see into the interior of the machines and even underneath them in a way that up to then would have seemed incredible; and further that it was not possible to make a shadow of any description, even when holding a hat only two inches above the floor: all that could be seen in the centre of the covered part was a comparatively slight deepening of the shade. In other departments of the factory he found the same plan equally effective, and the diffusion of light so complete as to be astonishing.

Incandescent Glow-Lamps.—At that time the author's firm were engaged in replacing gas by incandescent glow-lamps on the Edison-Swan system in a large machining room at their own works, which is 345 feet long by 76 feet broad and only 12 feet high, containing 239 machines tended by 200 workpeople in the area of 26,220 square feet. The exigencies of trade had required that annexes should be constructed almost all round the building, thus further diminishing the amount of natural light that could gain admission. Along the whole of the centre of the shop, for a breadth of some 50 feet, gas was burning day and night; and in the close muggy weather of autumn and the fog-laden days of hot summer, the atmosphere of the room became most oppressive, in spite of the best ventilation by Blackman propellers; even at six o'clock in the morning, on entering the room, the smell was most objectionable. It was noticeable too that an undue proportion of the men suffered from diarrhœa, which was in fact a standard complaint, and furnished the constant explanation for absence from work. Although sometimes this was simply an excuse, there can be no doubt that the exhalations caused by the imperfect combustion of a gas not absolutely pure will suffice to explain the possibility of a large number of men being affected thereby.

The incandescent glow-lamps, each with its own switch, and covered with a wire guard, were attached to the gas brackets, which for this purpose were left just as they had been. Within a week of the application of these lamps, the importance of the third requirement, with regard to glare, was amply proved; for nearly every workman had devised a shade of one kind or another, some of white or brown paper, some opaque, and some translucent. No better device than this has been found; it does not look neat, being simply a make-shift; but it answers the purpose, costs nothing, and is applied in a moment. The results of the alteration were curious: the atmosphere was improved, the heat considerably diminished, diarrhœa as a general complaint ceased, and was at first succeeded by bronchitis, which however was found to be of a temporary nature, and disappeared as soon as the workpeople in that room had become acclimatized.

Nevertheless with the result of this lighting the author was not satisfied. The shop was as dark and gloomy as with the previous gas-lights. The number of lamps broken by accident and by carelessness was so great as to become a serious consideration, their price being out of proportion to their actual cost, and no allowance being made in regard to royalty in replacing broken lamps which had already paid royalty. The writer then made two further journeys to the Continent, in order again to examine the plan of the inverted arc-lamp; and on the first occasion returned more favourably impressed than before. The second journey was therefore made with the view of going more thoroughly into the details, and of concluding arrangements for conducting a trial of the plan in his firm's establishment. On this occasion he had the opportunity of examining a large weaving shed at Ruysbroek, near Brussels, on a dark winter night. The dynamo was driven from the main engine of the mill, and was a fine piece of work. Corridors lighted by incandescent lamps led thence to the vast weaving shed, which had the usual roof containing glass panels almost upright facing north, with a plastered ceiling sloping southwards from the top of each glazed panel, and lighted from an inverted arc-lamp in each bay between the pillars. The impression upon entering the doorway was that the large room was brilliantly lighted by the mid-day sun: no glare, no flames to be seen, but a golden light pervading the whole of the vast enclosure; the colour of the hair, complexion, and costumes of the workwomen perfectly distinct; under the looms not the slightest trace of shadow. In fact the result attained was an absolutely perfect ideal light for textile work. The bluish tinge of the arc light itself, when lighting direct, is more apparent than real, because it does not prevent the most delicate shades of colour from being appreciated. If however it is considered disagreeable or undesirable, it can be altered, as it was in this particular weaving factory, by mixing a trace of yellow with the ordinary white-wash; the ceiling is then still white, but the apparently bluish tinge is eliminated.

The result of this visit was the application of four inverted arc-lamps in the large low machining room at the writer's works. Over 50 tons of castings are daily taken in and out of this room; and there must be at least 300 tons of castings of various sizes and descriptions, in progress of treatment, stacked and piled in different places on the floor; there is therefore all the more necessity for good lighting in order to avoid accidents. The darkest portion of the shop was chosen, and the four arc-lamps were placed in approximately the best positions for lighting a certain area. The ceiling not being plastered, it was considered advisable to nail up to the joists light scantlings, which were afterwards white-washed. These lights have now been running almost day and night for about two years, and with unqualified success. The four arc-lamps have replaced twenty-six glow-lamps; but whereas each glow-lamp lighted up its own work only and a few inches around, the whole of the area lighted by the four inverted arc-lamps is bathed in a gentle temperate light, absolutely equal in all parts. This was encouraging, as an arrangement of this description involves a heavy expenditure; and it was therefore considered advisable to have further experience before going more largely into it. Moreover this plan of lighting would not always be applicable. If the ceiling were very low it would scarcely be practicable, because the arc-lamp must hang a certain distance below the ceiling and still leave head room. Also there are places where the amount of light required is so small that it would be injudicious to go to the expense of applying these lamps, which are capable of so much more duty. It was determined however to make an experiment on a practical scale at the author's works, and with this object to apply inverted arc-lamps for the lighting of a three-storey building with large attic floor above, the latter being used as an iron and wood pattern-room.

Fire Insurance.—With the object of avoiding any difficulty in the future it would seem advisable, before proceeding with the further development of the plan of inverted arc-lighting, to consult the insurance companies in each individual instance. The old style of insurance, where heavy risks were taken by one or two companies only, has now been altered, so that in large works such as those here considered, where the amount of insurance may be near £300,000, the risks are divided among a large number of different companies, who in their turn sub-insure their risks in other companies not primarily engaged. There is a tacit understanding between the companies that one surveyor may act for the whole of them in any one particular case, thus judiciously securing uniformity of action. But it unfortunately happened that the four lamps in question, which had been tried for some months at the works of the writer's firm, were lent by them, along with a dynamo and driving power, for the purpose of ascertaining how a certain cotton mill, which had the disadvantage that one corner of the bottom room was darkened by buildings outside, could be lighted so as to replace the missing daylight. The four lamps were placed in position and tested. The result was far beyond expectation. It was found that the cleanliness of the work, which is an essential requirement in cotton spinning, could be supervised to a degree hitherto unattainable by artificial light. The owners of the mill were then anxious to adopt this kind of lamp immediately; but they met with an absolute refusal from the insurance companies to allow any open arc-lamp to work in a cotton mill. This led to the question of its further use in the ironworks of the writer's firm, and at first a blank refusal was received, without any reason being given; but correspondence of some months resulted in permission being at length granted to continue its employment under certain rigid conditions. These indeed were reasonable as regards the conducting area of the wires, the voltage, safety fuses, and other necessary precautions.

In order to see whether there could be any valid objection to its use in cotton mills, the author made a fairly complete series of experiments. The danger in cotton mills is supposed to be that the finest fibres or filaments are liable in the process of spinning to escape in a certain proportion, under the action of the draught caused by the moving parts; and being of much the same specific gravity as the air, they are easily carried by upward draught. When they reach any ironwork, either columns, beams, shafting, or gas pipes, they have a tendency, owing to the latent electricity always developed in textile fabrics, to attach themselves radially to the electric or magnetic centre; and as the carding-room air in a cotton mill is always more or less charged with these floating filaments, the insurance companies feared the result of combustion by contact with the open arc would be that the fire would be conducted to a dangerous quarter by the loose filaments adhering to wires &c. This fear is found to be absolutely groundless. Repeated and extended experiments have in every case failed to show any indication of danger from such a cause. The fallacy of the insurance companies' objection is rendered apparent by the fact that at the present time they allow open gas-jets in all cotton mills. If there were any danger in an open arc-lamp, there would surely be more in open gas-jets, which of course are more numerous than arc-lamps would be. Furthermore the arc-lamps have to be lowered every eight hours of work for the purpose of changing the carbons. The gas-jets are turned off when not required, and lighted again when wanted; this may occur two or three times a day. But every time the electric lamp is lowered it is thoroughly well cleaned, which is especially easy, as it consists simply in wiping the wire and the inside of an enamelled reflector. To prove that the arc-lamps cannot convey fire by contact with the cotton fibre, the author has let fall in the inverted reflector quantities of what is termed cotton-fly, being the lightest and most inflammable part of cotton fibre; and as soon as the level of the arc was reached and the top fibres were ignited, the fire spread rapidly round the cone of the reflector and burnt downwards towards the bottom. When keeping the eye level with the top of the reflector, it was impossible to see anything escape over this level except the black tinder resulting from the combustion of the fibre or fly. With the true cotton itself, smouldering particles might be seen to the extent of from four to six inches above this level; but it was proved that these smouldering embers had no heat beyond that necessary to give them their colour, for they were not even capable of exploding gunpowder.

For the purpose of further elucidating the question of fire risk, the author visited a mill in Belgium, not far from Ghent, where very coarse numbers were spun, the cotton being of short fibre; and the amount of evaporation, as it is termed, of fly from the lower filaments was particularly great, the cotton used being of the poorest quality. Directly over the carding engines was an arc-lamp of more than 1,200 candle-power; and during four hours spent in watching and noting the effect of the lamp upon the fly, on not one single occasion was the slightest spark visible outside the reflector. Sometimes when the fly was unusually thick in the air, owing to a carding engine being brushed out, a slight corruscation could be perceived near the centre of the reflector, like the twinkling of a star; but this would only occur once now and then. Undoubtedly a certain amount of fly was consumed, because when the lamp was lowered for examination a residue was found in the bottom of the cone, composed of the very lightest tinder of cotton, but utterly uninflammable under any circumstances. In this country the insurance companies declined to countenance any experiments, on the ground that mill-owners had been satisfied up to that time with the ordinary gas-light and with their insurance regulations, and therefore they could see no good reason for a revolution of ideas. Furthermore the definite allegation was made that on two occasions fires had been caused in cotton mills abroad which were lighted with arc-lamps. Feeling the importance of ascertaining what amount of truth there was in this statement, the author wrote to the proprietor manager, and others interested in each instance. In the first it transpired that not a cotton mill but a cotton store had been burnt, which was lighted not by arc-lamps but by glow-lamps only; and the theory to account for the conflagration was that of spontaneous combustion, which is by no means rare when cotton is stored in bulk. In the second instance the lighting was not by the open arc-lamp inside an inverted conical reflector, but by an ordinary arc-lamp surrounded with a glass globe. There was an aperture in the bottom of the lamp; and owing to some disarrangement of the clockwork regulating the carbons, a portion of an incandescent carbon had been split off, and falling through the aperture upon a mass of cotton beneath had set it on fire. When cotton in a loose condition does get on fire, it is much like a train of gunpowder; and this mill, which was kept in a condition far from clean, being covered with a thickness of fly steeped in oil over the floor, walls, and ceiling, became so suddenly a mass of flame that the workpeople had considerable difficulty in making their exit from the burning building.

Arc-Lamp.—The complete absence of danger from the arc-lamp used by the author will be more thoroughly appreciated from a description of its construction. It consists of two carbons of different diameters, the upper or negative carbon being solid, and the lower or positive carbon being annular and rather larger in diameter. Their areas are 0·200 and 0·486 square inch respectively: which proportion ensures their both consuming at the same speed, thereby avoiding the necessity of any complicated clockwork arrangement to differentiate the speed of the feed. In this lamp indeed there is no clockwork, but the carbons are drawn together by a pulley, string, and counter-weight, their distance apart being regulated in the usual way by a magnetic brake. The pulley, weight, and brake are all contained in a cylindrical box attached to the underside of the cone of the reflector; and the only interruption to the light above is that occasioned by the thin arms forming the clip which holds the upper carbon. The crater carbon is here the lower one, in order that the larger number of rays produced may be thrown upwards. The cone reflector is 25 inches wide at the top and 7 inches at the bottom, the angle of the cone being 88 degrees. The interior surface is ordinary white enamel upon the sheet-iron exterior. The external appearance of the lamp is shown in Plate 59, and also the position the lamp occupies in relation to the white-washed ceiling; and in Plate 60 a portion of the detail is shown separately. Each lamp is balanced by a counter-weight over pulleys, Plate 59; and the counter-weight hangs conveniently alongside either a wall or a pillar, so that it may not be in the way of traffic. Thus it is easy to lower the lamp for the purpose of renewing spent carbons, which has to be done about every eight hours, and requires not more than one minute per lamp.

Practical Results of Working.—The plan of inverted arc-lighting has now been in use in some portions of the writer's works for twelve and thirteen hours a day during the last twelve months, and sometimes almost night and day; and the results of its working he has every reason to believe may be considered successful. The building, as already mentioned, consists of three storeys, each room 123 feet by 55 feet; the bottom room of all is surrounded to such an extent by other buildings that it was necessary to keep the gas burning the whole of the day. In this room the work consists of turning, fluting, polishing, and repairing what are known as fluted bottom-rollers for spinning machines. These rollers, illustrated in Plate 61, require to be finished with mathematical accuracy, and the majority of them have to be channelled or fluted to the closeness of from sixteen to nineteen flutes per inch, the shape of the flutes being of the greatest importance. In the room above are manufactured top rollers to work on the fluted rollers, Plate 62; these also have to be mathematically correct, and their surface finished to a high degree of accuracy. In the third room are manufactured what are known as flyers, represented in Plate 63, having one hollow leg, through which the cotton must pass down in a slightly twisted condition. Owing to the affinity of cotton fibre for metal affected electrically, however little, it is evident that any roughness of the interior surface of the hollow leg must be prejudicial to the working; and it is therefore necessary that the smoothness of finish should be unquestionable. The attic or roof room is used for the storage of patterns, as previously mentioned. In the bottom room there are 51 machines, consisting of lathes and fluting machines and others, and employing 60 workmen. The second room contains 164 machines, employing 139 workmen; and in the third room there are 69 machines and 112 workmen. The accompanying views of two of the rooms, Plates 64 and 65, show the position of the lamps that has been found to be most serviceable as the result of experiments. These views give an idea of the area lighted by each lamp, and also of the manner in which the reflected rays from one lamp cross and blend with the rays of the adjoining lamps. The only glow-lamps used are those in the attic or pattern store, most of which are portable for the purpose of finding patterns on the various shelves; and also, strange though it may seem, two glow-lamps in the bottom room, for the examination and repair of slightly defective flutes. The latter lamps had to be applied because the reflected light from the arc-lamps gives no shadow; and in order to perceive the minute defects in the flute it is necessary to have a light that will give a prolonged shadow, for the purpose of exaggerating what is to be seen. The writer quite thought it would be possible to accomplish the same object by the use of a reflector; but the prejudices of the workpeople were too strong.

When first this mode of lighting the rooms was set going, and the gas turned off at the mains, there was much grumbling of the workmen, who protested it was impossible to perform their work by the new light. This difficulty however had been foreseen, and they were informed that as the light had been put in at a large expense for their comfort and health, they must at least give it a fair trial. Within six weeks of starting its regular working, something occurred which prevented the requisite steam power from being furnished to the dynamo; and the gas had therefore to be turned on again, exactly as it had been in the former time. The result was a deputation to the manager on the part of the workmen to know what they were to do, as they could not see how to perform their work by gaslight; and on one or two occasions since then, when the light has failed through one cause or another, the workpeople have declined to

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work with the gas, stating that they preferred to wait until the electric light was on again, and that they could pull up the time lost.

Dynamo and Lamps.—The dynamo is of Belgian construction, and known as the four-pole dynamo. It runs at 600 revolutions per minute, and gives a voltage of 115. It is driven by a counter-shaft from the main engine driving the machinery in the building, and with 60 arc-lamps and 66 incandescent lamps it absorbs 70 horse-power. The lights are steady and free from flicker; if ever a lamp is seen to flicker, it may be certainly concluded that it has not been thoroughly cleaned, and that the carbon slides are sticking in the magnetic brake. Photographs are exhibited of each room at ten o'clock at night in the winter; they were taken of course from the reflected light itself, and the exposure was in each case rather less than ten minutes. Upon examination it will be seen that the detail is wonderfully distinct, even at the distance of 120 feet; this is particularly noticeable in the photograph of the bottom room. Attention must be called to the absence of shadows. It can be seen that there are no dark places on the floor, and that underneath the lathes and other machines, although directly below the reflected light, there is no such thing as a defined shadow.

Horwich Locomotive Works.—Four inverted arc-lamps were tried by Mr. John A. F. Aspinall in one of the Lancashire and Yorkshire Railway workshops at Horwich, where however, owing to the great height at which they had to be fixed, they were not successful. They have since been placed in the large drawing-offices, and the light for drawing purposes is as perfect a light as can be. Failing on account of the height of the workshop to arrive at a satisfactory result with the solely reflected light, Mr. Aspinall has succeeded in lighting the main machine-shop with ordinary open arc-lamps, each protruding through a white-washed disc formed of light boardings framed together. A curious combination is thereby produced of lighting by the reflected and the direct rays. It has not the whole of the advantages of the reflected light, because the eye has a tendency to glance upward towards the dazzling arcs, and shadows are projected. Nevertheless the writer is convinced that by this combination of reflection a gain has been achieved of at least 25 per cent. over the ordinary direct arc-lighting without reflection; and all concerned are satisfied with the result.

Cost.—The question of cost of electric lighting, which after all is of the greatest importance, is somewhat difficult; and the writer is hardly in a position at present to give data sufficient to be of much practical value. Having regard to the number of workpeople who could be served with the light, the cost is less than that of gas, and of course the light is stronger and more general: so that in respect of candle-power it would be considerably cheaper than gas. In the three-storey building at the author's works there were 502 gas-jets, each burning four cubic feet per hour. Gas costing 2*s.* 8*d.* per 1,000 cubic feet would therefore come to something like 5*s.* 4*d.* per hour for this consumption. In the 60 electric lamps the only consumption is that of the carbons, which are reckoned at one halfpenny per lamp per hour. This has subsequently been reduced considerably; but taking this basis the 60 lamps would together cost 2*s.* 6*d.* per hour for carbons. The 66 incandescent lamps which are included in the 70 horse-power absorbed by the dynamo would of course add to this cost, as they are only 1,000-hour lamps. The greatest cost after the original installation is depreciation and horse-power. Taking the whole into consideration, it is probable that the cost of electric lighting would be more than that of gas; but as the light is so much more satisfactory, it may prove an economy in most cases to adopt it. Thus in the present instance the total candle-power of the 500 gas-jets would be roughly 8,500; while the arc and incandescent lamps combined would have 73,000 candle-power, much of which however is of course useless except for the general effect of the light. [See page 431.]

Conclusion.—The light now described has proved in practice to fulfil the requirements enumerated at the beginning of this paper as the necessary qualifications of a good artificial light, and for any class of manufacture for which it is applicable. For bleach and dye works, where it is necessary to distinguish minute differences in shades of colour, it must be invaluable, permitting this delicate work to be carried on in the dull winter days, which is now difficult if not impossible. If the insurance companies can be persuaded that not only is there no danger from this light, but that it is perhaps safer than any other mode of lighting, there seems every possibility that the use of this arc-lamp will undergo a rapid development.

Discussion.

The President said one of the inverted arc-lamps described in the paper had been sent by the author for exhibition alight in an adjoining room; and by the kindness of Messrs. Siemens Brothers the temporary wiring and connections necessary for enabling it to be lit up had been fitted, in order that the members might have the opportunity of seeing it in action. A lamp taken to pieces was also shown, for examination of its construction; together with a collection of photographs of the shops lit by this means, and specimens of the flyers and fluted rollers manufactured in these shops, as represented in the illustrations accompanying the paper.

Mr. John A. F. Aspinall, Member of Council, considered the description given in the paper of the atmosphere of Bolton was by no means overdrawn. There was no doubt that it was a particularly smoky place, where it was most difficult to get daylight into buildings which consisted of several storeys, and in which the rooms were of considerable width. Fortunately for the locomotive works of the Lancashire and Yorkshire Railway at Horwich they were about six miles away from Bolton, so that they did get the sunlight sometimes, and had not to light up so early in the evening or to keep the light going so long during the day as had to be done in the author's works in Bolton. In Fig. 10, Plate 67, was shown a cross section of one of the bays of the fitting shop in the Horwich works, Plates 68 and 69.

The wooden reflector R fixed overhead was about 13 feet diameter, and about $23\frac{1}{2}$ feet above the level of the rails. In that shop it was absolutely essential to get the reflector put in the position shown, as no other place could be found in which it would not have been in the way of the belting or of some of the machines or of the crane which travelled up and down the shop, and of which the top of the jib was indicated at J. The lamps were arranged in three rows, as shown at L in the plan, Fig. 9, Plate 66, and at the height shown in Fig. 10. The arc was formed about $3\frac{1}{4}$ feet below the surface of the reflector. The area of the floor lighted by the lamps shown in Fig. 9 was about 151 square yards per lamp. The positive or crater carbon was the lower of the two, as shown in Fig. 11, and the rays of light were thrown upwards towards the reflector. He thoroughly agreed with what had been said in the paper about the perfect lighting which resulted from this system of reflection. It was not new, he was aware ; "the thieving ancients had stolen most of our modern ideas." Nevertheless he considered the author was to be thanked for drawing attention to the fact that this plan was so much in use in Belgium ; and it was after Mr. Dobson had spoken to him about it, and after he had himself seen the lamps, like the one now shown alight and illustrated in Plate 59, that he had tried an experiment to see what could be done with it at Horwich. That form of lamp however did not suit his workshop there; and he therefore simply used the ordinary lamps of the Brockie-Pell pattern which he had previously in use for lighting in the ordinary way, putting now the positive carbon below and the negative carbon above; and when the system was extended, special lamps were made to suit the workshop requirements. The result of this inverted position was that the positive carbon with its crater became a reflector. The positive carbon gave out about 85 per cent. of the light, the negative about 10 per cent., and the arc itself only about 5 per cent. ; so that as a matter of fact nearly the whole of the light got thrown upwards, and the lamp was burning so high above the eyes of the workmen that it really did not interfere at all with their work, even if they did glance upwards. It was no doubt due to the fact of the positive carbon giving such a large proportion of the light that it was not

(Mr. John A. F. Aspinall.)

considered necessary in street-lighting with arc-lamps to have a reflector above the lamp, the positive carbon being there the upper of the two. If the inverted form of lamp used in the workshop were placed much lower down in an ordinary room, then undoubtedly it would become somewhat inconvenient, unless there were a bottom reflector underneath it, such as was shown in Plate 59. The bottom reflector was open to the objection in certain manufacturing places that it was naturally a great collector of dirt, and required a good deal of cleaning. It was worth noticing in connection with the inverted position of the carbons, that the minute particles of carbon which dropped off the negative or upper carbon fell into the crater of the positive, producing at the moment a little flicker of the light, which was rather disagreeable if there was only a single lamp giving the light; but it did not appear to have the slightest effect on the light, where there were a large number of lamps in the room.

The Honourable Charles A. Parsons believed that about fifteen years ago a somewhat similar lamp had been devised in Paris by Messrs. Sautter Lemonnier and Co.; but at that time the carbons were imperfect, the regulation of the lamp was not sufficiently accurate, and the result was not at all satisfactory. With the present improved carbons and automatic lamps the light was absolutely steady, and the effect of the illumination very good indeed. For workshops the light was admirable; it so closely resembled daylight that workmen could see the smallest work with perfect clearness, much more so than with gaslight or the ordinary incandescent lamp. It seemed possible that this system of illumination might be extended to further uses than those of the workshop, such as large halls, libraries, museums, and places of public resort, where it might be applied on a large scale and might well replace glow-lamps and other modes of lighting. This form of illumination he thought was much more economical than the ordinary incandescent lamp, in respect both of total cost per total candle-power usefully distributed over the area to be lighted, and also of first cost and of the amount of electrical energy required; and in his opinion it would no doubt become in the near future a largely recognized and generally useful and extended system of using the arc-lamp.

The President asked whether Mr. Parsons used this mode of lighting in his own works at Gateshead; and if so, what was the power of the lamps employed.

Mr. Parsons replied that his firm had a certain number of these inverted arc-lamps in use, and a certain number of ordinary arc-lamps as well; and they intended to adopt the inverted lamps generally throughout their works. The inverted arc-lamps were pre-eminently suited for low workshops, where arc-lamps of the ordinary kind could not be used. The inverted lamps could be placed about 15 feet apart, and the light was then practically uniform all over the floor. Some of the lamps were of ten ampères and some of fifteen. There was apparently a very small loss of light from the whitened surfaces of the reflectors; and the high initial light-giving efficiency of the arc rendered such loss of small moment. Some fourteen years ago, the late Sir William Siemens had tested the distance at which the direct rays of an arc light were visible, and then the distance at which a white screen illuminated by the same arc was equally visible; and he had been surprised to find that in many states of the atmosphere the screen was the most clearly seen of the two.

Mr. James Platt, Member of Council, had had an opportunity of seeing the lamps at Horwich, and had been much pleased with the effect, in the drawing office particularly, which was a room 16 to 18 feet high with a flat ceiling. The light was perfect for the draughtsmen; and in the large shops it was exceedingly good. He was so much pleased with it that it was about to be adopted in his own works.

Mr. Henry J. Rogers suggested that the difficulty with the insurance companies might be got over by having a clear glass dome over the conical reflector described in the paper.

Mr. E. C. DE SEGUNDO thought any system of lighting by reflection must necessarily be more expensive than lighting by direct rays. The cost, as rightly remarked by the author (page 409), was after all the chief thing to be dealt with; but a calculation of the relative cost naturally involved a determination of the relative illuminating efficiency, and the latter might be much a matter of opinion. According to the figures given in the paper, it appeared that, with gas costing 2*s.* 8*d.* per 1,000 cubic feet, the cost of gas consumed by the 502 gas-jets at the author's works had been about 5*s.* 4*d.* an hour. The cost of carbons for the 60 arc-lamps was reckoned to be 2*s.* 6*d.* per hour. Judging from the statement that 70 horse-power was absorbed in supplying 66 incandescent and 60 arc-lamps, he calculated that the former must be 60-watt lamps and the latter 15-ampère lamps. If then to the halfcrown per hour for the carbons there was added the cost of the horse-power, it appeared to him that the total cost would amount to considerably more than it ought for the amount of light produced. The candle-power of the 500 gas-jets was said to be roughly 8,500; and it was also stated that each gas-jet burnt four cubic feet per hour. It must be a remarkably good gas-jet he thought which would give seventeen candle-power for four cubic feet of gas per hour. The arc and incandescent lamps combined were said to have 73,000 candle-power; but he feared a good deal that was said about candle-power of arc-lamps was without sufficient warrant. One thousand candle-power was often spoken of as being obtained from an arc-lamp consuming from 500 to 750 watts. In testing arc-lamps which were said to yield 1,000 candle-power, he had found in one instance only 300 candle-power recorded by the photometer at an angle of about 30° with the horizontal. On this system of reflected light it seemed hardly right to speak of the candle-power of the arc-lamp, because the overhead reflector was really absorbing a great part of the light. The amount of light reflected from a white-washed ceiling would of course become less and less as the white-wash lost its original whiteness; and even at its best a white-washed ceiling could hardly be very efficient as a reflector. If it were necessary, as described in the paper, to guard against the extension of any combustion of the cotton fly, why should not the reflector surrounding the arc-lamp be made of some translucent material, so as to allow some of the rays to come directly down through it? Such a light he thought would not necessarily throw any distinct shadows; and it seemed to him that the opaque conical reflector surrounding the arc light described in the paper would be more conducive to a general shadow than an opalescent shade. It would seem strange if the uniform lighting of a workshop could not be effected except with so large an amount of light. It would be difficult at first sight to form an opinion as to how much of the light was lost by being used in that way; but he thought it must be considerable, because in page 401 of the paper it was stated that four inverted arc-lamps had replaced twenty-six glow-lamps. Those arc-lamps would apparently be 750-watt lamps, that is roughly lamps consuming 15 ampères at 50 volts. Therefore the four arc-lamps must together consume about 3,000 watts. Assuming the twenty-six glow-lamps to have been 60-watt lamps, the electrical energy required for them would have been about 1,600 watts. Therefore a considerably greater lighting effect should be expected from 3,000 watts when used in the arc-lamps than from 1,600 watts used in the incandescent lamps. In arc-lamps one candle-power at least ought to be got for 1·7 watt; and therefore arc-lamps consuming 3,000 watts of energy should amount to about 1,800 candle-power, as against $26 \times 16 = 416$ candle-power for the incandescent lamps. In page 401 it was said that, whereas each glow-lamp lighted up its own work only and a few inches around, the whole of the area lighted by the four inverted arc-lamps was bathed in a gentle temperate light, absolutely equal in all parts. From such an expression as a gentle temperate light it was evident that the diffusion of the light must be very complete, and the illuminating effect pleasant; but it must be remembered that the intensity of light had been increased $1{,}800 \div 416$, or about $4\frac{1}{2}$ times, and the electrical energy consumed had been increased about twofold. If some reliable photometric measurement could be obtained under both conditions, it might be possible to judge of the relative efficiency; but he doubted whether the energy of 3,000 watts which was being used in

(Mr. E. C. de Segundo.)
the arc-lamps was being used to the best advantage. With some other kind of reflector, of opalescent or translucent material, instead of enamelled iron, the same effect he considered ought to be produced with much less expenditure of energy.

The attitude of fire insurance companies to electric lighting was at present often anomalous. It seemed absurd to allow naked gas-lights in a cotton mill, and to refuse to allow arc-lamps.

In page 403 it was stated that the arc-lamps had to be lowered every eight hours of work for the purpose of changing the carbons. But at the present time arc-lamps were made which were working satisfactorily for at least 32 hours; and one was now being made to work 64 hours, while it was hoped eventually to increase the duration to 128 hours. It was needless to say how cordially he agreed that electric light was superior to gas for workshops; but it seemed a pity that the particulars of cost which were so essential were not yet forthcoming with more accuracy. If a separate plant were erected for the generation of the electrical energy required for 66 incandescent lamps and 60 arc-lamps, the electric lighting by these lamps could undoubtedly be produced at a lower cost than the equivalent lighting by gas, taking all circumstances into account; and therefore he could not understand why the author thought it probable (page 409) that the cost of electric lighting would be more than that of gas; for he had his own mill engine from which the driving power was taken, so that this power was obtained in the cheapest possible way next to water power. Hence the cost of the electrical energy in this instance should be considerably less than the author appeared to think. If some better plan could be devised, whereby the light, which was now absorbed unnecessarily and he thought wastefully, could be diffused, it was probable that half-unit arcs might be employed, requiring each only 500 watts instead of 750. In 60 arc-lamps that would make a difference of something like 20 horse-power. In the incandescent lamps he thought not much improvement could be made; but now that the first cost of these lamps was becoming reasonable, it occurred to him to suggest that it might be found economical to use a larger number of incandescent lamps working at a much higher efficiency, namely at an efficiency approaching that of the arc-lamp, that is to say at about two watts per candle-power; and then to replace each lamp when it became too dim. An incandescent lamp he thought might be used at an efficiency of two watts per candle-power, and would then last about one-third of its present reputed life of 1,000 hours; that is, it might be calculated to last about 300 hours. If the first cost of incandescent lamps were to come down to one shilling each—and he did not see why it should not, judging from their intrinsic value and from the numerous improvements made for facilitating their manufacture—he thought it probable that for lighting workshops it might be found economical to use incandescent lamps of this higher illuminating power, properly shaded in the manner in which the author mentioned (page 400) that he had found the workmen had shaded their glow-lamps. Shades of various degrees of opalescence could be obtained for incandescent lamps; and instead of having naked arc-lamps shielded by a reflector which necessarily absorbed so much light, it might be more economical to apply incandescent lamps direct, and change them when their brightness waned.

Mr. Dobson asked if Mr. Segundo had seen the arc-lamp which was shown in action in the adjoining room.

Mr. Segundo replied he had not done so yet.

Mr. Henry Human, being surveyor to an insurance company, would refer to that portion of the paper which treated of the fire risk. In the case of engineering works, or works where nothing of an inflammable nature was dealt with, there could be no objection to the arc-light; but in cotton mills a different condition of things had to be met. In point of inflammability, cotton was well known to be second only to gunpowder; and it was necessary therefore to be most careful what light was introduced into such places. The impression was conveyed in the paper (page 403) that the chief danger of arc-lighting in cotton mills was the burning of naked arc-lights in the presence of cotton fly. This theory was at once refuted by the fact that naked gas-lights had been used for years past in cotton mills

(Mr. Henry Human.)

without any apparent danger so far as the fly was concerned. But he would point out that, if gas-lights were liable to drop particles of incandescent matter, then assuredly they never would have been used in cotton mills, except under extraordinary precautions; and it was the liability of particles of incandescent carbon escaping from the arc-lamp that rendered its presence in cotton mills so exceedingly dangerous. Though he was not acquainted personally with either of the two cases referred to in the paper (page 405), in which fire had been attributed to arc-lighting, it was clear from what was there stated that the first did not apply, for the reason that there was no arc-lamp in that building. The second case however did apply, and was clear evidence of the danger attending the use of ordinary arc-lamps in cotton mills. Some further explanation seemed desirable as to how it was that there came to be an aperture in the bottom of the lamp in that instance: whether it was due to defective construction of the lamp itself, or to some negligence on the part of the trimmer. There was yet another case, which touched more particularly upon this form of inverted arc-lighting. It was a cotton mill at Luneville in France, which was destroyed by fire in December 1892, as the result of an accident with a Pilsen inverted arc-lamp, similar in external appearance to an ordinary arc-lamp, but with the poles reversed, the crater carbon being below. Attached to the lamp was an inverted conical reflector suspended by chains, and made detachable to admit of trimming. In order to trim, it was necessary to detach only one chain, thus tilting the cone and thereby giving sufficient space to get at the carbons. On the occasion of the accident, the lamp had been re-trimmed at one o'clock in the morning; and it was assumed either that the trimmer had neglected to re-fasten the attachment properly, or else that a part of the lamp had given way. At all events, half an hour afterwards one of the suspending chains fell, tilting the cone violently on one side, and causing an incandescent particle of the carbon to fall upon the cotton in a spinning mule beneath. The place was immediately in flames, the fire spreading with fearful rapidity, and resulting in the destruction of the mill. The falling of a suspended lamp was by no means an uncommon occurrence, particularly of a heavy lamp with a correspondingly heavy counter-weight upon the suspending gear. Moreover, however well a lamp might be designed and constructed, it was still largely dependent upon what was after all a more or less unknown quantity, namely the human factor; for it was the trimmer rather than the lamp that was most to be feared. Should one of these lamps fall, in either the spinning or the carding room of a cotton mill, the result would probably be as disastrous as the tilting of the cone in the Luneville mill. The fire offices had now been twice bitten; and on the principle of "once bitten, twice shy," they were more than twice shy of admitting arc-lamps into cotton mills.

Mr. James M. Small drew attention to a point not noticed in the paper, namely the necessity in large factories of providing for the prevention of panic in the case of a breakdown of the dynamo. His partner and himself having lately been consulted as to lighting a large jute factory in Scotland had there arranged for what was called a "police" circuit. The regular lighting of the mill itself was carried out by about 700 incandescent lamps, which were run directly from the dynamo; but in addition there was this independent police circuit, comprising 70 lamps, which could be supplied either by accumulator batteries, or, as was actually done in this instance, from the town circuit, that is, from the central station in the town itself. During working hours the mill was lit by the 700 lamps driven from the small dynamo; but an arrangement was provided whereby, if the dynamo were to break down, the police circuit would be instantaneously switched in. This prevented any chance of panic, such as might be likely to occur in a textile manufactory where there were a large number of women engaged. Not only was it useful in the case of a breakdown, but it could also be employed in the early morning for getting things ready and allowing the workpeople to come in; and again in the evening for allowing them to go out, instead of having to keep the dynamo running, which would probably mean keeping the mill engine running. For the purpose of switching the police circuit in, the simple arrangement shown in Figs. 14 to 17, Plate 70, was employed. It consisted of a

(Mr. James M. Small.)

cast-iron magnet M with a coil L round it. The armature A was pivoted on a centre C; and the position shown in Figs. 14 and 15 was that during the daytime when the dynamo was not running, the armature being then held up pretty near to the face of the magnet M by a small catch H. The coil of the magnet was connected with the mill dynamo through the terminals TT. As soon as the lighting of the mill was started, the armature was attracted by the magnet and held up by it so long as the mill dynamo was running; and the little catch H dropped down into the vertical position shown by the dotted lines in Fig. 15. If the mill dynamo happened to break down, the result was that the armature, being no longer supported by the magnet, instantly fell into the position shown in Fig. 16, and the knife K entered into the switch S, Fig. 17, which was connected with the police circuit PP. When the dynamo was got to work again, the armature was turned up again to the magnet by hand, disconnecting the police circuit, and tripping up as it rose the catch H. This simple arrangement had now been working for a short time, and he had received a report a few days ago which stated that it acted admirably. Some such plan he thought might well be introduced in all cases of mill lighting.

Mr. William H. White, C.B., Member of Council, had visited the works of Messrs. Sautter Lemonnier and Co. in Paris on the occasion of the Exhibition there in 1878, and had seen them lighted upon a general principle resembling that described in the present paper. The building was one which it would be difficult to light satisfactorily; there were a number of pillars supporting an upper floor, and there was a good deal of machinery to be kept working. The result however was perfect, so far as diffusion of light and absence of shadow were concerned; and it had often been a surprise to him that the plan had not been more largely adopted in machine shops in this country; he was therefore all the more glad to learn that Mr. Dobson had now worked it out so successfully as he evidently had done. Criticism as to cost, or as to the best electrical arrangements, was in his own opinion subordinate to the main fact that this mode of lighting, applied in the manner described in the paper, was found to be eminently satisfactory for the purpose for which it was intended. As bearing upon this point, he well remembered that some years ago, after a considerable amount of experience in the north of England, and with the assistance of Mr. Parsons, he had arranged for portable electric lighting appliances to be used during the construction of warships, in the interior of which there was so large an amount of work to be done in confined spaces. But on subsequently coming to consider the application of the same plan in the Government dockyards, he was met with a statement that the cost of the candles and gas which had been burnt during the construction of a battle-ship was very moderate when compared with the outlay necessary to procure the proposed plant for electric lighting, and its subsequent cost for maintenance and depreciation. He had not attempted however to argue the matter then further than to say that he knew as a solid fact that the larger expense in electric lighting was more than recouped by the results which were obtained in the work done; and no doubt the author would say the same with regard to his mode of lighting his own works.

Mr. A. P. Trotter thought one reason, which might account for the fact that so little attention had been paid to this mode of lighting, was that people did not believe white-wash to be as good a reflector as it really was. If a sheet of white paper were held behind a candle, a reflected beam could not be cast by it on the wall, as could be done by a looking-glass; and it was immediately inferred that white-wash was not to be compared with a looking-glass for reflecting light. As a matter of fact, this was quite a mistake. The looking-glass would reflect in one direction only, whereas the white paper reflected in all directions. The reflecting power of white paper could not easily be measured without going into rather complicated calculations, because the light varied with the cosine of the angle of incidence. Such measurements had been made by himself, and had been repeated with much greater accuracy by Dr. W. E. Sumpner, who had made experiments on the reflecting powers of many different substances, and had found that about 82 per cent. of the incident light was reflected from white blotting paper. Such a

(Mr. A. P. Trotter.)

percentage was in fact higher than could be got through an opal or ground-glass globe, which often absorbed more than 20 per cent. As a matter of fact a dirty glass, of an ordinary glass globe or lantern, would frequently absorb 15 per cent.; and then there were shadows, in which perhaps more than 95 per cent. of the light was lost. With the mode of lighting described in the paper there were no shadows; and if the white-wash was clean there was a reflection of about 80 per cent. of the light. Photometrically this would compare favourably with any other mode of lighting; and it seemed, in cases where it could be used, to be the best plan of applying arc-lamps. The only question—one which might have to be considered in railway stations, for example—was the cost of white-washing.

The value of such a reflector depended entirely upon the solid angle which it subtended at the arc of light. The reflector shown in Fig. 10, Plate 67, appeared to subtend an angle of something like 120° or more; and it was essential that the reflector should be large, or else nearer to the lamp, so as to subtend not less than that angle. The amount of light lost by the conical hood would be but little; for it would be seen that with the inverted arc, as shown in Fig. 11, hardly any direct light from the carbons went away below the horizon. It was therefore no use putting a white-washed reflector above an ordinary arc-lamp in which the positive carbon was above the negative, because in that case hardly any light went above the horizon. In the same way an opalescent hood beneath the inverted arc-lamp would let scarcely any light worth speaking of pass down through it.

Professor Alexander B. W. Kennedy, Vice-President, had been much interested in reading the paper when it was originally printed for the previous meeting, and had gladly taken advantage of Mr. Dobson's experience as therein set forth, and also of what he had heard from Mr. Aspinall, to recommend the use of this plan of lighting in one or two places where he thought it would be found to be exactly what was wanted. He had been so much pleased with the way in which it worked out, that he had been thinking with Mr.

Trotter that it seemed a wonder it was not used a great deal more, seeing that it was available for so many purposes. For instance he had lately had to consider the lighting of rooms in the art school of a town in the north, where for years past there had been assembled every evening during the winter some seventy men and boys working at drawing, with sixty-eight gas-burners in one room—a gas-burner for each drawing-board. The atmosphere of the room when so occupied must have been appalling; and the dirt in the room was certainly terrible, as might be expected after the use for some years of sixty-eight gas-burners not very carefully regulated. The whole room could be lit perfectly, after it was white-washed, by a couple of inverted arc-lamps; and the advantage of such a plan he believed would be great in respect of health. He had also met with several other cases where the plan might advantageously be employed. What the author really seemed to want was to get light from as many points as possible; and he carried out that object by using for the source of light, not the small arc itself, but a huge reflector of slightly rough material, which practically gave off light from an enormous number of points, as had been explained by Mr. Trotter. Those who had not yet seen the reflected light which was on view ought not to leave the building without visiting the room in which it was exhibited. The absence of shadows underneath the hood was really remarkable, and could scarcely be believed without actually seeing it with their own eyes. The whole floor was lit up by the light coming, not from the place where the arc-lamp was, but from the entire surface of the ceiling; and the natural consequence was that the floor underneath the conical hood was lit up from portions of the ceiling that were beyond the angle of the cone.

On one point he thought the author had been slightly misled. It seemed to have been forgotten in the paper that even in these modern times arc-lamp makers had adopted one of the most antiquated and objectionable expressions in the phraseology of mechanical engineering. They had adopted a "nominal" candle-power, which bore inversely somewhat the same ratio to real (mean spherical) candle-power that nominal horse-power bore to real horse-power: that is to say, instead of getting really double or treble or quadruple

(Professor Alex. B. W. Kennedy.)

the candle-power that they were supposed to get, they really got only half or a third or even less of the nominal light. Where therefore lights of 1,600 to 2,000 candle-power were mentioned in the paper, it was important to bear in mind that these were merely nominal quantities, and instead of being multiplied must be divided by two or three or four in order to get the actual mean candle-power. The question dealt with in the paper however was of course not really candle-power at all; it was the question of a thoroughly good and satisfactory method of illumination, to be used under singularly difficult circumstances; and the probability was that the applications of this method of illumination would be much more numerous in the future than had hitherto been thought of.

The President said that, without professing to know much about electricity, he certainly thought the method of lighting described in the paper was not only good, but must also be economical. At the Royal Arsenal, in one of the factories in which small work was done, and which was lit up by arc-lamps and glow-lamps, the roof was a saw-tooth roof, like that of a weaving shed (page 400); and it was difficult on that account to get direct reflection from the ceiling. The point which always struck him when visiting that part of the Arsenal in the evening was, what an enormous stream of light must be thrown out upon the sky; for with the direct light of the arc-lamps a large proportion went out through the glass roof, and was wasted outside; whereas, if reflectors were applied, the bulk of that light would be thrown back into the building and become usefully employed. With the direct-acting arc-lamps, even when shielded by ground-glass globes, it was impossible to do without glow-lamps at the machines engaged upon small work, because of the strong shadows thrown from the arc-lamps. On an inspection of the lamp exhibited in the adjoining room, he was much astonished to find that there was no shadow at all; he could read from a book with the back of the book to the light and his own face towards the light, quite as well as if the face of the book was turned towards the source of light. Such a result certainly surprised him greatly, and induced him to think that for workshop purposes this method of lighting, in which there was no shadow whatever, would be highly advantageous, however costly it might be, because the small glow-lamps, which otherwise had to be employed for supplementing the general lighting by arc-lamps, were expensive in every way, and were not easily manœuvred about when small work had to be done.

Mr. Dobson said the paper was not intended, and made no pretension, to be a scientific treatise. His experience had been obtained in a rough and ready way, when making experiments for his own firm; and he was himself so satisfied with the results of those experiments, that he thought it perhaps his duty, and a pleasant duty it was, to give the benefit of his experience, and so possibly to shorten the labours of others in the same direction. The most difficult point connected with the subject he thought was the question of reflection. It had been explained clearly by Mr. Trotter (page 421) why a white-washed ceiling was such an admirable reflector; it was both a reflector and a refractor, and in fact it had every action upon the light that it ought to have. If therefore employers would only spend a small sum a year in white-washing the ceilings of their workshops, the expense would be saved in gas or electricity over and over again. Experiments with opalescent and ground-glass shades had been made on many occasions, and had invariably failed. The thinnest clearest glass over one of the conical reflectors was sufficient to dim the light so greatly as to frustrate the whole plan. First of all, glass itself intercepted a great deal more light than he believed any scientific investigation had yet given it credit for. In the second place, when it had been on five minutes in the workshop it had already acquired a film of dust, which, added to the effect of the glass itself, was sufficient to reduce seriously the value of the light; and that reduction went on steadily, until it was necessary to take the lamp down and clean it, because it did not give its light. As pointed out by Mr. Aspinall (page 412), in a shop where there was dust of iron and steel constantly flying about in the atmosphere there must be a deposit of it in any place where it could fall; and it fell into the lamp, which in due course required cleaning.

2 P 2

(Mr. Dobson.)

In connection with the fact that the arc-lamp had to be lowered every eight hours for the purpose of renewing the carbons, it had been mentioned (page 416) that there were lamps which would last 16, 32, and 64 hours, and that one was contemplated which would last 128 hours. The longer duration was obtained by the use of parallel carbons, so that the arc could change from one set to the other, and regulate itself in that way. Having tried the plan, he had found the result to be that every time the arc changed from one set of carbons to the other there was a distinct flicker, whilst the object aimed at with these inverted arc-lamps was to make them as steady as possible. The lamp now exhibited alight in the room adjoining was not absolutely steady, the reason being that the carbon was not absolutely pure; but carbons were already much better than they ever were before. Whenever the carbons became perfect, the lamp would burn without the least flicker. The reason the lamp had to be lowered every eight hours, in addition to the fact that it was a lamp in which only the two single carbons were burnt, was that it was necessary to make certain the lamp was clean, so as to ensure getting the full value of the reflecting power of the reflector, and all the duty out of the lamp that was possible, provided the ceiling was kept properly white-washed.

The question of candle-power had troubled him a good deal, because he was not responsible for the expression, and confessed he hardly knew what it meant. It was therefore a great relief to hear from Professor Kennedy (page 423) that it was so entirely arbitrary a method of designating a lamp.

With regard to the question of cost, some months had elapsed since the paper had been written, and a good deal more experience had been gained in the interval. Even now however his experience was not yet sufficiently positive for enabling him to state the cost definitely; but as soon as he was able to do so, he would get the actual particulars of the cost of the electric lighting against the previous gas lighting. [See page 431.]

As to the fire risk attending this plan of lighting, he remembered that, when the matter was brought up and dealt with in the north of England by the inspectors and engineers of the insurance companies, one of the arguments made use of was that the chains, the suspension cord, and all the tackle outside the lamp might get covered with fly; and that, if by any accident this got lit by the action of the arc-lamp itself, the fire would be carried as by a train of gunpowder to perhaps a dangerous part. Such an occurrence he must admit did seem feasible on the face of it. But with regard to the dropping of particles of incandescent carbon, no accident could occur, short of the lamp itself breaking down, because as already explained there was no aperture in the bottom part of the conical reflector or in the mechanism of the lamp itself; and it was impossible by any fair means to make a spark come out of the lamp. Even if the incandescent ends of the two carbons were knocked against each other, not a single spark would fly outside the rim of the conical reflector. Cotton fly might be poured into the reflector until it came up to the arc, when it would catch fire and burn down to the bottom of the reflector; but not a spark could be made to go outside the reflector. In this respect therefore there was no danger; and the insurance companies would find the inverted arc-lamp, protected by the conical reflector beneath, was one of the safest lamps that could be used.

In the objection to lighting up large shops from a single centre of electric energy (page 419) he fully concurred; and the difficulty had been felt so much in his own works that they were now arranging a number of what were there called "pilot" lamps. These were placed along the passages here and there, and were lit from a separate small engine not connected with the main circuit. The small engine was always running, and there were from 70 to 80 pilot lamps driven by it, which were sufficient to show light in the passages, and so prevent panic. The plan of taking the current for the pilot lamps from the town supply was a good alternative, and would no doubt answer admirably. An automatic arrangement of switch was necessary when the two plans of lighting were employed together; and something of the same sort as that described was being carried out in his own works by Mr. Parsons, which was not yet finished.

The saw-tooth roof referred to by the President (page 424) was admirably adapted for the plan of lighting by reflection. In spite

(Mr. Dobson.)

of the apparent loss through the windows, yet, if there was sufficient head-room to place a lamp far enough down the slanting roof, and the ceiling was white-washed, it would be found that almost as much benefit was obtained as if it were a flat ceiling.

The President was sure the members would all agree in passing a hearty vote of thanks to Mr. Dobson for his most useful paper.

Mr. J. Lyons Sampson wrote that he considered the plan adopted by the author was a distinct advance in the important matter of workshop lighting. One of the defects of the electric arc as a source of light is that, as the light is emitted from so small a surface, the shadows are sharp and defined, a small object produces a parallel shadow, and even small floating particles produce long pointed shadows. Light obtained from a large surface is therefore preferable; it shortens the shadows, and renders the transition from light to shade gradual, instead of sudden. On the plan described in the paper the arc light is made partly to fulfil this condition by reflecting its rays from a large white surface. Unfortunately in some workshops a white ceiling cannot be secured. In iron foundries, for instance, it would be impracticable to keep a ceiling white for many days together.

Some time ago, when the writer had to remodel the lighting of a workshop of this description, the difficulty was aggravated by the fact that central lights could not be used on account of the travelling cranes. The plan adopted, which has proved highly satisfactory in regard both to lighting and to cost, is illustrated in Plate 71. The building to be lit is an iron foundry 105 feet long by 39 feet wide; as part of the length is occupied by a drying stove, cupolas &c., the working area to be lit is reduced to 85 feet by 39 feet, Fig. 19. Along the side walls are a row of columns, carrying the gantry on which work two heavy travelling cranes C, Fig. 20, with a head-room of 15 feet beneath. The previous lighting consisted of long arms of gas-pipe with ordinary fish-tail burners, placed about six feet apart and projecting from a gas main running along the gantry. The light from this arrangement was bad, especially in the centre of the foundry; and each moulder had to have an oil lamp for enabling him to finish his work. Large gas lamps on the regenerative principle, which were first tried, gave a better light; but the smoke and dust necessitated constant cleaning, which together with cold draughts rendered the breakage of glass a heavy item. Having seen large flare lamps, burning creosote oil, used successfully in erecting new buildings and for temporary purposes of that nature, the writer determined to try whether they could be arranged to serve for permanent lighting; and selected the Wells plan as most suitable for the purpose.

The burner, Fig. 18, consists of a hollow iron coil, into which creosote oil is forced under a pressure of from 20 to 25 lbs. per square inch. One end of the coil terminates in a small hole, through which when the coil is heated the vapour escapes, and being ignited forms a long brush of brilliant flame; this passes through the centre of the coil, so that, when once lit, the flame supplies the coil with the heat necessary to keep up the supply of vapour. Two of these burners are used, which are placed as shown at BB in Figs. 19 and 20, one on each side of the foundry on long swing brackets, and as high as the travellers C would permit. They are free to swing aside if touched by the traveller chain; and are provided with a slight guard to prevent the chain from fouling the burner. The supply of oil is led to them through a 3-8ths inch gas-pipe, connected to a small air-vessel or pressure-tank P, into which the oil is pumped under a pressure of from 20 to 25 lbs. per square inch. The pump is so arranged that either oil or air can be pumped in, as required; it draws its supply of oil from a larger tank T holding about $1\frac{1}{2}$ ton, in which the oil is stored.

Some difficulty was found at starting, in heating the burners preparatory to lighting them; and various devices were tried. Eventually a large Bunsen burner was fixed to the gas main, in such a position that the coil could be swung over it. About eight minutes is ample to heat the coil; then the oil is turned on, and the gas extinguished. The two Bunsen burners each consume at the rate

(Mr. J. Lyons Sampson.)

of 30 cubic feet of gas per hour. Owing to the large surface of the brush of oil flame, and to the position of the burners, the effect of the light is so good as to be even better than daylight in the locality in which the foundry is situated; and there is a practical absence of shadows. The size of burner used is said by the makers to give 2,000 candle-power for each burner.

As regards the cost of the plan, the rate per hour cannot be given, because no record has been kept of the lighting hours; but the total cost for three years has been ascertained. During that part of the year when artificial light is required, the lamps are lit at 5 a.m., and extinguished on the average at 6 p.m. In foggy weather they might be kept alight all day; otherwise they would be extinguished in the morning as soon as the daylight becomes bright enough to do without them, and would be lit again in the afternoon as early as required. The total cost of oil for three years ending January 1893 was £60, or £10 per burner per annum. The Bunsen burners add five shillings to the annual cost of each light. As regards the cost of maintenance, the plan was started four years ago with three burners, two in use and one spare. Since then two have been replaced by new burners; they cost about 35*s*. each. The first cost of the air-vessel or pressure-tank P with pump and the three original burners was £20; the storage tank T, swing brackets, Bunsen burners &c., came to about the same amount; hence the total first cost was about £40. In use, a deposit of carbon takes place in the tube of the coil; but as the coil is formed round a square, and has a plug at each corner, the deposit is readily removed by passing a drill through; as this is done by the engine-driver when otherwise unemployed, it has not been taken into account in the cost. By having a spare burner, one is always kept ready to replace either of the other two that may want cleaning. By storing the oil in bulk in the tank T, any impurities in it have time to settle.

Mr. Dobson wrote, respecting the comparative cost of gas and electricity (page 426), that the result of four years' experience shows that with the plan of electric lighting described in the paper remarkably little repair is required; but constant attention is necessary, which if properly bestowed will avoid the necessity of repairs, by keeping all parts of the lamps thoroughly clean. There are now in daily use at his works 120 of these inverted arc-lamps, and preparations are being made for a large addition to this number. In considering the question of cost, it ought to be stated that, as compared with gas, all electric-light installations can be economical only when the light is used for at least five hours a day; because, when gas light is not required, the gas is turned off at the main, and there is no waste and no wages for attendance, and the depreciation as calculated is on a much smaller capital outlay. For electric

Gas Installation.

	£	s.	d.
505 gas jets on ground floor, first floor, second floor, and attic, at 6s.	151	10	0
Gas meter, fixing, and connection	56	3	0
Total capital outlay	207	13	0

	s.	d.
Gas per hour for 505 burners of No. 4 size, each burning 4 cubic feet, at 2s. 8d. per 1,000 cubic feet	5	4½
Depreciation at 5 per cent., and repairs at 4s. 6d. per week	0	2
Cost of Gas per hour	5	6½

Electric Installation.

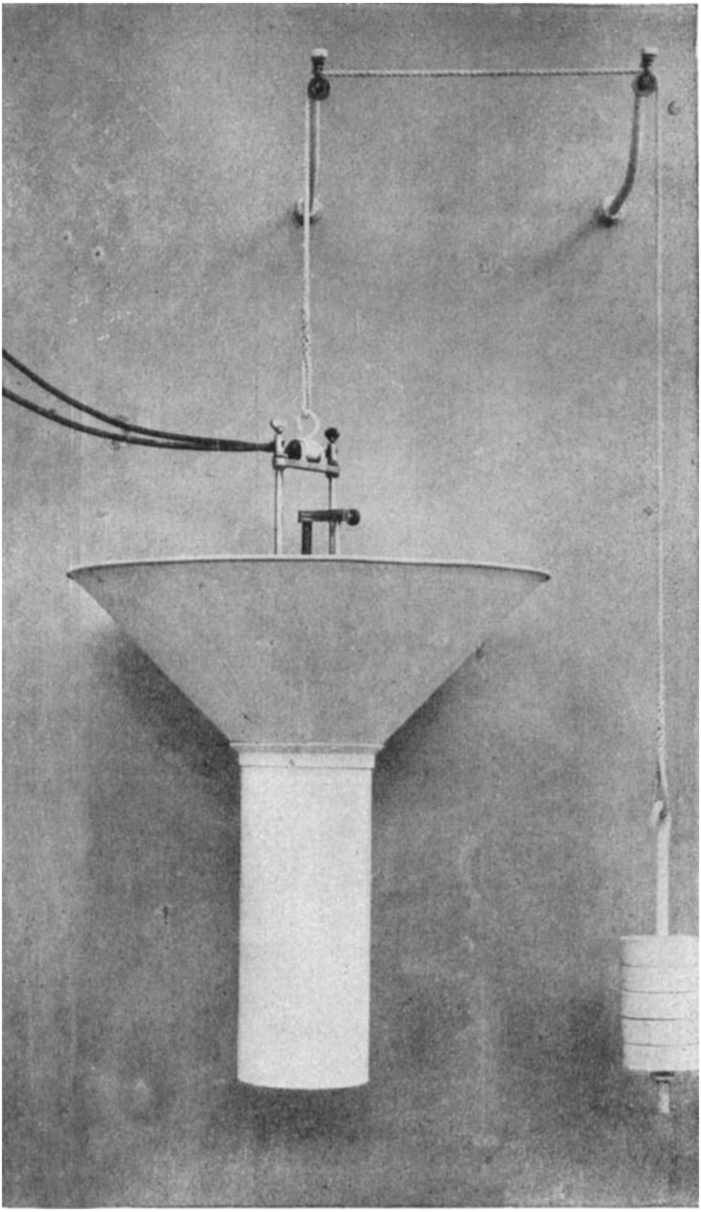
	£	s.	d.
60 arc-lamps fixed, at £10 each	600	0	0
90 incandescent lamps fixed, at 25s. each	112	10	0
Switch-board and dynamo	285	0	0
Proportion of engine and boiler	760	0	0
Total capital outlay	1,757	10	0

	s.	d.
Carbons per hour for 60 arc-lamps (of 12 ampères and 115 volts) at 1·2 penny per pair lasting 8 hours	0	9
90 incandescent lamps (1,000-hour lamps), at 1s. 3d. each	0	1½
Coal at 7s. per ton, for 80 I.H.P., at 3 lbs. per I.H.P.	0	9
Attendance, oil, &c.	1	0
Depreciation and repairs, at 10 per cent.	1	4
Cost of Electricity per hour	3	11½

(Mr. Dobson.)

lighting the capital outlay, including the driving power, will be from eight to ten times that of gas; and the depreciation will be calculated whether the apparatus is working or not. In the accompanying figures (page 431), which have been carefully worked out for No. 9 building at the writer's works, the economy of electricity is marked and real, because the nature of the building and the work require constant employment of the electric light.

Fig. 1. *Outside Elevation of Inverted Arc-Lamp.*



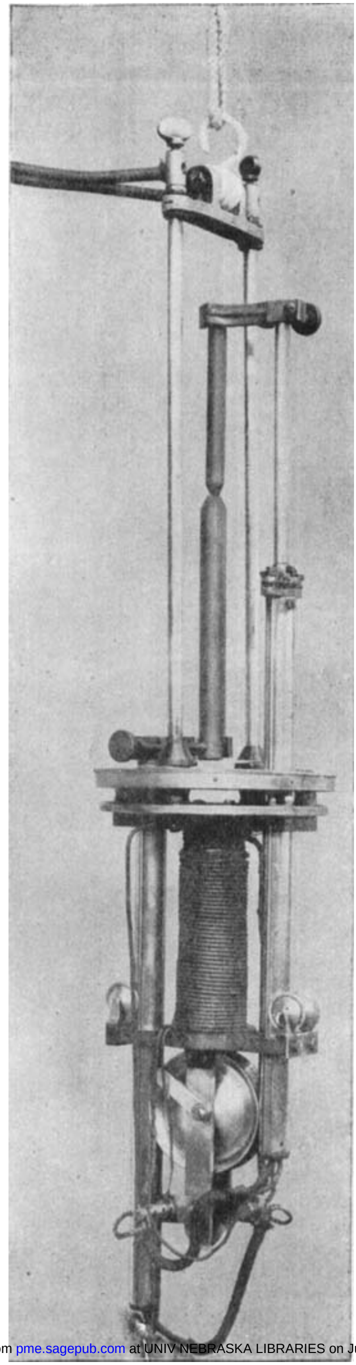


Fig. 2.
Elevation of Inverted Arc-Lamp with Reflector and Casing removed.

Fig. 3. *Fluted Bottom-Rollers.*

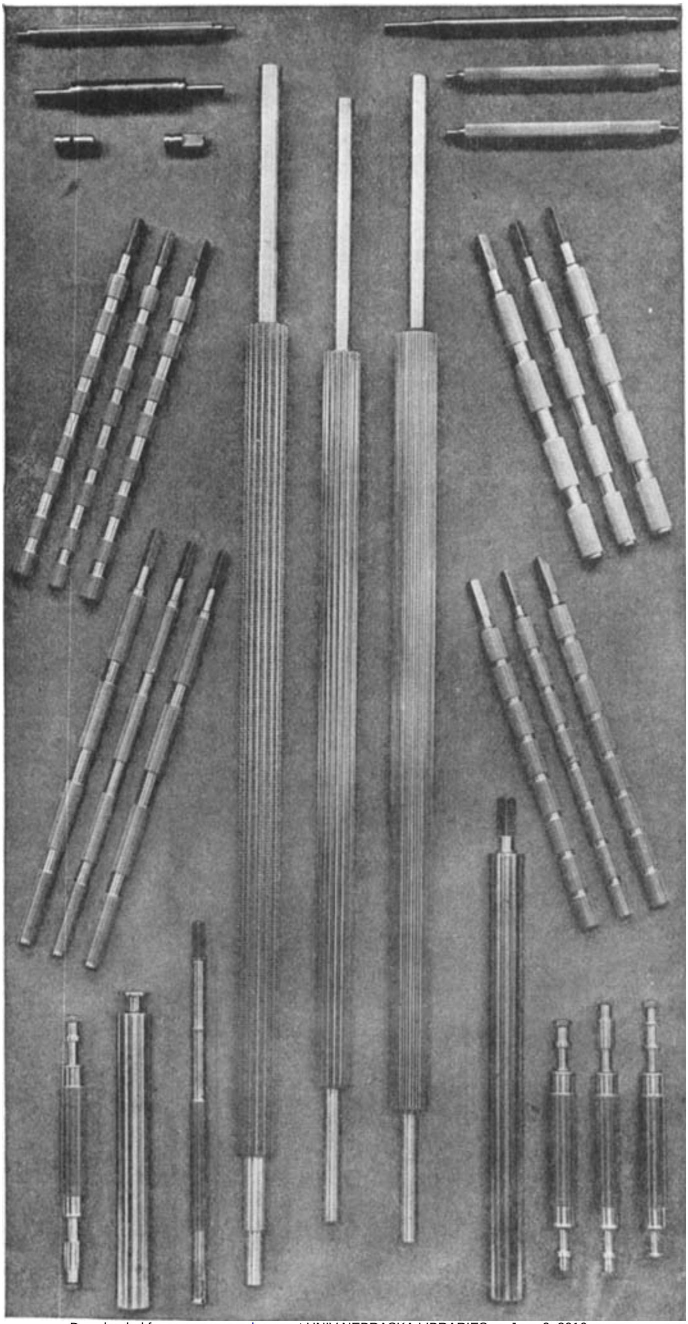


Fig. 4. *Top Rollers.*

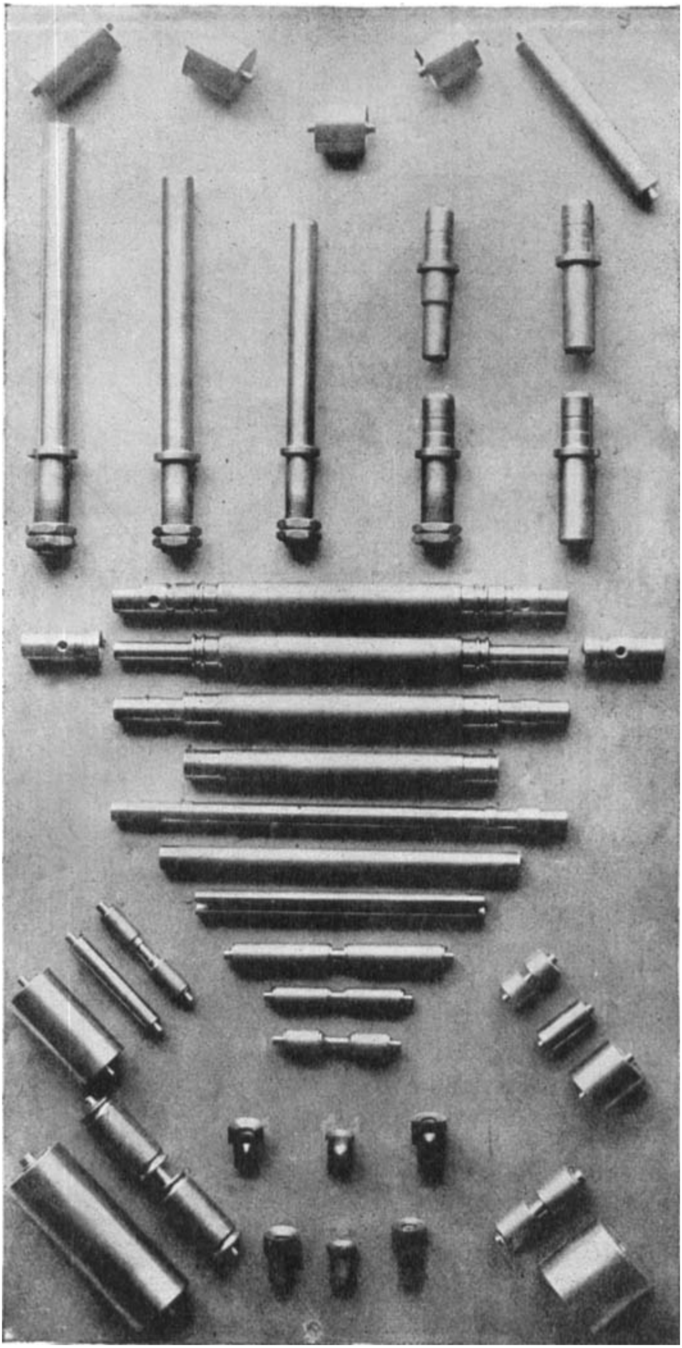


Fig. 5. *Flyers.*

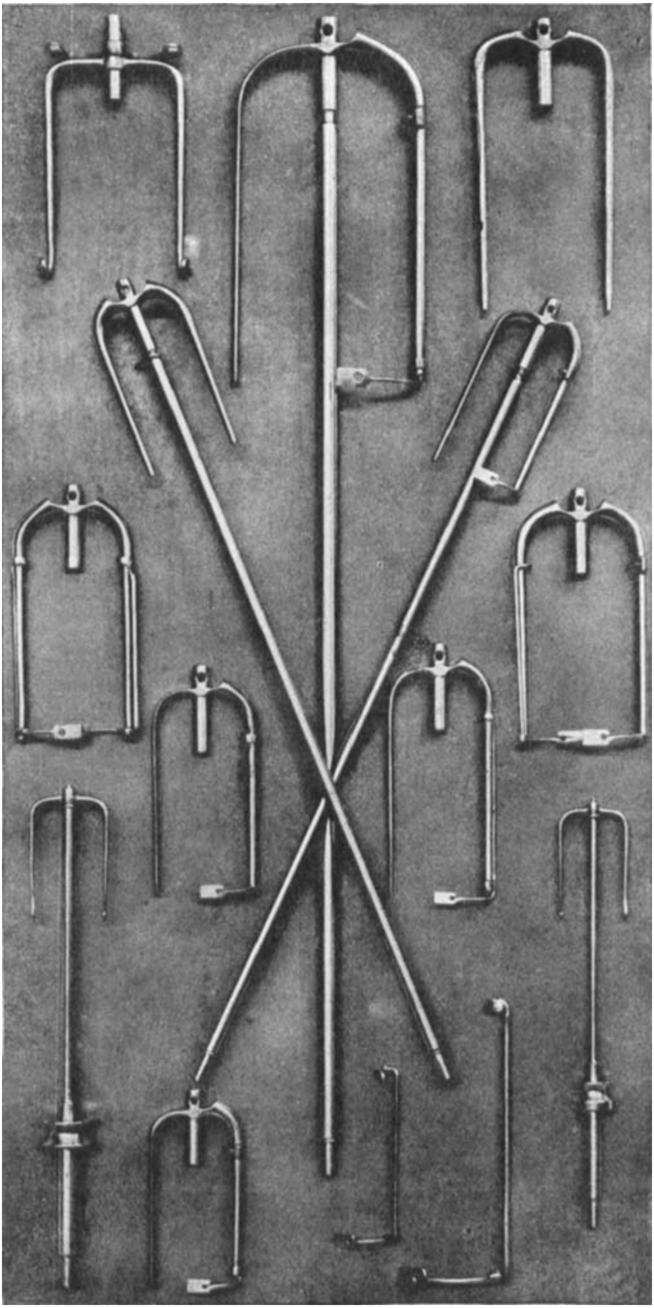


Fig. 6. *Bottom-Roller Room, Kay Street Works, Bolton.*

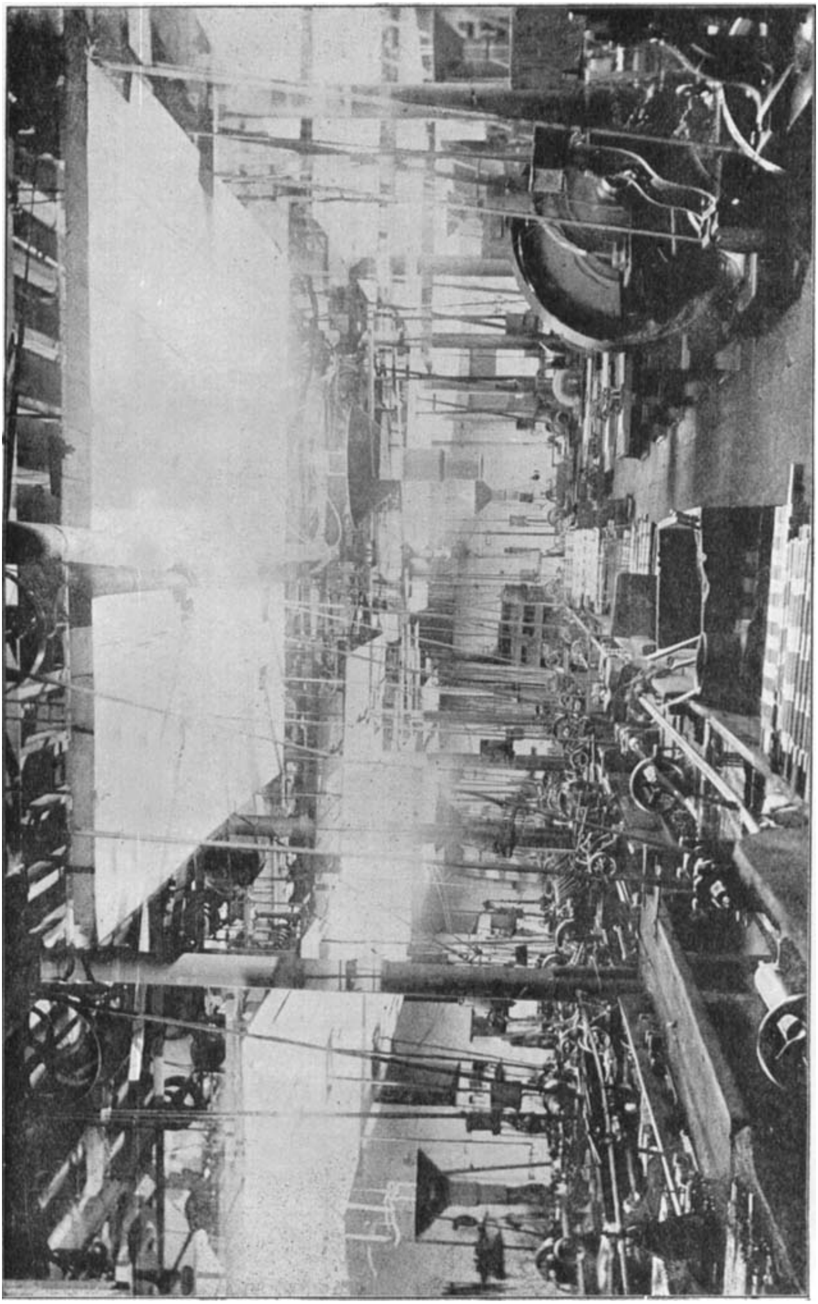
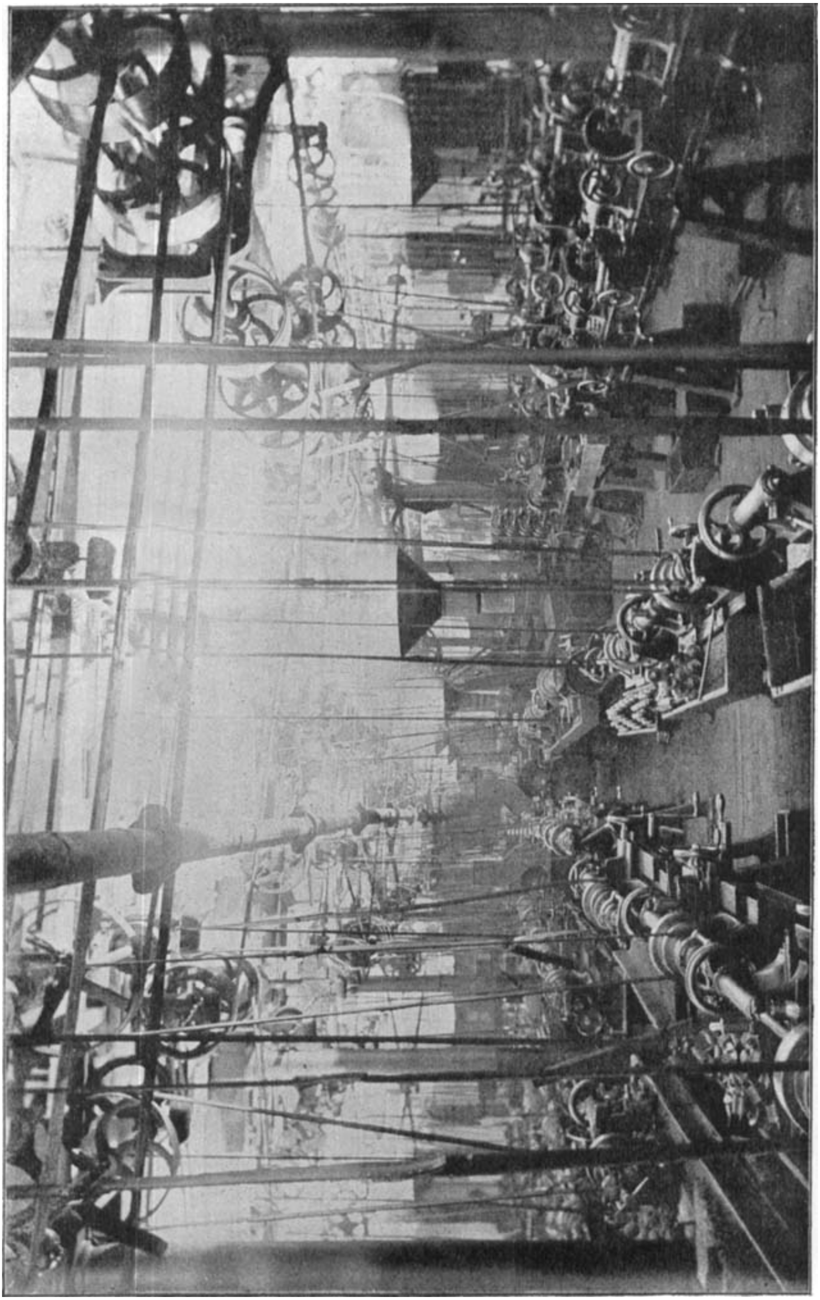


Fig. 7. *Top-Roller Room, Kay Street Works, Bolton.*



Scale 1/420th.

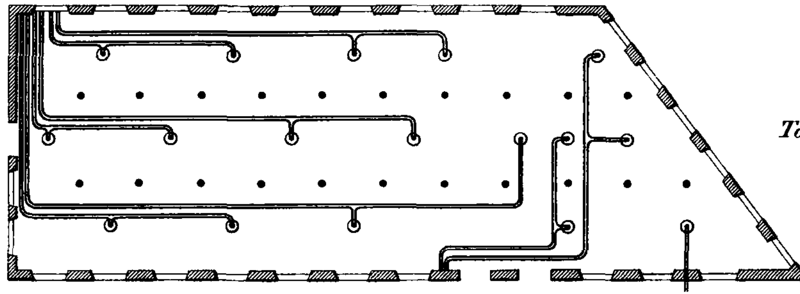
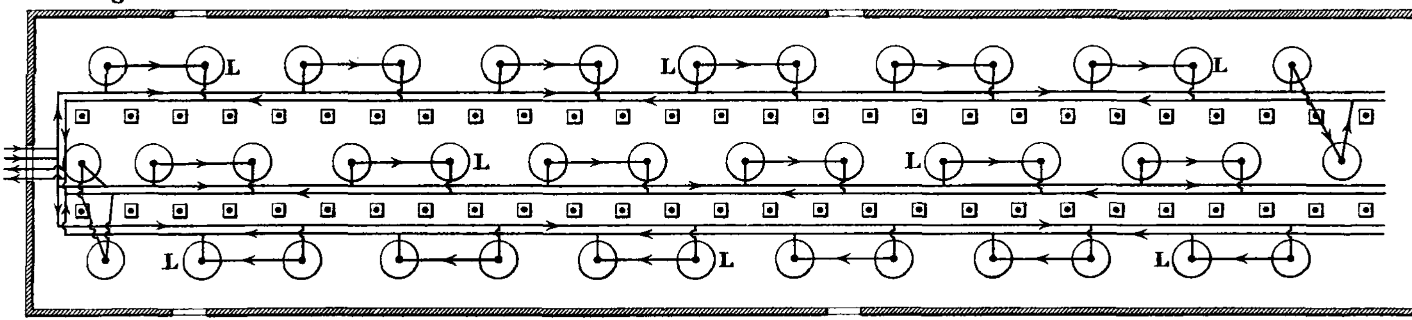


Fig. 8. Plan of Top-Roller Room, Kay Street Works, Bolton.

Fig. 9. Plan of Machine Shop, Lancashire and Yorkshire Railway Works, Horwich.



Scale 1/840th.

0 50 100 150 200 Feet

Fig. 10. *Transverse Section of Machine Shop, Lancashire and Yorkshire Railway Works, Horwich.*

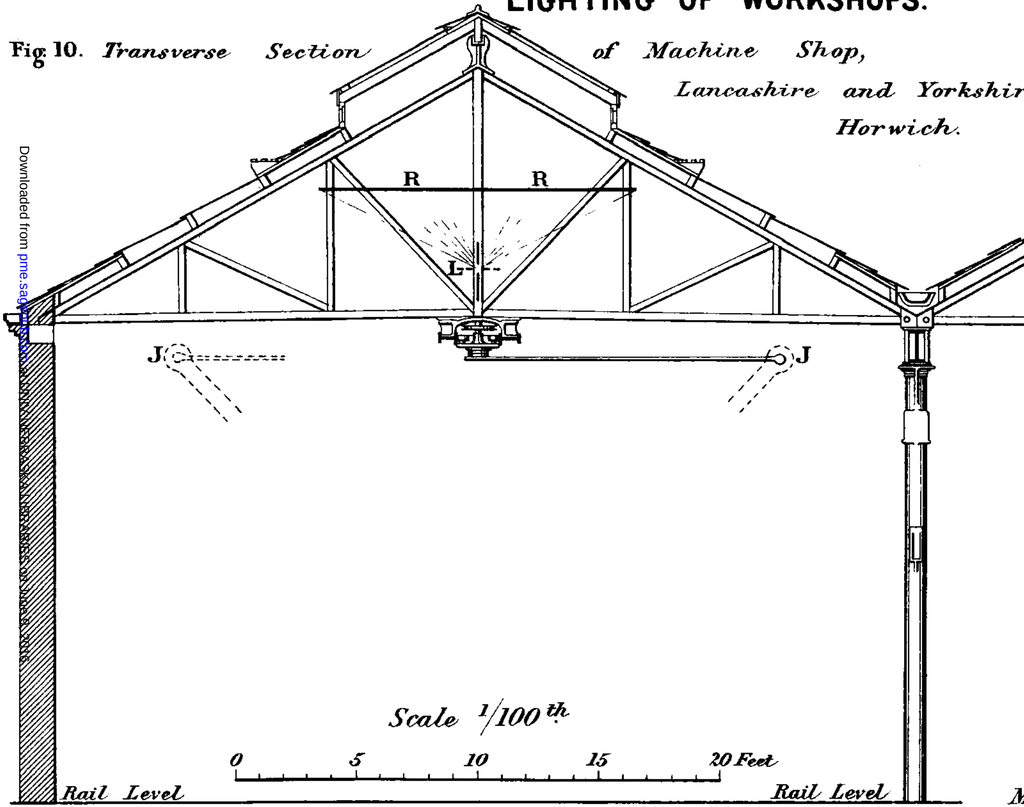
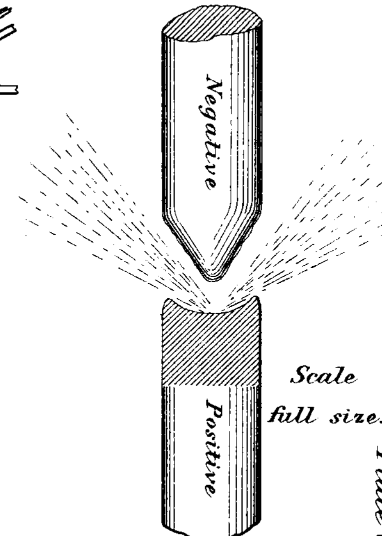


Fig. 11. *Carbons.*



Scale full size.

Fig. 12. *Fitting Shop,*

Lancashire and Yorkshire Railway Works, Horwich.

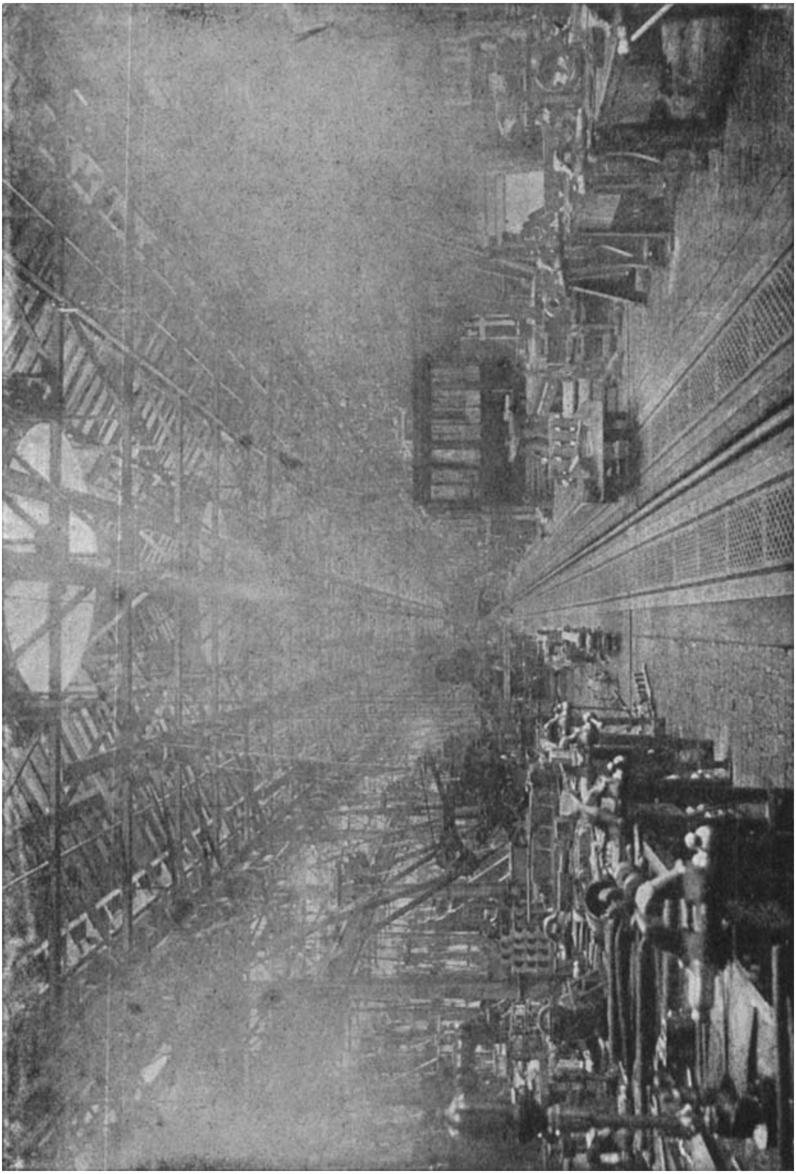
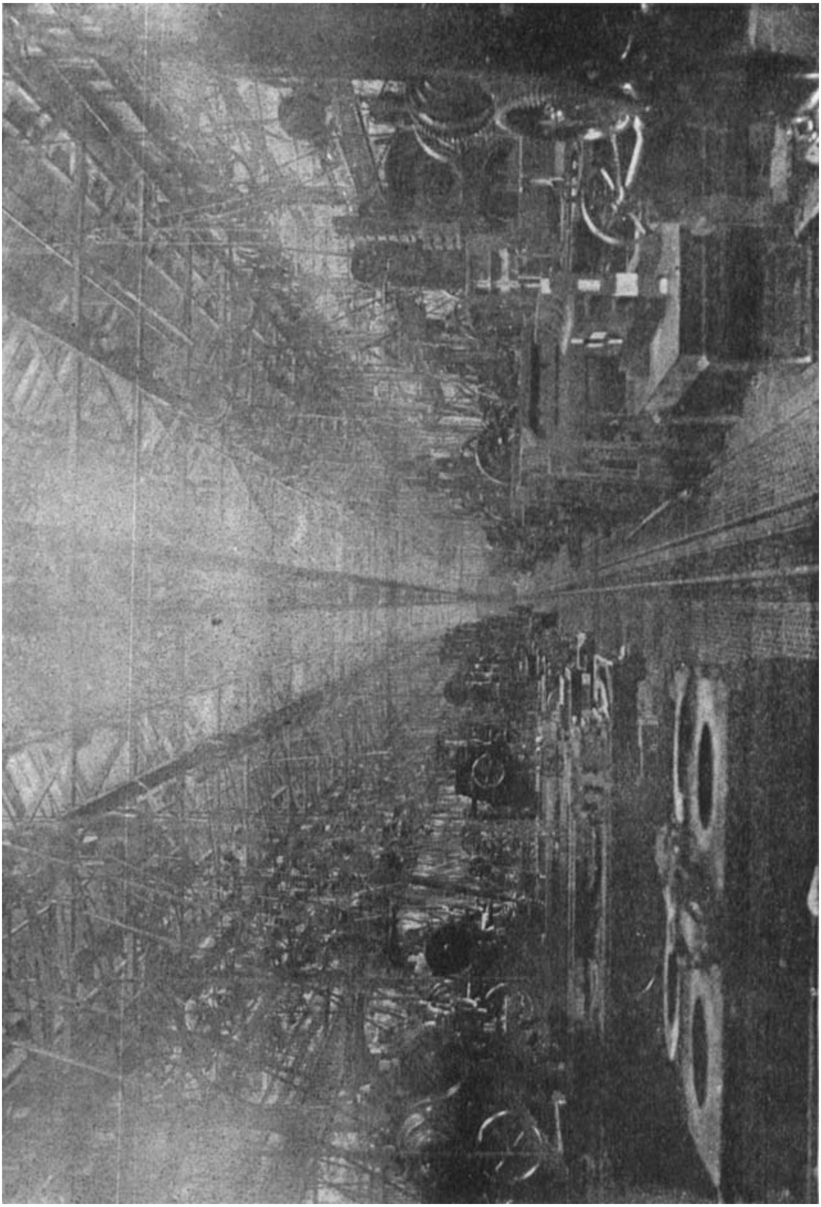


Fig. 13. *Fitting Shop,*
Lancashire and Yorkshire Railway Works, Horwich.



LIGHTING OF WORKSHOPS.

Automatic Switch. *Scale half size.*

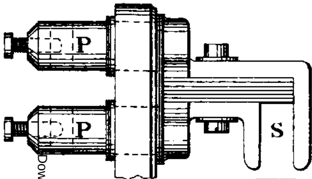


Fig. 17. *Plan of Contact.*

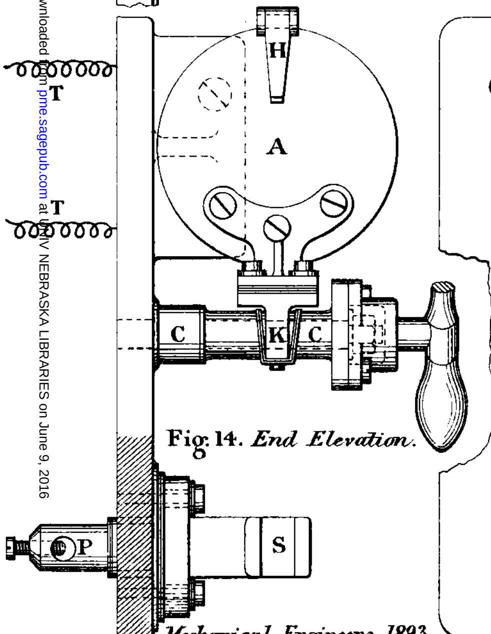


Fig. 14. *End Elevation.*

Fig. 15. *Switch open.*

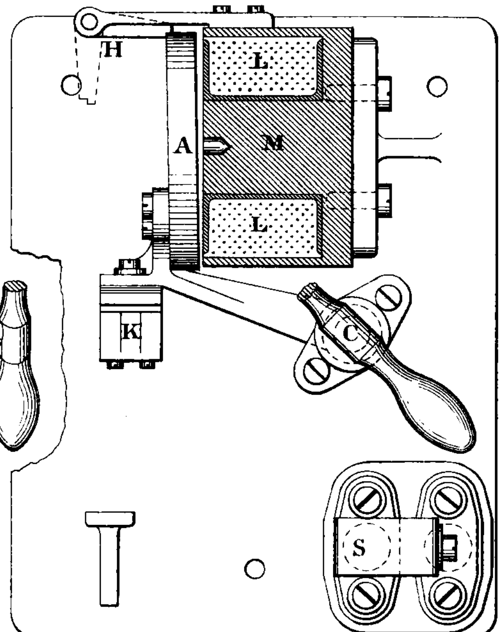
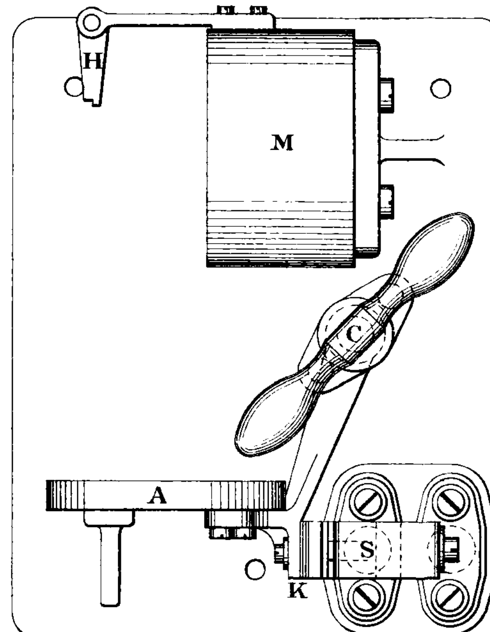


Fig. 16. *Switch closed.*



Mechanical Engineers 1893.

Plate 70.

Oil-Vapour Flare-Lamps.

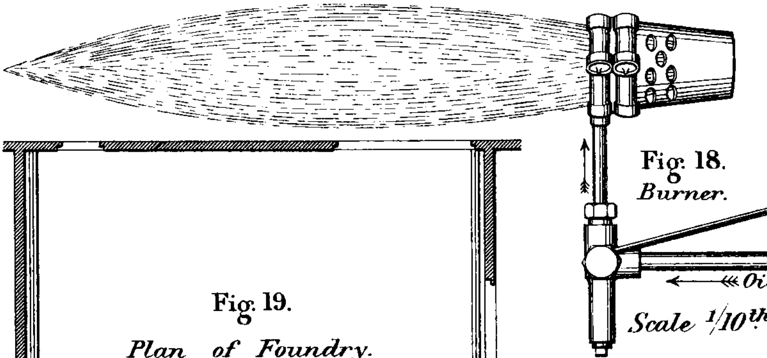


Fig. 18.
Burner.
Scale 1/10th.

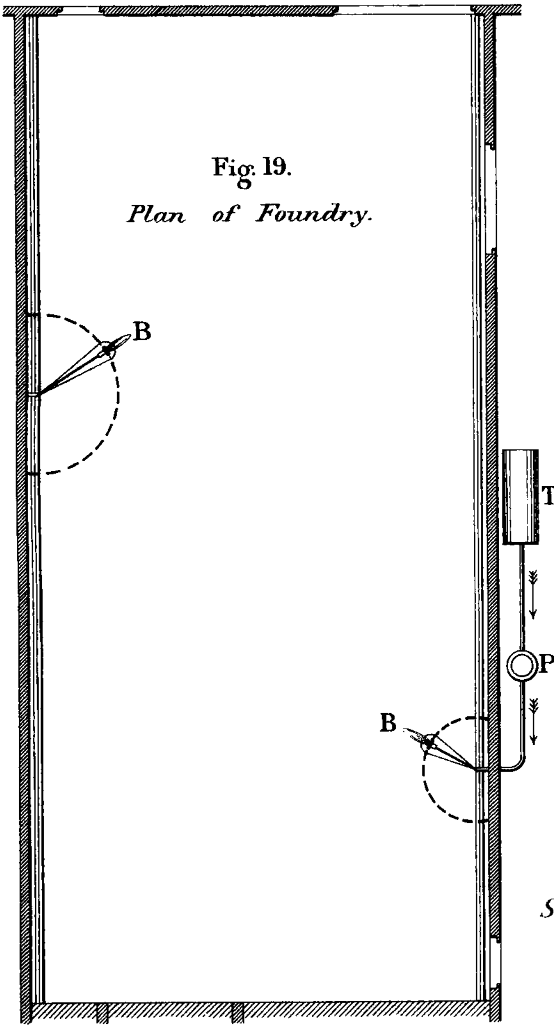


Fig. 19.
Plan of Foundry.
Scale 1/200th.

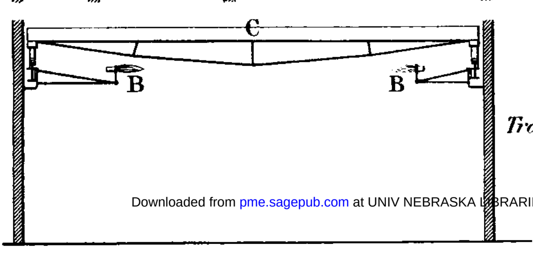


Fig. 20.
Transverse Section of Foundry.