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President—JOHN INGLIS, ESQ., LL.D.

BRISTOL CHANNEL CENTRE.

President—Professor A. C. ELLIOTT, D.Sc.

VISIT TO THE CITY OF BRISTOL.

THE members of the Bristol Channel Centre paid a visit to the historic city of the Merchant Venturers on Saturday, August 13th. Cardiff was the starting-point and Lawrence Hill the terminus, the Newport contingent being picked up *en route*. There were present Professor Archibald C. Elliott, D.Sc., the President of the Centre; Messrs. T. W. Wailes and M. W. Aisbitt, Vice-Presidents; Messrs. T. A. Reed, J. Fleming, J. F. Walliker, R. Williamson, J. Boddy, and J. Chellew, Committee; Mr. G. Sloggett, Hon. Secretary; and Mr. A. E. Smithson, Hon. Treasurer, and a large proportion of the members.

On arrival at Bristol the company passed from the railway train to electric tram-car, and were soon scudding along noiselessly, except for an intermittent clang of a bell as car passed car on the well laid track, and for more or less intelligent audible comment upon features of the trolley overhead wire system which they had come to inspect. Reaching the Bristol electric tramways power station, the party was received by Mr. Wood, the engineer; Mr. Challenger, traffic manager of the electric tramways; Mr. Faraday Proctor, electrical engineer of the city of Bristol; Mr. Nicholas Watts, Hon. Secretary of the Bristol Association of Engineers; and Messrs. Pearce and Parkinson, on the engineering staff of the Bristol Docks. The features of the well-equipped power station were pointed out by Mr. Wood; and the party came away impressed with the up-to-date character of the plant, and the spick-and-span appearance of the whole place.

Next, a visit was paid to the electric light station of the City Corporation, where Mr. Faraday Proctor, the engineer, gave a highly creditable description of the electric light installation. The station has a water frontage to the floating harbour which enables the coal to be got in direct. It is delivered from the boats direct into coal bunkers; on the top there is a waggon-way and a weighbridge. The coal falls through sliding dampers into the boot of the elevator pits. The elevators are ordinary chain-and-bucket apparatus which lift up the coal and deliver it into conveyers, these being screw type, travelling the whole length of the boiler house—about 220 ft. There are twelve Lancashire boilers, with Galloway tubes, fitted with Vickers' patent mechanical coking stokers. The station has been recently almost doubled in capacity. In the older portion all the auxiliary plant in the boiler house, for donkey pumps, feed pumps, and stoker engines, is driven by steam. In the new portion this plant is all driven by electric motors, three-throw feed pumps being used. There are two chimney stacks

180 ft. high. Live steam heaters are used in the old portion of the building, owing to the land space being rather too narrow to enable economisers to be put in. In the new part of the station the economiser has been introduced, an arrangement that will continue to be pursued. The engine room runs the whole length of the building immediately behind the boiler house. A single steam pipe is carried through from each boiler into the engine room. Here the dynamos and alternators are all driven by Willan's central-valve engines. These engines are too well known to require detailed description. We may simply comment that the whole of the working portions, with the exception of the governors, are contained inside a sealed chamber. This chamber is filled with a mixture of castor oil and water up to the level of the middle of the crank shaft. The cranks, revolving at speeds varying from 300 per minute and upwards, dip into this lubricating mixture at every revolution, and thus disperse the oil all over the working parts, ensuring efficient lubrication. For the general supply of private customers there are nine alternators. Two of these are 88 kilo. Watt capacity, four are 210 kilo. Watt, and two are 400 kilo. Watt, a third of the latter capacity being now put in. With one exception, all the alternators are of Siemens' make, the exception being one 400 kilo. Watt Ferranti machine driven by a Willan engine. For arc lighting there are four 52-kilo. Watt dynamos, giving continuous current by a pressure of from 600 to 650 volts. Only one of these is at present in use, there being now 96 continuous current arc lamps in the city. To these arc circuits are now being added upwards of 200 lamps. The circuits are arranged with twelve lamps, in series, on each. All the circuits are run in parallel. There are two dynamos, each of 52-kilo. Watt capacity, giving a continuous current of 100 volts, for exciting the other machines in the works, and also for charging a small battery of accumulators. This battery is used for the station lighting, and for supplying the exciting current at times of very

light load. At the present time there are about 55,000 eight-candle-power lamps joined to the mains. From the works there are nineteen high-pressure feeder cables running direct to the sub-stations. One of these primary sub-stations is used as a high-tension distributing station; two cables run into it; and about ten other sub-stations are supplied with high-pressure current from it. In all there are thirty nine sub-stations. Most of these have been built underneath the pavement, the general size being about 10 ft. by 6 ft. by 6 ft. high, the ordinary capacity of each one being 52 kilo. Watt, though some are larger. From these sub-stations there are low-tension cables, joined up in networks. Now that the capacity of the station is increased, the networks have been divided up so as to form four distinct sections. The high-pressure cables are all concentric, lead-covered and steel-armoured, and are laid direct in the ground, being merely protected from mechanical damage by having bricks loosely laid over them throughout their entire length. The low-pressure cables are triple concentric, lead-covered and steel-armoured, and laid in the ground in a similar manner. The cables are almost all of Messrs. Siemens Bros.' make, the insulation being of jute compound, though some few miles of the British Insulated Company's paper insulated cables have been used. To conclude this rough description, the station has been running just five years, and last year, after paying interest on capital, and paying off about £4,000 of the redemption fund, there stood a balance of over £3,000, and this was placed to reserve.

Having concluded their inspection of the electric lighting station, a steamer, kindly provided by Mr. J. M. McCurrich, M.A., M.I.C.E., engineer of the Bristol Docks, conveyed the party to the large granary at Prince's Wharf, and thence to the Docks' engineering works at Underfall Yard, the entrance locks, landing stages and cliff railway; thence crossing St. Augustine's Bridge with keen appetites to the Royal Hotel, College Green, where all gathered round a well-supplied table. Dr. Elliott presided at the festive board, and in due course submitted the loyal toast, which was heartily honoured. Then the President called upon

Mr. NEVILLE APPELBEE, electrical engineer to the Cardiff Corporation, who read the following paper on "Electric Lighting Works":

ELECTRIC LIGHTING WORKS.

By Mr. NEVILLE APPELBEE (Associate Member).

The above title is so comprehensive that an elaborate treatise might well be written upon it. However, even if I were capable of doing this, it would, I feel, be out of place to-day; I propose therefore to very briefly sketch some of the more prominent points which have to be taken into account in designing the mechanical portions of steam-driven electricity works, and the plant which is used in them. Some of these points are so intimately connected with, and dependent upon, the electric systems of the supply as to be inseparable from them; but with such exceptions electrical matters will not be touched upon.

The design of a successful electricity works is not quite so straightforward and simple a matter as it may appear at the first glance. At one time it would almost seem to have been thought that all that was required was a building in which to house a sufficient number of boilers, engines and dynamos, and in consequence many unfortunate failures and disappointments have occurred. Now there is not anything particularly strange about this, as all engineering undertakings in their early stages are largely experimental.

The great and rapid growth of electric lighting works may be said to date practically from 1888. It is true there had been such works before that time, for several years or so, but they were works principally put down to exploit some particular system ; and our Government, in their desire to prevent the formation of new great monopolies, put such restrictive legislation in force as to effectually stifle the growth of the new light. It was not until the Electric Lighting Act of 1882 had been amended by the Act of 1888 that real progress began to be made.

One of the most interesting of the early electric lighting works in my opinion was that of the Grosvenor Gallery Company. It was commenced in the first instance about 1887 to supply the building of that name in New Bond Street, London, and the neighbourhood, but rapidly grew into a large concern, supplying some 35,000 lamps in the West-end by means of over 100 miles of cable carried on poles over the housetops, and most successfully demonstrated the practicability of electric lighting by means of high-pressure alternating currents—on which system Bristol, Newport, Cardiff, and many other towns are supplied to-day. It was evident, from the demand for current from this station alone, that there was an enormous business to be done, and the formation of electric lighting companies, each with its allotted area under Parliamentary powers, proceeded apace.

The various municipal authorities also entered the field, with the result, according to the latest returns, that out of some 283 provisional orders which have been granted by the Board of Trade 202 are held by them and 81 by companies. From the experience gained with the earlier works there is now a large amount of information to guide the engineer how to lay down a station in the most suitable locality, and with the most approved plant for the system of distribution adopted. Under the following various heads I will endeavour to give you a brief *résumé* of present conditions and practice.

Site and Buildings.—Though not strictly of a mechanical nature, a suitable site on which to build is a matter of great importance. If it has been decided that the electric system of supply is to be what is known as a low-pressure one, the economical range for distribution is a comparatively small one, and it is therefore essential to select a site which is geographically approximately in the centre of the area to be supplied. As may easily be supposed with such a condition as this controlling one's choice, it is often almost impossible to select a site to which coal in large quantities can be cheaply delivered and from which ashes can be carted away, while water for condensing purposes is often simply out of the question. With a high-pressure system there is a much wider range; the works need not be in the centre of the area but may be a mile or so on one side of it, and can therefore be most conveniently placed on the bank of a river or other water or adjoining a railway, with all their attendant advantages.

Other points to be considered are the nature of the land and its suitability for carrying the heavy weights, ample room for the extensions which are certain to be required, and the character of the surrounding property, to avoid action at law for causing a nuisance. The necessity for due consideration of these latter points is exemplified in the history of some of the metropolitan electric lighting companies, who constructed works a few years ago in the midst of London's population, and who are now seeking powers to construct new works further out. The buildings should also be constructed with a due regard to the larger units of plant which will certainly be required a few years after a supply has been commenced. Designers appear to often overlook this even in quite modern stations, and plant is in consequence housed in buildings neither wide enough nor high enough. The buildings should also be of fireproof construction, and may well be arranged so that the boilers and engines are in two parallel rows. The coal bunkers are naturally opposite the furnaces, and contain as it were the raw material, which, passing as steam to the engines, is converted into electricity, and after going through the measuring instruments on the switch-board is delivered to the town mains as the finished article.

Steam Engines.—The electricity works' engineer requires a great deal from his engines. The demands are most exacting, and have led to the development of special classes of engines for the work. They must be economical of steam on varying loads, their mechanism must not be too complicated, they must be strong, must govern well, must have a most equable turning moment, must not require too much attention, and must not occupy too much space. Almost every type of steam motor has been employed for driving dynamos, and there still remains a wide difference of opinion as to which is the best to adopt. In the early days, owing to the high speed required by the dynamos, they were usually connected to the engines by ropes and belts, but direct-coupled sets are now the universal practice. For both safety and economical reasons the generating units are often ten or fifteen in number, and may each be anything from 100 to 2,000 H.P. in provincial stations. The principal types now employed, without having regard for valve gears, may be said to be three in number. (1) Slow-speed horizontal double acting engines, with the flywheel between the H.P. and L.P. engines, as at Newport. This type is fairly simple, durable, and strong, but takes up too much space. (2) Moderate quick-speed vertical compounds and triples. By moderate quick-speed I mean 150 to 200 revolutions per minute. As a compound this type is usually arranged as No. 1. As a triple the three engines are placed close together as on ship-board, and the dynamo is connected to the shaft of the L.P. engine, as the first four sets at Cardiff. (3) High-speed engines either compound or triple, and which are usually tandem engines, as at Bristol. This type is used more than either of the first two. In the municipal lighting works the horse-power developed by the high-speed engines is more than double that of the other two put together. Of engines of the Willans type alone something like 60,000 H.P. have been supplied to such stations, and another 51,000 to company-owned stations. One need not go far to seek the causes of this preference, and I put them down to the following: (1) High speed means a minimum of capital outlay on the dynamo. (2) High-speed means a minimum of floor space occupied in proportion to the power developed, and which keeps down the cost of buildings and foundations. (3) The high-speed vertical engine is universally a self-lubricating engine, and therefore requires but little attention when once started. It is also enclosed, which a horizontal never is, and therefore requires but little cleaning. (4) The cylinders and steam chests are small. It is therefore quickly warmed up and set to work, which is a useful property. Other conditions applicable to all types are the necessity for accurate governing, a usual condition being that the speed must not vary more than 10 per cent. when the whole load is suddenly thrown off.

Boilers.—The conditions under which steam is required in the electric lighting works is different probably to those in any other commercial undertaking. In such towns as Newport and Cardiff artificial light is required on an average for only two or three hours per day. The boilers must be opened out on to the pipes as the hours of darkness come on, and after steaming for quite a short time, three-quarters or so of them are not required again until the next evening. The coal consumed in keeping a number of boilers in readiness for this intermittent duty is very considerable, and should be taken into account in deciding upon the class of boiler to be used. I find the Lancashire boiler, with all its brick flues, is at present more used than either the marine or water-tube types, as in 46 municipal lighting stations there are no less than 175 Lancashire boilers and only 55 water-tube and 39 marine. The explanation of this seems to be that the well-known long life and comparative simplicity of the Lancashire boiler, as compared with the two latter, is preferred, whether it uses more coal or not. In stations where there is any likelihood of fog or other sudden darkness a rapid-steaming boiler is absolutely necessary, and in consequence we find Lancashire and water-tube boilers side by side in the same works. It is my opinion that with the continual increases of pressure, all shell boilers must eventually give place to the water-tube types, with their small parts and definite circulation, as compared with the uncertain circulation and enormous plates of the former. Another consideration which should extend the use of the water-tube boiler is that it practically never becomes necessary to lower its working pressure—a property which when a number of boilers of different ages are working on to a common steam main is a matter of no mean importance. It is also well adapted for being forced in cases of emergency.

Steam Pipes.—Steam pipes next merit consideration. One of the principal requirements is to so arrange matters that if a section should fail the supply of steam to engines can be maintained just as usual. To this end the steam pipe is usually a ring main with stop valves between each engine and boiler, and thereby only throwing one or so of these out of use if a mishap occurs in any one section. There will also be usually an auxiliary ring main to supply steam to the feed pumps and other auxiliary plant, and which will be supplied from the main steam ring in two or three places. The stop valves on these ring mains are invariably of the straight-through type to facilitate opening them whichever side happens to be under pressure. In view of the fact that most of the steam piping is idle for so many hours per day, a complete system of drains and steam traps becomes necessary to carry off the water condensed in them. The materials mostly employed for the pipework are wrought iron and steel, either lap welded or riveted, and having the flanges screwed and brazed or electrically welded. The T pieces are made of cast iron, and the bends are frequently copper. Expansion joints are not often used, the necessary freedom for the pipes being provided for by supporting them without restricting their movement. Automatic isolating valves are often fixed both on the boiler branch pipes and blow-offs, to render the working of a number of connected boilers as safe as possible.

Condensers and Pumps.—Most electric lighting works are now arranged to work condensing even if there be no natural source of cold water for the purpose. The type of condenser is naturally largely dependent upon the question of a suitable supply of feed water. Where this is available jet or ejector condensers are the rule. Speaking generally, the condensing plants are independent self-contained sets, the pumps being driven by small compound engines or electric motors. The greatest disadvantage of this arrangement is the long lengths of exhaust pipe, which impair the vacuum. An exhaust to the atmosphere also has to be provided for use in case of emergency. An ejector condenser placed close to each engine I consider to be a good arrangement—no air pumps being needed—and the long pipes under vacuum are avoided. The design of feed pumps is a matter which repays attention, the ordinary direct-acting pump being well known to be a steam eater. Three-throw pumps driven by a small engine with a good flywheel or an electric motor are now usual. The feed pipes from the pumps, like the steam pipes, are usually in duplicate. There are a number of other auxiliary parts, such as feed heaters, filters, fuel economisers, coal and ash conveyors, etc., on which I should like to have said something, but time will not permit, and so I conclude here.

TRACTION BY ELECTRICAL POWER.

The President (Professor A. C. Elliott, D.Sc.) followed Mr. Appelbee—who was cordially applauded for his suggestive contribution—with some notes on the system of traction by electrical power.

Dr. ELLIOTT said: The system of traction by mechanical power transmitted electrically, which now occupies a tremendous territory in America, on the Continent, and to a less relative extent in this country, has been practically developed within the experience of the youngest of us here present. It is 60 years ago, however, since the early experiments began with rude magneto-motors and primary batteries, the most notable perhaps being those of Robert Davidson, of Aberdeen, who between 1838 and 1842 did not a little work in this connection, and with an electric engine of his own construction ran long trips on the Edinburgh and Glasgow and other Scottish railways at speeds of four or five miles an hour.

The practical period commenced of necessity subsequently to the invention and introduction of the dynamo. In 1879 the Berlin branch of the Siemens firm constructed there a small experimental electric railway in the grounds of the exhibition of that year. The rolling stock consisted of a small car and an even less bulky locomotive, which picked up its current from a middle rail and returned it through the two ordinary rails. The shaft of the motor—an ordinary Siemens series dynamo—lay parallel with the line, and a double reduction plain and bevel spur gear conveyed the power to the driving wheels. The load was 20 persons and the speed eight miles per hour. Immediately many noteworthy experiments were undertaken, chiefly in the United States and this country; but Siemens were again to the fore with the Lichterfelde line, opened for business in 1881, as the first electrical tramway. It is still working. The method of picking up current by a third rail, originally employed on this line, is quite suitable, and now universally adopted for electric railways properly so-called. For obvious reasons it is unsuitable for a tramway, which is distinguished from a railway by the condition that the surface between the rails shall be available for the accommodation of all kinds of traffic besides that peculiar to the tramway. The distinction was discovered at this early period, and to it belongs the advent of the single and double trolley. Anything like effective insulation of a third rail laid at surface level on a tramway is impossible. It appeared that the thing to do was to raise the third rail out of harm's way, in the sense of wet, mud and snow—never to speak of horses and pedestrians not inured to substantial electric shocks—and to establish connection between it and the car by a flexible conductor and a little contact carriage, hence the name trolley. This third rail, or, so to speak, supply conductor, became for tramway work a stout copper wire suspended over the centre of the track by means of side posts and guys; and the trolley took the form of a swivelling, spring-supported, steel tube mast carrying a slipper or pulley contact. Junctions and crossings were negotiated by "frogs" and more guys. All sorts of slings, clamps, brackets, shackle and strain insulators, were invented, cast and erected haphazard by the thousand, till at last in some American towns neither the brightest moon at midnight nor the strongest sun at mid-day could penetrate the metallic cobweb overhead. But in the fulness of time and experience, order and even beauty emerged, and there are now in existence scores of overhead electric tramway installations that neither offend the eye nor shut out the light of heaven.

On the double trolley system it was proposed that the current should come by one overhead wire and trolley and return by a second overhead wire and trolley—the word trolley now standing in a generalised sense for the connection between the moving car and the fixed conductor. Lines on this plan have been erected; but since one overhead conductor is better than two — all things equal — and one connection between a moving car and fixed conductors is better than two—all things equal—it follows that if the condition, all things equal, can be realised there is very little chance of the double trolley system spreading.

Practically all electric trams use the ordinary rails for the return. In the early days of electric traction it was supposed that the rails made what telegraph engineers call a " dead earth." To get zero resistance in the return it was merely necessary to put one terminal of the dynamo to line and the other to good earth. That this was a huge error might easily have been foreseen; what is good earth for a small current is by no means good earth for another a million or so times greater. The conviction, something wrong, was probably brought home by the coal bill; anyhow, the idea got abroad in America that their ancient suspicion that the terrestrial globe was rather a small thing could be proved a fact by measuring the resistance of a tramway earth. The rails were in some instances connected to gas and water pipes to secure a better return. This, it would seem, served to precipitate a crisis: water and gas pipes became, through galvanic action, sieves, and telephones, which had before become inarticulate, delivered shocks. Then came the later order of things: rail sections were increased to 70 lb. and 80 lb. per yard; electrical continuity at the joints was secured by substantial copper bands or by welding; the negative terminals of the dynamos were connected not only to earth but directly to the rails; and insulated return feeders were run exactly like supply feeders. The water and gas pipe trouble disappeared; much of the telephone trouble disappeared, and works' costs were more satisfactory. In the early days a matter of 50 or 60 volts difference of pressure between the end of the ordinary rails and the negative terminal of the dynamo was a mere ordinary thing. Our Board of Trade now limits that difference to 7 volts, and the return current is practically confined to the paths designedly provided.

The method of picking up through, or by means of, a slot was quite early in the field. The general appearance of the track exactly resembles that of a cable tramway; and, to carry the analogy further, the running wire rope of the cable tram becomes a fixed conductor and the gripper a contact carrier. This system has undoubtedly tremendous advantages compared with overhead pick-up. On the other hand, the drawbacks to what is outwardly nothing short of a fascinating plan are only too well known to the electrical engineer. In a moist climate the insulation is prodigiously difficult to keep up to standard; repairs are heavy, and, worst of all, difficult to effect in the confined and inconvenient space at disposal; and lastly and least, the first cost is considerably greater. It is difficult to imagine the ordinary slot system working through a week of snow-slush and Cardiff road mud. Though I think there is at present a grave balance against the adoption of the slot system in this country for any important installation, I do not completely despair of its future. The installation difficulty can be contended with by good design and by automatic section switching, and some others could be reduced by sinking more money. In a word, we, as engineers, know that it would be folly to set limits to the mechanical progress of the future, however strongly and justly we may hold opinions about the present state of affairs.

The separate locomotive for tramway traction has totally gone out. Sufficient power can be placed underneath the platform, on the wheels of the otherwise ordinary passenger car, not only to propel the car itself, but on occasion of heavy traffic to haul a trailer unprovided with power. Thus the gross load is considerably reduced while the paying load remains as before. Two motors regulated on the series parallel system—series for starting, parallel for straight running—are ordinarily employed. The motors may be mounted direct on the driver axles, but for ordinary tramway speeds and wheel diameter it is usually necessary, or at least preferable, to use single reduction gear. For fast-running heavy traffic, conveyed at infrequent intervals after the manner of a steam railway, the separate electric locomotive with direct-driving motors will be employed.

The pioneer City and South London uses separate locomotives, but experience and reason points to the conclusion that even on railways of this character the motor car is likely to prove victor.

On a tram line with no exceptional gradients, worked at 500 volts pressure and an average speed of eight miles per hour, the average current for a 7-ton motor car carrying 53 passengers seems to be about 10 ampères—$6\frac{3}{4}$ E.H.P. The addition of a 4-ton trailer brings the passenger accommodation up to 99 and the current to about 13 ampères—$8\frac{1}{2}$ E.H.P. During the operation of starting the current may run up to three times these values, showing the tremendous power available for starting and speeding up on an electric car as compared with the slow and painful process on a horse car. It will be noticed that electric cars are usually much heavier and have a far greater carrying capacity than horse cars, the simple reason being that wherever electric trams are installed the traffic tends to become heavier, and it pays to have plenty of accommodation during hard pressure—sudden rain, going and returning to business and work hours, etc.—rather than be forced to refuse passengers as on the old system so sadly familiar to us all. Another way of regarding the question of the amount of power required by an electric tramway is to reckon on the average ·8 Board of Trade unit per car-mile. A Board of Trade unit can be, as you know, delivered by the Corporation electric lighting stations of Bristol and Cardiff for a works' cost of about 2d. Hence it follows that the works' cost of power, corresponding with the cost of keep of horses, renewals chargeable to revenue, and wages, is about 1½d. per car-mile—the passenger capacity of the electric car-mile being about double that of the horse-car mile.

An electric power station does not differ much from an electric light station. The tram people have on the whole a very much more evenly distributed load, but the variations of load are incessant, sudden as pistol shots, and very severe. In some of the early ill-governed and overloaded stations the plant used to plunge and stagger like the engines of a light-ship in a heavy gale, or behave like Satan struggling through chaos, as, in the historic present of Milton, he "swims or sinks, or wades or creeps or flies." But these experiences are to a large extent overpast. They pointed to large margins of strength and current capacity, to high speed, or rather short-stroke engines and to governing by automatic cut-off.

I have already remarked on the folly of setting limits to future mechanical progress. The matter is recalled to my mind by an incident which occurs while I write. In search of a historical date I have just made a reference to a now somewhat old work, to which, however, Lord Kelvin, Rankine, and many other great scientific men and engineers contributed. Speaking of electro-magnetic motors as then known, the author of the article on "Electro-magnetic Machines" says: "It is magnetic attraction alone that can induce rotation or become a source of mechanical effect, so that there is in the very source of this new power a cause of feebleness over which no mechanical ingenuity can ever prevail." To-day the Baltimore and Ohio Railway Company possess numbers of electric locomotives of over 1,000 H.P. each, by which it works the Baltimore Tunnel, constructed to save the water transport they were formerly compelled to maintain across the harbour. These electric locomotives haul trains of 400 tons or more, together with the steam locomotive of, say, 100 tons, steam shut off, over the approaches and through the tunnel with its gradients, a distance of about four miles, at a speed of thirty-five miles per hour. There is but little doubt that the recent remit of the directors of the Metropolitan Railway to Sir John Barry and Mr. Preece means business, since it is backed by authority to spend £20,000 on experiments; and in more than due time we shall without doubt see the Underground worked by electric locomotives more powerful than the steam locomotives now in use on that most excellently managed line. Let it be clearly understood that I am not one of those people unfamiliar with railway working, who are pleased to opine that the steam locomotive will be immediately superseded by the electric locomotive. If time served I could show you very excellent reasons to the contrary. But in the peculiar circumstances of the Metropolitan Railway with regard to ventilation I have for twenty years advocated electric traction as the only sure remedy for the really horrible state of affairs which, having existed so long, is daily getting worse, and if not speedily amended will bring the directors of the Metropolitan Railway face to face with diversion of traffic due to the competition of other underground railways electrically worked, if indeed that has not already commenced.

Experience has shown that wherever a rapid and reliable tram service is placed at the doors of a community the facilities offered are warmly welcomed, and increasing traffics make glad not only the hearts of the promoters but those of the townspeople and of all those who are watching the working of this comparatively new factor—mechanical traction—in city life. The business man can afford to live in a district remote from the bustle and dust of the city, where flowers and trees may flourish, where wide streets and open spaces make for the preservation of the health of his wife and the upbringing of sturdy children. In this way not alone the middle class is affected—the working man has as much, if not more, to gain. River steamers are better appreciated because it becomes easy and pleasant to journey to the piers and landing stages. Likewise theatres, scientific institutions, colleges, schools, churches, increase their radii of accessibility and of usefulness. Even existing railways benefit and give benefit, inasmuch as feeders are essential, and the more efficient the feeders the better for all. Bristol has set a splendid example—Cardiff is preparing to follow. But let the Cardiff people bestir themselves—let us have no more waste of time. The present tram service of Cardiff is a disgrace; there is, in fact, no town of equal importance in the country where the service is slower, more painful to witness, inadequate and unreliable. It is unworthy—utterly unworthy—of the Welsh metropolis.

Mr. Faraday Proctor, after conveying a hearty welcome to the Institute to Bristol, said Mr. Appelbee seemed to have taken the Bristol example as his model electric lighting station. The Bristol station complied with most of his suggested requirements. It was alongside the water, it was in the middle of the area, and three-throw feed pumps which he advocated were used. Mr. Appelbee did not specifically declare which engine he preferred, but he mentioned that the Willan engine was more largely used than any other make. His (the speaker's) experience supported the favourable view of the Willan engine taken by Mr. Appelbee for lighting work. In electric light work the essential thing was to have the plant running in parallel. With a slow-speed engine driven by ropes parallel running was almost impossible. They could put the machines in parallel, but it was well-nigh impossible to run them satisfactorily. With the medium-speed engine they would run in parallel, but the result was not so good as with the Willan and the Bellis type. For a high-speed engine it was better to get a single-acting, when they had absolutely no knocking. In the Willan engines which he used there was no top brasses at all. If there was no knocking, no noise, there was practically no wear.

Mr. M. W. AISBITT proposed the health of and a vote of thanks to Mr. Appelbee for his valuable paper. He thought there was distinct disadvantage arising from the tendency of every small town being ambitious to put in and run its own electrical installation. The paper stated that in 281 towns the corporation was its own supplier of the electric light, compared with 181 towns where the work was entrusted to private firms. As a ratepayer, he should like to have seen the figures reversed. Supposing in the time of Stephenson 281 corporations had decided to run their own locomotives —what a nice mess they would have made of it!

Mr. T. A. REED seconded the vote of thanks to Mr. Appelbee. Reading the *South Wales Daily News* the other day, he was amused and somewhat indignant on reading a report of certain proceedings of the Cardiff Corporation with regard to the electric lighting station. Here the Corporation had a talented engineer, and yet they would not take his advice. In Bristol the electrical engineer got practically what he wanted, and everything worked smoothly and to the advantage of the community. But in Cardiff there was a disposition on the part of members of the Town Council not to take the advice of their electrical engineer. "What do our councillors know about electricity?" asked the speaker, and the company's unanimous reply was "Nothing."

Mr. R. WILLIAMSON proposed, Mr. J. F. WALLIKER seconded, and the PRESIDENT supported, a vote of thanks to the Bristol Dock Company, and Mr. PEARCE spoke in acknowledgment.

Mr. T. W. WAILES gave "The Bristol Electrical Tramways Company and the City Corporation Electric Lighting Supply," and Mr. CHELLEW seconded.

Responding on behalf of his company, Mr. CHALLENGER said the visitors had been able to see what electric traction could really do. They had noticed how easily the car mounted the hills. They had passed over a gradient with an average of one in sixteen, and at one point it was one in twelve; yet one car and a trailer attached, the car having upon each of its two axles a motor of 15 horse-power, had climbed the hill with 230 people aboard at the rate of five miles an hour. This year the tramways of Bristol had carried no fewer than 21,000,000 passengers, and not five persons of that number had sustained injury. On August 1 last—Bank Holiday—34,000 passengers were carried on thirty-five electric cars; and on the whole of the cars in Bristol 147,000 passengers were carried in one day, without the slightest injury to any of them. Turning to the papers, rope-driven engines, which were first erected at the Bristol tramways' power house, had been dispensed with. It had been decided to have direct-coupled engines, and also, he believed, tubular boilers. Parliamentary power had been obtained to convert the whole of the existing tramways in Bristol into electric tramways and to make considerable extensions. All would be worked by the overhead wire system.

Mr. FARADAY PROCTOR responded for the City Electric Lighting Department. He said he hoped the Cardiff Corporation would allow Mr. Appelbee to have his own way, and to adopt Bristol as his model central lighting works.

The remaining toast was that of the President, submitted by Mr. WATTS, who observed that he had had the pleasure of meeting Dr. Elliott at meetings of the South Wales Institute of Engineers, and other places, and he had always been struck with his great ability.

Received with cheers, the PRESIDENT acknowledged on behalf of the Centre the cordial welcome which had been extended to them in the ancient city of

Bristol, a city glorious with the memories of the merchant venturers, with gigantic railway enterprise, with the great Brunel.

At 9.30 p.m. the members were again on the railway speeding homeward.

GEORGE SLOGGETT,
Hon. Sec., B.C. Centre.

DISCUSSION

AT

58 ROMFORD ROAD, STRATFORD,

ON

MONDAY EVENING, FEBRUARY 27th, 1899.

CHAIRMAN:

MR. A. BOYLE (MEMBER).

THE CHAIRMAN: We have for discussion to-night a paper on "Electric Lighting Works," which was read at a previous meeting, and also a contribution on "Electric Traction" by Dr. Elliott, which quite assumes the dimensions of another paper. In addition we have a paper to be read on "Auxiliary Machinery on Board Ship," which is certainly a very important subject for marine engineers. With reference to the paper on electric lighting works, I may say that although papers on such a subject might not be considered as altogether in the ordinary run of marine engineering, yet they are extremely valuable to marine engineers, for there can be no doubt that electricity during the last twenty-five years has made enormous strides, and if the same rate of progress is maintained in the next quarter of a century it will then almost assume the importance, and perhaps the dimensions, of its elder brother, the steam engine. Even at the present time it is necessary for the marine engineer to have a considerable acquaintance with electricity, so far as electric motors and electric lighting are concerned, and as time goes on it will be absolutely essential for marine engineers to have a thorough knowledge of electricity, especially as regards the details of the various electrical motors which in the future are likely to be fitted on board ship. I think that Mr. Adamson has some remarks to read that have been contributed by Mr. Keay on the paper on electric lighting, and after that we shall be very pleased to hear the remarks which any of the gentlemen present may be disposed to offer on the subject.

The HON. SECRETARY then read the following remarks by Mr. R. D. Keay.

Mr. R. D. KEAY (Member): Mr. Appelbee's paper is an interesting one, and I think he has in an able manner accomplished the task which he set himself, namely, that of briefly sketching "some of the more prominent points which have to be taken into account in designing the mechanical portions of steam-driven electricity works, and the plant which is used in them."

It is well that a paper of this kind should be read before the members of this Institute, for there can be no greater mistake than for an engineer to confine his attention to his own special branch of engineering. It is both interesting and profitable that we should learn what is being done by those who are called upon to face problems of a somewhat different nature to those which confront the marine engineer.

There is every reason to believe that the engineer of the future will have to know a good deal about the generation and application of electric power, for its use is daily increasing.

Electricians sometimes make mistakes owing to an insufficient knowledge of mechanical engineering, but the day is not far distant when no mechanical engineer will be able to consider himself properly equipped without a thorough knowledge of electrical engineering, and it is advisable for all of us to see that we do not get behind the times.

We should therefore welcome Mr. Appelbee's paper all the more heartily, because it is on a subject which is outside the experience of most of our members.

Having recently had the opportunity of visiting several electric supply stations, it may be of interest to comment upon various interesting points which attracted my attention.

One of these points is the fact that in many cases the engineer in charge was a marine engineer.

I have nothing to say in criticism of Mr. Appelbee's paper except that it is too short, and most of us would have liked him to deal more fully with many of the points touched upon.

Boilers.—So far as boilers are concerned there seems to be a tendency to adopt water-tube boilers in preference to the marine and Lancashire types. The Babcock and Wilcox and the Hornsby are successful types of water-tube boilers, and seem to find favour in electric power stations.

The disadvantages of Lancashire boilers are (1) the space occupied. This is an important consideration where land is valuable. (2) Steam cannot be raised quickly in case of sudden demand. Against these disadvantages we have the long life of the Lancashire boiler; and where a certain number of boilers have to be kept in use during the day some of them may with advantage be of the Lancashire type.

The Halpin heat storage system is specially applicable to electric power stations, for some of the boilers may during the day pass their steam to a large tank of water, which is thus heated and used as feed-water at night time during the period of maximum load.

This system results in an economy of as much as 15 per cent. in some cases.

Engines.—Most stations adopt high-speed engines of the Bellis or Willans-Robinson types, both of which are doing good work.

The Bellis engine is more simple in construction, and is understood by any mechanic who may have to overhaul it, but the Willans-Robinson engines are usually overhauled by a special mechanic, who has had experience with this type. The system of making all parts to standard, and perfectly interchangeable, is very strictly adhered to with the Willans engine, and is very important, as new parts can be supplied from stock at a moment's notice.

In the Bellis engine, oil is pumped to all the bearings at a pressure of about twenty pounds, and the wear is so slight that in most cases the bearings will run for two years without requiring to be stripped.

This is due to the fact that there is always a film of oil between the metal surfaces. The 500 horse-power Bellis engines are generally run at about 330 revolutions per minute. For economical reasons the power is split up into various sizes of engine, the largest engines of this type used being about 1,000 horse-power. At some stations the total horse-power is as much as 10,000, including additional engines at present being supplied.

In some stations the marine type of vertical triple-expansion engine is used with good results.

In these cases the current is usually generated in a Ferranti alternator which forms a fly-wheel to the engine. Such engines are made up to 2,000 horse-power, and may run about 150 revolutions per minute.

An engine of 10,000 horse-power was designed and partially constructed for one station, but was never put to work.

Condensers.—The question of condensing is an important, and generally a difficult, one, for it is seldom that an ample supply of circulating water is available for use in injector, jet, or surface condensers. Mr. Appelbee recommends the injector condenser, and it is certainly convenient, but some form of surface condenser is better, inasmuch as the condensed steam is the most suitable feed-water obtainable.

Evaporative condensers are often adopted, and these are in various forms, but all make use of the same principle. The steam is inside the tubes, and the condensing water trickles over the tubes, which are at the same time exposed to the air, or have air blown over them by means of a fan.

A certain amount of the cooling water is evaporated, and each pound evaporated carries away about 967 units of heat from the steam, the total effect being that the condensing water lost is only about $\frac{3}{4}$ lb. per pound of steam condensed. The quantity of water circulated over the tubes is of course much larger than this, but the same water is used continuously, the only supply required being that necessary to make up the amount evaporated.

Sometimes ordinary surface condensers are used, and the circulating water instead of being sent to waste is passed over cooling towers where the above principle of cooling by evaporation is made use of, and water may thus be cooled below the atmospheric temperature, and used again in the condenser.

Some attempt has been made to use gas engines in electric power stations, but I believe the only station so worked at present is at Leyton ; so there seems little prospect of its being adopted, especially where ground is valuable, as gas plant requires more room in proportion to power generated.

There are other interesting details which might be touched upon, but my notes have already extended to too great a length.

Mr. BASIL JOY (Associate Member): I have only just had the opportunity of looking through this paper, but, as electrical apparatus is coming so much into practice in connection with marine work, it seems to me to be a matter which very much concerns marine engineers. The author of the paper seems to think that high-speed engines are the most popular for electrical supply stations; I should think, however, that an engine with a medium rate of speed would be the most popular—an engine running at about 150 revolutions. I have come across a good deal of electrical work, and the small very high-speed engines have seemed the exception rather than the rule. In the course of the remarks that have just been read mention was made of the Willans-Robinson type of engine, and Mr. Keay said that all the parts were made to standard and were interchangeable. As an illustration I may state that I saw a piston which was taken straight from the tool and put into the cylinder direct, and so well did it fit that the air in the chamber cushioned. The piston had come straight from the tool without any fitting, which gives you an idea of how perfectly the parts are made in the first instance.

Mr. C. WATSON (Graduate): I notice that in the course of his paper Mr. Appelbee makes certain remarks about difficulties in connection with condensers. Would there be any objection to using air for cooling in condensing? It might be an objection that it would take up a lot of room, but otherwise there would seem to be no difficulty in using that method.

The CHAIRMAN: That is condensing simply by the cooling action of the external air?

Mr. WATSON: Quite so.

Mr. J. G. HAWTHORN: The paper itself, to my mind, is descriptive rather than argumentative, and there is very little in it that calls for remark in the way of controversy or argument. There is a good deal of thought to be exercised as to the best type of engine for running electric lighting plant, and as to the best class of boiler for the work; but it must always be borne in mind that facilities for the rapid raising of steam are a necessity in connection with electric lighting works; in cases of fog, for instance, they have to get up steam at very short notice. That is an essential condition in laying down boilers for electric lighting. But with regard to what has been read to us to-night, I fail to see that there is a great deal of economy in utilising the boilers when the light is off for warming up the water to supply the boilers at night when the light is on. There must be a certain amount of radiation when the water is standing, and it certainly does not strike me as being a very economical arrangement.

Mr. G. HALLIDAY (Member): Mr. Hawthorn has raised a question as to the advantages of heating the water in the boilers during the daytime when the light is not in use. The system was introduced by Mr. Druit Halpin because he had not sufficient boilers to supply all the steam that was required in the evening. The work of the station became so great that he had to heat the water during the day in order to maintain a sufficient supply of steam at night. When he commenced the system he thought there would be a loss, but he was willing to pay this loss in order to secure the required quantity of steam in the evening. He instructed his assistant to find out what was the efficiency of this system. The assistant thereupon set to work to find out the number of thermal units of heat obtained by the new system as compared with the old, and he found the new system to show a gain in efficiency of 16 per cent. On being told this result, Mr. Druitt Halpin directed the assistant to go into the matter a second time, with the same result. Professor Unwin was then called to go into the matter thoroughly and see what the gain in efficiency really was. He found the gain to be 18 per cent. There is a gain, therefore, in heating the water during the daytime separately from the boilers, and then sending it into the boilers as heated water. I should have been glad if the author had enlightened us as to the economy of the boilers that have been used for electric lighting stations, also the best kinds of dynamos to use for different purposes, and compared the uses and advantages of the continuous current with those of the alternating current. Perhaps on these and some other points he may be able to supplement his paper. With regard to Professor Elliott's paper I am not prepared to speak; but on the question which has been so long agitating the minds of the members of the London County Council on the advantages and disadvantages of the trolly system as compared with that of the conduit system, he has not given us sufficient to guide us as to which system it would be best for us to adopt. In Sheffield and other places there is the trolly system in some of the most suitable streets. In other places there is the conduit system. One would have expected that Dr. Elliott, when dealing with the question, would have given us something definite. I should also have liked had he gone more into the question of motors, and it would have been a splendid opportunity for him to have introduced the question of water power as the motive power in this country. Dr. Elliott is on the Severn, with its enormous tides. Is no one to utilise the great waste power which goes through the narrow way near Newport every day? Perhaps a hint will direct Dr. Elliott's attention to the question of the utilisation of the water power of the Severn. For were one to devote a lifetime to the solution of this one question it would not be wasted. We are greatly indebted to Dr. Elliott for the paper he has given and the thoughts he has expressed on the subject.

Mr. W. McLaren (Member): I think the author has taken us through most of the troubles and difficulties that have been experienced in the construction and running of electrical works, up to the switch board. But still I fail to see why there should have been so many unfortunate failures and disappointments in designing a boiler and engine house, after the experience gained with the earlier works. If we go only so far back as 1888, what with factories, mills and exhibitions, I think the electrician has had the advantage of his less fortunate brother on land and sea in designing power stations. As this paper includes considerations in the interests of ratepayers, as well as of engineers, I hope the West Ham Corporation will profit by being surrounded with water and railways, though coals are dear, and work with a low-pressure system, even at the expense of a few stations feeding into the centre instead of a central station with a high-pressure system feeding from the centre or from one side only, with the risks to life incidental to attending and handling such plant. With regard to steam engines the author states that almost every type of steam motor has been employed for driving dynamos, and that there is still a wide difference of opinion as to the best to adopt. He then refers to the vertical Willans type as one of the most popular that has been supplied to stations; and I believe that engine builders can produce high-speed engines to govern within 5 per cent. when the whole load is suddenly thrown off. With regard to Professor Elliott's paper on the question of electric traction, I was looking the other night at the traffic passing Old Street in the City Road, and having regard to the number of horse cars now passing that spot—I counted as many as twenty within three minutes—the thought occurred to me as to where, with electric traction and the increased number of cars and the increased speed expected, the necessary accommodation was to come from. It seems that in course of time the congestion of traffic in the streets of London will become so great that it will be necessary to build another storey over London—electric tramways overhead and the ordinary horse traffic in the streets below.

The CHAIRMAN : If there are no further remarks upon this paper we will consider the discussion closed. I may just say, however, that it is very interesting to learn from the first paragraph of Dr. Elliott's remarks that so long ago as the year 1838—sixty years ago—an electric engine ran long trips on the Edinburgh and Glasgow and other Scottish railways. It is a fact that I was not aware of before. I suppose the engine was one of those electrical magnetic machines, and probably the power was supplied by a galvanic battery. The expense must have been very great, and I suppose it was the heavy cost that led to this particular engine being stopped. I think that much of the trouble which has been experienced in connection with electric lighting stations has been due to the fact that the boilers and engines were too light for their work. If any gentleman thinks of anything further that he would like to say on the subject, perhaps he will kindly send it to the Hon. Secretary in writing so that it may be embodied in the discussion. Such a course is always open to members for any paper read.

The CHAIRMAN continued : As there is time to do so, I will now ask the Hon. Secretary to read a paper on "Auxiliary Machinery," which has been already read at Cardiff by the author.

PREFACE.

CARDIFF,

January 25th, 1899.

A Meeting of the Bristol Channel Centre of the Institute of Marine Engineers was held in the University College, Cardiff, this evening, presided over by Professor A. C. ELLIOTT, D.Sc. (President of the Centre), when a paper on "Cargo Machinery" was read by Mr. EDWARD NICHOLL, R.N.R. (Member). The Discussion afterwards took place and was adjourned till next meeting.

Previous to the paper being read, Professor ELLIOTT referred to the distinguished honour which Her Majesty had conferred upon Mr. FORTESCUE FLANNERY, M.P., Ex-President of the Institute. He said he was sure they all felt gratified that the honour of knighthood had fallen upon so worthy a man, so distinguished a member of the profession of marine engineering, upon a gentleman who had the cause of the future progress of the Institute at heart, and who in his place in Parliament could no doubt further its objects.

GEO. SLOGGETT,

Hon. Local Secretary.

INSTITUTE OF MARINE ENGINEERS

INCORPORATED.

SESSION 1898-9.

President—JOHN INGLIS, ESQ., LL.D.

AUXILIARY MACHINERY ON BOARD SHIP.

BY MR. EDWARD NICHOLL, R.N.R. (*Member*).

READ AT UNIVERSITY COLLEGE, CARDIFF,

ON WEDNESDAY, JANUARY 25TH, 1899.

THE subject of this paper seems to have received very little, if any, consideration at the hands of marine engineers. Why this should be has long been a great puzzle to me, especially when we consider the time and money that has been spent in increasing the efficiency of the propelling machinery of steamships. But every suggested improvement would seem to have been either tried or approved on board ship, with the exception of winches, and the poor, much-abused donkey boiler.

It is also generally accepted as a fact that steam winches are about the most wasteful things of their kind in existence, yet so little interest seems to have been taken in their performance that I am not aware of any tests having been carried out to determine,