The Incorporated Association of Municipal and County Engineers

INTERNATIONAL ENGINEERING CONGRESS

(GLASGOW) 1901

PROCEEDINGS OF SECTION VII. (MUNICIPAL)

EDITED BY

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Honorary Secretary, Section VII.

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London:
E. & F. N. SPON, LIMITED, 125 STRAND
New York:
SPON & CHAMBERLAIN, 12 CORTLANDT STREET
1901

LONDON:
PRINTED BY WILLIAM CLOWES AND SONS, LIMITED,
GREAT WINDMILL STREET, W., AND DUKE STREET, STAMFORD STREET, S.E.

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INTERNATIONAL ENGINEERING CONGRESS

GLASGOW (SECTION VII.)

September 3, 4, 5, 6, 1901.

THE CHAIRMAN'S ADDRESS.

By E. GEORGE MAWBEY, M. Inst. C.E., President of the Incorporated Association of Municipal and County Engineers.

Gentlemen,—I am sure the Members of the Association of which I have the honour to be President, will heartily agree with me in saying that we fully appreciate the compliment paid to the Association in its being selected to take charge of the municipal section of this great International Engineering Congress, and, speaking for myself, it gives me the greatest pleasure to open the proceedings. As your Chairman, I regret that our esteemed immediate past President, Mr. Lowe, owing to the state of his health, is unable to be present, because the Congress was instituted and arranged during his term of office.

As representatives of that branch of engineering practice which is, perhaps, more closely identified than any other with the health of the people of the United Kingdom and our Colonies, it is fitting that we municipal engineers should take a duly prominent part in this International Congress at what is possibly the greatest exhibition ever held away from London in the British Isles. I may here remark that it would have been difficult, if not impossible, to have selected a more suitable site for a great exhibition, and particularly for a congress of civil and sanitary engineers, than this city, which is the commercial capital of Scotland, the Manchester or Liverpool of the north, a seat of profound learning and a veritable hive of industry. Indeed, comprehensive as the scope and character of the Exhibition is, it is doubtful whether it can convey more vividly and strikingly an adequate idea of the indomitable energy, pluck, skill and enterprise of the British race than is conveyed by the great manufacturing works of Glasgow itself, and the world-famed ship-building establishments and other gigantic centres of production on the Clyde; for a mere enumeration of the vast and varied industries so successfully carried on in this city and its environs would occupy much more time than I can devote to my brief address. You will, however, I am sure, pardon me for alluding to one typical instance of the enterprise of the citizens of Glasgow. I feel that I must take this opportunity of congratulating the Civic Fathers of the city, who have been the pioneers of British municipal tramways, upon the inception and completion of one of the most important tramway undertakings in the United Kingdom, and in these congratulations must be specially included Mr. Young, the tramways general manager, and Mr. Clark, the engineer. Even those of us who live at a remote distance from this city, have watched with the keenest interest the progress of the undertaking, and if our admiration had not been voluntary it would have been compelled by the splendid way in which really phenomenal difficulties have been overcome as they have arisen. The principal characteristic of the scheme may be said to be that it is so thoroughly up-to-date in every particular, and it is evident that neither pains nor money have been spared to ensure complete success. The equipment of the Pinkston Power Station is especially interesting and instructive. The plant includes both British and American engines of the best types produced in their respective countries, and an unique opportunity is here afforded of judging their relative merits when working under precisely identical conditions. I would strongly advise our Members to take the fullest advantage of the facilities afforded for obtaining every possible information as to this grand undertaking, and the admirable system of working and management. Proceeding to the business before this Section, I would observe that in the three papers to be read by Mr. K. F. Campbell, Mr. MacDonald and Colonel Jones, we may anticipate that the whole field of modern research and practice in bacterial and other methods of sewage purification will be covered, and that a valuable contribution will be made to our existing knowledge of this absorbing question of the day.

Then we are fortunate in having from the President of the Institution of Civil Engineers, Mr. Mansergh, a lecture on his great Birmingham Water Supply Scheme, which many of us, by his courtesy, have had the very great advantage of seeing in progress, and we look forward with interest and pleasure to further inspections as the various sections of that huge undertaking are completed. I am sure, too, that we shall gain much instruction from the paper on Municipal Sanitation, by our Vice-Chairman, Mr. Weaver. Deeply interesting, also, will be Mr. Mager's paper on Coal Mining Subsidences in Relation to Sewers, for by those subsidences the skill and ingenuity of engineers in mining districts is often taxed to the utmost. In dealing with Recent Tramways Practice, Mr. More, a gentleman of great experience in that direction, will touch upon one of the most popular topics of the day, and I can conceive of no more appropriate subject to bring to our notice at this juncture and in this city. And further, I must direct your attention to the paper by Mr. A. H. Campbell on the provision of Dwellings for the Working Classes. This paper I consider to be also a particularly appropriate one to be brought forward and discussed at Glasgow, where immense interest is being taken in the question, as evidence of which I need only point to the great conference on Cheap Dwellings which is to be held in the Council Hall of this city at the end of the present month. Just one brief observation in conclusion. There is assembled here to-day a very large and representative body of engineers, and it will naturally be expected that from such a gathering much information will emanate as to research and experience, and that some new light, at least, will be thrown on the various problems of the day coming within the scope of our deliberations. I would, therefore, appeal to you to enter with earnestness into the discussions, and to let us have the advantage of your knowledge and experience, so that the public, as well as ourselves, may derive material and lasting benefit from the part we take in this great Congress.

RESEARCHES INTO THE SYSTEM OF SEWAGE PURIFICATION AT HUDDERSFIELD BY BACTERIAL AND OTHER METHODS.

By K. F. CAMPBELL, M. Inst. C. E.

Of recent years many enticing statements have been made by eminent scientists and other investigators, showing with wonderful simplicity and thoroughness how the noxious matters in sewage can be destroyed by bacteria; great prominence being given to the salient features of the various processes, whilst the defects are either smoothed over or entirely omitted.

These statements have caused an idea to be very prevalent that the use of chemicals, in any form or quantity, is not only useless but detrimental to any subsequent bacterial treatment which the sewage may have to undergo.

Domestic sewage may be termed a waste product of nature, and is provided by nature with organisms necessary for its conversion into a harmless and even valuable liquid. However, the sewage from many of our large towns can hardly be called the work of nature, and it is not surprising that nature either fails or requires a considerable length of time in which to render harmless its noxious constituents, and it may be advantageous in many cases to aid nature by using chemicals, whereby the treatment in tanks can be considerably shortened and the sewage rendered more suitable for treatment in contact-beds.

There is no doubt that in the purification of sewage containing trade waste there are still many difficulties to be contended with, and that the forms of treatment which are at present known to be capable of purifying such liquids leave much to be desired.

In therefore bringing before you a brief description of the experiments which have been conducted at Huddersfield during the past three years, the Author does so with a hope that it will solicit a full discussion of the treatment of trade sewages, and that the experience of others will be given and compared.

The staple trade of Huddersfield is woollen, the waste from which contains fat, soaps, dyes and a variety of chemicals used chiefly in the dyeing and finishing of the goods, resulting in a highly-coloured soapy liquid. The dry weather flow of sewage contains 30 per cent. of trade waste, of which but a very small proportion is derived from other than the woollen industries.

For a number of years a portion of the sewage was purified by means of chemical precipitation and subsequent filtration through beds composed to a great extent of sand. These, however, rapidly became clogged, and although elaborate provision was made for the cleansing of the filtering material by upward washing, it became impossible to thoroughly do so unless removed from the beds, and as this would have been of frequent occurrence the process was abandoned, the cost of working being already prohibitive.

Attention was then directed to the more modern systems of sewage purification, and experiments have since been conducted with three methods, which are as follows :—

1. The treatment of the raw sewage in contact-beds.

2. The purification of the effluent produced by chemical treatment in contact-beds.

3. The treatment of the sewage in an open septic tank and contact-beds.

For the treatment of the raw sewage by contact-beds two were constructed—a coarse and a fine.

The particulars of the coarse bed were as follows :—

Superficial area	178 square yards.
Average depth	3 ft. 6 in.
Total capacity	207 cubic yards.

It was composed of clinker, varying from $\frac{5}{8}$ in. to 4 or 5 in. in size, and was well drained by means of land tiles running parallel 4 ft. 6 in. apart.

The particulars of the fine bed were :—

Superficial area	200 square yards.
Average depth	3 ft. 3 in.
Total capacity	216 cubic yards.

It was composed of clinker and constructed as follows :—

Top layer . . .	9 in. $\frac{1}{4}$-in. to $\frac{5}{8}$-in. clinker
	1 ft. 11 in. $\frac{1}{4}$-in. to $1\frac{1}{2}$-in. ,,
	7 in. rough clinker
	3 ft. 3 in. average depth

Before flowing on to the coarse bed, the sewage passed through a trough constructed of sheet zinc, having $\frac{1}{16}$-in. perforations, the object of which was to remove as completely as possible the wool fibre from the sewage. A large quantity of other matter was necessarily removed at the same time.

The sewage was distributed upon the coarse bed by means of wooden troughs, and upon the fine bed by iron troughs.

The experiment commenced on August 10, 1898, and terminated January 23, 1900.

From August 10, 1898, to September 4, the beds received one filling per day, and worked five days per week. From September 4, 1898, to the end of the trial the beds were filled twice a day on six days of the week, or a total of 12 fills per week.

The periods of rest afforded the beds were a week in January 1899, and a week in September in the same year.

The nature of the sewage dealt with varied very considerably; on many occasions liquids from certain trade processes predominated so as to be easily recognised. The separation of the various qualities of sewage is one of the disadvantages of this system. When tanks are used as a preliminary process, as in the case of chemical precipitation and the septic system, a certain amount of mixing of the various wastes takes place, especially under the latter process. This mixing ensures a more even quality of effluent, which, however, cannot take place when contact beds are preliminarily used, as the strongest and weakest qualities of sewage are dealt with separately, resulting in an effluent varying to a very great extent in quality from time to time.

When the raw sewage was highly coloured, which was often the case, the effluent from the beds was always more or less tinged, and it was very turbid when "scours" or other soapy liquors were present in the sewage.

The averages of analyses made in connection with the treatment of raw sewage by double contact were as follows :—

—	Grains per Gallon.			
	Ammonia.		Oxygen Absorption.	
	Free and Saline.	Albuminoid.	3 mins.	4 hours at 80° F.
From Aug. 23, 1898, to March 21, 1899—				
Raw sewage	·73	·437	2·36	6·96
Coarse bed effluent	·56	·155	·94	2·32
Fine bed effluent	·29	·090	·47	1·36
Purification . . . . . per cent.	61	79	80	80
From March 22, 1899, to Feb. 23, 1900—				
Raw sewage	·80	·469	2·49	7·17
Coarse bed effluent	·40	·150	1·00	2·53
Fine bed effluent	·22	·094	·50	1·50
Purification . . . . . per cent.	72	80	80	79

The capacity of the coarse bed was from time to time ascertained, with the following results :—

Date.	Times Filled.	Capacity (gallons).	Sewage Treated (gallons).	Gallons Treated per Acre per Day.	Loss of Capacity (per cent).
August 9, 1898 . .	1	19,000	..	886,764	..
March 3, 1899 . . .	317	9,000	4,438,000	420,046	52
May 31, 1899 . . .	465	7,300	5,644,200	340,704	62
July 11, 1899 . . .	535	6,100	6,113,200	284,698	67
October 17, 1899 . .	691	5,600	7,025,800	261,362	70
January 24, 1900 . .	855	4,800	8,731,400	224,033	75

In February 1900, when the coarse bed had already lost 75 per cent of its capacity, it was decided to terminate the experiment and to remove the bed, as the matter which had accumulated in it was found to be of an irreducible nature.

Analyses made of the deposit taken from various parts of the bed are given in the following table:—

Average Sample of Deposit from—	Dried at 212° F.	
	Mineral (per cent.)	Organic (per cent.)
Near troughs, from surface to 12 in. down the bed. Taken after heavy rains in February 1899 . . .	93·8	6·2
Near troughs (within 18 in.), from surface to 18 in. down the bed. Taken after dry weather, October 1899	73·5	26·5
Peeled off clinker, from 6 to 30 in. down the bed, but not within 18 in. of the troughs. October 1899 . .	64·2	35·8
Peeled off the surface of the bed, but not within 18 in. of the troughs. October 1899	44·1	55·9
Taken off clinker, within 24 in. of the bottom, when the bed was being taken out. March 1900	63·7	36·3

In March 1900, the bed was removed, and it was found that the cavities between the clinker, within a foot of the bottom, were entirely filled up with matter; above that height they were only partially filled. The matter or deposit contained in the cavities was a dark brown substance of a spongy nature, possessing an earthy smell which was not in the least disagreeable. Various kinds of animal life, such as *naiads*, *podura aquatica* and *infusoria* were observed in the deposit in large numbers, and upon placing some of the clinker, disturbing as little as possible the deposit upon it, in a wide glass cylinder, kept covered, mosses and algæ soon commenced to grow, and later on ferns, indicating a complete change of the solid matters in the sewage to a comparatively harmless and healthy substance.

It may be interesting to know that a similar substance is obtained by allowing the sludge formed by chemical precipitation to remain in lagoons, when a more or less anaerobic condition is maintained for some months, after which an aerobic action sets in, commencing at the surface and gradually extending downward, forming a dark spongy substance, containing 69 per cent. of mineral matter when dry, identical in appearance to that taken from the coarse contact-bed which had been treating crude sewage.

From the foregoing observations it is very evident that the life of a bed treating Huddersfield raw sewage would be at the maximum two years, when it would be necessary to take the material out, and to either wash or re-riddle it; also a very large area of beds would be required in order to compensate for their reduced capacity prior to their disturbance.

These two items would render the process far too costly to be adopted upon a large scale.

Simultaneously with the experimental treatment of the raw sewage in contact-beds, experiments were conducted with the treatment of the effluent produced by chemical precipitation in contact-beds.

For the precipitation of the sewage, lime and copperas is used in sufficient quantity to cause the suspended matter to coagulate and settle in ten or fifteen minutes, when poured into an ordinary drinking glass. The average amount added is 3·5 grains of lime, and 2·9 grains of copperas, per gallon.

The settling tanks, twenty-four in number, were designed for working upon the quiescent system, but owing to the limited quantity of sewage which can be dealt with, and the large amount of manual labour necessary when so doing, it was abandoned, and the precipitated sewage has for a number of years been settled on a continuous flow.

The total capacity of the tanks is 1,250,000 gallons, whilst a flow of 6,000,000 gallons is passed through them daily—a rate equalling 4·8 times their capacity per day.

The effluent from the tanks is of a reddish-brown colour, often dark owing to the dyes not being completely removed; it is turbid, containing a few grains of finely-divided suspended matter per gallon, which, however, takes a considerable time to settle. It has a slight odour, not in the least like ordinary sewage.

There are twenty-four contact-beds for the treatment of the tank effluent, but as many are identical or very similar in construction, it will be needless to trouble you with details of each.

The results obtained by No. 10 bed have been constantly recorded since its completion in July 1898.

The particulars of this bed are as follows:—

Superficial area	200 square yards.
Average depth	3 ft. 3 in.
Total capacity	216 cubic yards.

It is constructed of furnace clinker as follows :—

Top . . .	10 in.	$\frac{1}{4}$-in. to $\frac{5}{8}$-in. clinker
	2 ft. 0 in.	$\frac{1}{4}$-in. to $1\frac{1}{2}$-in. ,,
	5 in.	of rough clinker
	3 ft. 3 in.	average depth

The effluent from this, and the other beds of the same series, varies considerably ; at times it is as clear as drinking water, and at others very turbid and coloured, according to the quality of the tank effluent being dealt with. The colour imparted to the raw sewage by dyes, and which is not removed by chemical treatment, but still present in the tank effluent, is partially destroyed by the contact-beds. The percentage of colour removed is not, however, as great as the percentage purification effected as measured by the albuminoid ammonia or oxygen absorbed tests. This was also noticed when raw sewage was being treated in contact-beds.

The peculiar smell of the tank effluent already referred to is removed, and substituted by an earthy odour during the contact-bed treatment.

As a single contact of the tank effluent failed to produce on many occasions an effluent deemed of sufficient purity, it was decided to ascertain whether a second contact would effect the desired result. On account of the situation of No. 10 bed, it was impossible to construct another in close proximity, but a small one, composed of clinker taken from No. 10 bed, was constructed and kept in a shed. It was thus possible to give to a portion of the tank effluent which had received one contact in the large beds, a second one, under similar conditions regarding time of filling, resting, emptying, etc., as would exist with a large bed. The shed, whilst not increasing the temperature of the sewage, prevented it from freezing, which would have taken place had the bed been kept outside.

Three averages of analyses, representing three periods of the single contact trial, and one average of the analyses representing the whole of the double contact trial, are given in the following table :—

SINGLE CONTACT.

—	Grains per Gallon.	
	Albuminoid Ammonia.	4 hours' Oxygen Absorption Test.
From July 1898, to March 1899—		
Tank effluent	·168	2·95
Bed effluent	·088	1·51
Purification . . . . . per cent.	48	49
From March 1899, to March 1900—		
Tank effluent	·197	3·34
Bed effluent	·098	1·63
Purification . . . . . per cent.	50	51
From June 1900, to March 1901—		
Tank effluent	·186	3·21
Bed effluent	·082	1·35
Purification . . . . . per cent.	56	58

DOUBLE CONTACT.

—	Grains per Gallon.	
	Albuminoid Ammonia.	4 hours' Oxygen Absorption Test.
From July 1900, to March 1901—		
Tank effluent	·186	3·21
No. 10 bed effluent, single contact . .	·082	1·35
Small bed effluent, double contact . .	·050	·78
Purification . . . . . per cent.	73	76

Out of 151 samples of the effluent after double contact, none became putrescent after being kept in the incubator in stoppered bottles, which were completely filled, for seven days at 80° F.

No. 10 bed has been filled three times a day, and worked six days per week, with the exception of a few periods of rest, nine weeks in all, and an occasional fill or two when the tank was being sludged.

As before stated, No. 10 bed is composed of furnace clinker, most of which was obtained at the gasworks, and consists partly of coke breeze. Beds are also in operation constructed of the clinker produced by the destructors on the works. This clinker is much harder and smoother than the ordinary furnace clinker.

The purification effected by two beds, Nos. 10 and 7, the former being furnace clinker and the latter destructor clinker, are given in the following table, from which it will be seen that the oxygen absorption results are almost identical, whilst the amount of albuminoid ammonia removed is slightly greater in the case of the destructor clinker.

Average of Twelve Daily Analyses.	Ammonia.		Oxygen Absorbed.	
	Free.	Albuminoid.	3 minutes.	4 hours.
Furnace clinker and coke—				
Tank effluent	**·62**	**·154**	**1·11**	**2·68**
No. 10 bed effluent. . . .	**·34**	**·066**	**·39**	**1·13**
Purification . . . per cent.	**45**	**57**	**65**	**58**
Destructor clinker—				
Tank effluent	**·63**	**·152**	**1·21**	**2·66**
No. 7 bed effluent	**·35**	**·057**	**·41**	**1·15**
Purification . . . per cent.	**44**	**62**	**66**	**57**

With regard to the size of the material employed in the construction of contact-beds for the treatment of the tank effluent, the following has been found to be most suitable—the main portion of the bed to be composed of material which is retained on a $\frac{3}{16}$ in. mesh, and will pass through an inch mesh, with a 6 in. layer of material varying from $\frac{3}{16}$ in. to $\frac{1}{2}$ in. on the surface. For the construction of the first contact-beds a very large proportion of the pieces should be from $\frac{1}{2}$ in. to 1 in. in size, whilst for the secondary beds the bulk of the pieces should be under $\frac{1}{2}$ in.

Considering the success attending the open septic system as a preliminary process in the purification of sewage at Manchester, Leeds, and other places, it was decided to give a trial to the system at Huddersfield.

For this purpose one of the existing tanks was altered so that it could be used as an open septic tank, and two contact-beds were constructed for the purpose of purifying the septic effluent.

The capacity of the tank is 50,000 gallons, and its average depth is 5 ft. 6 in.

The sewage enters the tank about a foot below the water level, by an 8 in. pipe with a baffler placed opposite to it, and leaves by means of a slotted pipe 18 ft. long running along the end of the tank, at a similar depth to the inlet. After leaving the tank the sewage passes through a trough and over a weir, when the flow is gauged, and then to the contact-beds.

The two contact-beds are constructed on such levels as permit the contents of the first to flow by gravitation to the second.

The superficial area of each is 32 square yards.

The average depth is 3 ft. 9 in.

The total capacity of each is 40 cubic yards.

The coarse bed is composed throughout of destructor clinker, varying in size from 1 in. to about 3 in., with the exception of a layer 3 in. deep, of $\frac{3}{16}$ in. to $\frac{1}{2}$ in. clinker, extending over a third the surface of the bed. The sewage flows on to this part when the bed is being filled, which prevents a large proportion of the suspended solids from entering the body of the bed.

The fine bed is constructed as follows:—

Top layer .	6 in. of $\frac{3}{16}$th to $\frac{1}{2}$-in. clinker.
	3 ft. 3 in. of $\frac{3}{16}$th to 1-in. clinker.

The volume of sewage passed through the tank per day compared with its capacity has been as follows:—

From	July 22, 1900, to September 5 . . .	·81 of its capacity.
„	September 5, 1900, to October 3 . .	1·02 „
„	October 3, 1900, to October 11 . . .	Resting full.
„	October 11, 1900, to October 31 . .	·93 of its capacity.
„	October 31, 1900, to November 28 . .	1·00 „
„	November 28, 1900, to December 26 .	1·15 „
„	December 26, 1900, to February 20, 1901	1·30 „
„	February 20, 1901, to April 24 . . .	1·11 „
„	April 24, 1901, to May 29	·59 „

When the sewage was first run into the tank, a quantity of putrescent sludge was added, but it was not until the tank had been in operation for three weeks that a septic action was set up, and by the time it was thoroughly established cold and wet weather was experienced, causing the sludge which rose to the surface to break up and fall to the foot again, thus preventing the formation of a scum.

The septic effluent is a dark-coloured liquid, and when filtered through paper it is usually brown coloured. It has a smell very similar to that of coal tar. The amount of suspended matter present was comparatively small at the commencement of the trial, but as the septic action became more energetic, causing frequent upheavals of sludge from the foot, it increased. The average amount present during the first six weeks was 4·6 grains per gallon; during the 23rd, 24th, 25th and 26th weeks, 8·7 grains; and during the 40th, 41st, 42nd, 43rd and 44th, the last five weeks of the trial, 16·3 grains per gallon.

There is frequently present in the raw sewage an orange-coloured aniline dye, in such quantities as to colour a 24 hours' average sample. This passes through the septic tank unreduced, although the effluent is in a septic condition. Chemical treatment has little or no effect upon it, but on passing it through a contact-bed it is to some extent removed.

To ascertain whether this dye was capable of being decomposed by septic action a small quantity of sewage containing it to the extent of causing a two-inch layer to be the colour of a lemon, was mixed with 3 per cent. of septic sludge and placed in a bottle, which it completely filled. This was kept in darkness at 60° F. The bottle was inverted every day so as to cause the black sludge which settled to become distributed throughout the liquid. The result was that the colour slowly disappeared, until, on the eighth day, it was colourless.

The experiment was repeated with a sample of sewage containing a much larger proportion of the dye. The mixture did not, however, become septic before forty days, and even after ninety days some of the colour was still present.

The condition of the septic tank as regards the amount of sludge at the foot was ascertained from time to time by means of a glass rod. After the tank had been in operation eighteen weeks there was on an average 1 ft. 3 in. of sludge; after thirty weeks there was 1 ft. 7 in. of sludge; and after forty-four weeks there was 2 ft. 4 in. of sludge. The average rate of accumulation being ·64 of an inch per week.

The amount of solid matter both in solution and suspension was regularly determined in the raw sewage and septic effluent, from the results of which it has been calculated that there was 13·3 tons less of matter in suspension and 1·8 ton less of matter in solution in the septic effluent than in the raw sewage. However, when the tank was emptied, only 9·4 tons of sludge (calculated dry) was found to be present, 38 per cent. having been disposed of by septic action.

It cannot be expected that the septic process itself should purify the sewage to any great extent, the action being chiefly to break down the more complex bodies; therefore it is to the contact-beds subsequently used that we must look for a reduction of the impurities. The two beds used for this purpose, which have already been described, have never failed to effect a certain amount of purification, which, although more than necessary at times, is insufficient when the sewage is of a strong character as it is during dry weather.

The final effluent is usually slightly turbid and often has a brown tinge. It has an earthy smell, but when kept in the incubator for seven days at 80° F., 80 per cent. of the samples become more or less putrescent.

The beds were filled three times a day until April, after which they were only filled twice a day. They received one complete day's rest per week, and others, amounting to fourteen days.

The averages of analyses made during three months, when the beds were being filled three times a day, are as follows :—

—	Grains per Gallon.	
	Albuminoid Ammonia.	4 hours' Oxygen Absorption Test.
January, February and March, 1901. Beds filled three times a day—		
Raw sewage	·396	6·90
Septic effluent	·248	4·13
After first contact	·121	2·12
After second contact	·079	1·19
Purification . . . per cent.	80	83

The averages of analyses made during a month, when the beds were filled twice a day, are as follows:—

—	Grains per Gallon.	
	Albuminoid Ammonia.	4 hours' Oxygen Absorption Test.
April 10 to May 8, 1901. Beds filled twice a day.		
Raw sewage	·474	7·52
Septic effluent	·319	5·02
After first contact	·143	2·10
After second contact	·100	1·20
Purification . . . . . per cent.	79	84

The accumulation of irreducible matter in the contact-beds appears to be the greatest difficulty to be contended with in the purification of the sewage.

Even after septic or chemical treatment, there is a certain amount of suspended matter which is more or less of a permanent nature.

After chemical precipitation the amount present in the tank effluent depends upon the efficiency of the chemicals, the construction of the tank and the rate of flow. The quantity varies from ·5 to 7 grains per gallon, of which about one-fourth is mineral.

Under suitable conditions the average amount should not exceed 3 grains per gallon, when using a moderate quantity of chemicals, and every endeavour should be made to retain in the tanks as much of the suspended matter as possible, as experience shows that it is only partly reducible by bacteria in the beds.

The sewage or tank effluent may also contain matter in solution which is deposited upon the material of the beds by contact.

The amount of suspended matter in the septic effluent is considerable, and very different in appearance to that present in the effluents produced by chemical precipitation or subsidence in tanks alone, the former being black and putrescent, whilst the latter is brown and in a non-putrescent condition. The suspended matter present in the septic effluent varies in quantity from 3 to 20 grains per gallon, the average amount being 9 grains per gallon, of which 38 per cent. is mineral.

Upon examination, samples of deposit taken from beds treating the effluent from chemical precipitation, were found to contain about one part of organic matter for every two parts of mineral, and about 80 per cent. of water. Thus the deposit consists approximately of 79 per cent. water, 14 per cent. mineral matter, and 7 per cent. organic matter. A deposit of 7 grains will therefore be formed for every grain of mineral matter which the bed retains, and if this quantity be from one gallon of sewage, it will form in the course of a year, assuming the bed to be filled three times a day, six days per week, and fifty weeks per year, a deposit equal in bulk to 7·2 per cent. of its liquid capacity; or, in other words, the retention from each gallon of sewage of one grain of mineral matter and half a grain of permanent organic matter, will occasion a loss of 7·2 per cent. of the liquid capacity of a bed in one year. It is therefore very evident that the amount of matter in suspension in the sewage or tank effluent, prior to contact-bed treatment, is of great importance where a sewage similar to that of Huddersfield is being dealt with, and that the effluent from chemical precipitation is much superior in this respect to that obtained from a septic process. At the same time it must be admitted that whatever process is adopted a material reduction in the capacity of the beds will in course of time take place—much more rapidly in the case of the septic than of the chemical treatment. In order to reduce this difficulty as much as possible the Author is of opinion that by having the surface of the beds composed of fine material, say about $\frac{3}{16}$ in., it will be found that a very large proportion of the suspended matter is retained, and by restricting the use of troughs those portions upon which the sewage flows will clog and will require renewing from time to time, thus preventing to some extent the accumulation of irreducible matter in the main portion of the bed, thereby confining the silting-up process to a comparatively small area of the filter.

The following table shows the loss of capacity of various beds at Huddersfield, and also the period they have been in operation:—

——	Initial Capacity (gallons).	Latest Capacity (gallons).	Loss of Capacity (per cent).	Period (weeks).
Rough contact-bed, treating crude sewage	19,000	4,800	75	76
No. 7 bed, treating chemically treated sewage	19,230	11,425	41	110
No. 10 bed, ditto	19,940	9,763	51	142
No. 12 bed, ditto	19,200	8,829	54	134
No. 15 bed, ditto	18,072	11,425	37	68
Rough contact-bed, treating septic effluent	3,990	2,030	49	34

After the above observations were taken the rough contact-bed treating septic effluent was allowed to rest one month, during which its capacity increased to 2560 gallons (36 per cent. of original); after five days working and the tenth filling the capacity decreased to 2220 gallons (45 per cent. of original); and after a fortnight to 2130 gallons (47 per cent. of the original capacity).

The Author, after three years' careful investigation of the subject, has arrived at the following conclusions:—

1. That by no process can the formation of sludge be obviated.

2. When the crude sewage is treated in contact-beds the rapid accumulation of matter in the beds renders the process impracticable.

3. That by the use of a small quantity of lime and copperas, followed by contact-bed treatment, a satisfactory effluent can be produced.

4. That the contact-beds used for the purification of the effluent after chemical precipitation will not retain their capacity indefinitely, and that in the course of a number of years it will be reduced to such an extent as to render necessary the washing or riddling of the material.

5. That by the open septic process about 40 per cent. of the sludge is destroyed.

6. The septic effluent is not as amenable to subsequent contact-bed treatment as the effluent from chemical precipitation.

7. The capacity of the beds treating the septic effluent decreases more rapidly than that of the beds treating the

effluent after chemical precipitation, owing to the excessive amount of suspended matter in the septic effluent.

8. The septic effluent after double contact is frequently unsatisfactory.

In conclusion, the Author trusts that the information contained in the paper submitted may be of interest to the Members of the Association, and if the results obtained and the reasons advanced differ from the experience of others who have made a special study of the question, it only tends to show that the sewage problem is one which, even to-day, requires further investigation on the part of the engineer and chemist before the hidden mysteries in connection with it are properly solved and accepted in practice.

SEWAGE TREATMENT.

By Lieut.-Colonel A. S. JONES, V.C., Assoc. M. Inst. C.E.

"*Science with Practice.*"

Chemistry and electricity have introduced such marvellous improvements in arts and manufactures of all kinds that one cannot be surprised to find Town and District Councils looking and longing for a short and easy way out of their sewage difficulties to arise from applied science; and during the last thirty years there has been no lack of science-mongers and enthusiasts to trade upon the demand, as the priests are never wanting where believers abound.

Chemistry has been first, and for twelve or fifteen years was foremost in the field, because its votaries were unscientific or astute enough, in their demonstrations, to include natural subsidence (by gravitation of the heavier suspended matter in town sewage) under the chemical term precipitation, which *true* science should reserve for the precipitate thrown down out of solution by the added chemical agent alone.

Then while "precipitation" was the popular idea for sewage treatment, electricity came upon the scene, and Members of our Association will remember the hopeful enthusiasm with which the usual experimental bottles of sewage effluent and precipitate were produced to illustrate Mr. Webster's paper on the change which could be produced by passing an electric current through a tankful of sewage.

The late Lord Bramwell's Royal Commission on Metropolitan Sewage Discharge produced most valuable Blue-books of report and evidence which crystallised the floating knowledge of experts on two very important points, viz.:

(*a*) The above noted distinctions between "deposition" and "precipitation";

(*b*) The adoption, as far as possible, of the principle of separation in works of sewerage and drainage.

But it led to a still more important advance of theory and practice when it compelled the Metropolitan Board of Works to take action as regards "*a preliminary and temporary* measure by which much of the existing evil will be abated" at Barking and Crossness.

That action took the form of instructions to Messrs. Dibdin and Dupré to experiment with samples of London sewage, and those chemists at first dealt with deodorants like permanganate, and minute doses of lime and iron, but from the first they must have been conversant with Schlessing and Hirst's nitrifying organism, then recently introduced to English readers by Warington, of Rothamsted, and after a few years they became bold enough to announce that antiseptic treatment by lime and other agents, on which "precipitationists" and "sterilizers" had always pinned their faith, was a mistake.

Mr. Dibdin asserted in 1887 that, instead of attempting to arrest decay of waste organic matter, we ought to further and expedite that natural process, and the truth of his revolutionary doctrine has been fully established.

His friend Dr. Dupré well knew that the old-fashioned application of sewage to land as manure affords the most perfect translation of that theory into practice, and that the biological discovery—interesting as it is—has not introduced any new condition of efficiency in the process known and still observed in sewage farming for generations.

But the Metropolitan Board of Works demanded a more sensational result of their costly experiments, and Mr. Dibdin became somewhat too sanguine about the capability of coke filter beds in dealing with a round million gallons per diem of town sewage on one acre.

Coke filters had been tried again and again, and always disappointed people by rapidly becoming choked; but on the other hand, the late civil engineer, J. Bailey Denton, had demonstrated the principle of intermittent downward filtration by draining twenty acres of gravel at Merthyr-Tydvil to deal successfully with about a million gallons a day, and the greater porosity of material adopted by Mr. Dibdin would, of course, augment the efficacy of the essential principle of aëration in coke beds.

The theory of a feeding organism gave rise to the idea that two hours should be allowed for each meal, and hence Mr. Dibdin introduced a valve on the drainage outlet; but that is still a detail of doubtful value to distinguish his filter beds from those of Bailey Denton.

But experiments with sprinklers, and more recently Mr. Stoddart's patent distributor, indicate a more distinct advance still on the old line of aëration, and it is evident all success depends upon care in manipulation of experiments.

The action of Mr. Dibdin's effluent valve in the emptying of the coke bed is simpler, and perhaps draws air more completely into its pores on issue of the water, which is the great desideratum.

In rapid movement of fluid through the pores of coke there must, however, arise denudation of soft material to fill crevices lower down the bed, and consequent loss of capacity from that source alone, independently of any mineral or solid matter introduced with the sewage.

The fact that an acre of coke breeze was laid over a stratum of agricultural drain pipes at Barking, to prove Mr. Dibdin's formula "one acre to one million gallons per diem," at once made sanitary authorities throughout the country impatient to try what was supposed to be a new remedy for an old complaint, as the cure was heralded by proclamation of most interesting microscopic discovery.

Mr. Scott-Moncrieff and Mr. Cameron, C.E., must not be omitted from this rapid survey of recent experiments in sewage treatment, for both have drawn attention to the work of disintegration and solution of a certain portion of the organic matter suspended in fresh sewage, which is accomplished by anaerobic bacteria in a cesspool, in contradistinction to the nitrification by aerobes acting in land or its equivalent, under-drained coke, etc.

There can be no doubt that both anaerobe and aerobe must and will have their way sooner or later with all sewage, and that the former is associated with the noxious smells of putrefaction.

Mr. Cameron conceived the idea that the retention of the gases of putrefaction in a confined space over the sewage promotes the action of the anaerobes, and built his Exeter septic tank much after the fashion of many unventilated old cesspools; but in each of the experimental stations, Manchester, Leicester, Leeds, and Lawrence, Massachusetts, there has been found no difference between the effluent from a septic tank on the Exeter model and that from similar sewage passed through an open tank.

At the time of preparing this paper we are awaiting the report of Lord Iddesleigh's Royal Commission, and the writer has no means of knowing, nor desire to prophesy what evidence or opinion will be put forth by that authority on the whole subject, but he anticipates endorsement of his frequently expressed remonstrance against the unnecessary expense of arching over sewage tanks, which can be kept in a much more wholesome and cleanly state when open to light and air.

Mr. Scott-Moncrieff has gone further than any other experimenter in following out the bacterial theory at Ashtead and Caterham, combining the septic tank with subsequent contact beds process like others, but subdividing the latter or aerobic element into a tier of no less than nine trays, whereby the drip from each tray drops for a few inches through an air space on to the next lower tray, his theory being that aerobic bacteria may sort themselves out according to the quality of the food dripping upon each tray, the coarsest feeding microbes inhabiting the highest tray in the tier and those of most delicate appetite enjoying more attenuated meals in the lowest or ninth tray.

Like Mr. Stoddart and others, he has occupied himself much in designing apparatus for distributing the liquid so as to fall like a shower of raindrops on the filtering surfaces, and Mr. Scott-Moncrieff appears to favour tipping vessels for this purpose; but it is a condition essential to "continuous" as opposed to "intermittent" filtration, and very difficult of fulfilment even on a small scale experiment, with a rate of sewage flow, as at Caterham, of 20,000 gallons a day, and with absence of suspended matter in the liquid treated.

It may here be stated, as an instance of common failure in sewage works arising from their designer's pre-occupation, with the requisite and consequent forgetfulness of other equally important considerations, that the Author's attention was recently called to a great nuisance, after only six months' working, with the sewage of a population of not more than 1000 persons supposed to be provided for on the most modern and elaborate scale of the bacterial system up to date.

He there found the septic tank effluent dripping not on to a moistened surface of contact-bed, but into some inches in depth of stagnant liquid overlying (with a water seal) a carefully prepared and under-drained bed of broken coal, evidently intended to act as a continuous filter, but in practice requiring a considerable "head" before its effluent could pass away as fast as the sewage entered.

The Author's experience all points to the supreme importance of studying local conditions, from the very first inception of plans of works in each particular case, to their completion with the best available materials.

And the patent fact remains that probably after construction of the best works a sanitary authority will take no further interest in its sewage, and will employ careless ignorant work-people at inadequate wages to carry on the hourly varying labour, on efficient performance of which success depends.

It may seem pedantic to complain of the frailties of human nature as responsible for so many failures in sewage disposal, and that engineers should introduce automatic machinery, or lay down clear instructions for management of the works they have designed and constructed, so as to obviate the consequences of neglect.

Mr. Cameron and others have taken the former course, but it has its disadvantages, and is regarded as unreliable by many practical managers, while the alternative of a code of rules has many exceptions, and can, at any time, be tampered with to meet the views of economically minded ratepayers.

Mr. Dibdin has truly said that the coke beds should be attended by skilled labour "like any other delicate piece of machinery"; but he had hardly turned his back on the first experimental ones erected at Leeds before the local Committee upset their trial by passing *unscreened* sewage to the *coarse* coke bed which Mr. Dibdin's own instructions had led the Committee to believe was sufficient protection for the *fine* coke bed which was to turn out a pure effluent from "the crude sewage" applied to the coarse one.

Regard to truth has often obliged the Author to take public notice of this important question of "crude sewage," "screens," "grit chambers," etc., which is often passed lightly over as concerning trifling though inconvenient details of universal practice.

When comparative analyses of crude sewage are produced experts understand well enough that suspended matter is easily eliminated by filter papers in the laboratory, and that it is difficult to effect an equivalent separation of suspended matter in the case of a stream of town sewage; but the average town councillor hardly realises the difference when he is told that a "coarse contact bed" takes "the crude sewage," and that not even a screen is required if a septic tank be employed to break up solid matter and leave no sludge.

The only honest course is to look the difficulties of each place fairly in the face, and provide screens, grit-chambers, tanks and necessary attendance for removing rags, etc., and sludge, as a preliminary process of more or less importance according to local conditions *before* aerobic purification is attempted or preached about.

This course was adopted by the civil engineer associated with Mr. Dibdin at Barking, where an elaborate system of screens and destructors (in which filth raked from the former has been burnt) has had a great deal more effect, in rendering the foreshore and water of the Thames of late years more endurable, than the more expensive chemical precipitation and sea transport of sludge.

It has, however, been deemed more politic and convenient to exalt the latter process, together with *experimental* work on coke contact-beds, as if that formed the sole cause of improvement.

If we recollect that the real practical object of sewage treatment is the improvement of our rivers, it must evidently be a mistake to concentrate the attention of sanitary authorities upon the provision of "contact-beds"—interesting as their action may be—and leave those bodies to wake up at some later period to the fact that such delicate machines may be ruined by any neglect of precautions to ensure their only having properly prepared sewage in definite quantity to deal with.

Disappointment when an authority finds itself deceived by "no more sewage sludge" advertisements, must tend to set back the tide in favour of sanitation, and the prospect of such a result has made the Local Government Board rightly cautious about sanctioning contact-bed and septic-tank schemes on any large scale.

So much was made of Professor Sims Woodhead's warm and early support of coke beds, that the Author feels justified in drawing particular attention to his paper read at a conference of engineers at Westminster, in which that gentleman at a later date was careful to define the only kind of crude sewage which ought to be admitted to a coke bed by a description which does not at all accord with the practical man's experience of crude sewage.

And, in spite of all the screens, grit-chambers, and care with which all the experimental contact-beds have been nursed, their progressive loss of capacity has always been manifest.

Take the Report of Committee on the Leeds experiments, for instance, wherein we find a very instructive "Table showing the Variations in Capacity of Contact Beds," from which the following examples are culled, viz.:—

Extract from "City of Leeds Report on Sewage Disposal, 1900":—

TABLE SHOWING THE VARIATIONS IN CAPACITY OF CONTACT BEDS.

	No. 1 Rough Contact Bed.		No. 3 Rough Contact Bed.		No. 5 Rough Contact Bed.		No. 7 Single Contact Bed.		No. 8 Single Contact Bed.	
	Dates	Gallons	Dates	Gallons	Dates	Gallons	Dates	Gallons	Dates	Gallons
Original water capacity after putting in the coke. . .	1897 October 1 .	83,300	1898 Nov. 21 . .	51,800	1899 February 28	53,100	1899 March 24 .	55,700	1899 March 23 .	29,500
After experiment. .	1899 May 6 . .	22,700	1900 March 10 .	14,700	1900 June 1 . .	13,200	October 20 .	21,600	1900 June 1 . .	9,800
Duration of each of above experiments and loss in gallons	19 months .	60,600	15½ months.	37,100	15 months .	39,900	7 months .	34,100	14 months .	19,700
Loss in percentage of original capacity .	= 73 %		= 71 %		= 75 %		= 61 %		= 67 %	

N.B.—The average duration of the above experiments was 14 months, and average loss of capacity about 70 % of original water capacity in that period.—A. S. J.

With such evidence before it of the clogging of contact-beds, the Leeds Committee could come to no other conclusion than the following, stated in their own words :—

"The real difficulty with contact-beds is to maintain capacity. No doubt the loss of capacity is due partly to degradation and consolidation of the material of the beds; but even if material can be found of even size and not liable to break up, and even if the bulk of solids in suspension is first settled, the choking up of the beds would be likely to arise sooner or later. The hope that accumulations would be dissolved by rest has not been fulfilled at Leeds."

The Leeds Committee then began experiments with contact-beds composed of more durable material, which could be washed out by hose with town water, and coarse enough to pass some suspended matter for subsequent settlement, while bacterial action remains to deal with so much of the organic matter as it can seize upon in the contact-beds during passage of sewage in the intervals between successive purging with clean water; and the report expresses a hope that storm-water may possibly be enlisted hereafter as a more economical purge than clean water.

But such storm-water would have to be purified at great cost, and time will be lost in the production of a fresh lot of microbes in the bed after each tribe has been washed away in succession with the clogging matter.

The Author is inclined to think that this new idea of washing will not come to much, and that it will pay better to carry out all possible clarifying work by screens, grit-chambers and tanks *before* rather than *after* passage through the contact-beds, and to break up and replace all material in the latter when they become clogged, providing sufficient relays of such beds to carry out that measure in regular succession, as is done with the sand-filter at waterworks.

The Author of this paper would, however, suggest an alternative mode of renewing the material of contact-beds which might answer well in places where coke is cheap, and could be used as fuel in destructor furnaces to raise steam for electric light and power as soon as it had become clogged in its bacterial service.

With a well-arranged system of tramways and steam power, the emptying and refilling of a series of coarse contact-beds might be carried on in regular succession, wherein one bed of the series should become the fuel-expense store of the works, and another be in process of refilling while the rest of the series were acting as contact-beds for any average period found best for efficiency.

And with such a plan less care would be required in screening, as every part of the organic matter not dealt with by the bacteria would be destroyed in the most effectual way by fire.

After this summary of sewage treatment under local difficulties, which call for great concentration of the bacterial energy, it is time to revert to the enquiry how the same energy has been used, and is still most extensively employed by intermittent downward filtration, or broad irrigation, in sewage farming.

Thirty years ago agriculture was in a prosperous condition—very different from its depression of late seasons, and hopes then justified have been grievously disappointed all over the kingdom. Therefore, we cannot be surprised that the high expectations founded on manurial value of sewage have also collapsed; but it is not necessary to discard the best remedy for a great sanitary evil because it costs more than its original too sanguine advocates anticipated; and in this case the evidence of efficiency in the remedy has never been wanting, and has accumulated from year to year in the following instances, viz.—

1. *Berlin*, with some 20,000 acres under sewage, and its convalescent homes in close proximity thereon.

2. *Paris*, where chemical precipitation gave way, in 1872, to single irrigation at Guennivilliers, and under the fostering care of the late M. Durand Claye, Ingénieur en chef des Ponts et Chaussées, the system has been extended at Achères and other places on the left bank of the river Seine for a general systematic distribution of all the sewage of Paris to private cultivators, in much the same way as irrigation water is distributed among the ryots of India and the Egyptian fellaheen.

3. Take the case of Birmingham, Nottingham and other large cities where the practical work of sewage disposal on land has been carried on from day to day for many years, and note that our Local Government Board, with all the data before them, still regard land as the safest destination of sewage which cannot be discharged directly into the sea.

The land possesses this advantage over any other form of contact bed, that—even if at first only sand—it is naturally covered with a surface layer of mould and humus far superior to any artificial screens or settling tanks as a means of protecting its pores.

Consequently, there is no clogging or falling off of *water capacity* if the surface be cultivated, and much of that which clogs the artificial bed is annually removed from the natural one as a crop of vegetation.

The Author had once nineteen years' such experience with six or eight inches of good loam resting on sand and gravel, the perfection of land for sewage purposes—like that of the Nottingham Sewage Farm—and of late years it has been his lot to work with barren sand, so he can write feelingly on this point.

After five years' good cultivation, with plenty of farmyard manure, sewage and lime, both effluent and crops have improved, but experience on that farm affords ample reason for discarding the popular delusion that a sandy soil is the best for sewage purposes.

That error was adopted by a press writer in an article on the Camp Farm, Aldershot, in *Engineering*, 30th November, 1900, but nevertheless we may cite some of his views in describing "an excellent object-lesson to all who desire to find the truth on the subject of sewage farming" as follows :—

"The Aldershot Camp Farm began operations in 1865, and for more than fourteen years it satisfied the military authorities and the neighbours. Then it gradually declined until it became a by-word and a loathing to the district, and a menace to the public health: finally to be again raised to even a better sanitary condition than at first, and to be an example of all that such an institution may and should be. At different times in its history it has furnished evidence of exactly opposite kinds. Formerly and recently, the advocate of land treatment could point to Aldershot as incontrovertible evidence in favour of his ideas. Between these two periods his opponent could truthfully describe the place as a putrefying quagmire. Yet during the three periods the land remained the same; the sewage was of the same quality, and practically of the same amount, and, generally, there was no change of conditions, except in one respect—the management. Herein lay the difference, and if those who go to inspect sewage farms would pay more attention to learning the habits and objects of those in charge of them, they would often gain more information than can be gathered from walking over the fields and looking at the ditches. There are three purposes which sewage farms are made to serve: (1) to purify sewage; (2) to grow crops; and (3) to provide comfortable berths for those employed on them. Now, it is only when the second is given a very subsidiary place and the third no place at all that success is attained. The great point is to get a pure effluent—that is the product of the farm; the crops are a by-product, while the ease and comfort of the manager can only be compared to poisonous weeds, which spoil everything on the place. What would be said of the manager of a gasworks who lowered the illuminating power of the gas in order that he might get more tar and ammonia? Yet to do so would be no more unreasonable than to degrade the quality of an effluent in order to get a bigger crop of cabbages. Greed and incompetence have been the two evils that have ruined sewage farming, and it is only when the reins are in the hands of strong and capable men who can defy economical temptations, either from within or from boards and committees, that it has a fair chance. . . .

"The Aldershot Camp Farm has been converted by intelligent treatment from a nuisance and a continual menace to health, into the model establishment in which all the operations go on in a regular and orderly manner, and in which waste animal products are broken up by the kindly operations of Nature into their original innocuous elements, and many of them are utilised as plant food to re-enter the cycle of supporting first the lower creation and then man, and finally returning to the farm for a second conversion. All this is effected without annoyance to the neighbourhood. We do not say there is no smell, but there is none that the ordinary dweller in the country would raise any objection to."

Mr. Eardley Bailey Denton, C.E., commissioned by the *British Medical Journal*, soon after the improvement of the Camp Farm commenced, reported in that newspaper of 1st May, 1897, as follows: "Whereas the condition of the farm two years ago was repulsive, it to-day presents a tidy and businesslike appearance, etc.," and from the absence of any subsequent allusion to the Camp Farm it may be concluded that the *British Medical Journal* is content with the action of His Majesty's

War Department in regard to a nuisance prominently brought forward by the Medical Officer of Health for Survey and others in its columns of 1894–5.

The Public Health Engineer of 11th November, 1899, gives the following concise account of the working of a sewage farm which has been the subject of much discussion in Parliament and the press:—

"The sewage flows to the farm in covered drains by gravitation only. It is drained from the camp only, the surface and storm water being drained by separate channels into a brook. The population varies from 20,000 to 25,000, and the average daily volume of sewage is one million gallons. The sewage reaches the farm by four different outfalls. It is dealt with in precipitation tanks of special construction. The sewage passes first into a grit chamber, whence it is conducted in an open channel to an iron strainer, where the solids are arrested; these are removed and treated with the sludge of the depository tanks. These tanks are made in duplicate, are placed side by side, and used alternately; that is to say, when one is full the other is put into use. They are in cement, and resemble long slipper baths, the bottom of which is an inclined plane which rises gradually to within about two inches of the level of the extreme end of the tank. While having a distinct slope from one end of the tank to the other, the bottom or bed of the tank has also a scarcely perceptible gradient from one side of the tank to the other. Near the outlet a straining board is stretched across the tank, dipping a little into the sewage, and retaining any scum on its surface. The sewage then flows in a very thin stream over a broad weir into the primary distributing channel, and is already very clear. No chemicals are used, because there is no need for them, the sewage being purely what is called domestic sewage, and containing no trade refuse; in this respect it is similar to the sewage of Hampton-on-Thames. When I visited the farm it was a warm muggy October day, but there was absolutely no odour to be detected anywhere. Dr. Andrews in his report says: 'I stood by the side of the tanks, with a heap of solid matter which had been strained off from the sewage in the immediate vicinity, and yet I could detect no offensive smell whatever.'

"The sludge from the tanks is removed to the land, to place with the solid matter strained off from the sewage; it is mixed with the farmyard manure, stacked in large heaps, and dug into the soil when required.

"The clarified sewage from the tanks is conducted by open channels, dug in the ground at slight intervals all over the farm. The channels are carefully continued so that the sewage is equally distributed over the land. Once the sewage has left the tanks, it is never allowed to remain stationary, or get stagnant, but is kept perpetually moving. Attendants are kept on the farm, they live in small cottages round it, whose duty it is to see that channels do not get choked up, and to keep the sewage moving. The land is levelled and under-drained so that no ponding of stagnant sewage can take place. The under-draining has been carried out with ordinary agricultural pipes laid thirty-three feet apart at a depth varying from three to four feet. From these drains the effluent sewage is collected into larger and larger channels to a main effluent which is provided with an inspection chamber of luxurious workmanship, the only extravagance on the farm. The effluent is clear, and is regarded by the chemist of the Thames Conservancy Board, as we have seen, as not a bad one.* Dr. Andrews in his report says that the farm appeared to him to be excellently managed, and 'as free from objectionable features as any sewage farm can be.' He adds: 'I could detect no nuisance at the time of my visit. I cannot state from my own observations that this is always the case; on this point I take the testimony of those on the spot. In particular, I questioned Surgeon-General O'Dwyer as to whether any nuisance now arises. He has not been by any means a warm advocate of the sewage farm in the past, but he was very emphatic in his testimony to the great change that has taken place in it during recent years; he told me that it had improved from day to day under Colonel Jones's management.'

"It is rather interesting to note that the hostility of Surgeon-General O'Dwyer was due to the fact that the sewage farm is in close proximity to the Connaught Hospital, and that owing to this fact the very closest watch has been kept over the farm, but that no grounds for complaint have so far been found. This in itself is eloquent testimony.

"Some time ago the Aldershot Urban District Council approached the camp authorities with a view to taking over the

* Dr. Andrews, of St. Bartholomew's Hospital, London, was appointed Referee on questions in the House of Commons on the Camp Farm.

sewage of the camp, the camp to be rated in the ordinary way. I understand, however, that the camp authorities are so well satisfied with the farm that they do not see any advantage in accepting the offer."

The above quotations from the professional press have failed to elicit challenge or criticism, and may therefore be relied upon, but the Author has still more confidence in appealing to the impressions recorded below by Mr. George W. Disney, Assoc. M. Inst. C.E., of the Public Works Department of India, because they emanate from a mind coming fresh to the subject in his mature study of the latest data of sewage treatment during a year's leave in Europe.

Mr. Disney writes as follows: "I had an opportunity of inspecting the Camp Farm at Aldershot and a detached portion thereof at Sandhurst (the former at midsummer and the latter at the end of February 1901, after heavy rain), and was much struck by the effective manner in which the sewage was dealt with there. The comparative absence of disagreeable smell at both farms was remarkable, and is due, I believe, to accurate levelling of the carriers, whereby the sewage is kept in motion until distribution on the land, where it is rapidly absorbed; the farms are bright and clean in appearance, and rank vegetation is not allowed to grow."

Civil engineers could hardly visit Glasgow without taking a great interest in the sewerage and sewage disposal of this great city, and it is a source of satisfaction to know that the able city engineer, Mr. MacDonald, has been prevailed upon to read a paper on that subject at this Conference.

It is almost a truism to say that in the matter of sewage disposal each locality requires special plans and treatment, and the Author of this paper only pretends to put forward a few general conclusions from the data and arguments above stated, viz.:—

1. In works of sewerage, limit and regulate, as far as possible, volume of sewage by excluding sub-soil and clean surface water.

2. Interpose a narrow deep catch-pit* or grit-chamber at

* Of course the sand catch-pit and depositing tank referred to in conclusions 2, 3 and 4 above must be built in *duplicate* with penstocks on their inlet from sewer, to provide for one of each pair being at work while the other is being emptied, of sand and gravel or sludge respectively, and the catch-pit is made "narrow" as compared with the depositing tank, in order to preserve a good current and carry on to the latter all solids from the sewer *except heavy mineral matter.*

some convenient spot for taking *clean heavy* matter out of sewer, and then an iron screen ($\frac{5}{8}$-inch opening between bars) before the sewer discharges into *the deepest part* of tank large enough to hold two or more hours' flow.

3. The tank outlet should be over a level weir 1 inch below level of invert of sewer mouth, and as long as convenient; the floor of tank should slope up to this weir from deepest part under inlet of sewer.

4. Such a tank will be quite inoffensive for fifteen or twenty days, and be then nearly full of sludge, to be run off, if level permits, or pumped out. *Or* it can be left to act as a "septic tank" for six months or more, if it is desired to encourage anaerobic action, with its advantage of less sludge and drawback in offensive smell.

5. There is no practical difference, as regards the subsequent aerobic process, between the tank effluents resulting from the clean and the dirty alternative modes of working the depositing tank described in the last conclusion (4).

6. The essential point in the aerobic process, whether in land or "contact-bed," is *sufficient* aëration (excess, as by blowing, has no result commensurate with cost of its introduction), and it can be attained by intermittence of sewage and rest, or by continuous passage of sewage through a contact-bed *kept always just moist in all its atoms* by rain-like dropping on the surface so carefully adjusted as to moisten all parts, and not to form a water seal in any part of the bed. Intermittence is easily arranged on any scale of working, and continuous filtration on the contrary is difficult even for a few thousand gallons a day.

7. A low estimate for the construction of contact-bed may be taken as £5000 * per acre, but 131 acres of land may often be purchased for that sum (at £38 per acre), and we know that area of land, at Aldershot, to have dealt with about one million gallons of sewage a day for nearly forty years, and to be more efficient than ever; while Mr. Dibdin's formula—"one acre of contact-bed to one million gallons a day" has been cut down by most of his disciples to 500,000 or 250,000 gallons, and we have yet to learn what the fate of such bed will be ten years hence.

The heavy first outlay of capital for land purchase often

* Such beds at Salford and Birmingham cost £10,000 and upwards per acre.

deters councils from a freehold investment which must be of great value to a future generation, and leads them into hand-to-mouth expedients which will leave little or no asset when the sewage problem has at last to be faced in real earnest.

P.S.—Since the above was written, the Interim Report of Lord Iddesleigh's Royal Commission has been published, and the Author cannot send his paper to press without adding an expression of his satisfaction with the conclusions put forth by that authority.

Land therein evidently holds its position as the only *natural* process, and all other modes of sewage treatment are conveniently classified together as "the *artificial* processes." We are assured that the latter are still in the experimental stage, and are promised a continuance of the careful examination commenced three years ago of the problems involved, "which are so many and so varied that only investigation and, we may add, experience of a prolonged and varied character, will suffice to solve them."

DISCUSSION.

Mr. FOWLER (Manchester): I propose that we give a hearty vote of thanks to the authors of these two papers, both of which are extremely interesting, and contain experiments, opinions and researches of great value. This delicate process of bacteriological treatment must really come to nothing if we have not a good manager and somebody to faithfully carry out the engineer's designs, and this does not only apply to the bacterial treatment, but to the management of sewage farms generally. During the last few years I have carried out some large sewage farm schemes. One manager would produce good crops, whilst another, working under exactly similar conditions, could not produce anything at all. I would advise all engineers, before designing a sewage scheme, to make it a condition that they have a free hand in the appointment of manager, for whether he is a paid official, or has a master's voice, a scheme must certainly fail if the engineer has not the whole thing under his control. It is not the first time by many that an engineer's reputation has been injured by having an inexperienced clerk of works, or sewage farm manager. On page 33 Colonel Jones says:—"Consequently there is no clogging or falling off of water capacity if the surface be cultivated, and much of that which clogs the artificial bed is annually removed from the natural one as a crop of vegetation." Now I quite agree with that. My experience as a water engineer during the last fifty years at Leeds Waterworks, Bradford Waterworks and other places, is that you get so much the more out of your filter beds according to the coarseness or fineness of the material over which you allow the water or sewage to pass. My investigation of bacterial beds leads me to believe that the coarser you have the material, the more the suspended matter penetrates into the filter. If it is too fine, there will only be sand on the top. If the filtering medium is finished similar to a waterworks filter-bed, of course the filtering process is slow and soon gets clogged, but the clogging cannot go beyond the top layer of sand. As I have before stated, it does go through the top layer when the filtering medium is of coarser material, consequently the filter becomes clogged and loses its capacity.

Mr. MIDGLEY TAYLOR (Westminster) seconded the motion. He said: Any experimental works that are put up for bacterial treatment of sewage, unless they deal with the whole of a district or area, rendering it possible to obtain a true sample of the flow of the sewage, will be a failure, and the experiments will be abortive. With regard to the question of the clogging of bacterial filters, the time that would ensue before the filter was clogged can be easily calculated. Say the effluent coming from a septic tank contains 5 or 10 grains of suspended matter per gallon, and 50 per cent. of this is mineral and 50 per cent. organic, and of this latter a considerable proportion cannot be touched by the contact-bed. Then, calculating the turbidness of the effluent after it has been over the contact-bed, it is easy to see how long the bed will last. The question of cleaning bacterial beds has been gone into rather closely by me, and I find that it takes sometimes between 200*l.* and 250*l.* per annum per acre to keep a bacterial contact-bed in order, and I think this annual expense is very much lost sight of by engineers recommending authorities to put in bacterial installations, because they cannot arrive at the figures until they have had the beds in operation three, four or five years.

Mr. A. J. MARTIN (Exeter): Mr. Campbell has laid down a little plant on the closed septic tank system, which I had the pleasure of seeing yesterday. It does not deal with the main portion of the sewage of Huddersfield, but with the concentrated sewage of an outlying district. So far as I could judge by the eye, the effluent was very good. I have listened to Colonel Jones's paper with a great deal of interest, and I cannot help thinking that, while he holds very strong opinions as to the sin of enthusiasm in the direction of these new departures, he himself might be classed as an enthusiast in respect of land treatment. I do not think he can be blamed for this, for the results which he has obtained at Wrexham and Aldershot entitle his opinions on the subject to a great deal of respect. The results also which our Chairman has obtained at Leicester show what can be done with land treatment. In this connection I would like to call attention to a remark by Colonel Jones that, "The efficiency of a system of sewage disposal may be tampered with to meet the views of economically-minded ratepayers." I think that possibly, the weakest point of land treatment is that it lays itself open more than any other system to being tampered with in the supposed interest of the rates. The temptation to grow crops, and to sacrifice the purification of the sewage to the interest of the crops, is one which few authorities are able to resist. Moreover, men of the stamp of Colonel Jones, or our President, are not to be secured by the average local authority; and not one council in a hundred is prepared to pay the salary of a man as competent to manage a farm as these two gentlemen are. Colonel Jones has misinterpreted Mr. Cameron—unintentionally, I am sure—in saying that Mr. Cameron wished to retain the gases of putrefaction in his tanks. Mr. Cameron's idea is not so much to retain these gases as, in the first place, to exclude atmospheric oxygen, and in the second to preserve an equable temperature in the upper layers of the tank. These are the great objects of covering a septic tank. Colonel Jones has spoken of the enormous cost of covering a tank, but I have known some tanks covered for 7*d.* per head of the population, and others which have not cost more than 5*d.* per head. This is not a great cost, and there are other advantages in covering a tank which should not be overlooked. There is, for instance, the possibility of nuisance from open tanks. The Leeds Sewage Committee, in their report on their experiments at Knostrop, point out that there is a great risk of nuisance from the treatment of strong domestic sewage in open tanks. I would not go so far as to say with Colonel Jones, that decomposition is invariably accompanied by noxious smells. On the contrary, the odour from a tank that is covered is often by no means of an unpleasant character, and not only are open tanks liable to be a nuisance of themselves, but there is another point which appears to me to constitute a weak point in the treatment of crude sewage in the open, either in open tanks or in bacteria beds. I refer to the immense number of small flies which are bred on the surface. It certainly is not good from a sentimental point of view, and probably not from a health point of view, that flies bred on sewage matter, and possibly carrying the germs of disease, should be free to fly off in all directions. From this point of view I think there is a good deal to be said in favour of closed tanks.

Colonel Jones and the last two speakers have drawn attention to what is one of the great problems in the treatment of sewage, and that is, the question of the capacity of bacteria beds. There is no doubt whatever that extravagant claims have been made on behalf of these beds; but on the other hand it is unfair to put forward figures, such as we see here, showing that they are likely to clog up and lose their capacity in about a year. The beds at Exeter have been in use for five years, with the simple washing of 18 inches of material. The treatment of sewage in bacterial works depends for its success not solely on the principles employed, but also, and to a very great extent, on attention to detail in the design of every part of the works.

Mr. J. Price (Birmingham): In dealing with sewage it is well to know what strength of sewage we are dealing with. Exeter sewage has been referred to. It is something like one-seventh the strength of Birmingham sewage. In a town like Birmingham we cannot have an entirely separate system; the sewage must be dealt with on accommodation lines. Mr. Martin has passed over very lightly the question of detritus tanks. In Birmingham such tanks are an absolute necessity for the septic treatment. I am very glad my old friend Colonel Jones has read his paper. There is one thing he is consistent in; he has always advocated the land, and I think he is on the right lines. At Birmingham we have been able to get a sufficient area of land at present to deal with our sewage, but I think in the next twenty years we shall have something very different, and we shall either have to go a considerable distance to a larger area or to the bacterial treatment on an extensive scale. Already we have had several acres laid down by Mr. Charles Hawksley, whom I saw in the room just now. I cannot see any reason for covered tanks. All I have had to deal with are being superseded by open tanks, which cost much less money. It is said they cost 5*d.* per head. I should like to know the cost per 1000 gallons. We shall have the bacterial treatment to a certain extent, but the land will have to be kept to still.

Mr. S. S. PLATT (Rochdale): I have read the paper by Mr. Campbell with a considerable amount of interest, as I too have been experimenting with sewage largely charged with the same kind of manufacturing refuse, viz. wool-scouring, which adds considerably to our difficulties. My experiments have been conducted with sewage free from added chemical precipitants, in an open septic tank of 200,000 gallons capacity, the effluent from which is passed on to a couple of coke filters, worked continuously, on which it is distributed by revolving sprinklers, according to Whitaker and Bryant's system, as carried out at Accrington. Mr. Campbell says, "The septic tank effluent is not so amenable to subsequent contact-bed treatment as the effluent from chemical precipitation." This is different to the views generally entertained.

With regard to the remarks of a previous speaker, who referred to the experiments at Exeter, I have nothing to say against them, but there is no comparison between the sewage of Exeter and such sewage as Mr. Campbell, myself and some others have to deal with, charged with manufacturing refuse, and you cannot specify any particular method of treatment which will be applicable or suitable to all. Each must be dealt with according to its special circumstances.

Mr. Campbell says, "By no process can the formation of sludge be obviated." My experience is that it can be to a large extent, but not absolutely. I have experimented for two years upon 160,000 gallons per day of twenty-four hours, and the amount of sludge accumulated in the open septic tank in that time is about two feet in depth, equal to about ten per cent. of what it would have been by chemical precipitation method in the same period of time. With reference to the open septic tank, I find that, with manufacturing refuse, it takes months at first to get a scum on at all, and unless there is some cover

over it the first high wind or heavy rain disturbs the scum and upsets the whole arrangement, and the septic action is not as well carried on. Considering the foul character of the sewage dealt with, I corsider we are getting good results. Mr. Creer, the City Engineer of York, is also obtaining good results with an open septic tank, sprinkler and a continuous filter.

The CHAIRMAN: Do you give rest to the sprinklers during the twenty-four hours?

Mr. PLATT: No, except for any slight necessary stoppage for attention to the mechanical part of the system.

Mr. THOMAS STEWART (Capetown): I have been engaged in the introduction of the bacterial treatment of sewage in South Africa. The conditions obtaining in England cannot, by any manner of reasoning, apply to the conditions obtaining in Cape Colony. We have, for example, five different climates; and the climate at Wynberg, near Capetown, is very different to what it is up country. There we have a strong wind which blows from the south-east in summer, and it is a wind which I have not the least doubt would interfere with the scum which one speaker has spoken about; and it is not possible on those grounds to adopt the septic tank treatment. At any rate this has been left over for the present. Municipalities in South Africa do-not do things in a hurry. It took about four years to do the works, and I think it very likely instead of adopting the septic tank we shall pass it on to the land. The disposal works are about two miles away, near the Military Hospital. The ground consists of sand, with about nine inches to one foot of surface soil, and instead of grass we have the cactus bush. From this ground we get a very excellent fall of about 25 feet to about 20 acres. As I have said before, we want to go carefully, step by step, because no one sewage installation is strictly applicable to any other place.

Mr. J. MUNCE (Belfast): We have for two years experimented with bacterial beds, and we have found that the greatest difficulty in Belfast is sludge. We have tried several things for the contact-beds, and have found broken bricks are the best. Coke seems to get broken, and it runs away as fine coke dust. I should like Members attending the Congress to visit Belfast to see the works.

Mr. GILBERT THOMSON (Glasgow): It strikes me that the bacteriological system has been treated much more severely than we are accustomed to hear it treated, and I think this tends to a very useful redressing of the balance of public opinion. We are accustomed to hear it lauded very highly by people who do not know anything about it. Public opinion is in favour of adopting the bacteriological system without knowing why; and public bodies, instead of giving their engineers full control over the selection and working of a system, go to the other extreme, and instruct their engineer to carry out a certain scheme of treatment—a certain method of sewage disposal—and this is a most serious question, especially in our present state of knowledge. Local authorities, as a rule, consider that they know better than their engineer which system to adopt, and this tends very largely to bad work. They do not realise that one system is best for one district and one best for another, but they appoint a deputation to go round the country, and they consider system "A" or system "B," and decide as they think best. This state of affairs is much to be deprecated.

Mr. A. J. PRICE (Lytham): If the amount of sludge mentioned in Mr. Campbell's paper is going to accumulate in the septic tank, it will be very soon fouled. Mr. Platt has told us that in two years they have had to clean out two feet of sludge. Mr. Martin, of Exeter, has told us that they have had to clean out none. Now this makes it very difficult to get at the facts. I suppose it all depends on the strength of the sewage. At any rate we shall have to go on for some time yet before we shall know how long a septic tank will last.

Mr. T. CORBETT (Salford): It is about nine years since the first working system of sprinkling was used on bacteria beds in Salford. Then we called them aërated filters, and my experience is, on beds used practically continuously for five years, we have shown no deterioration whatever. Some have been in use for five, some for four, and some for two years, and are apparently improved. The surface has required raking, but the under part remains untouched. The scheme we have now completed was developed seven years ago, so that it is not on modern lines. We have no septic tanks, but have two series of silt pits, then a mixing chamber, about ten feet square, through which the whole flow of sewage passes, a dry-weather flow of 8,000,000 gallons and an average flow of 12,000,000. There the milk of lime is added, and mixed in by a vertical revolving mixer. The sewage then passes along a channel 600 feet long, and salts of iron may here be added to it. Thence it passes to the precipitation tanks, of about 5,000,000 gallons capacity, where the deposits of sludge will be removed by special machinery without interrupting the flow of sewage. The tank effluent passes through roughing filters of fine gravel, 3 feet deep, which intercept a considerable quantity of fine sludge, etc., and require almost daily cleansing, for which special machinery will be provided. Finally the clarified effluent passes through sprinkler jets on to beds of fine cinders 8 feet deep, through which it trickles freely, drawing air down with it, passes through an open flooring of tiles into the filtrate culverts, and so, finally, to the Ship Canal. We have worked large experimental beds on this principle at rates of flow from 2,500,000 to 7,000,000 gallons per acre per day, with filtrates averaging about 0·60 grain of oxygen per gallon in four hours' test. We have no difficulty with sludge. We dispose of it for 8*d.* per ton, sending it to sea by steamer by way of the Ship Canal. Our works are now practically completed, and within a year we hope to have the whole in full operation.

The CHAIRMAN: To-morrow Mr. MacDonald's paper will be before us, and we can discuss the question further. It is too late in the day to discuss the question of bacterial treatment *versus* land. What we have arrived at is this: that we can satisfactorily deal with the sewage of manufacturing towns as well as domestic sewage by bacterial treatment—that has been proved beyond all doubt: but my own idea at the present time is, that where you have very excellent land available, and plenty of it at reasonable cost, the time has not come to disregard this opportunity and go in wholesale and recklessly for bacterial treatment. If you have got the land at your door the proper thing is to make the best of it. If you can get splendid land cheap, take it; supplementing it with bacterial methods where land in sufficient quantity cannot be obtained, although, as Mr. Taylor has said, we do not know quite enough about the clogging of the beds. I do not think it is fair to pounce down too heavily on advocates of the septic system. The septic people, I know, owe me a big grudge for my experiments at Leicester, but this must not be taken too seriously. What I proved at Leicester was, that the septic system is no good for preliminary treatment before passing to the surface of the land.

It has not been, generally speaking, decided whether we should have open or covered tanks. I know plenty of places where open tanks are all that is necessary, and I know places where covered tanks are better. I will not pursue the matter further, but I think it would be fair to give Colonel Jones an opportunity of replying, and also Mr. Martin an opportunity of saying a few words.

Colonel JONES, in reply, said: I think Mr. Martin is wrong in saying I have misrepresented Mr. Cameron, It is certainly the last thing I desire to do.

Mr. MARTIN: I hold no brief for Mr. Campbell. and I should like to take the opportunity of apologising to Colonel Jones for taking exception to his remark *re* the grit-chambers. Grit-chambers are necessary, but not in all cases. I heartily endorse the remark of one gentleman in the discussion, that all cases must be treated on their own merits. With regard to sludge, I do not claim to get rid of it all; I claim to destroy all that can be destroyed.

Wednesday, September 4, 1901.

THE BIRMINGHAM WATERWORKS.

A DESCRIPTIVE SKETCH, ILLUSTRATED BY LIMELIGHT VIEWS.

By JAS. MANSERGH, F.R.S.,
President of the Institution of Civil Engineers.

Mr. Mansergh said: The city of Birmingham, with the district around it which the Corporation supplied with water had an area of 130 square miles, and the present sources were six wells in the Red Sandstone, and four or five comparatively small local streams. The present user of water at ordinary times was 18 or 19 million gallons a day, but during the last dry season they had to meet a demand for 24 millions, which they did with great difficulty, and the Corporation did not go a year too soon to Parliament for power to construct the works which by means of the lantern slides he would now describe. It was a little curious that thirty-five years ago, when he was contractor's engineer on the railway which passes this district, he had laid down on an inch plan the reservoirs in the Elan Valley. In 1890 the Birmingham Corporation asked him to advise them on the matter, and the scheme was ready in time for the next session of Parliament, and they got it through in 1892. The source of the supply was the river Elan, which was a tributary of the Wye. The distance from the lowest reservoir to the centre of the city was just about 80 miles, and between that reservoir and the service reservoir at Frankley was 74 miles, divided pretty equally between tunnel and cut-and-cover, on the one hand, and iron and steel pipes crossing valleys, on the other. A map of England was then shown on the screen, giving the relative positions of Birmingham, the watershed and the aqueduct, also a plan of Manchester and the Thirlmere scheme, Liverpool and the Vyrnwy scheme, and the scheme which is suggested for London by Sir Alexander Binnie. Manchester had to fetch its water 100 miles, Liverpool 66, Birmingham 74. These were the distances between the reservoirs. Another slide was of the city of Birmingham and the district to be supplied. The district varied considerably in elevation. In the north-east corner it was 250, and in the south-west it rose to 800 above O.D. This view was followed by a group of engineers visiting the site of the works in 1891 (Sir Frederick Bramwell, Mr. Hawksley, and others), a model of the watershed, and rainfall diagrams. Fortunately the lord of the manor at Nantgwillt had for twenty years prior to 1890 kept a record, which was most useful to them. The mean rainfall on the shed was 68 inches, rising to 94 inches in years of heavy fall, and falling to 44 inches in times of drought. The mean for three consecutive dry years was 55 inches. A slide showing sections of the two valleys, with the positions of the reservoirs, was followed by one by means of which the function of the submerged dam was explained. Continuing, Mr. Mansergh said they expected to get 72 million gallons a day, and in addition, to supply 27 millions as compensation water. Views followed of Caregddu in ordinary flow and flood, and there was also shown the bell-mouth of the culvert. Mr. Mansergh said, when he first delivered a lecture on this subject at the Royal Institution some years ago the question of stone dams was very much to the front, because the Bouzey dam in France had given way, doing an immense amount of damage, and he had therefore prepared a slide showing for comparison the section of that dam and of those he was building on the Elan. Pointing to the latter, he said, "I don't think there is any fear of this one going." Slides followed showing how the flood water was dealt with during construction —a very serious business, as the quantity passing at the lowest dam was 700,000 cubic feet a minute—and then, starting at the beginning of the works, Mr. Mansergh explained how at the Caban dam they cleared the river bed of big boulders, built stanks enclosing the culvert sites, erected the culverts and diverted the water through them, and so got complete control of the floods. In the valley were the old manor house of Nantgwillt and the house that Shelley once lived in. Pictures of these were shown on the screen, also of the church of Nantgwillt. This would be drowned under about 100 feet of water. A church to replace it was built a little higher up the valley. A cross section of the cut-and-cover part of the aqueduct in course of construction was shown, and the Carmel bridge, eight or nine miles from the start. The cut and cover conduit and the tunnels provided for taking 72 million gallons a day, so that that work was done for all time. They had few constructions above ground, and those they were building so as not to disfigure the country. He showed a view of a stone bridge which the owner of the land, being an engineer, insisted on having instead of steel or iron, and a view was also shown of the bridge crossing the Teme at Ludlow, 116 feet span, and a bridge crossing Deepwood Dingle. This was 80 or 90 feet high, and was built by Messrs. Morrison and Mason, of Glasgow. A view of the Severn bridge followed. The pipes were laid on this bridge 40 feet above the level of the river, and they had to stand a pressure of 530 feet. There were five brick arches on one side, and a steel arch of 150 feet span. A view was also given of the bridge crossing the Worcester canal. They were under an obligation to cross this canal with a 100 feet span, and they got the pipes over as an arch in the manner they would see in the illustration. To get lateral strength, they put in three pipes instead of two. Views followed of the Frankley reservoir, which was semicircular in plan, as that provided the maximum of storage with a minimum of work. It was built with concrete, asphalted, and the walls blue-brick faced. There were also photos of the filter works. They could supply 80 per cent. of the district by gravitation, but the water for the rest would have to be pumped. Mr. Mansergh touched then on a most interesting part of his subject, when he went back to the valley. "This," he said, pointing to a picture of the village, "is the village which we have built to accommodate the men. It contains about 1200 people. We have schools, a recreation hall, baths and wash-houses, and complete water and sewerage works, also a general hospital, and one for infectious diseases, but this has been very seldom used on account of the precautions to keep out small-pox and typhoid. We have what we call a doss-house, into which all men who come on tramp have to go for a week. They are put in quarantine, in fact, under the supervision of the doctor. They also have to take a hot bath, use a clean nightshirt, and their clothes are disinfected. They go to work, but they are not allowed to go to the village until they have passed out of quarantine. This is most useful in keeping out infectious disease." A picture of one of the wards in the general hospital was shown. There were a matron and a nurse, and one or two more came from Birmingham if necessary. They had not had anything serious —accidents, cases of pneumonia, and things of that sort. A picture was shown of the entrance to the village. The bridge was a suspension bridge over the river Elan, which divided Radnorshire from Breconshire, and here they had a gate-keeper, whose business it was to examine all carts taking provisions into the village, to make sure no spirits or intoxicating liquors were introduced. They also had a village superintendent whose business it was to generally supervise and to see that the regulations were carried out, and all sanitary rules adhered to. The superintendent was also the bandmaster. The canteen-keeper had no interest in the sale of beer, and the Corporation was able to make a substantial profit; the money was being spent for the benefit of the men employed upon the works, on the schools, hall, recreation grounds, sports, entertainments, etc. Mr. Mansergh concluded his lecture by interesting views of the works in chronological order.

DISCUSSION.

The CHAIRMAN: I think you will all agree with me this is no ordinary paper. It is eminently in the category of a presidential address, and therefore, of course, not open to discussion and criticism. If it were, I do not think that any of us would presume to criticise such a great work, but I have great pleasure in calling upon Mr. Harpur, one of our past presidents, to propose a most hearty vote of thanks to Mr. Mansergh for his great kindness.

Mr. HARPUR: I rise with very great pleasure to move that a most hearty vote of thanks be given to Mr. Mansergh for the very able address he has given us, and for the graphic way in which the works have been illustrated. As one who has paid frequent visits to these works and who has a considerable knowledge of the district, I have very great pleasure in moving this resolution. I have made it a pleasure to pay a visit at any rate once a year to the works at the Elan valley, and Mr. Mansergh's address was most interesting to me as having just a superficial knowledge of the works—such as one can see from casual observation. The district itself is undoubtedly one of the finest watersheds which could possibly be conceived, and the works which are being constructed are undoubtedly the very best of the kind which up to the present time have been attempted. I can only say, Mr. Chairman, that if any of you gentlemen living south can possibly make it convenient to break your journey and view the works on your return, you would be amply and well repaid for the time and trouble. The provisions which Mr. Mansergh referred to for the inhabitants —the men working there—are excellent in the extreme, and the doss-house which has been described is one to which sanitary engineers should pay special attention. I think it is one of the finest ideas when constructing such a work—the housing of the people and seeing to their comfort—and, as Mr. Mansergh has already told us, it has resulted practically in the exclusion from the works of every kind of infectious disease. The village itself is a model one. I move that the hearty thanks of this meeting be given to Mr. Mansergh for his able address.

Mr. Weaver: I have very great pleasure in seconding the vote of thanks proposed by Mr. Harpur. I was very interested in following Mr. Mansergh in his illustrated description of this gigantic work. It has been most interesting, I am sure, to every person in the room. I myself was very much struck with the point alluded to by Mr. Harpur with regard to the workmen's village. It bears a little upon some points which I raise in the paper which I shall inflict upon you presently. I do not understand under what legislative or statutory powers these people are kept in quarantine for a week; but the provision I think is productive of very good results. I hope statistics are kept of the village, because they will be very valuable in five or ten years' time, as bearing upon the sanitation of the place. I am sure if disease can be kept out of the village it must have a very good effect upon the district.

The resolution was carried unanimously.

Mr. Mansergh, in replying, said: I am very much obliged to you for your kind vote of thanks. We have no parliamentary powers to quarantine the men; but I think they in no way resent it. We have men, as you know, working for us—navvies —who tramp all over the country, and they come and work for us four or five months, go away, and return, repeating this round periodically. It is the only place where they can get a "good general clean up," and they seem to enjoy it. The results are no doubt most satisfactory. I do not know whether I said that all the work in the valley is being done without a contractor, being under Corporation administration. When I got my Committee to agree to that, I told them, " now you must provide for the housing of the workmen." I explained to them the ordinary method of housing men on public works up to quite lately—putting twenty-four men in a big hut, two men in a bed, and sometimes using them night and day so that they never got cold. That seemed to me very nasty, and after describing the practice with *some emphasis* I produced designs of the huts I proposed they should erect. In the lodgers' huts the keeper and his wife have a good living room, a couple of bedrooms, scullery, and all decent sanitary appliances ; and the men have a large room in which are eight single cubicles, so that each man is decently provided for in his own little den, and I believe they appreciate the comfort of this privacy. The result has been that we keep constantly on the job a nucleus of good steady men on whom we can rely, and that is an enormous advantage in works of this sort. For the married foremen and leading artisans of the better class, we have huts of a different class, in all five types. Altogether the thing is done extremely well. With regard to Mr. Harpur's suggestion that you should try and see the works, I may say we have made a good road passing close to three of the dams, and if any of you will write me to Westminster I will send you a small plan and a card to my Resident Engineers, which will ensure you courteous treatment. Those of you who were good enough to accept my invitation in August 1897, will know all about getting to the valley.

DISPOSAL OF SEWAGE.

By A. B. MACDONALD, M. Inst. C.E.,
City Engineer, Glasgow.

The disposal of sewage, as the members of this Congress are well aware, is a question that does not admit of universal solution.

The methods best adapted for a rural community are as widely different from those applicable to a great industrial centre as they are from the sanitary arrangements of a residential establishment.

The aim of the present contribution to the subject is not the presentation of anything new. It is intended merely to afford the members of the Congress such information regarding the Glasgow Main Drainage Scheme as may render their visit to the works of the Corporation more interesting than it might otherwise prove.

The limits of the present opportunity effectually preclude elaborate detail, but it is hoped that the brief outline submitted may serve its purpose.

The Main Drainage Scheme adopted by the Corporation for the collection and treatment of the sewage of Glasgow and the adjacent burghs and local authorities was authorised by special statutes sanctioned by Parliament in 1891, 1896, 1898 and 1901. The included territory stretches along both sides of the river Clyde for a distance of about 15 miles, the superficial extent being 39 square miles, which is likely to be increased by the inclusion of other local authorities not yet arranged with.

The drainage area is divided into three sections, each being distinct from the others, with separate works for the disposal of the sewage.

The first of these, authorised in 1891, and doubled in area during the last Session of Parliament, is about 11 square miles in extent, one half being situated within the city; and the remainder, within the county of Lanark, being almost entirely agricultural land, is not likely to require special drainage for a considerable time.

The works for the disposal of the sewage arising from this area are situated at Dalmarnock.

The second section authorised in 1896, includes the remainder of the municipal area on the north side of the river, the burghs of Partick and Clydebank, with intervening parts of the counties of Renfrew and Dumbarton, the whole extent being 14 square miles.

The works for the disposal of the sewage arising from this area are now in process of construction on the river bank at Dalmuir, about 7 miles below Glasgow.

The third section, authorised 1898, comprises the whole of the city on the south bank of the river, along with the burghs of Rutherglen, Pollokshaws, Kinning Park and Govan, with various residential and rural districts situated in the counties of Lanark and Renfrew. The extent of this section is 14 square miles, which is likely to be increased by the inclusion of the burghs of Paisley and Renfrew.

The works for the disposal of the sewage of this area are to be situated on the river bank at Braehead, about 4 miles nearer Glasgow than Dalmuir.

The three different sections into which the Corporation scheme is divided are shown in distinctive colouring on the accompanying sketch map.

The collecting and intercepting sewers which deliver sewage into the Dalmarnock works have all been constructed, and the works have been in successful operation since May 1894.

The daily volume of dry-weather sewage treated there at the present time is 16 million gallons.

The volume of dry-weather sewage which will ultimately be treated at Dalmuir will be 49 million gallons, and the corresponding volume at Braehead will be 45 million gallons.

For the collection and disposal of the 94 million gallons of sewage within this territory there will be constructed 30 miles of sewers, varying in size from 2 ft. 6 in. in diameter to 10 feet, which have been calculated to discharge, in addition to the sewage, an amount of rainfall equivalent to one-quarter of an inch per day, or 189 million gallons of combined flow.

The leading features of the Northern Scheme are the construction of an outfall sewer, which will convey the drainage of the higher levels of Glasgow and Partick to Dalmuir, where it will be treated at the works now in progress there; the construction of an intercepting sewer to collect the drainage of the lower levels of the city; the construction of an intercepting sewer to collect the drainage of the lower levels of the burgh of Partick; and a third intercepting sewer, which will convey to Dalmuir the drainage of the burgh of Clydebank.

The Glasgow and Partick intercepting sewers will be pumped into the outfall sewer at Partick Bridge, the difference of level being 35 feet. The Clydebank intercepting sewer will be pumped at Dalmuir, the difference of level being 15 feet. Rather more than one-half of the total sewage will be carried to Dalmuir without pumping. The whole sewage carried by the outfall sewer will be delivered at such a height above the tidal level as will enable it to be discharged at once into the precipitation tanks.

On the south bank of the river the surface levels of the drainage area are less favourable for the conveyance of sewage and rainfall by gravitation than they are on the north side, dealing with the figures that represent the distribution of population at the present time, although the future development of the included territory will bring the volumes conveyed by the gravitation and pumped sewers into less disparity.

The sewers to be constructed on the south side of the river follow for the greater part of their course the line of public streets and roads, and the charge for wayleave will be less than that incurred on the northern division of the undertaking. There will be a pumping station at Pollokshields, where the low level sewage will be raised 35 feet, and another at Braehead, where the lift is to be 25 feet.

The sewage of Paisley and Renfrew will be brought to the works in low level sewers, which will also require to be pumped.

The Braehead works for the treatment of the sewage will, like those at Dalmuir, have the great advantage of river frontage, with every facility of water carriage for receiving and transporting materials.

The system of treatment adopted in disposing of the sewage at Dalmarnock is chemical precipitation by means of under surface continuous flow. The sewage is of a complex and most intractable character, consisting for the most part of industrial refuse, charged with suspended matters, that vary from 20 to 250 grains per gallon. The treatment of such sewage is necessarily a matter of no ordinary difficulty, and the proportion of the chemical ingredients undergoes frequent change during the day. The chemicals employed are hydrate of lime and sulphate of alumina. The cost of the different processes is shown in the Annual Report of the Manager, appended to this paper.

After careful deliberation, and much patient investigation on the part of the Sewage Committee, it was resolved to adopt at Dalmuir and Braehead the same method of sewage treatment as that which has for the last seven years been in use at Dalmarnock, with the exception that sludge presses are to be dispensed with, and the liquid sludge carried out to sea.

The most diligent inquiry regarding the methods adopted by other authorities in England failed to provide the Sewage Committee with any reasons which would justify them departing from what they regard as a securely-ascertained and efficient system of sewage precipitation and disposal.

The working result of the sewage treatment at Dalmarnock is that every trace of suspended matter is removed, and that 30 per cent. of purification is attained, calculated on the basis of oxygen absorbed in four hours at 27° centigrade. The result may leave something to be desired, but it must be borne in mind that reason imposes a limit on achievement in this direction. The quantity of sewage disposed of at Dalmarnock is, as we have seen, 16,000,000 gallons, and it is discharged in its altered condition into a tidal stream of vastly superior volume. Measured at a station 7 miles higher up the river, far beyond the tidal range, the downstream flow is 700,000,000 gallons per day —more than forty times the quantity of sewage at Dalmarnock, where the dilution is further augmented by the tidal water. It has not yet been ascertained what degree of saturation is needed to secure perfectly innocuous conditions, but it may be safely asserted that there is here a near approach to the complete elimination of every element of objection. Further down the river, at Braehead and at Dalmuir, the 94,000,000 gallons of purified sewage will come in contact with 3,000,000,000 gallons of tidal water, and may with safety be left to natural agencies for their further improvement, the more especially as the quality of sewage dealt with on the lower reaches of the river will be of a simpler character than that presently treated at Dalmarnock, and consequently more likely to yield an effluent of a better character.

There is the greater reason to expect this, as the form and dimensions of the precipitating plant at Dalmuir and Braehead will be more effective than the installation at Dalmarnock. The works there were designed by the late Mr. G. V. Alsing, and were justly regarded at the time of their construction as creditable in the highest degree to their designer, embodying, as they then did, the latest results of experience and scientific research. They were at first arranged for intermittent precipitation, and worked in connection with a system of coke filters, through which the sewage effluent was passed on its way to the river.

More recently it has been found desirable to extend and convert the Dalmarnock works, and the precipitation tanks are now worked in continuous flow, and the use of the filters has been abandoned, as it was found that the process deteriorated the effluent instead of improving it.

The precipitation tanks now in course of construction at Dalmuir, which are to be worked on under-surface continuous flow, are more favourably situated than those at Dalmarnock, each being about 750 feet in length, thus allowing opportunity for more complete precipitation than is afforded in the shorter tanks at the Dalmarnock works, and effecting a saving in the reduced proportion of chemical agents required for the process.

Towards the end of last year the Author was instructed to report to the Sewage Committee on the extent to which bacterial methods might be adopted in treating the sewage at Dalmuir, with a statement of the relative cost of the system already in use at Dalmarnock as contrasted with the cost of the works necessary for the bacterial treatment of sewage.

The great importance of this matter impelled him to avail himself of the wider experience of the late Mr. W. Santo Crimp, M. Inst. C.E., who then acted as Consulting Engineer of the Sewage Committee.

The outcome of this joint investigation, based on the experience of other local authorities, was that in capital expenditure alone the installation of pumps, sedimentation tanks and filter beds required to dispose of the sewage at Dalmuir would be at least ten times greater than the estimated outlay for ordinary precipitation works, without taking any account of the cost of renewing the filtering plant.

Since that date careful observation has been made of the working of an experimental plant installed at Dalmarnock for the bacterial treatment of sewage at the cost of 1000*l.*, exclusive of the original charge for the construction of the tanks.

The plant consists of one open septic tank, and four first and four second contact-beds.

For the purpose of a septic tank one of the large precipitation tanks has been utilised. This tank has a superficial area of 426·94 square yards, and a capacity of 200,000 gallons. The sewage is pumped direct from the catch-pits in the machinery buildings, and is conveyed to the tank by means of a 6-inch pipe.

When the experiment was put in operation in September 1900, it was proposed to fill the tank twice in twenty-four hours, but this was departed from, and it has been filled only once in twenty-four hours (200,000 gallons), although the supply pump, from actual test, is capable of delivering the larger quantity if it were necessary.

The contact-beds have been formed in two large precipitation tanks, and have a superficial area of—

	Square yards.
First contact-beds	399·30
Second contact-beds	398·04
Making a total area of	797·34

The beds are each 3 ft. 3 in. deep. The filtering material is of engine ashes, gauged from $\frac{3}{4}$ to $\frac{1}{8}$ of an inch as follows :—

FIRST CONTACT-BEDS.

Description.	Depth. ft.	in.
Bottom layer, $\frac{3}{4}$ inch ashes		9
Middle ,, $\frac{1}{2}$,, ...	1	9
Top ,, $\frac{1}{4}$,, ...		9
Total depth	3	3

SECOND CONTACT-BEDS.

Description.	Depth. ft.	in.
Bottom layer, $\frac{1}{2}$ inch ashes		8
Middle ,, $\frac{1}{4}$,, ...		7
Top ,, $\frac{1}{8}$,, ...	2	0
Total depth	3	3

The capacity of the four first contact-beds when empty—that is, before the filtering material was put in—was 72,996 gallons; and the working capacity—that is, after the filtering material was put in—was estimated at 50 per cent. of this amount, viz. 36,498 gallons; but when the beds were set in operation a series of practical tests gave a capacity of only 32,617 gallons, which is equal to 44·6 per cent. of the capacity of the empty beds.

Taking the total area of the first and second contact-beds—797·34 square yards—this 32,617 gallons is equal to a capacity of 40·9 gallons per square yard, or 197,956 gallons per acre *for one filling of the beds.*

The beds were again tested about the middle of December 1900, three months after the start, when the capacity was found to have fallen to 19,700·64 gallons, which is equal to 24·7 gallons per square yard, or 119,548 gallons per acre for one filling.

In March 1901, or six months after the start, a third test was made, when the capacity was found to have fallen still lower, to 17,492·52 gallons, which is equal to 21·9 gallons per square yard, or 105,996 gallons per acre for one filling.

Owing to a break-down of the shafting in the machinery buildings, the beds were idle from the 2nd to the 21st May. When they were again set in operation a fourth test was made, and it was found that the beds had benefited by the rest—the capacity being 21,412·67 gallons, which is equal to 26·8 gallons per square yard, or 129,712 gallons per acre for one filling.

A fifth test was made on the 14th and 15th of August, when the capacity was found to be 20,321·949 gallons, which is equal to 25·48 gallons per square yard, or 123,323 gallons per acre for one filling.

When the experiment was put in operation it was proposed to fill the beds four times per twenty-four hours after they had matured. Reference to Table No. 1 will show that three fillings per 24 hours is the highest that has been attempted, and that only for a period of some six weeks. It was estimated that the capacity of the beds would fluctuate for a period until they matured, when the capacity would be found to be somewhere about 66 per cent. of the original, or the test made at starting.

TABLES.

TABLE No. 1.—FILLINGS OF CONTACT-BEDS BETWEEN 17TH SEPTEMBER, 1900, AND 15TH AUGUST, 1901.

One Filling per Day.	Two Fillings per Day.	Three Fillings per Day.	Four Fillings per Day.
From 17th September to 21st October, 1900. *Note.*—The beds were set in operation on 17th September.	From 22nd October, 1900, to 27th January, 1901. From 16th March to 2nd May, 1901. From 21st May to 15th August, with the exception of 8th August.	From 28th January to 15th March, 1901.	The beds have never been filled four times per day.

TABLE No. 2.—SHOWING RESULT OF TESTS OF CAPACITY.

—	Test No. 1, September 1900.	Test No. 2, December 1900.	Test No. 3, March 1901.	Test No. 4, May 1901, after a rest of 19 days.	Test No. 5, August 1901.
	gallons	gallons	gallons	gallons	gallons
Bed No. 1 ..	8,415·38	4,815·08	4,166	5,266·32	5,006·326
" 2 ..	8,251·97	5,018·10	4,352·09	5,037·88	5,129·56
" 3 ..	7,817·75	4,935·30	4,386·62	5,307·075	4,990·89
" 4 ..	8,131·99	4,932·16	4,587·81	5,801·40	5,195·173
Totals ..	32,617·09	19,700·64	17,492·52	21,412·67	20,321,949
		Equal to 60·4 per cent. of No. 1 test.	Equal to 53·65 per cent. of No. 1 test.	Equal to 65·65 per cent. of No. 1 test.	Equal to 62·34 per cent. of No. 1 test.

TABLE No. 3.—SHOWING CAPACITY OF BEDS PER SQUARE YARD AND PER ACRE, *for one filling*, IN RELATION TO CAPACITIES AT EACH TEST.

—	—	Total Capacities. Gallons.	Gallons per Square Yard.	Gallons per Acre.
Test No. 1 ..	Area of 1st and 2nd contact beds, 797·34 sq. yards.	32,617	40·9	197,956
" 2 ..		19,700·64	24·7	119,548
" 3 ..		17,492·52	21·9	105,996
" 4 ..		21,412·67	26·8	129,712
" 5 ..		20,321·949	25·48	123,323

Table No. 4.—Showing Acreage per Million Gallons *for one filling* in Relation to the Several Tests.

Acres per million gallons—	Test No. 1—5	acres for one filling.	
	Test No. 2—8·3	„	„
	Test No. 3—9·4	„	„
	Test No. 4—7·7	„	„
	Test No. 5—8·1	„	„

Referring to Table No. 2, it will be observed that the highest percentage obtained has been 65·65, and that only after the beds had rested for nineteen days. The next highest is 62·34 per cent., the result of the August test, but such a result has only been obtained by restricting the beds to two fillings per twenty-four hours; for in March, after six weeks of three fillings per day, the percentage fell to 53·65 of the original. The results obtained in December 1900—60·4 of the original—look like the highest that could be followed for practical purposes, and this gives the following results:—

Capacity of beds when matured in relation to empty beds (that is, before the filtering material is put in), 27 per cent.

Gallons per acre *for two fillings* per twenty-four hours, 239,096, or 4·18 acres per million gallons for two fillings with a double contact.

The degree of purification attained by double filtration was 95 per cent.

Notes on the Sludge obtained from the Septic Tank.

Between September 15, 1900, and May 2, 1901, 44,525,128 gallons of sewage were pumped into the septic tank. Of this quantity only 9,863,442 gallons were passed on to the bacteria beds, while 34,661,686 gallons passed over the overflow weir.

The work was suspended on May 2, and on the 19th the tank was "run off," when 818·5 tons of crude sludge, containing 92 per cent. of moisture, were taken from the tank. This gives 18·3 tons of sludge per million gallons, which is equal to 45·75 per cent. of the sludge extracted by precipitation (40 tons per million gallons).

From the chemist's returns, it is shown that 8 grains of solids per gallon have passed on to the beds or over the overflow. This is equal to 6·25 tons of crude sludge per million gallons, and if this were taken into account, 278·27 tons of crude sludge, containing 92 per cent. of moisture, would require to be added to the 818·5 tons, making a total of 1096·77 tons extracted from the sewage. This gives 24·6 tons per million gallons, which is equal to 61·5 per cent. of the sludge extracted by precipitation.

This 278·27 tons should not, however, be added, as it does not fall to be dealt with as sludge; therefore the sludge should be taken at 18·3 tons per million gallons, or a reduction of 54·25 per cent. on precipitation methods.

Considerable importance attaches to the result of this experiment, which has been carried out under the personal direction of Mr. Harris, the able Chemist of the Sewage Committee; and it will no doubt be observed that the maximum charge of the contact-beds has proved to be two fillings per twenty-four hours, which would represent for the treatment of the 16 million gallons a day that await disposal at Dalmarnock an area of 64 acres, in addition to the duplication of the present tank capacity of 5½ acres. These combined figures imply that for the employment of bacterial methods at Dalmarnock a surface of 75 acres would be absolutely needed for an operation that is satisfactorily carried on just now in the space of 5½ acres.

In the joint report of the late Mr. Santo Crimp and the Author it was pointed out that the space required at Dalmuir for filters, on the assumption of three fillings a day, would be 133 acres, and that the space required for sedimentation tanks would be 31 acres, or 164 acres in all, for the bacterial treatment of 49 million gallons of sewage, which, according to the design now being carried out, will be satisfactorily accomplished in the space of 23 acres.

APPENDIX.

Report by the General Manager of the Dalmarnock Sewage Works on the Operations during the Year 1900–1901, and Comparison with those during the preceding Year.

Glasgow: *22nd July*, 1901.

—	1899–1900.	1900–1901.
Total sewage dealt with	4,514,300,000 gals.	5,391,536,000 gals.
Average daily quantity	12,367,945 „	14,771,332 „
Average cost of chemicals	£0 10 $1\frac{2}{10}$	£0 6 $11\frac{8}{10}$
Crude sludge extracted by precipitation	176,112 tons.	216,248 tons
	tons cwts.	tons cwts.
Sludge cake from filter presses	23,227 10	27,828 17
Sludge raised by elevators	1,091 15	1,342 15
Total solids	24,319 5	29,171 12
Cost of pressed sludge cake	2*s.* 4*d.* per ton	2*s.* $4\frac{6}{10}$*d.* per ton
Cost of sending sludge cake to tips, including hire of sewage department wagons	$9\frac{3}{4}$*d.* per ton	$10\frac{4}{10}$*d.* per ton

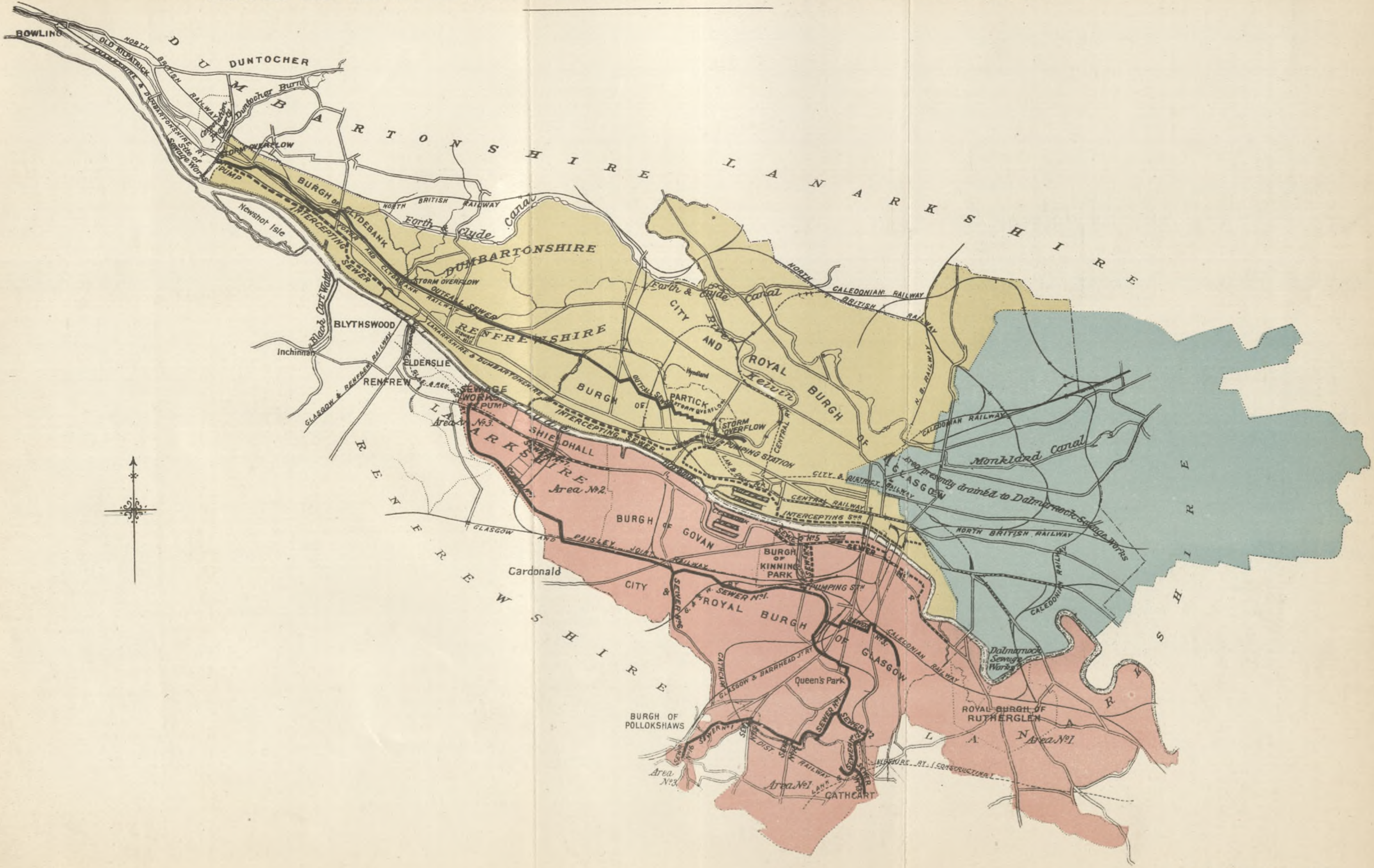
Working expenses per million gallons of sewage treated—

—	1899–1900.	1900–1901.
	£ *s.* *d.*	£ *s.* *d.*
Pumping	0 10 $4\frac{8}{10}$	0 14 $2\frac{1}{10}$
Precipitation, including chemicals ..	0 15 $7\frac{9}{10}$	0 14 $9\frac{8}{10}$
Filtration, including coke	0 7 5	0 4 3
Sludge pressing	0 12 0	0 12 $3\frac{6}{10}$
Sludge to tips	0 1 $3\frac{6}{10}$	0 1 $9\frac{4}{10}$
	2 6 $9\frac{3}{10}$	2 7 $3\frac{9}{10}$

From the above statement it will be seen that during last year 5,391,536,000 gallons of sewage were treated at the works, which are equal to a weight of 24,470,501 tons 6 cwts. 0 qrs. 21 lbs., being an average of 14,771,332 gallons, or 67,042 tons 10 cwts. 0 qrs. 9 lbs., per twenty-four hours.

SEWAGE DISPOSAL.

SKETCH MAP SHEWING THE DIFFERENT SECTIONS OF THE GLASGOW MAIN DRAINAGE SCHEME.



ROBERT GARDNER & Co.
ENGINEERING LITHOGRAPHERS. GLASGOW.

A.B. McDonald,
City Engineer.

From that liquid sewage there were extracted by precipitation, 216,248 tons crude sludge, which were reduced by filter pressing to 27,828$\frac{17}{20}$ tons, at an average cost of 2*s.* 4$\frac{6}{10}$*d.* per ton of pressed cake.

In addition to that quantity, 1342$\frac{15}{20}$ tons were raised direct from the catch-pits by the elevators. These two quantities make a total of 29,171$\frac{12}{20}$ tons as solid matter removed from the sewage during the year, which were disposed of thus:—

	tons.	cwts.	tons.	cwts.
Deposited on ground at works	6,898	0	5,619	19
Sold as manure by sewage department	8,300	19	8,365	0
Manufactured in "Globe" Fertiliser ..	1,552	16	819	11
Despatched by rail to refuse tips ..	7,567	10	14,367	2
	24,319	5	29,171	12

Disposed of from stock—

	1899-1900.		1900–1901.	
	tons.	cwts.	tons.	cwts.
Sold as manure by sewage department	3,817	6	1,691	7
Despatched by rail to refuse tips ..	16	3	..	
	3,833	9	1,691	7

During the year 507$\frac{6}{20}$ tons of "Globe" fertiliser were sold at prices ranging from 8*s.* to 14*s.* per ton, free on rail, and 10,056$\frac{7}{20}$ tons of pressed cake were sold at about 1*s.* per ton, free on rail, which shows a decrease of 393$\frac{17}{20}$ tons in the sale of the "Globe" fertiliser, and a decrease of 2061$\frac{18}{20}$ tons in the pressed cake.

The total expenditure in connection with the manure account, as shown in the Treasurer's Statement, is 899*l.* 12*s.* The revenue is 1213*l.* 7*s.* 7*d.*, thus showing a balance of 313*l.* 15*s.* 7*d.* in favour of Manure Account. Adding for the present stock of "Globe" fertiliser 52*l.*, the balance in favour of the Manure Account would be 365*l.* 15*s.* 7*d.*

There is a further saving of 714*l.* 16*s.* 6*d.*, being the saving effected at 10$\frac{4}{10}$*d.* per ton on the 16,495$\frac{17}{20}$ tons pressed cake made into "Globe" fertiliser, sold as rough manure, and deposited on grounds at works, which would otherwise have been expended in sending it to tips. It will therefore be seen that between revenue and savings in expenditure, 1080*l.* 12*s.* 1*d.* should be credited to manure account.

I am pleased to state that 10,875$\frac{18}{20}$ tons of pressed cake have been sold direct or manufactured into "Globe" fertiliser. This is considerably less than I anticipated would have been disposed of at the beginning of the year, but the extraordinary wet weather during the autumn and early spring completely upset all calculations.

THE COMMITTEE ON SEWAGE DISPOSAL.

GENTLEMEN,—In submitting for your consideration my Seventh Annual Report for year ending May 31, 1901, I have also given, for ready comparison, the figures for the preceding year. The extra repairs and erection of a Green's patent fuel economiser has added considerably to the working expenditure.

The works have gone on steadily throughout the year, with the exception of a break in the main driving shaft on May 2, which caused the treatment of sewage to be dispensed with for nineteen days.

The necessary repairs have been executed during the year, and the machinery is at present in a satisfactory state.

The expenditure for the ensuing year will be somewhat reduced, wing to the reduction in the price of materials.

Numerous visitors still continue to visit the works, and express themselves as highly satisfied.

The analyses of the raw sewage, effluent, pressed cake, etc., have been submitted to you by the Corporation chemist.

Deleterious trades refuse still continues to be discharged into the works.

The filter presses are still taxed to their utmost capacity to keep down the crude sludge.

There was added to the plant during the year, a Green's patent fuel economiser put down in May, and not yet in complete working order; and also a small locomotive shed.

The experimental biological installation for the treatment of raw sewage without chemicals has been in operation since September 17. No report has as yet been made on the experiments.—I am, Gentlemen, your obedient servant, THOS. MELVIN.

MUNICIPAL SANITATION.

BY WILLIAM WEAVER, M. INST. C. E.
BOROUGH ENGINEER AND SURVEYOR, KENSINGTON,
Vice-President of the Incorporated Association of Municipal and County Engineers.

1. IN submitting the following paper upon municipal sanitation, the Author desires to state that he has framed his remarks on general lines, refraining, as far as possible, from entering upon professional details and technicalities which might better form the subject of exhaustive and analytical essays, such as are usually submitted to and considered at meetings of the Incorporated Association of Municipal and County Engineers.

2. Included in the duties of a municipal authority, those appertaining to sanitation rank as most important, inasmuch as upon their efficient discharge the health and comfort of the community to a very large extent depend. These duties embrace—

(*a*) Sewerage and drainage.
(*b*) Water supply.
(*c*) Habitations and their occupants.
(*d*) Highways.
(*e*) Refuse.

SEWERAGE AND DRAINAGE.

3. During the last half century, the vital importance of securing for each district an efficient sewerage system has become fully recognised, and cesspool drainage, with water-courses and streams converted into open sewers is no longer tolerated in districts claiming advancement in sanitation. Without entering upon the comparative merits of the various systems of sewage treatment and disposal, each of which would provide material for a lengthy paper and discussion, suffice it to say, that any

sewerage scheme for a district should provide adequate conduits for the reception of the drainage of each premises, and for its rapid transmission without nuisance to the outfall, there to be treated in such manner as to insure the non-creation of nuisance. Wherever practicable the surface water should be received into a separate system of sewers in order to divert the water from the sewage outfall. The conduit should be of sufficient capacity for present and future needs, but excessive size is to be deprecated. The proper method of ventilating the sewers must be decided with due regard to the character of the locality. A system of ventilation suitable for a rural district may prove objectionable in the narrow streets of a busy city, but the Author inclines to the opinion, that in ventilating sewers, simple methods are preferable to complicated and costly systems of combustion or chemical aëration. If sewers and drains were treated as component parts of one system, and each drain made to assist in getting rid of the smell it helps to create, road surface ventilators would not be necessary, and the costly comparative merits of the various patent systems for dealing with sewer air would no longer require attention.

4. House drainage supervision is one of the most important duties of a sanitary authority, and in no direction has municipal advance been greater during the past twenty-five years than in the construction and superintendence of drains, and the present supervision should result in future economy by saving much of the present day expenditure upon sanitary inspectors, a great part of whose duties consists in testing and finding out inefficient drains, the result of non-supervision in the past.

5. The mode and materials of house drain construction vary in different districts, and efforts (especially in London) have been and are being made to frame general bye-laws on the subject. Considerable difficulty attaches to the matter, as details of drain construction applicable to buildings of all degrees of magnitude are hard to formulate. In London the County Council have been engaged on the subject for the past four years, and the bye-laws have not yet been circulated amongst the Borough Councils.* In considering the draft bye-laws for the Metropolis, the question of intercepting traps on the main house drain received a great deal of consideration, and at a conference of the Metro-

* The new Bye-Laws have been received by the Metropolitan Borough Councils since this paper was written.

politan Municipal Surveyors, presided over by Sir A. R. Binnie, such traps were unanimously condemned, and it was urged upon the London County Council that wherever in future such traps were fixed, ventilating pipes from the outflow side of same should be carried up the premises. In the bye-laws as settled, however (although as before stated, not yet circulated), intercepting traps are made compulsory, and the unanimous opinion of the surveyors supervising the work is ignored.

6. House drainage, as far as consistent with efficiency, should be made as simple as possible. Complication necessitates extra expense, and this, with other details of sanitary administration, means extra rent, and it is a matter which cannot be disputed, that sanitary inspection has been an active factor in bringing about the present difficulty of making house room too expensive for the poor.

Water Supply.

7. Water, like air, is a necessity of life, and in the Author's opinion both should be pure, free and unstinted. The two latter qualifications may be unattainable, at any rate under present-day possibilities, but there should be no question as to the purity, and only by municipal ownership can there be any future chance for a free and unstinted water supply. It will be a great day for civilisation when everyone can use water as freely as air, without considering whether you can afford to expand your chest and inhale without restriction.

8. Most of the provincial towns own their respective water supplies, but in London, where the supply, pure and efficient, is in the hands of private enterprise, many inconveniences are inflicted upon the consumers, arising to a large extent from the somewhat absolute statutory powers conferred upon the companies, and the manner in which those powers are exercised. Quite recently, at enormous trouble and expense, the Metropolitan authorities have had to make a determined stand (fortunately with success) against the water companies, who were submitting for State approval, bye-laws dealing with water supply and fittings. Although the London County Council, innocently or otherwise, have interpreted the storm of indignation thus aroused with regard to the *fittings*, as having been directed against the *supply*, it cannot be gainsaid that whatever arguments (and they are many), may be urged in favour of the Metropolitan

Water Companies, it remains a sound principle that a vital public necessity, such as water, should not be left to the supply and control of private enterprise for purposes of profit.

Habitations and their Occupants.

9. Under this head, municipal supervision of building construction should insure dwellings fit for occupation, properly ventilated and provided with sufficient open space, with adequate water supply and all sanitary adjuncts. Rules governing building construction, and the occupancy of rooms in relation to cubic space, should not be of too drastic a character as they tend to raise rents beyond the means of the poor. The migration of population from country districts into crowded town areas, combined with increased cost of building, with keen municipal supervision during erection and afterwards during occupation, have brought about the present day problem of the housing of the poor. The increased cost of building principally arises from the modern trade union policy of limitation of output, governing all the materials and trades connected with the structure. The result is thus brought about, that by the curtailment of their efforts workmen are making their handiwork too expensive for their own enjoyment.

10. Without embarking on considerations perhaps outside the scope of his paper, the Author as the result of forty years experience of work and men, is of opinion that the prosperity and comfort of the workers almost wholly depend upon themselves, their habits and training. The phrase, "a fair day's work for a fair day's wage," looks pretty on paper, but no individual or nation can attain front rank by following it.

11. The gradual concentration into towns of the rural population demands the serious consideration of the Legislature. The national decadence inherent on such migration can only be prevented by national measures; municipal efforts, sanitary and otherwise, can only retard, but cannot prevent, the national decadent results attendant upon the progressing changes in the home life of the nation.

12. Town rents are proportionate to cubic space, and in dealing with families in relation to room space, sanitary authorities should not lose sight of the fact that the requirement of an additional room may just make the expenses of the

occupier exceed his income, and the coming of an additional child instead of being welcomed, is anticipated with consternation, and there is reason to suspect that these considerations, combined with the facilities for child-life insurance, lead to infanticide amongst depraved parents.

13. One of the great defects in sanitary administration arises from inability to enforce cleanly and sanitary habits on the *occupier*. Recurring sanitary notices can be served upon the *owner* to whitewash and clean walls, etc., as often as made dirty by the unclean clothes and bodies of the occupiers: as long as the body is not over-exposed it need not be washed during a lifetime, and the same legal immunity attaches to the clothes. Some slight remedial effort in this direction has been made within the past two years, by the passing of the Verminous Persons Act, but the practical application of the measure is extremely limited owing to its inherent difficulties. The national love of freedom and views as to the sanctity of human life, foster the propagation of the unfit with involved gradual national deterioration, but it deserves serious consideration whether our present ideas on these points do not require revision. Sanitary nuisances, whether arising from man or matter should be dealt with, and the present limitation of sanitary effort to the latter only, should be revised, and no nuisance should be allowed to stalk about in freedom, and multiply broadcast, because it happens to be in human form.

14. In dealing with space in relation to population, the growing appreciation of parks and open spaces is to be commended. Such places not only form sanitary lungs in crowded districts, but afford opportunities for pleasant intercourse between individuals whose interchange of courtesies would otherwise be restricted to gossip over garden walls and public-house counters, in fact, the parks to the lower orders serve the same purposes as the social reunions amongst the upper classes.

15. In their anxiety to secure open spaces for parks, etc., local authorities should be on their guard against paying too much for them, as it is quite possible for an owner of land in developing his ground for building to limit the garden space to each house, and sell the acreage thus saved to the local authority for a public park, without having to reduce the ground rent on each building plot. In such case the land owner gets paid twice, and the tenants get a large general garden kept up at

public expense, instead of each tenant maintaining a small garden at his individual cost.

16. Subject to wise use, the power to acquire land generally would be a great boon, if conferred on local authorities, instead of being as at present restricted to special acts for special purposes. If each municipality owned the site of its town and its environs, the enhancement of the value of the latter by the work and prosperity of the former, would form a valuable corporation asset in reduction of rates, and corporation land stock would form a popular and profitable investment for the savings of the inhabitants, encouraging local energy and habits of thrift.

HIGHWAYS.

17. The proper formation, cleansing and watering of the highways are not the least important of municipal duties, and the comfort and health of residents depend largely upon the manner in which such duties are discharged. The carriage-ways and their abutting footways should be of adequate width for present and future requirements, having due regard for the character of the street; in shop thoroughfares the footpaths should be wider in proportion to roadway than in residential streets.

18. The materials used in forming the streets must of course largely depend upon the situation and requirements of the particular town, but speaking generally, the demand in towns of any importance, for impervious carriage-ways, is so general that either granite setts, asphalt or wood has to be used, and owing to the noise attaching to the first-named material, the choice is generally restricted to asphalt and wood. Upon the comparative merits of these two paving materials, with their many sub-divisions, the Author could dilate to any extent, but refrains from so doing out of respect for the patience of his hearers, and to the general limitations which he has prescribed for his paper, and contents himself by submitting the statement, which he thinks will receive general expert endorsement, that apart from horse-flesh considerations, asphalt is the most sanitary and best material that can be used for road surfaces, and if motor traction generally supersedes horses the adoption of asphalt will naturally follow.

19. Whatever material is used for roads, the cleansing of

the surface and removal of the refuse therefrom form a heavy item of expenditure. Main paved streets should be thoroughly washed at night and the solids prevented from passing into the sewers, unless the latter are large with a good flow to outlet independent of pumping. Machine brooms should thoroughly sweep the surface whilst saturated, leaving the refuse in ridges about 2 feet from kerbs. Such refuse after draining, should be heaped and picked up in the early morning. By following this system of cleansing, the surface water flushes the sewers during their minimum flow, and only comparatively solid refuse has to be carted away—an economical consideration. One drawback to the above method arises from the fact that, however thoroughly the wood or asphalt is washed and broomed, a thin film is left on the surface until dry. To obviate this the Author is having made a steam motor, consisting of a watering van 600 gallons capacity, with a revolving india-rubber squeegee fixed behind, as by this method a clean and virtually dry surface can be secured.

20. After the nightly attention bestowed on cleansing the streets, constant attention is required during the day to keep them free of horse-droppings and litter. The disappearance of the former under the advent of motor traction, is an anticipated boon welcome alike to the road surveyor and the public generally. With regard to litter, the great nuisance is paper, and the remedy for this evil, as with many others, rests with the public themselves. If each individual would burn his waste paper, cardboard, straw, etc., instead of casting same on to the highway or into the dust bins, the municipal expenditure would be considerably reduced; but so long as these and other individual responsibilities are shirked, and "passed on" for some central effort to cope with, so long will rates and taxes increase, accompanied by the groans of the person responsible for the increase. Pending future reformation, the Author is using hollow lengths of iron kerb, faced on top with Mason's safety treads, for the reception of horse droppings, and is fixing to the base of lamps receptacles for litter, with notices thereon inviting the public to use them instead of littering the public way.

21. The watering of road surfaces needs little comment, except perhaps to throw out a suggestion of susceptibility to amendment. Some thirty years ago an expensive experiment was

tried in the City of London, by laying perforated pipes under the kerbs just above the level of road surface, but practical difficulties soon led to the abandonment of the method. The Author of the paper is now conducting experiments by using a jet of water from the ordinary mains, mixed with a small quantity of water from the Hydraulic Power Company's mains. This combined jet is diffused from a finely perforated boss introduced on lamp-posts at about 15 feet above ground level. The object of the Author is to attain if possible by adjustable perforations, a fine shower-like sprinkle for ordinary road watering, or a heavy saturation for road washing, and especially for snowfalls. Up to the present the experiments have yielded the following results: Water at 36 lbs. pressure to the square inch from a 4-inch main, united with a jet through a $\frac{1}{2}$-inch union from the Hydraulic Power Company's main, was passed through leather hose to a cast-iron conical distributor perforated with holes $\frac{1}{20}$th of an inch in diameter. This combined jet was converted into fine spray and projected to a distance of about 21 feet, the leather hose bursting at 130 lbs. pressure. A second experiment, with iron pipes substituted for the leather hose, gave the following result: At a pressure of 150 lbs. to the square inch the fine water spray covered an area 30 feet radius, and at this pressure, the cast iron, $\frac{3}{8}$-inch thick, forming the perforated distributor, cracked and gave way. The Author mentions these facts, thinking that some of his younger professional brethren may be induced to turn their attention to the matter, with beneficial results.

Refuse.

22. The prompt and regular removal and sanitary disposal of towns' refuse is an imperative necessity. The collection of street refuse has been hereinbefore touched upon, its disposal is another matter. Cremation is inapplicable to street refuse, and its disposal must vary according to the situation of the town and the nature of the refuse. If the roads of the town are paved, and agriculture is carried on in the vicinity, a possible market may exist for a manure composed of the paved street sweepings, other than from creosoted wood, mixed with soft core from dust bins together with a certain proportion of sweepings from gravelled roads. If such agricultural outlet

does not exist, the refuse must be got rid of into tips on land or sea—in either case generally an expensive shoot. In Kensington the Borough Council has found it economical to acquire a large area of land, and excavate same 26 feet deep for sand and gravel, depositing street refuse in the place of the excavated sand, etc. The net financial result after the whole of the land has been dealt with will be, that the Council acquires for nothing some 15 acres of freehold land which cost them about 1400*l.* an acre.

23. The house and trade refuse can best be got rid of by means of a destructor, many efficient and competing types of which are now before the public. The surplus heat from the furnaces may be used for creating steam power, available for driving machinery for any municipal purpose, but in estimating the working value of this adjunct, it must be carefully borne in mind that it is a very variable quantity, dependent upon the changing character and amount of the refuse and the varying efficiency of the furnaces.

Concluding Observations.

24. The Author having in the preceding pages, he trusts at not too great length, touched upon the chief sanitary duties of a municipal authority, admits that he has not by any means exhausted the subject. Public baths and wash-houses, public conveniences, infectious hospitals, abattoirs, disinfecting chambers, municipal lodging houses, and (to a certain extent) public libraries and technical schools, and public gymnasia—all have a sanitary effect on a town, but the Author does not propose to touch upon them, except to venture the opinion, that several small public baths and wash-houses, erected in poor districts, are to be preferred from a sanitary point of view to one imposing edifice erected in a central position, although the latter building may yield better financial results, and add to the appearance of the town.

25. Perhaps the latest phase of sanitation is the appointment by some authorities of Health Visitors, entrusted with the duty of visiting among the poor and giving them hints as to the management of their homes and the rearing of their offspring. A good deal may be said in favour of this procedure, but the

Author inclines to the opinion that such knowledge should form part of education and should precede marriage, and if such knowledge was so extended and enforced, as to prevent the indiscriminate propagation of the mentally and physically horribly unfit, the fostering care under our present system would not be needed, and some of the seeds of national deterioration would be eliminated.

DISCUSSION.

Mr. MIDGLEY TAYLOR (Westminster): I have much pleasure in proposing a vote of thanks to the Authors of these papers. All those who visited the works at Dalmarnock on Tuesday, I am sure, were struck with the ability with which the works are managed, and also the kindness shown to all members of the Congress by Mr. MacDonald himself and Bailey Anderson, the chairman of the Drainage Committee. I do not propose to say anything on Mr. Weaver's paper—I do not know sufficient about it—but with regard to the paper read by Mr. MacDonald, I would like to refer to page 57, where the chemical treatment is referred to, and I think everyone must agree that the result attained is something marvellous. I do not know of any other instance where the sewage effluent from chemical precipitation alone is absolutely free from suspended matter. Not only is the suspended matter removed, but there is about 30 per cent. purification attained in the liquid. Altogether it is equal to 65 per cent. purification of the crude liquid. Under these circumstances, and in view of the large amount of storm water and tidal water into which the effluent had to be discharged, I think we must all agree that the engineer has been wise in advising the corporation of Glasgow not to attempt further purification of the effluent, and as Mr. MacDonald very rightly put it, it would be a waste of public money to attempt to do more than is done at the present time. The river is perfectly able to carry the effluent as placed in it, judging from the relative quantities. There is one other point in connection with the working of the septic tank—the amount of solids. Mr. MacDonald claims a reduction of about 54·25 per cent. on precipitation methods; but I do not think that Mr. MacDonald has taken into account that the addition of chemicals to crude sewage naturally increases the amount of sludge, not only from the chemicals added but from the inorganic matters precipitated with the lime and other matter added, and if that is taken into account, the annual reduction between the precipitation method and the septic tank method comes down to between 25 and 30 per cent., and I think that would be found to be nearer the figure than the 54·25 Mr. MacDonald gives.

Mr. GEORGE CHATTERTON (Westminster): I beg to second the vote of thanks. I feel certain the works will be successful. It is a curious coincidence that the city of Dublin has much the same sort of difficulty as Glasgow, with the exception that in the upper part of the river Liffey there is much less tidal water. In 1891, I was asked to prepare a scheme for Dublin, and I did so. It is the same scheme as Glasgow will have. That happened without knowing what Glasgow was doing. I never went in for the sludge question. I went in for taking the sludge out to sea, but the conditions in Dublin are simpler than in Glasgow. There is another curious coincidence. I believe Glasgow had originally a recommendation and a Royal Commission advising that the sewage should be taken a good long distance out to the open sea. Dublin also had a recommendation and also a Royal Commission recommending much the same thing. Another coincidence is that the work has been in operation ten years. It is ten years since the Act was obtained, and in Dublin and in Glasgow the works are not finished. At Dublin we are just now seeing our way to completion. We have got all the contracts let. I had hoped in Mr. MacDonald's paper he would have given a little more description of the manner of constructing sewers. I have great difficulty in regard to that in Dublin.

Mr. MACDONALD, in reply, said: Something has fallen from Mr. Chatterton that I should like to answer. The delay that has taken place in the construction of the Glasgow works is not quite so bad as he says—ten years. The Dalmarnock works have been in operation seven years. The main drainage works were authorised in 1896–98, and although a regrettable amount of time has elapsed since we obtained power, it is explained by the advance in the price of money consequent on the outbreak of the war. The Corporation issued an edict prohibiting any capital expenditure; but for that circumstance, instead of now having about four miles of large sewers constructed, we should at least have had ten, and the works probably have been in partial operation. We have now got authority to resume work. Mr. Taylor's observation about the proportion of sludge—54·25—was given me by the manager of the works. I have no doubt Mr. Taylor is perfectly right in his figures.

Mr. WEAVER, in reply, said: The subject I have dealt with is so mixed up with political economy that I am not surprised members have refrained from entering into the arena, but I have not the slightest doubt that the labour question is one we shall have to deal with in the future—especially municipal engineers. It will have to be faced some time or another. We shall also have to deal with the difficulty of applying sanitation to the individual as well as to buildings. My experience is that it is a question of the greatest difficulty, as other things hinge upon it.

Thursday, September 5, 1901.

RECENT TRAMWAY PRACTICE.

By JAMES MORE, Jun., M. Inst. C.E. F.R.S.E.

In this paper the writer has merely attempted what its title implies, viz. a review or record of present practice and such results of existing tramways as he could obtain, with a few remarks on different methods. The records are unfortunately scrappy and not by any means complete, but he hopes such as he has given will be of some interest to those associated with tramway schemes.

In dealing with this subject, one has some difficulty in deciding what the term "recent" may mean. It may mean recent as compared with practice twenty years ago, which period covers many different systems of traction, or, it may mean recent as compared with five years ago, which practically means electric traction, with a small amount of cable traction.

Electric traction in this country can hardly be considered of much practical value longer back than five years, but it has greatly developed and matured in that time. The writer will, therefore, confine himself to a review of this method of traction, with a brief observation on the few cable lines in this country.

Permanent Way.

Regarding the permanent way, however, it is worth considering over a longer period, as it applies to all methods of traction in principle, only differing in degree as to stability under the different methods.

Rails.—During the last twenty years there has been a considerable change in the chemical composition, physical qualities and section of tramway rails. Until about 1885 there were many built-up systems used, principally "T" and "Channel" sections of rails carried on cast-iron chairs or sleepers, to which the rails were fixed by various methods, generally bolts or cotters. Some of these were fairly successful with the light cars used for horse traction, but failed completely when steam locomotives were used.

Steel.—Ten years ago the common percentage of carbon was 0·35, which was a very soft steel for the purpose of rolling friction, needlessly so for a tramway rail, which in most cases has a continuous bearing on a concrete foundation, and is subject only to compression and friction, in this respect differing from a railway rail carried on cross sleepers and acting as a girder, and subject to the various strains common to these. Railway rails, however, are being rolled of much harder steel than they were ten years ago.

At the present time the steel used for tramway rails contains from 0·55 to 0·65 per cent. of carbon, and is consequently much harder and more durable, besides being sufficiently tough. Such steel will stand an ultimate tensile stress of 45 tons per square inch, with an elongation of 15 per cent. and a contraction of over 40 per cent. in a 2-inch test piece, ½ inch diameter. This is a very great improvement and very essential for electric traction, which is particularly severe on the rails.

Table 4 shows the actual tests of rails used at different places, from 1891 to 1901.

Girder Rails.—About 1880 light sections of girder rails were used to some extent (about 58 lbs. to the yard), and in two or three years the weight was increased to about 75 lbs. per yard.

In 1883 the girder rail was generally adopted, to the exclusion of most others, and the weight was increased to from 80 to 100 lbs. per yard. The fish-plates, however, were, as a rule, much too light (Fig. 1).

The usual standard lengths of rails at that time were 24 feet, with 10 per cent. of shorts. Later on 30-feet lengths became the rule, and at the present time 45 feet may be called the standard, although some are being rolled 60 feet long. These long lengths are, however, somewhat inconvenient, requiring vessels with long hatches, and on the railway, guard trucks, which increase the cost of carriage. They are also cumbrous to handle on the road, but, as they save bonds and joints, are a great advantage after they are laid.

The sections have also much improved, owing to the Board of Trade relaxing to some extent its objection to wide grooves and broad treads. This has, in a great measure, been brought about by Corporations constructing their own tramways, and adopting sections that would not have been allowed to a private Company.

TABLE NO. 4.—PHYSICAL TESTS OF TRAMWAY RAILS.

Name of Tramway Rails supplied to.	Year.	Weight of Rail per yard.	Elastic Limit per sq. in.	Breaking Stress per sq. in.	Elongation in 2-inch pieces.	Contraction of Area.
		lbs.	tons	tons	per cent.	per cent.
Glasgow . . .	1891	79	30·33	46·69	11·00	31·90
" . . .	"	"	29·92	45·27	14·50	47·40
Toronto . . .	1892	98	33·97	45·65	19·50	51·00
" . . .	"	"	32·33	45·27	17·50	36·90
" . . .	"	69	30·73	44·06	16·00	36·00
" . . .	"	67	28·25	44·44	20·50	45·20
" . . .	"	"	27·87	43·43	21·00	45·90
Glasgow . . .	1893	79	29·56	45·90	15·00	26·70
" . . .	"	"	30·75	45·46	15·00	25·00
Huddersfield .	"	98	32·33	45·07	19·75	57·10
" .	"	"	33·82	45·05	15·00	60·14
Dublin . . .	"	66·5	27·90	45·88	15·00	41·50
Nottingham . .	1894	92	30·05	43·43	18·75	61·60
" . .	"	"	28·32	42·16	17·75	60·90
Anglo-Argentine	"	103	27·90	42·73	18·75	48·20
" "	"	"	27·10	42·22	19·00	46·00
" "	"	"	28·40	43·17	21·00	48·70
Toronto . . .	"	73	33·16	42·03	14·00	33·60
" . . .	"	"	30·33	41·46	23·00	45·90
" . . .	"	86	28·31	40·76	20·25	60·90
" . . .	"	"	25·47	40·63	24·00	62·20
Dublin . . .	1895	66·5	28·11	44·66	15·50	48·30
Bombay . . .	"	77	26·28	42·85	23·50	53·80
" . . .	1896	"	28·30	44·89	17·50	45·20
" . . .	"	"	29·90	44·06	20·00	59·00
Melbourne . .	"	61	32·32	44·25	15·00	59·60
					8-in. piece.	
Glasgow . . .	1901	98	..	45·00	17·00	43·40
" . . .	"	"	..	48·30	15·50	39·70
" . . .	"	"	..	46·40	12·50	32·30
" . . .	"	"	..	47·90	8·00	14·50
" . . .	"	"	..	46·60	15·00	41·70
" . . .	"	"	..	46·40	15·00	42·30
					200 mm.	
Portsmouth . .	1901	96	31·30	47·50	13·50	26·90
" . .	"	"	29·90	46·30	14·50	28·60
" . .	"	"	28·30	47·50	12·50	27·70
					100 mm.	
Portsmouth . .	1901	96	31·50	46·90	22·80	36·80
" . .	"	"	34·90	47·70	15·00	25·20
" . .	"	"	34·00	48·30	23·00	39·90
" . .	"	"	28·70	45·40	21·00	31·90

Fig. 2 shows a good section of 6-inch rail, with the patent "check" joint. This section has been used at Hartlepool, Ashton, Carlisle, the Potteries and elsewhere, with this joint, and it has given most satisfactory results. From the writer's experience it is more effective in keeping a tight joint than any form of sole plate. Most of the sole plates in use prevent the proper and effective packing of the joint with concrete where it is most necessary.

Fig. 3 shows a very good 7-inch section of rail, as adopted by the Glasgow Corporation.

Fish-Plates.—Until recently rails were rolled with a much too obtuse angle at the shoulders, or fish-bed. The writer pointed this out in a paper to the Institute of Civil Engineers before the year 1887, and when the Cape Town Tramways were laid this suggestion was adopted, and a rail similar to Fig. 2 was rolled, but with a narrower tread. This acute fish-bed gives a much better support to the rail heads, and prevents the head wedging in between the fish-plates.

The difference between good and bad fish beds will be seen by comparing Figs. 2 and 3, and Figs. 1, 5 and 8. No. 5 section was a most popular one, and largely adopted between the years from 1885 to 1895.

Fish-plates, besides being heavier now, are also used longer, the common practice being to have six 1-inch fish-bolts to each pair of fish-plates. The writer thinks this is an improvement on the old practice of having four bolts, but can see no advantage in putting in more than six.

Sole-Plates.—There are several devices in the form of sole or joint plates used to obviate the loosening of the rail joints, and consequent pounding of the car wheels in passing over them. It is evident that a flat joint plate bolted to the flange of the rail will not give much increased vertical strength to the joint. Their purpose seems to be to prevent the rail ends working into the concrete foundation. This action does not occur, however, until the joint is already loose. These sole plates are nearly all too broad to allow of good tight solid packing with concrete, the bottom being broken up by bolt heads (Fig. 8). This section is a better arrangement than the ordinary sole plate, as the bolts pass through the rail and fish-plate flanges.

The real thing to aim at, in the Author's opinion, is good vertical stiffness, obtained by heavy fish-plates with good fish-beds, and a tight solid concrete bed under the plain rail flange.

Figs. 6, 7, 8 and 9 show some angle fish-plates and sole-plates. They are all objectionable, in so far as they cannot be tightly packed, Figs. 6 and 7 being particularly bad in this respect.

Fig. 6 is a development of the "check" joint, but the writer thinks it is not an improvement, and prefers the original Fig. 2 to this or any of the other arrangements.

Points and Crossings.—There has not been any important improvement in these, excepting that at the present time the cast steel is somewhat harder by the addition of manganese, first adopted by Mr. R. A. Hadfield, M.Inst.C.E., of Sheffield. While the steel is harder, this end has been attained at the expense of soundness, the metal being more gassy and the castings rather liable to have a spongy structure. This, however, is not of great importance, provided the tread of the points —that is, the rolling surface—is kept sound and homogeneous for at least half an inch from the skin.

Certain American companies are making cast-steel points and crossings with special hard manganese steel filling pieces where the wheels of the cars drop. They are very clumsy in appearance, and there is a very large surface of metal exposed, with consequent danger, owing to horses slipping on them. In 1884, similar points with renewable filling pieces were used in a large steam tramway system in England, and before six months were over the filling pieces were loose. The car wheels dropped from the hard filling pieces on to the ordinary cast tread, with the result that the pounding caused a depression where it dropped on the body of the casting. After renewing the filling pieces, naturally this drop was accentuated, and ultimately the points and crossings had to be taken up and replaced by chilled iron and ordinary cast steel.

The filling pieces in the American points of to-day are considerably larger and probably better fitted, and therefore may be an improvement, but the writer doubts if they will work properly for as long a life as an ordinary good cast-steel point. He also doubts whether the renewing of the filling pieces can be done, and still allow sweet running to the cars.

Chilled iron points and crossings are becoming rarer every day for tramway purposes, and the Author thinks this is only due to the makers not making their patterns to suit the heavy electric cars.

Considering the fact that the authorities allow a much greater metallic surface on the road than they did, there is no difficulty in chilled iron points being made with sufficient body of metal to withstand the lateral shocks from the heavier cars. There is no question as to its superior durability to cast steel. Originally, the points were made to the section of the rail used, and the small body of metal was too brittle to stand the shocks.

Foundation.—All tramway permanent way should have a foundation of Portland cement concrete not less than 6 inches deep. There are several methods of laying this foundation, and the writer has tried them all.

Probably the first method was to lay the 6-inch layer as nearly as possible to the levels with a smooth top, and, when the rails were laid, to run in cement grout into the spaces left between the flanges of the rail and the hollows of the concrete. This is a bad method, as it cannot be done tightly enough, and the rail is always bearing on the high points of the concrete.

The second method was to get the rails blocked up to their level before the concrete was put in, and then the 6-inch layer was put in in one mass, packing it under the rail flanges and finishing it off. This has a serious defect. It is not possible to pack a mass of plastic concrete 6 inches thick so as to take the weight of the rails, the result being that the rails are only bearing on the original points of support. If it were possible to get it tight, the lightest tap with a hammer three or four rails ahead will cause vibration and the plastic concrete to sink under the level of the rail flanges.

The method the writer has found to be best in every way is to put the 6-inch layer in as truly to level as possible, but say 1 inch lower than the finished level of the rail flange. After this has set, say two hours after laying, the rails are put in place and brought to a true level by cement packing at the joints and two intermediate places in a 40-feet rail; then two men are put on, one on each side of the rail, and the 1-inch space thoroughly packed from both sides of the flanges. This packing should be composed of one part of ½-inch shivers, granite if possible, two parts of sharp sand, and one part of Portland cement. It should only be damped slightly for packing, but after the packing is finished it should be well watered with a watering can through a rose. The writer does not float the surface of the concrete, but leaves it as rough as possible to make a bond with the cement bedding for the sets, which he has found to be a great advantage in economy in the maintenance of the paving.

Plastering Rails.—Some engineers are in the habit of plastering up the haunch of the rails with cement mortar. This was tried and abandoned in 1883 by tramway engineers. The writer could never see the object of it, unless it was to save pitch grout. This is not economy. The whole advantage of pitch grout is its elasticity, and it is of the greatest advantage at the joint next the rails, where the vibration occurs. The plastering of the rails most effectively neutralises this advantage, and facilitates the passage of water down the joint and under the paving. This loosens the bedding, and the sets subside and work loose.

Paving.—We have made considerable progress in paving, these last twenty years, as regards tramways. Pitch grout is now generally used, and is the best of all grouting for tramways. It was, however, used in Lancashire as far back as that time, although it was not known in the south. Its superiority to cement grout for tramways is due to the fact that it is more elastic, and, instead of breaking, yields to the vibration in the rails, and remains water-tight.

One notable difference is, that the sets are now laid as closely as possible, whereas formerly a ¾-inch joint was often insisted upon. This was supposed to give a better foothold for horses. The writer does not agree with this theory. With the wide joints the tops of the sets round very quickly, and a horse's foot slips from one joint on to the next, causing a sudden jar to his back tendons, and doing probably more damage to him than would a clean slip. Close joints also mean reduced cost of maintenance and repairs.

Granite sets need not be discussed here, as everyone has his own ideas as to the best for street purposes. It may be said, however, that they cannot be too well dressed for tramway purposes, the courses being so short. They should, however, be varied in lengths, from 5 to 9 inches. Where sets are used nearly all about 7 inches long there may be as much as 15 per cent. cut to waste for closers at the four straight joints at sides of the rails. It is very important that the sets should not be too deep, as they should have at least half an inch of bedding between the rail flange and the bottom of the set.

Where a tramway is laid in a macadam road, the paving of the margins should be finished at the outside with a straight joint. This greatly facilitates the proper maintenance of the macadam next to the paving and the paved margin itself. The macadam can be rolled right up to the margins. Where the margins are toothed there is always trouble, as the macadam can only be rolled to the outside of the long tooth, and the space between the long tooth and the short tooth is left loose. As a matter of fact, what happens in practice is, that the roller driver tries to roll into the short tooth by running the roller over the long tooth, thus loosening the sets and breaking the grout. The surface water then gets under the sets, and every passing vehicle rocks the outside sets, thus churning the water, grout and bedding up, and ruining the marginal paving in a comparatively short time.

Cable Traction.

It is worth while just to mention this method, as notwithstanding the great advance in electric traction there are still routes that should be worked, owing to heavy gradients, by some method which is not dependent on adhesion between the car wheels and the rails. Even on the level, where there is traffic to justify a service of five minutes and under, a properly designed cable installation can be operated at 5·5 pence per car mile, including all expenses. The total capital need not be much higher than for an overhead electric installation, owing to the lower cost of the cars. It is not far off the mark to say that, taking equipment and everything into consideration, for a five mile tramway with say a four minutes' service, the total outlay should be about the same for both systems.

The first cable line of any importance in this country was the Edinburgh Northern, then the Birmingham Central, then the line from Kennington to Streatham now owned by the London County Council, and the Upper Douglas Line, I.O.M. All these lines have been financial successes. Others at Highgate and Matlock have not been so successful, being so short.

The Edinburgh Corporation cable lines, just being completed, have not so far paid their way for several avoidable reasons. This installation is perhaps the most substantial of any that have been made in this country or abroad.

Electric Traction.

Electric traction may be considered the traction of the present day, and excepting where the gradients are so extreme as to require a cable in the interests of safety and economy, the writer thinks it is unnecessary to discuss any other.

There are of course various methods of adapting electricity to the propulsion of tramway cars, although all of them excepting the overhead trolley wire may be considered still in the experimental stage.

Storage Batteries.—Perhaps the earliest system tried on tramways in this country on an entire route was the Bristol Road route in Birmingham. This was until recently worked by storage batteries, and several different kinds of cells have been tried. All these, however, failed to make the line a financial success. This has been owing to several circumstances, including the time occupied in charging the batteries, the extreme weight of the cars with batteries and motors complete, and the short life of the batteries themselves.

There are, of course, several minor objections, but if a light durable cell can be discovered that can be charged in say, one-third of the present time, the writer thinks the secondary battery system will supersede all others. This is easily understood, as the track is practically the ordinary horse track laid in a more substantial and intelligent manner, and each car is a unit of power in itself and free to run anywhere that the rails are laid. This admits of great flexibility in a system, and facility of extension.

The advent of a suitable primary battery is too utopian for consideration, at the present time at least.

Surface Contact.—The next method in inverse order as to practical application in the writer's opinion is the surface contact system. This system, as everyone is aware, has studs or contact pieces between or alongside the track rails. These studs are dead or outside the electrical circuit until the car passes over them. When the car comes above them an electro-magnet operates a switch, which completes the circuit through them and the motors of the car for a sufficient time to allow the car collecting bar to reach the next stud. When the influence of the magnet ceases to act the circuit is broken by the switch, actuated by a spring or gravity, resuming its natural position.

Mechanically this system is undoubtedly a success in an exhibition or on a laboratory table, but the conditions are entirely altered in a public road, where there are circumstances which will interfere with the reliable working of the mechanism for switching the current off and on to the studs. The studs themselves are also a defect in the road surface.

Conduit.—The conduit system has yet to prove its financial advantages in this country. It is needless to mention the lines which have been laid and abandoned, as they were neither mechanically nor financially successful, although there is no reason why the former should not be attained.

Everyone will be greatly interested in the result of Professor Kennedy's experiment in the Clapham Road for the County Council. Professor Kennedy, the writer thinks, has reduced the conduit to the minimum of cost and capacity. As regards the latter, the writer agrees with him, and considers the large conduits used in America unnecessary in this country. Every extra inch in the depth of the excavation involves an unknown amount of expenditure in alterations to gas, water and drain pipes, thus adding dead weight to the capital account, which in this system is already heavy enough. The writer wishes Professor Kennedy all success with this experiment, and hopes the financial results will turn out to be better than the writer expects, as the system has much in its favour compared with the overhead system, as regards public safety and amenity. The nstallation is being carried out in sufficient magnitude to give reliable and comprehensive results, in this respect differing from the others in this country.

Power-house Boilers.—In the modern power house there are several kinds of boilers adopted, some of the tubular marine type, others of the water-tube type, such as the Stirling and Babcock & Wilcox boilers. These are specially useful where space is restricted and where a lighting circuit is worked from the same station as the traction circuit. They are quicker in getting up steam, and where there is a combined depôt such as this, the maximum loads come on about the same time of the day, besides the sudden calls on the lighting plant due to fogs, etc. Steam is quickly got up in a spare boiler in this emergency. The thin tubes in these water-tube boilers are, no doubt, the reason of their quickness. They are also considered to be safer, being less liable to total destruction. Lesser accidents are, however, more frequent than in the Lancashire type. They are easily cleaned and readily repaired.

In some cases the boiler room is carried on a floor above the engine house, and the ease with which their parts are handled is a great advantage in this case. This applies also to a case where a supplementary boiler has to be put into an existing boiler-house in full work.

There are, however, many engineers who will, if it is at all possible, adopt the old-fashioned Lancashire boiler with Galloway tubes. The writer has had good results from these, but prefers the Galloway boiler itself as having a higher efficiency, and being quicker than the ordinary Lancashire type.

In the Galloway boiler the circulation is most thorough, without the chance of the plate becoming dry, as in the tubes of the water-tube boiler, through forcing the generation of steam.

They have a large steam and water capacity, which is all in favour of dry steam. In this respect they stand higher in the tests than any water-tube or tubular boiler.

The heating surface is internal, and is very effective. As to the efficiency of the boiler, this has been proved beyond question. While most tubular boilers give 7 lbs. of steam to about 24 lb. of coal per square foot of grate per hour, the Galloway boiler gives between 8 and 9 lbs.

This boiler is also easily examined and cleaned, and is comparatively free from accidents of all kinds, and this at a comparatively low up-keep and long life.

Another important point in its favour, as in other Lancashire types, is that it does not require such skilled attention as the tubular or water-tube boiler.

It is advisable, and is common practice to have two safety valves on each boiler.

There should be a dead-weight valve (which is preferable to a lever one), and also a high-steam and low-water valve. The latter type blows off both for high steam and low water, as its name implies.

Economiser.—An economiser is considered a necessity now-a-days, and properly so, to get the highest efficiency from an installation. This was realised many years ago by the Lancashire mill owners. They had to bring their minds to bear on the question of cheap production of steam power, perhaps, before any other class of users, and it is to their own and Messrs. Green's experiments that we are indebted for the evolution of the modern waste-gas economiser.

The load in a mill is fairly uniform, and when the economiser was admitted to be a saving under these conditions it was readily seen that with varying loads and sudden heavy calls it would be of greater value still in saving time as well as money. There were various difficulties to overcome at first with these economisers, but Messrs. Green have made a long study of the question and a speciality of their manufacture, with the result that they have evolved a most effective system, that will redeem its first cost in from five to eight years, dependent on the size of the installation.

It is being largely used in this country and America in the power houses of electric tramways, and actual practice shows most satisfactory results, varying in fuel economy from fifteen to twenty per cent.

The following table gives, roughly, actual results from Canada and America, from reports by the engineer.

—	Feed Water.	
	In Tank.	After leaving Economiser.
	° Fahr.	Average ° Fahr.
Montreal Street Railroad	90	270
South Chicago City	90	219
Detroit Railway	80	246
Douglas Cable Tramway (pressure 96 lbs.)	46	238

The last, Douglas Cable Tramway, was erected by the writer, and he made various tests, which were all very satisfactory.

One important advantage of an economiser is, that it reduces the expansion and contraction of the boilers, thus saving them a considerable amount of wear and tear.

There are also several useful exhaust steam heaters, which may be used in conjunction with the waste-gas economisers, for heating the water before it passes through the economiser tubes.

Table 10 shows the kind of boiler, economiser, working pressure and evaporation results of several existing overhead installations. The evaporation is taken from the coal and steam per I.H.P. per hour, or per kw. per hour, from working results.

TABLE 10.—BOILERS.

Name of Town.	Type of Boiler.	Working Pressure per sq. in.	Type of Economiser.	Water Evaporated per lb. of Coal.
		lbs.		lbs.
Glasgow Corporation, Springburn	Babcock & Wilcox	175	None	2·76
Leeds Corporation . .	Lancashire	140	Green's	3·00
Sunderland Corporation .	Galloway	130	Green's	2·75
Dublin United Tramways	Babcock & Wilcox	160	Green's	4·00
Aberdeen Corporation .	Babcock & Wilcox	160	None	6·6

Conveyors.—The writer will only mention these in passing. There is no doubt that where there are a large number of boilers with a large consumption of coal, conveyors can be made to pay. In the majority of cases, however, expensive gantries to bring in the wagons, large storage hoppers, etc. have to be erected before the coal gets to the conveyors, and the writer is satisfied that in these cases the capital cost neutralises largely the economy, if any, in the stoking. Careful consideration on the part of the engineer is necessary as to site, consumption, etc. before deciding to put in conveyors.

Mechanical Stoker.—These (and there are several good ones) have other advantages besides economy of stoking. They are particularly useful in avoiding black smoke, owing to the even firing. They also avoid the cooling of the gases due to the opening of the doors in hand-firing. Most electric traction power stations have mechanical stokers, and, on the whole, they are advisable where first cost is not an important consideration.

Steam Piping.—For pressure up to about 100 lbs., C.I. pipes are used. The modern practice is, however, to work with pressure considerably above this, varying from 120 lbs. to about 175 lbs. Steel steam piping is therefore generally used now. In many cases they are in duplicate. This, the writer thinks, is not necessary, although very convenient for the purpose of making repairs, etc. With steel piping most repairs can be done during the night.

Where rigid economy is not absolutely necessary in the capital account, it is well to have the piping in duplicate.

With steel piping expansion bends are used, and it is well to have the pipes properly anchored between these bends, so that each bend may take its proportion of the expansion, otherwise, too much may be thrown on one bend.

All steam pipes are, or should be, coated with a good non-conducting substance, of which there are several.

The writer prefers those made in sections and fixed on with hoops; the section can be easily removed and replaced to admit of repairs to the pipes. It is of course understood that the steam pipes should be fitted with automatic drainage traps, and that the pipes themselves should have a fall towards the traps for the purpose of collecting the condensed water.

Feed Pumps.—There are now many feed pumps of high efficiency, and it is hardly necessary to discuss in such a paper as this the various types. It is, however, worth remarking that some engineers are rather prone to use the generated electricity for every little purpose, including the driving of the feed pumps. The writer does not agree with this. The pumps are generally, or should be, in the boiler house, and consequently near the boilers. Under these conditions the proper and economical method is to use the steam direct. They are generally some distance from the generators and switchboard, which is an argument against electrical driving, and lastly, the boiler house is not a favourable place in which to run an electric motor.

Injectors.—Besides a feed pump, it is useful to have an injector. It can be used when the economiser is under repair, or the exhaust steam heater, as the case may be, and, of course, is better in such cases owing to the fact that the injecting of the feed water raises the temperature considerably. They can also be used to feed through the economiser, which considerably increases the efficiency and durability of the latter.

Engines.—Until about four years ago, the usual practice was to have low speed engines, with the generators geared up from the crank or countershaft, and driven by belts. Later on, the generators were driven direct, the armature being keyed on to the crank shaft of the engines. These engines at first were high speed, about 400 revolutions, and were far from economical as regards coal and oil consumpt. Some were single and others double acting, the former perhaps being preferable as to wear and tear. Since they were first used there has been a notable improvement in their performance, alterations having been made in their designs, and defects remedied. At the present time there are several high speed closed engines which give satisfactory results as regards economy of working.

Table 11 shows the consumpt of steam at different loads of a Bellis and Morcom 200 H.P. compound condensing engine. The efficiency is high, and the consumpt of steam is low for this type of engine.

TABLE 11.—TRIAL OF BELLIS 200 H.P. "SELF-LUBRICATING" COMPOUND CONDENSING ENGINE. Steam Pressure 120 lbs. per sq. in.

Trial No. 1.

Load.	Maximum.	Normal Full.	Three-Quarter.	Half.	One-Quarter.
Mean indicated horse-power . I.H.P.	217·5	193·6	147·1	102·7	49·8
Mean brake horse-power . . B.H.P.	209·5	186·0	140·6	97·0	44·5
Mechanical efficiency $\frac{\text{B.H.P.}}{\text{I.H.P.}}$ per cent.	96·3	96·1	95·2	94·4	89·3
Water per hour per B.H.P. . . lbs.	18·0	18·2	18·7	19·8	20·0

Trial No. 2.—*Coupled to Continuous Current Dynamo.*

Load.	Maximum.	Normal Full.	Three-Quarter.	Half.	One-Quarter.
Mean indicated horse-power . I.H.P.	..	186·7	129·4	98·2	54·1
Mean electric horse-power . E.H.P.	..	168·6	115·1	83·8	40·9
Combined efficiency $\frac{\text{E.H.P.}}{\text{I.H.P.}}$ per cent.	..	90·3	88·9	85·3	75·6
Water per hour per E.H.P. . . lbs.	..	19·2	19·36	20·1	21·92

This engine also governs well under extreme variations of load, which will be seen from Table 12, which shows the results of three trials on the City and Waterloo Railway.

The writer gives these results of the Bellis engines because he has the records by him, and does not mean to imply that they are the best, although he thinks that, for an engine of this type, they are satisfactory.

Most engineers, of course, prefer a low speed engine with an effective automatic expansion valve gear, and the problem was set for electricians to construct an effective generator to work direct from such an engine.

The first of these large low speed generators was, the writer thinks, made in Germany, but since then they have been constructed and largely used in America and this country.

These engines are generally run about 90 revolutions per minute, and have Corliss, Proell, or other automatic expansion valve gear. They generally are slightly more economical in consumpt, but not invariably so.

There are also some very convenient horizontal and vertical

TABLE 12.—WATERLOO AND CITY RAILWAY (half minute readings).

No. 1 Engine. *Date*—May 22nd, 1899. *Time*—1.11 p.m. to 1.21 p.m. *Mean Boiler Steam*—160 lbs. *Mean Volts*—515. *Tach.*—384·5. Actual 388.		No. 3 Engine. *Date*—May 24th, 1899. *Time*—11.50 a.m. to 12 noon. *Mean Boiler Steam*—170 lbs. *Mean Volts*—512. *Tach.*—388. Actual 385.		No. 4 Engine. *Date*—May 24th, 1899. *Time*—8.14 a.m. to 8.24 a.m. *Mean Boiler Steam*—155 lbs. *Mean Volts*—520. *Tach.*—381. Actual 391·5.	
Amperes.	(Tach.) Speed.	Amperes.	(Tach.) Speed.	Amperes.	(Tach.) Speed.
300	381	95	387	60	380
310	381	95	387	180	378
330	380·5	60	387·5	165	379
80	383·5	110	386	180	378·5
50	384	150	385	190	378
85	383	250	384	200	377·5
50	384	255	384	130	380
50	384	265	384	75	380
150	382	165	385	140	378
130	382·5	200	386	60	380
145	382	240	385	80	380
110	382·5	110	387	85	379
110	382	100	387	220	376
165	381	60	387·5	180	378
210	381	60	387·5	170	378·5
265	380	110	386	210	377
300	380·5	230	386	230	377
312	380·5	120	386·5	255	376·5
330	380	70	387·5	280	376
140	383	50	387·5	110	379
70	384	50	387·5	200	378

Note.—Deviation from mean speed less than ½ per cent. for any variation of load under actual working conditions.

compound condensing engines made to run at 200 revolutions, and generators at the same speed, of capacities varying from 100 to 300 kw.

The question as to whether the high, medium or low speed engines are most suitable for supplying power for an electric tramway scheme requires careful consideration. It can only be answered when the whole of the conditions as to the distributing area, mileage, gradients, service and probable extensions are known and carefully studied. The units in use should have capacity sufficient to meet all ordinary fluctuations of load due to extra heavy traffic. Of course there must be one unit at least as a stand-by under ordinary circumstances, and also to act as an auxiliary for extra power during heavy loads in snowstorms, etc.

The writer is of opinion, therefore, that it is better to divide the total ordinary load (with, of course, a margin for fluctuations) into two, and to have three units of this capacity. These two units would be in daily use, and the third would

TABLE 13.—ENGINES.

Name of Town.	Type of Engine.	Revolutions.	Steam Consumpt.		Coal Consnmpt.	
			Lbs. per K.W.H.	Lbs. per I.H.P.H.	Lbs. per K.W.H.	Lbs. per I.H.P.H.
Glasgow, Springburn . . .	Horizontal Compound Condensing. McIntosh & Seymour	200	22·3	15·59	8·4	5·64
Leeds . . .	Horizontal Compound Condensing. Fowler's.	90 & 112	21·5	15·04	7·17	5·0
Sunderland . .	Vertical Compound Condensing. Bellis, 3 crank.	400	21·24	14·85	7·02	5·4
Dublin . . .	Vertical Compound Condensing. Corliss, E. P. Allis & Co.	90	21·45	15·0	5·587	3·8
Aberdeen . .	Willans Vertical Central Valve.	350	26·8	20·00	5·00	4·00

form a reserve. It must, of course, be taken into consideration that there may be future extensions and consequent increase in the ordinary load, and therefore due weight must be given to this in fixing the capacity of the units—that is, whether to divide them to suit the prospective, or first load.

The question of first cost is another important point to consider, and it is often good policy to adopt the cheaper high speed units to get the line installed quickly and cheaply.

Table 13 gives the consumpt of several existing installations. Several of the results had to be converted by estimation and calculation from consumpt per kw. per hour to I.H.P.

per hour and *vice versa*, so that, probably, they may be a decimal out of truth. They are sufficiently accurate, however, to give a rough comparison between the different installations. It may be said, in passing, that this applies to all the comparative tables throughout the paper.

Generators.

It will be sufficient in this paper to briefly describe continuous current generators, as they are in more general use than alternators, the radius of distribution in towns in this country being small.

The generators may be taken as all direct driven, and to the following brief specification.

Field Magnet Frame.—The field magnet, of the type and design for ironclad armature, has poles at equidistant points projecting inwards round the armature periphery.

Each field magnet consists of a circular yoke divided in two portions horizontally, in line with the centre of the armature shaft. The lower portion of the magnet yoke has two shoulders, or brackets, cast solid with it, one on each side, to carry the frame on the foundation or girders, as the case may be. The frame should be arranged to slide along the armature shaft sufficiently far to allow for the removal of the magnet winding without removing the upper portion of the frame or disturbing the armature. Slides or girders are generally supplied for this purpose.

Magnet Poles.—These are generally of wrought iron or soft steel, and are cast solid in the magnet frame, special care being taken to get a thorough weld in casting.

Magnet Winding.—The field winding spools should be of sheet iron, with brass ends, and fit neatly over and around the poles.

The spools are covered inside with an insulating lining about $\frac{3}{16}$ of an inch thick, composed of mica, paper and linen, the whole cemented together with shellac in solution.

The series and shunt windings of the generator are wound as distinct coils side by side in the spool with insulating between. The series coil is set at the end of the spool next the magnet yoke, and the two windings should be of an even depth, to show an unbroken surface. The winding wire should be well insulated with cotton, and the layers should have sheet insulation between.

The conductors are of pure copper, and insulated moisture-proof. The armature sections should be of sufficient number to reduce the average potential differences to the proper limit.

Commutator.—The commutator hub should be mounted on, and keyed to, a sleeve extension on the hub of the armature.

The bars must be of hard-drawn copper, drawn accurately to the proper section, with length sufficient to allow ample space for the brushes.

The insulation between the bars should be of the best quality of mica, laid in layers so as to break joint, and of a thickness not less than $\frac{1}{32}$ of an inch.

The connections from the armature conductors to the commutator segments must be sufficiently flexible to avoid all danger of breakage from vibration, and must be fixed by rivets and solder, so as to have an equal conductivity to the armature conductors.

Brushes.—The brushes are of carbon, and of such a capacity that the current density shall not exceed 35 amperes per square inch.

The brush holders must be arranged to allow perfect freedom of access to the commutator, and so as to allow no portion of the conducting metal to come within flashing distance of the frame of the machine.

There must be sufficient contact between the carbon and the holder, and the carbon must have perfect freedom to follow any unevenness that may occur in the commutator.

The brush supports are mounted on radial studs in the holder yoke, from which they must be insulated; the yoke itself is mounted on guides and is capable of a rotation movement concentric with the armature. This movement is made and position locked by a tangential screw and hand wheel.

Rheostats.—Each machine is fitted with a field shunt circuit regulating rheostat.

Construction.—The mechanical construction must be of the highest throughout. The armature must be in perfect running balance, and the construction of the commutator such that the segments, insulation, etc., are firmly clamped in position so as to be secure against all disturbing effects of working.

The ends of the field windings are brought out to substantial connecting terminals, easily connected and disconnected without danger of injury while being handled. The connecting terminals for the dynamo leads to the switchboard are placed on a special board in the pit below the machine, so that the leads do not appear above the floor.

Electrical Features.—The windings of the fields should be free from all electrical defects and properly insulated, and the individual insulation resistance of armature and field magnet windings, with respect to the frame, should be not less than one megohm.

The joint insulation resistance of the armature and field windings, with respect to the frame, should be not less than one megohm.

The machine should run without sparking or heating at all loads within the limits specified.

The design and proportions of the field shunt and series exciting coils must be such as to secure a practically perfect compounding, from zero to full load.

Armature Reaction. — The design and proportions of the magnetic circuit in the field magnet air space and armature core, as well as those of the armature and field windings, must be such as to have a fixed line of commutation for the brushes, so that the load may be varied from zero to 25 per cent. over the full rated load of each machine without requiring any change in the lead of the brushes or causing objectionable sparking. The machine should run at 50 per cent. overload without injurious sparking.

All parts should be well finished, made to standard gauge, and be interchangeable.

All bolts should be fitted and have hexagonal nuts and castings faced under both heads and nuts.

All unfinished parts must be filled, rubbed down as often as necessary to get an even, smooth surface, primed, painted and varnished.

Rating Conditions.—The output is measured at the dynamo terminals.

The normal current load is rated under a working E.M.F. of 550 volts at the terminals. The output in amperes and maximum voltage should be so related as to correspond to the formula: E.M.F. × Am. = Watts output.

Each machine should be capable of running at its full normal load continuously for 24 hours without sparking or heating itself more than 80° Fahr. above the temperature of the surrounding air. The temperatures should be measured in the usual way with a thermometer.

The dynamo should run at 25 per cent. overload for one half-hour without injurious heating, and take momentary overloads of 50 per cent. without flashing, even when the circuit is suddenly opened on such an overload.

TABLE 15.—GENERATING PLANT.

Name of Town.	Nature of Current.	Voltage.	Generating Units.					Average Radius of Distribution (miles).	Number of Cars Working (average).	Miles of Route.
			Type of Generator.	No.	Capacity in kw.	Total Capacity in kw.	Output in kw.-h.			
Glasgow, Springburn	Direct	500	Direct coupled, multipolar, Westinghouse.	3	200	600	293	2	47	5
Leeds . .	Direct	500	Direct coupled, multipolar.	2 1	750 800	2300	800	3½	130	23
Sunderland	Direct	500	Direct coupled, 4 poles.	4	275	1100	180	2½	41	9
Dublin .	Alternating and Direct	2500 500	Direct coupled, B.T.H.	6	550	3300	1000	3	201	46
Aberdeen .	Direct	500	Direct coupled, bi-polar and multipolar.	2 1	120 200	440	50·3	3	11	3¼

TABLE 16.—MOTIVE POWER.

Name of Town.	Cost per Board of Trade Unit	Price paid for Current Purchased.	Average Amperes per Car.	B.T.U. per Car Mile.	Cost per Car Mile.	Number of Cars.	Kw. per Hour per Car.
	d.	*d.*			*d.*		
Glasgow, Springburn	0·73	..	12–13	1·25	0·92	47	6·23
Leeds . .	0·67	..	13	0·917	0·6144	130	6·15
Sunderland.	..	2·0	15–16	0·92	1·84	41	4·4
Dublin . .	0·572	..	12	0·95	0·5434	201	4·97
Aberdeen .	..	1·929	9·1	0·85	1·639	11	4·6

The efficiency should be 95 per cent. at full load and 93 per cent. at half load.

Fig. 14 shows the construction of the type of generator just described, and Tables 15 and 16 show comparative descriptions of several important installations with their results in working, which may be of interest.

Bonding.—It is necessary to bond the rails for the purpose of the return circuit to reduce the resistance, and prevent electrolysis of adjoining water and gas pipes. The Board of Trade fix a maximum drop of 7 volts, and the bonding must be good to comply with this. Indeed, it is sometimes necessary to have insulated return feeders and negative boosters.

There is no part of the work on an electrical tramway installation that requires or should have greater care given to it, than the bonding. It is in too many cases let as piecework to inexperienced men, who consider that it is a mere mechanical operation of riveting, or driving a plug. They generally have a price per joint, which includes drilling or rimering the holes in the rail flange or web, and fixing and painting the bonds.

The maximum drop allowed by the Board of Trade is so small, that every care should be taken, considering the cost and trouble there is in pulling up the paving, to remedy bad bonding.

The writer thinks the fastening of the "Neptune" bond is the best, as it can be done from one side of the rail and requires no hold-on, and that, in driving the plug, the tendency is to drive in the head of the bond into the hole, and not out of it, as in the Chicago and Columbia bonds.

Besides making a good mechanical job, it is necessary to have good clean metallic contact between the steel of the rail and the copper head of the bond. To get this, all burr and oxide must be removed from the hole in the rail by rimering thoroughly. It takes a little longer to drill the holes, but not so much as is generally thought. A good man with a proper drill can drill the holes about as fast as he can rimer them properly; however, most rails are drilled at the works, and about $\frac{1}{16}$th inch diameter left for rimering. This should be done without oil.

After the holes are rimered, it is usual for the man to take a piece of emery cloth in his hand, and, grasping the head or terminal of the bond with the emery cloth round it, to swing the bond round so that the head revolves in the emery cloth. This is for the purpose of cleaning the skin of the copper head. It is, however, only a makeshift, slovenly method, and the writer thinks all bond heads should be made $\frac{1}{32}$ of an inch larger, and this amount turned off in a small hand-tool fixed on a movable bench. This would remove the skin entirely, and give a clean metallic surface of soft copper. It need not take longer than the emery cloth method, and would be much more effective.

All rail joints should have at least two bonds connecting the flanges or webs of both rails past the fish-plates. They should have a current capacity of the rail itself, and the heads or terminals of the bonds should have an excess of area of metallic contact with the rail. The usual practice is to have two 4/0 S.W.G. bonds to each joint.

All rails should be connected with long bonds past points and crossings, and the two rails should be cross-bonded every 100 feet.

Poles.—The poles for carrying the trolley wires should be of such a length as to allow the wire to be carried about 21 feet above the rail level when cars with top seats are to be used.

Certain firms manufacture taper poles made in one piece, but the commoner kinds are made in three pieces of different diameters, shrunk over each other while hot. They are made of mild steel tubing of varying thickness and diameter, according to the class of pole and purpose.

To give a trolley wire 21 feet from rail level, they are usually 31 feet long over all, and are planted 6 feet deep in the ground.

The following Table 17 gives the dimensions and physical tests of three ordinary standard poles, which should be sufficient.

TABLE 17.—OVERHEAD POLES. (Tests.)

Poles fixed 6 feet from butt.

Description.	Section.	Length.	Outside diam.	Thickness.	Approx. Weight.	Temp. Deflection.	Permanent Set.	Load applied at.
	No.	ft.	in.	in.	lbs.			
Manchester	1	17	$7\frac{5}{8}$	·5		700 lbs	1200 lbs	$29\frac{1}{2}$ ft.
Corporation,	2	$9\frac{1}{2}$	$6\frac{5}{8}$	·45				from
Pole No. 1	3	$7\frac{1}{2}$	$5\frac{9}{16}$	·4	1092	6 in.	$\frac{1}{2}$ in.	bottom
National	1	17	$8\frac{5}{8}$	·34		1000 lbs	1700 lbs	Top
Tube Co.'s	2	9	$7\frac{5}{8}$	·30				
Pole	3	8	$6\frac{5}{8}$	·29	870	6 in.	$\frac{1}{2}$ in.	
Manchester	1	17	9	·60		1000 lbs	2000 lbs	$29\frac{1}{2}$ ft.
Corporation,	2	$9\frac{1}{2}$	$7\frac{5}{8}$	·40				from
Pole No. 2	3	$7\frac{1}{2}$	$6\frac{5}{8}$	·30	1353	6 in.	$\frac{1}{2}$ in.	bottom

The poles are further tested by being dropped three times on their butts from a height of 6 feet on to a solid block, and must after this test show no signs of telescoping or bursting at the joints. This, in the writer's opinion, is a somewhat severe test.

The allowance for variation of diameter should not be more than $\frac{1}{8}$ of an inch out of the true circle at any part of the tube of the larger sections 9 to 7 inches, and in the smaller sections the variation should not be more than $\frac{1}{16}$ of an inch for any tube less than 5 inches outside diameter. The variation from straight in the entire pole should not exceed $\frac{1}{4}$ of an inch.

All poles, excepting centre poles on the straight, should be planted with a rake against the strain varying with the amount of strain. Pull-off and anchoring poles require a rake of from 6 to 9 inches.

Fig. 18 shows a span wire pole in three sections used by the Glasgow Corporation.

Fig. 19 shows a side and centre pole of taper tubing and cast-iron bracket used at Carlisle.

Wiring.—The overhead trolley wire is an important part of the equipment, and it is also important as to how it is hung or suspended. Within reasonable limits it is a good thing to have plenty of sectional area in the trolley wire. This allows for wear, and admits of greater current capacity, which is a great advantage under many circumstances, saving feeders, etc.

The trolley wire should be made of hard drawn copper of at least 98 per cent. conductivity at 60° Fahr. of pure copper. It should stand an ultimate tensile stress of 25 tons per square inch. The variation in diameter should not exceed ·004 inch, and it should be uniformly circular in section, and free from scale splits and other flaws.

It is usually delivered in lengths from one to two miles, and the number of joints per mile varies from three to four, being dependent on the gauge.

Table 20 shows the physical tests, lengths, etc., of the trolley wire supplied by Messrs. W. H. Dennis & Co.

The joints should be at least 3 feet long, and capable of bearing the same tensile breaking stress as the wire. The wire is delivered coiled carefully on reels; and it should be absolutely free from all kinks, twists, etc.

There are several methods of suspending the trolley wires, each with their advantages.

TABLE 20.—SPECIFICATION FOR HARD-DRAWN COPPER TROLLEY WIRE.
Conductivity, 97 to 98 per cent. at 60° Fahr.

Size of Wire. S.W.G.		Approximate Weight per Mile.	Physical Tests. Ultimate Tensile Stress.		Spiral Round Rod. Diam.	Twists in 12 in.	On Reel.	Lengths, Joints per Mile.
No.	Diam.		Tons per sq. in.	Lbs. per Wire.				
	in.	lbs.			in.		miles	
4/0	·400	2560	22	6200	2	10	1	4
3/0	·372	2220	22	5350	2	12	1¼	4
2/0	·348	1940	23	4900	1½	14	1½	4
0	·324	1680	25	4620	1	15	1½	4
1	·300	1440	25	3960	1	17	1½	3
2	·276	1220	26	3490	¾	20	2	4
3	·252	1020	26	2910	¾	20	2	3

Note.—The elongation in 10 inches varies from 2 to 3 per cent.

The first and cheapest is by fixing rosettes in the walls of the buildings on each side of the street. Provided the permission of the owners can be got, and the streets are narrow, this method is a good one. There is, however, some difficulty in getting all the proprietors to consent. In this case, side poles in the footpaths are generally used from which to suspend the span wires.

This method is adopted very generally, although it is somewhat costly. All trolley wires carried by span wires give a more elastic and easier track for the trolley wheel, thus lessening the jar at the ears, consequent vibration, and wear and tear.

When the roadway is very broad, centre poles with two side arms may be used, and these make the most sightly poles of all. The writer, however, is not in favour of this method where it can be avoided. It is dangerous to ordinary traffic and to foot passengers. Like all methods where the trolley wire is carried in the middle of the track, if a trolley wire, span wire or ear gives way there is danger of the trolley wire falling on the top of the car. This is a serious mechanical and electrical danger, as a passenger may be swept off the car, severely cut, or he may be injured by shock.

The other method is to carry the trolley wires at the side, clear of the car, by side poles with single arms. Although this is not so correct mechanically, it has been found to answer well in practice. It is, however, in many instances carried to an extreme, evidently only to save poles or to be consistent as to system. It should in most cases be assisted by double side poles and "pull-offs" at the curves, so as to widen the angles at the ears, some of which, it may be said in passing, have been made 3 feet long, to round the angles and save "pull-offs." This is asking too much from an ear. In most installations, however, it will be found that the best arrangement is a combination of all four methods at different parts of the route, adopting each at the parts most suitable to it.

Ears are of various designs, some merely clipping the trolley wire and others having the wire soldered to them. The latter method of fixing is preferable. The soldering must, however, be properly done, and must be perfect for the entire length of the ear. This is a point that deserves more attention and supervision on the part of the engineer than it generally gets. Many accidents through falling trolley wires might be avoided if the engineer insisted on seeing every ear properly soldered. It is also generally left to the foreman of the gang to judge the amount of tension to be put on in erecting the wires. The writer thinks this is not of great moment in winter, but in summer, with a high temperature, many wires are put up much too tightly, with the result that when the temperature lowers considerably in winter and a gale of wind comes the breakages are considerable.

Useful tables, giving the sag and strain due to different temperatures, will be found in Mr. Dawson's pocket-book, 'Electric Tramways.'

The trolley wires should be securely anchored at each end of all curves.

Guard Wires.—These should be fixed at least 18 inches above the trolley wires. In double lines they should be directly above the trolley wires, but in single lines, with two trolley wires close together, they should be hung, say, 9 inches wider than the trolley wires. They are generally insulated from the poles, but are put in metallic contact through them at intervals to the rails.

The strength and tension on them is worth attention, as when this is neglected they become a source of danger in themselves, instead of a protection.

Wooden insulator strips are sometimes used instead of guard wires, but, in the writer's opinion, they are more unsightly and not so efficient. They are generally fixed to the wires by clips about three feet apart. These cause an arc each time a worn trolley wheel passes, causing damage to the wire and to the wheel. The space between the wire and the wood lath in winter may be filled up with snow and ice.

The division of the trolley wire into half-mile sections is done by means of what are called section insulators. These are simply ears rather longer than usual, with feeding points at each end. There is a gap in the trolley wire which is filled up by insulating material to give a continuous track for the trolley wheel from the end of one wire to the beginning of the next. In fixing the position of these it is well to see that they are not placed on a severe ascending gradient.

Overhead Fittings.—In the above category is included the ears for carrying the trolley wire, section insulators, pull-offs, frogs, crossings, strain insulators, etc. etc. These are too well known and too numerous to require individual description in such a paper as this.

Lightning arresters are necessary along the track, as well as on the cars, and at or near the power station, to protect the generating plant. On the track there should be two on each half-mile section. Speaking mechanically, all these may be called safety or relief valves. All the large makers of electrical equipment supply them of different designs for various currents and purposes. The ground connection of these should be of the best possible, such as placing the copper plate in a running stream or damp subsoil. If in the latter, fine coke should entirely surround the plate. These precautions are all well worth taking, as on good earth connections depends the efficiency of all lightning arresters.

Feeders.—The distributing feeding system is a matter that requires very careful consideration, always bearing in mind that the trolley wires must be insulated in half-mile sections. It must also be taken into consideration that gradients, congested traffic, etc., must have due allowance made for them at different portions of the routes, and that the power used on these portions is greatly in excess of that on the normal portions.

The feeder cables are usually insulated with bituminous compounds or paper, and are sometimes armoured and lead covered. They are laid in wood or iron troughs and run in solid with bitumen in some cases, and in others conduits are laid underground and the cables afterwards threaded from the examination pits. Both of these methods have their advantages, but the writer is favourable to the stoneware conduit.

In suburban lines, where cheapness is everything, they are often laid underground bare, and where there is no paving to lift or other interference with examination, this is a good enough method. The cables, however, should be steel armoured, and the armour itself protected from moisture as much as possible by a waterproof covering.

The cables are generally made of strands of annealed copper wire of sufficient capacity for the current necessary. The wire should have a conductivity of 100 per cent. of Mathieson's standard at 60° Fahr. The wires should be of as long lengths as possible, according to gauge, and properly stranded to a suitable lay.

The joints of the wires must be perfect, and in making the strand the joints of the wires must be stepped so that no two joints occur at the same point in the strand.

The cables should be specified in suitable lengths, and delivered in one piece to these lengths.

The British Insulated Wire Co.'s insulation is as follows for 500 volt cables: Paper and paper fibre, waterproof and non-hygroscopic, of suitable thickness, according to the size of the cable, so as to answer the tension and insulation tests.

The insulation is protected by single or double lead sheathing, according to the size of the cable.

Where there is a double lead sheathing a layer of compound is put between the two sheaths. Outside the lead sheathing is served with jute and compound, and armoured with soft steel tape of suitable thickness. A second steel tape sheathing is then put on to lap over the spaces left in the first, so as to thoroughly protect the lead sheathing. The cable is then finally covered with jute and compound.

Tests at Factories.—Cables for a 500-volt pressure are tested in their lengths to stand a pressure of 2000 volts alternating current.

The insulation test is as follows:—The cables are immersed in water for 24 hours and tested with an E.M.F. of 500 volts continuous current. The insulation substance after one minute's electrification at 60° Fahr. must not be less than 500 megohms.

Another useful test as to the fatigue the insulation will stand in threading is as follows: A piece of cable is wound round a drum three times in one direction and three times in the opposite direction. It is then immersed in water, and must stand a pressure of 2000 volts alternating current for 15 minutes without breaking down. The diameter of drum for cables 0·2 square inches area is 1 ft. 6 in. A 2-ft. 6-in. drum should be used for large cables.

Tests after Laying.—After laying, the cables should be tested for an hour at 1000 volts direct current.

The tests for half-mile sections of the insulation resistance is that at 500 volts the insulation resistance shall not be less than 10 megohms at 60° Fahr.

Manholes are necessary at varying intervals for drawing in the cables when ducts are used. On curves of course they are at closer intervals than on the straight. These manholes should be roomy enough for a man to work in, and to allow of the lead-covered cables being drawn through easily. They must be water-tight and thoroughly ventilated by a trapped ventilator at the side, the manhole cover itself being watertight.

Fig. 21 shows draw-pit or manhole between the rails of a country line, with sets next to the rails and tar macadam between. The ducts are those of the Albion Clay Co.

Feeder switch boxes are necessary at the feeding points to contain the switches for cutting out any section of trolley wire. They are generally placed on the footpath or between the tracks, or on the poles in the centre-pole system of wiring.

Figs. 22, 23 and 24 show outside and inside, and switch arrangement of a cast-iron feeder switch pillar to be placed on the footpath or between the tracks where centre poles are used.

Fig. 25 shows cover box and cut-out to fix on the poles.

Fig. 26 shows cover box for fuse cut-out to be fixed on poles.

Fig. 24 shows section of the feeder pillar with the fittings mounted on the panel. The panels are made either of marble or of slate. The feeder cables carrying the current from the power station are connected up to the bus bar by means of two switches. The feeder cables are brought into this box through holes below the level of the ground which are shown in Fig. 23. The current is led from the bus bars to the trolley line through plug switches which also are at the same time fuses, the fuse wire being clamped between the two contacts of the plugs, and to prevent any accident through shock, burn, etc., shields are provided to protect the hand when removing the plug by the handle. The cables are of a highly insulated and armoured variety, and usually pass from the upper part of the switch pillar to the pole supporting the trolley wire. They are usually taken up from the interior of the pole to a point just above the bracket arm, along which they are laid and connected to the section insulator. A lightning arrester is fixed to each feeder pillar and connected to the main bus bar to protect the feeders from injury caused by lightning discharge. The lightning arrester fixed on these pillars is usually of the Garton Daniels or Wurtz type. The former consists of a spark gap, over which the lightning discharge can jump and so pass harmlessly to earth, but a movable plunger is so arranged that should the current from the power house follow the lightning discharge, the plunger is actuated so as to interrupt such flow of current.

The Wurtz arrester is an arrangement by which an over-high resistance is inserted between the trolley wire and the ground over which no appreciation or leakage of the working current can take place, but which would allow the high potential static discharge of lightning flash to pass over, and each type of arrester must, of course, be accompanied by the usual self-inductive resistance coil.

The pillars are provided also with pilot boards. On to these boards the test wires are connected for making nightly tests of the insulation and leakage of the feeders, also frequently this board is arranged to take two telephone wires to enable conversation to take place between various officials of the staff who are provided with portable instruments and the power station, or to different sections on the line. These test or pilot wires and the telephone wires are usually made up together as a multicore cable of No. 7/22 S.W.G.

Plug switches with knife contacts are shown, but in many cases ordinary quick-brake knife switches are used, in which case separate provision has to be made for inserting the fuses.

Fig. 25 shows a switch box suitable for fixing on a tramway pole. It contains two ordinary quick-brake knife switches in the upper part with a Garton Daniels lightning arrester, which I have already explained in connection with the description of the feeder pillar. The box is fixed to the pole by four set screws, and the fittings in the box are insulated from it by prepared slate bases.

Fig. 26 is somewhat similar to the previous drawing. This consists solely of plug switches in place of knife switches, and no lightning arrester is included in the box. The lightning arrester in this case would be located in a box of its own, and fixed separately on to the pole. It is necessary to attach this arrangement in positions where only a small size of box may be used.

The first method of combining the apparatus in one box is of course preferable, the only drawback being that the box has to be of some considerable size to hold the apparatus.

Rolling Stock.

Cars.—Cars for use in a large town should seat from 50 to 55 passengers.

The question as to whether they should be four-wheeled or eight-wheeled bogie cars depends upon the physical features of the routes. There is no doubt that a bogie car is preferable in respect of smooth running at high speeds, for working small curves, and for durability in itself. It is also much easier on the rails, the wear and tear on the rails on curves being considerably less than with a four-wheeled car. It has, however, two disadvantages. It takes considerably more power to run it; on some roads as much as 50 per cent. more than is necessary for a four-wheeled car. This is not entirely due to the extra weight, but to the extra friction. It is also at a disadvantage on lines with steep gradients on account of the weight being distributed over eight instead of four wheels. This is a serious objection, as the coefficient of friction on a tramway rail is low, unless the rail is absolutely clean and dry. This condition is not by any means usual in this country. On most days there is a greasy film of mud on the rail head.

To overcome this deficiency of adhesion, Messrs. Brill, of Philadelphia, have introduced the maximum traction truck, or bogie for eight-wheel cars. In this truck, the perch bolt is moved forward so that 80 per cent. of the weight is carried on the driving-wheels of each bogie. This, certainly, reduces the objection as to adhesion. It has, however, other disadvantages, such as the pilot-wheel lifting when starting.

It is likely in future that where bogie cars are to be used on roads with stiff gradients, ordinary bogies will be used with a motor to each axle—that is, four motors on the car. This will make a most useful car, although somewhat heavy, expensive, and greedy of current.

The four-wheeled car, however, is more suitable for all-round work, especially in towns where the speed is never very great. It is lighter, and therefore can be controlled more quickly. It takes gradients that a bogie-car could not do, and it absorbs less power in friction.

The Liverpool type of car which Mr. Bellamy has adopted is a particularly fine roomy car, and the reversed staircase is an improvement as regards the safety of passengers. This type of car was introduced in Edinburgh in 1887, and at that time the Board of Trade, although passing the car, suggested that the driver had his angle of view restricted by the staircase on his left. In the Liverpool car the controller is further forward than the gripper in Edinburgh, so that this objection does not apply so forcibly. The staircase is caged in with wire netting, thus making it safer for passengers even than the Edinburgh type.

Fig. 27 shows the Liverpool single-deck car, with maximum traction bogie.

Motors.—For tramway purposes the modern motor is almost always single reduction. They are made as light as possible, and completely closed in. In all cases it is well to leave them of a full margin of capacity, so as to have ample power at the curves and gradients. The difference of efficiency is not great at ordinary loads between a 25 and 35-H.P. motor. The starting torque must be high, and the motor capable of being run at least one hour at its rated capacity without heating more than, say, 120° Fahr., and at 50 per cent. over its capacity for short intervals without serious sparking.

This test is a severe one, and it is surprising that it has been possible to get a motor capable of standing it in so small a bulk and weight as is required in a tramway machine. The conditions under which a tramway motor works are most disadvantageous. They are necessarily close to the ground, and subject to the mechanical interference of mud and dust, and the conditions as to variations of load are extreme, varying from double their normal output to zero.

The following is a description of a modern single reduction tramway motor to give 25 H.P. at the armature shaft at the ordinary rating, viz. to give with atmosphere at 77° Fahr. an increase of temperature of not more than 167° Fahr. in its various parts, after running at full load for one hour.

When geared to 30 inches, wheels at 5 to 1 full load will give a speed of 10 miles per hour to the car. The lower half of the motor is hinged to the upper, as shown on Fig. 13. This allows of free access to the armature and the lower fields. The armature may be removed from the motor by loosening the bolts holding the bearing caps, so that the whole interior of the frame and the brush holders can be got at.

Frame.—The frame is composed of two cup-shaped pieces, hinged together. It serves three purposes, viz. provides bearings for the armature axles, forms the yoke of the multipolar field magnet, and provides an entire casing for the machine, making it mud and dust proof. There is an opening made in the frame for the purpose of getting access to the commutator and brushes.

The inner surface of the frame has four equally spaced rectangular surfaces, to which are bolted the four laminated pole-pieces, round which are wound the exciting coils of the field-magnets.

Two ventilating spaces are left in the pole-pieces to allow air to pass to the cool surface of the outer shell.

Feed Coils.—The feed coils should be of the best copper wire, well insulated with asbestos paper and linen. They are generally wound on moulds the exact form of the pole-pieces, and after being removed from the moulds are dipped in insulating compound, thus making them thoroughly waterproof. The ends of the wires are terminated in bronze castings, which are connected after fitting in the motor frame.

Armature.—The armature is of the ironclad type, and weighs about 484 lbs. The core is built up of thin discs of sheet steel, strung on to the armature shaft. Ventilating holes are made in the discs themselves, and they are spaced on the shaft to allow of ventilation at intervals. The discs are slotted parallel to the shaft for the purpose of receiving the coils.

Commutator.—The commutator of the motor in question is 11 inches in diameter, contains 123 hard-drawn copper segments with a wearing depth of 1 inch, and a wearing face of 3 inches for the carbon brushes. These dimensions are particularly large, and give long wear and cool running. The hub has openings for ventilation between it and the core.

Armature Coils.—These are of copper wire of 100 per cent. conductivity, thoroughly insulated individually with cotton, and collectively with insulating compound afterwards, and taped three together.

There are 41 triple coils for the armature, and 6 terminals to each coil, having thus 2 wires to connect to each commutator bar.

Winding.—This consists, after cleaning out the slots in the armature core, of placing the 41 coils into the 41 slots. The terminals of the coils are carefully soldered to the commutator bars, and the windings carefully and tightly bound together by bands of tinned steel wire, to counteract the centrifugal force set up by the rotation of the armature.

The brushes are of carbon, and placed so that they can be conveniently reached from the commutator cover.

Bearings.—The bearings are properly proportioned, and of the best bronze. They have a well holding about one pint of oil, which is syphoned through wicks to the journals. Emergency lubrication is supplied in the form of a grease-box filled with grease, which melts if undue heating occurs in the bearings, and so runs down on to the journal.

Gearing.—The pinion wheels are made from hammered machine steel, and the teeth are cut out of the solid metal. The spur wheel for the car axle is made of the best crucible cast steel, is cast in two halves, and the teeth cut from the solid metal. The halves are held together by eight bolts, and it can be fixed on the axle without removing the wheels.

Both the spur and pinion run in an oil bath.

Fig. 28 shows the method of suspending the motor, and Fig. 29 its characteristic curves.

Car Equipment.—Controllers are now either of the magnetic or solenoid blow-out type. They are both largely used, but the writer is more familiar with the latter, which is used on many corporation installations. It is, perhaps, more effective than the other, having a solenoid at each contact, and so reduces the damage done by flashing.

All cars should be fitted with incandescent lamps inside and outside, some of the latter to illuminate glass destination signs. They also are provided with the necessary resistances, lightning arresters, circuit breakers, fuses, etc.

Fig. 30 shows the wiring and connections between controller and the motors, the resistances, fuses, circuit breakers, etc., on a four-wheeled car with double equipment, without an electrical brake.

Fig. 31 shows the wiring and controller connections, etc., of the same car with an emergency electric brake.

Brakes.—Every one realises the necessity of quick, powerful brakes on an electric car. The old spindle brake was quite sufficient for a light horse-car travelling at about 6½ miles per hour. The electric four-wheel car is about five times as heavy, and as a rule the speed will be over seven, and sometimes as much as fifteen miles per hour. The momentum being so much greater, it follows that a quicker brake is necessary, and also an emergency or reserve brake. This is so apparent, that there is a tendency to have too many emergency brakes, adding to the weight of the car and the confusion of the driver when an emergency occurs.

Of course all the cars must have the ordinary hand brake, either spindle or screw. The latter is slower but more reliable, and can be put on more delicately to avoid skidding the wheels, which is most objectionable. When the wheels skid a car runs further than if there is just sufficient pressure on the blocks to get the maximum friction without stopping the wheels. It need not be pointed out that skidding soon spoils the wheels by causing flats, and necessitating the trueing up of the treads by grinding or turning if they are of steel.

If the wheels are not ground up, the flats make most uncomfortable running and cause serious fatigue to the motors, car bodies, and, as a matter of fact, to the whole fabric.

Assuming the car has a hand brake, it is interesting to consider what is the purpose of an emergency brake. Is it to act as a reserve in case of the hand brake giving way, or is it a stand-by to assist the hand brake? This point must be decided before one can say what kind of emergency brake is best. It may be said in passing that the prime purpose of such a brake will differ on different roads, and this is correct. When the roads are comparatively level, the main purpose will be to replace the broken brake; but where there are stiff gradients, the purpose will primarily be to augment the retarding power of the hand brake. By a properly designed hand brake a man can skid the wheels, and probably will in an emergency.

It is therefore evident that any increase of pressure on the wheels or on a drum on the axle is useless as an auxiliary. The writer thinks it is also useless in these circumstances to apply a slipper brake acting on the rails, as this only reduces the weight on the wheels, causing them to remain skidded.

Considering these facts, the writer has come to the conclusion that speed in applying the brake is the most important of all factors, especially in a runaway, as a few seconds mean an enormous increase in momentum. In this respect air brakes are most effective. They are also independent of the electric current, which in the case of a runaway is generally not available, owing to the trolley wheel leaving the wire. The air brake is an independent unit in such circumstances, and should be applied to the wheels and used as the ordinary brake, more especially in descending gradients.

A hand brake should be fitted as a slipper brake to act on the rails, and actuated by a screw as in locomotives, to give delicate application and so act as little counter as possible to the wheel brake. This screw spindle should have a heavy hand-wheel and the screw kept in fine running condition.

Lastly, there may be an electrical emergency brake to act on the wheels or axle.

The writer has had considerable experience of the action of brakes on severe gradients, and has had strongly impressed on his mind the great importance of quickness in application of any brake, but more especially the wheel brake, which is the most effective of all.

Operating.

Assuming that a manager has had a thoroughly efficient installation handed over to him by the engineers, his problem is how to get the best financial results from it. To accomplish this end he has many different circumstances to take into account. The principal one, however, in the writer's opinion, is to reduce the traffic expenses to a reasonable minimum. This can only be done by getting the maximum number of miles from his car per day.

He must bring his experience of traffic to bear on his practice, otherwise he would be losing fares by too infrequent stops.

Indeed, the principle could be reduced to an absurdity by running the cars without stopping.

If the manager decides to adopt stopping places, as is generally done now, he must give his mind to the subject carefully and fix them at the most convenient places to pick up passengers, even although they are not equidistant. Such natural stopping places occur in every town.

He must also avoid having his stops too frequent. The writer has known places where the old method of stopping anywhere was abandoned, and stopping places fixed, with the result that the effective speed of the cars was lowered and consequently the miles per day.

There are other cases where the stopping places are so few that undoubtedly many pick-up passengers are lost, who perhaps only want to travel 500 or 600 yards. They naturally will not take a car if they have to walk 200 of the yards.

In the large busy towns, the writer thinks that with halfpenny fares and very frequent stopping places, or, indeed, with no fixed stops, there would be a considerable increase in pick-up halfpenny passengers; put tersely, the seats would be kept warm. This, of course, does not apply to the suburban districts, where there are few excepting through passengers, and where the cars can make good speed, which they cannot in the town streets, even if they would.

The commonest fault in management, and one that absorbs many miles, is the unnecessary delay at the termini. The motor man and the conductor naturally consider it the finish to a piece of work, that a journey is "something attempted, something done," and that they are entitled to a spell of leisure. On short routes it is astonishing, if one calculates, how many miles are lost compared with those on a circular route of the same length.

A strong firm inspector should be posted at the termini to bustle off the cars within about two minutes of their arrival. Of course he must have discretion in a case of bunching of cars owing to a breakdown. He, however, should try to re-space them rather by accelerating the front cars than delaying the rear ones.

The manager ought always to be consulted and his advice taken, if he is an experienced man, as to the position and capacity of the various car sheds. These should be of moderate size and distributed over the system. Many mistakes have been made in this respect. Car sheds have been made so large and inconvenient that it unnecessarily occupies a great amount of time to get the cars out of and into them, irritating the men at a late hour, while they are being paid for wasted hours. The sheds are also fixed, in many cases, in the suburbs for sake of a cheap site, whereas, had a convenient site been selected in the town, the difference would have been redeemed in the first two or three years by saving the dead mileage of the cars. All cars should get into work as soon as possible after leaving the shed. Shorter hours for the men could easily be obtained, with economy for the manager, by carefully locating and distributing the car sheds.

In most towns the traffic is uneven, and on certain days and certain hours of the day, subject to heavy rushes. The manager has to consider and provide for this by bringing out more cars and sending them back to the sheds. If the sheds are conveniently situated this is simple enough, and is convenient for using the reserve men who are putting in short time. On the other hand, if the sheds are large and in outlying districts, both the men and the cars lose good time in going to and from the depôts.

Another disadvantage of large imposing car sheds is the serious result of fire, or a breakdown in the circuit. In the first case, many cars might be destroyed, and in the second, many would be locked up in the depôt, and the traffic dislocated for a needlessly long time.

As to the collection of fares and checking, it is surprising what differences of opinion there are. Everyone is agreed, however, that some means must be taken as to checking, whatever mechanical fare register there is in use. The number of checkers varies greatly in different towns. Bell-punch registers and fare boxes have each their advocates. The writer favours the latter, as the conductor never handles the actual fare. He has only to account for a certain amount of copper which he takes out for the purpose of giving the passengers change. One good principle to act upon, whatever system is used, is to collect the receipts from the conductors as often as possible during the day.

As to service or mileage, this should, along with high effective speed, be carefully gauged by the receipts per mile. In a large town with a service under five minutes and popular fares, the writer thinks the mileage should be run up till the receipts per car mile are brought below say 1*s.*

Table 32 gives the comparative working results of five different electric installations.

TABLE 32.—OPERATING RESULTS.

Name of Town.	Service in Mins.		No. of Cars.	Miles per Car per Day.	Total Car Miles per Day.	Total Car Miles per Annum.	Receipts per Car Mile.	Expenses per Car Mile.
	Quickest.	Slowest.					*d.*	*d.*
Glasgow, Springburn	2	6	47	91	3,000	927,870	13·89	6·26
Leeds . .	1	10	130	110	14,300	2,379,380	12·77	6·55
Sunderland.	2½	5	41	100	4,000	1,460,000	12·375	9·60 including depreciation.
Dublin . .	2½	10	201	92	18,800	6,500,000	8·0	5·0
Aberdeen .	5	15	11	117	1,287	402,831	15·5	6·03

The writer may just say in conclusion that some of the results given in the Tables appear to be incompatible. They are as he has got them from the various engineers and managers, and he has no means of checking them. The difference may be merely one of book-keeping, or allocation between the lighting and traction departments. In some cases the consumpt per kw. per hour, and per I.H.P. per hour, the writer has had to convert by calculation. He thinks, however, the figures are near enough to give an interesting comparison.

In concluding, the writer wishes to express his thanks to the following gentlemen for the results and information they have taken the trouble to give him: Mr. John Young, Glasgow; Mr. William Clark, M. Inst. C.E., Glasgow; Mr. W. Wharam, Leeds; Mr. J. F. C. Snell, Assoc. M. Inst. C.E., M.I.E.E., Sunderland; Mr. C. W. Gordon, Dublin; Mr. J. Alex. Bell, A.M.I.E.E., Aberdeen; Mr. E. R. E. Rotter, Assoc. M. Inst. C.E., Portsmouth; Mr. Chas. F. Wike, M. Inst. C.E., Sheffield; Mr. A. Ellis, M.I.E.E., Cardiff; Mr. Robert C. Quin, Blackpool; Messrs. Dick, Kerr

and Co., Limited, London; Messrs. The British Insulated Wire Company, Prescot; Messrs. The Electric Railway and Tramway Carriage Works, Preston; Messrs. The English Electric Manufacturing Company, Preston; Messrs. W. F. Dennis and Co., London; Mr. Arthur A. Day, A.M.I.E.E., Bolton.

DISCUSSION.

Mr. THOMAS HEWSON (Leeds): I beg to propose a hearty vote of thanks to Mr. More. It has occurred to me, whilst the author was reading his paper, that there were perhaps two questions upon which he would be able to give opinions that would be generally useful, though not perhaps referred to in his paper. I should like to know if he has any information as to the proposals for making the central groove in the tramway rail as laid some years ago in Liverpool?—whether there is any disposition to recur to that form? To my mind it has many advantages. Another question I should like to ask is, whether in the tramway world he finds any likelihood at present of the introduction of welding the tramway rails? I should be glad if he could tell us the position of these two features in tramway construction.

Mr. J. PRICE (Birmingham): I have great pleasure in seconding the resolution. I consider the paper which I have glanced through this morning an exceedingly practical one. I notice Mr. More, in the early part of his paper, with reference to the permanent way, lays great stress upon his joint. Now, I think those who have any knowledge at all of electric tramways know that this question of the permanent way is one which is very serious. In fact, some of the lines which have been recently laid down, I understand, are already giving considerable trouble. At Birmingham, when we turned one section of our tramways from accumulator service to overhead, I advised the Company that by doing so and putting on four-wheeled trucks instead of double bogies, as on the old cars, the permanent way would go quickly to pieces, and that has been the case. I advised them that they would not last more than twelve months, probably not more than six months. In three months the Company had to agree to relay the whole system at considerable cost. I like Mr. Hewson, should like to ask how the cast welded joint is found to work in practice, and what difficulty there is in dealing with the permanent way afterwards? The rail sections now have a tendency to be very considerably increased, and I notice that in the diagrams shown at the end of the paper Mr. More has taken very much the same lines that I myself took when designing the new rail for the Birmingham trams.

The joint in use in Birmingham at the present time is something like No. 8. That is to say, the fish-plate is something like No. 8. The cross section of the new rails is very much like No. 2. We find that by getting the bolts doubled, that is both at the bottom and sides, we get a very much safer joint. For several years we have used this joint, and I have not yet been able to see a better one. Of course no one can be expected to discuss in detail a paper involving so many heads as appear here, but I should like to say one more word about the rolling stock. I am glad to see the bogie car is coming into use when you have to deal with a large number of passengers and carrying, say anything approaching fifty in a car. The only point against it is the greater consumption of power. I am afraid that if we have to carry anything like that number with the 3 feet 6 inch gauge we shall require to alter our cars from four wheels to double bogies to have comfort and a permanent way fairly maintained.

Mr. A. H. CAMPBELL (East Ham): I desire to support very cordially the vote of thanks proposed to Mr. More for his paper. It is a very excellent and worthy contribution, and, I think, will be a very valuable contribution on a practical subject, of which we shall have the benefit in our published Proceedings. There are one or two points on which I should like information from Mr. More. He says, "The Edinburgh Corporation cable lines just being completed have not, so far, paid their way for several avoidable reasons." That word "avoidable" is very suggestive, and if it were not troubling Mr. More too much, I think it would certainly be instructive and interesting if he would tell us exactly what the word "avoidable" means. Those of us who have had occasion to study the Edinburgh cable problem know there is a very great deal of scientific controversy, and legal controversy too, as to the working of those cable tramways.

Mr. More gives the evaporation of different types of boilers. It seems to me that those rates of evaporation are exceedingly low, except Aberdeen. Passing to a particular section of the paper, which peculiarly concerns us as tramway engineers having the highway interests more particularly at heart, I should like to differ a little from Mr. More and those different methods he sets forth as to laying rails, packing them, that is to say, under the beds of foundation work. He recounts three methods of packing the rails. I have tried the first and second, and discarded both; the third I have not tried, but do not think, unless Mr. More can offer me inducements, that I shall give it a trial. I am just as sceptical and fearful of the results of the third method as I am either of the first or second. If I might, I should like to describe to the Conference the method we adopt. We have adopted the principle of embedding the rail into the concrete. We commenced with 6-inch sets, cementing the lower flange of the rail on the top of the concrete, but this had the effect described by Mr. More; therefore we attempted a differential thickness of set. With a 6½-inch rail we have a 5-inch set, and the flange of the rail is embedded in 1½ inch of concrete, rammed up; and it appears to me the principle of embedding is more successful than the third method suggested by Mr. More. With regard to rails, steel joints, etc., you will remember at Leicester one suggestion made was that we should be represented before the Standardisation Committee, and Mr. Mansergh brought that forward in his opening address. A representation was made to the Standardisation Committee to get a representative before the Committee, because the uniformity of steel rails would go very much towards economy in the construction of tramways, and do very much to develop and extend the use of tramways, particularly in the smaller districts.

Mr. Fowler (Manchester): I have just one or two words to say with reference to construction. I am at a loss to understand why an engineer should design a rail like No. 2, No. 3, and Nos. 7 and 8, for this reason, that you will notice on all those sections the weight or centre of gravity does not come in the centre of the rail; that is to say, the weight of the traffic goes on one side from the centre of the rail sections, and in course of time you must have a biassed pressure on the bottom flange of the rail. The next point as to the bedding of the rails. I am very much surprised that the last speaker should advocate such a plan as he does, inasmuch as the more bedding you place upon the bottom flange of the girder rail, on which to bed the sets, the more liable are the sets to settle.

At Stockport, some ten or twelve years ago, the plan I adopted for the first time was to bed on the bottom flange of the girder rail as solid as possible, simply bedding the set in sand on the flange. Of course the sets of the rail, and for 18 inches from it, and the rail itself, are laid on concrete. There being but a thin layer of sand on the bottom section of the rail, the sets are laid flush with the surface of the rail, and they are as good to-day as ten years ago. There has been no settlement whatever; the rails are as sound and secure as when laid. It must be borne in mind that the real wear of a tramway carriage road is next the rail. In Glasgow we have the opposite experience, for on driving outside the city I noticed opposite the Asylum, on the road there out in the country, that they are actually laying the tramway with tarred macadam next to the rails, and this after thirty years' experience. I went further on, and the macadam was down below the rail in some places and half-an-inch above in others, and it will be worse before the tramways get into actual working order. It is all very well to read papers, but unless we go on strict rules of engineering principles we cannot get success. Rule of thumb will not do. It is just the same as in the old road-making days. If one set gets down the vehicular traffic bumps and rebounds until the surface soon gets out of repair. If you get one set below the rail the defect does not end there, but the whole of the sets next the rails go.

Mr. Brodie (Liverpool): I had not intended to take part in the discussion, and I am sure it is my own fault that I have not seen the paper. We have been doing some work in connection with tramways in Liverpool that may be interesting in view of the discussion. I agree with the last speaker with regard to the depth of sets. We have tried both ways in Liverpool, and my present opinion is, that it is better to have a shallow set alongside the rail and a good sound concrete between the underside of the set and the rail flange. In Liverpool we have rails carrying six cars to the minute, and you can understand, where they are travelling so continuously as that, there is a certain amount of vibration, and we find, as a matter of practical experience, that a small depth of concrete on top of the flange is a distinct advantage. It is also an advantage because its presence helps to prevent the possibility of water getting underneath the rails, and if you get water underneath the rails you will have trouble with the paving. At least that is my experience.

THE CHAIRMAN: Would you give us a word or two about bedding the rails?

Mr. BRODIE: Like other engineers, I have tried pretty nearly everything. We have different methods of bedding, but so long as the concrete is of first-class material, properly mixed and in proper proportions, I do not think there is very much in the method of bedding. I think it is as well to get sufficient depth of new concrete below the rails, and to take good care that your new concrete has a chance of taking a good grip of the old concrete by wetting it properly, and also, to some extent, by putting a layer of cement on the old concrete. A question has been asked with regard to the central-groove rail, and though I do not wish to appear to reply, I may mention, from great experience of the central-groove rail in Liverpool and in other places, that, taken on the whole, from the municipal engineer's point of view, the central-groove rail is better than the side-tread rail. At the same time the latter is being laid throughout the country. I do not think it good, as a matter of policy, to have a central-groove rail in one place and a side-tread rail in another, and, therefore, though I believed in the central-groove rail, I advised my Corporation to put in a side-tread rail, because I foresaw the time when Liverpool would be connected up with the districts round about. With regard to joints, we have tried several, and the one I prefer is a good weld joint. A question has been raised with regard to bogie cars. We have had some experience with regard to bogie trucks as well as four-wheeled trucks. We have cars carrying 100 passengers—seating 100—on two double bogie trucks; and when we get in another 100, as we do sometimes on the occasion of a big football match, we have an exceedingly heavy car. Only a very small proportion of that load is taken by the steering wheels in a maximum traction truck, and the result of that heavy casual load on a maximum traction truck running at a high speed is one which is far from satisfactory—both from the road point of view and the rail maintenance point of view.

Mr. HARPUR (Cardiff): With regard to the question of rail packing, to some extent I disagree with Mr. Campbell, and thoroughly agree with Mr. Brodie. Before any concrete is placed above the rail flange, you must have the rail properly bedded underneath, if good work is to result. The thorough packing of the bed, or underside of the rail, has a very great deal to do with the ultimate life of the permanent way, and unless this work is thoroughly done, it is no use putting 1½ inches of concrete on the top of the rail flange to assist a bad or improper bedding of the rail on its foundation. At Cardiff we are doing practically as the Author suggests. We make up a 6-inch bed of concrete under the rail, leaving 1½ or 2 inches, which we then make up with concrete and thoroughly pack as solidly as possible with proper beaters, making the surface of the concrete as tight as possible to the underside of the rail flange. Then we put on another bed of concrete, something like 4 inches thick, finishing 2 inches above the bottom of the rail flange, and floating off the surface for the wood paving. As the depth of the rail is 6 inches, it would be an extravagant waste of material to make wood blocks 6 inches deep, so we have 4-inch blocks, which last just as long and make quite as good a permanent way. The Author has not mentioned any method of paving except that of granite sets, and I should have been glad if he had given us his opinion on other methods of paving. He does refer, however, in the matter of paving, to bituminous grouting, which he very properly favours. He says it was used in Lancashire 20 years ago, but was unknown in the south. I must contradict that statement, because bituminous grouting has been in use in my town—Cardiff—for upwards of 20 years, and the tramways laid there during the whole of that time have been grouted with bituminous grouting. I cannot understand how it has taken so long for municipal engineers and for tramway engineers, to find out the superiority of bituminous grouting over that of cement, and particularly for wood paving. It puzzles me beyond measure that in these days municipal engineers should continue to grout wood paving to a large extent with cement, just running the bottom inch or so with bituminous grouting, and then filling the remainder of the joints with cement grouting. There can be no possible affinity or cohesion between wood and cement, and how in the world engineers will continue to use such material I cannot conceive. I am glad, Mr. Chairman, to be able to make these observations, and I really hope those engineers who use wood paving will very seriously consider the question of the best material to be used for grouting. I have never used cement grouting for wood paving, and, from what I have observed, I shall never do so. I have had about 2 to 2½ miles of roads paved with Jarrah wood and grouted with bituminous grouting only, laid down in Cardiff for the past four years, and there has not been a single kerbstone, nor a square foot of flagging displaced a quarter of an inch through the swelling of the wood blocks, and I attribute that result mainly to the use of bituminous grouting. Where cement grouting is used, even if it be only in the top inch of the joint for the purpose, as it is alleged, of preventing the bitumen from boiling out of the joint in hot weather, you have an unyielding substance surrounding every block, and there are no places which will yield to the expansion of the wood when wet weather sets in, with the result that something has to give way, and the consequence is the displacement and upheaving of the footways, which is so frequently to be seen where there are wood-paved roads. Going back to the question of the bedding of the rail: if, first of all, the cement be thoroughly well beaten up to the underside or bed of the rail, so as to get a perfectly even contact between the concrete foundation and the rail, then by getting the cement continued above the flange of the rail, as Mr. Brodie says, you get a practically watertight joint, which will prevent rain and water getting down underneath the rail. Particularly is that so when you continue the cement for, say 1½ or 2 inches above the flange, and get the joint thoroughly well filled up with bituminous grouting. In that case you get, or should get, a perfectly watertight joint, preventing the wet getting under the rail; and, in my opinion, nothing tends to make the permanent way stand so well as to keep the wet from under the rail.

Mr. J. Lobley (Hanley): Speaking of the question of filling up the hollow between the flange and the bed of the rail, there are different methods to pursue, some to leave alone; to swallow up a vast amount of bituminous grouting, or to fill in with cement mortar. The other point, as Mr. Harpur mentioned, about bituminous grouting being used for 20 years; it is 30, and I fully agree with what he said about reserving only an inch in depth for cement grouting. With regard to Mr. Harpur's remarks about the system, I think it refers more particularly to London way, certainly not to Cardiff. It has been a surprise, no doubt, to many of us to see how long the London authorities have waited before they adopted bituminous grouting. They seem to be very fond indeed of cement grouting. With regard to packing, I can only endorse Mr. Harpur's method, partly in fine gravel, and cementing under the bottom flange.

The CHAIRMAN: There is a difference of opinion—whether to caulk solid under the rail with dry concrete, or whether it is better to grout it in. I myself think the caulking is vastly superior.

Mr. KENWAY (Birmingham): One thing seems to me to have been omitted in what I consider in the permanent way one of the chief things, that is the joint. Mr. More mentions one or two joints, but he appears to me to have overlooked the fact that there is a simple joint which has been adopted not only by the Birmingham Corporation, but very recently by the Wolverhampton Corporation, and taken up by others. It has, perhaps, not been brought before the public authorities in the best way to press it forward, but I have it on very good authority that the Victor joint, which is now adopted by the Birmingham and Wolverhampton Corporations, gives very great satisfaction, and the principal advantage is that there are no sole plates at all, only a twin joint at the foundation of the rails. The flanges of the rails are connected with each other to allow the twin joint to come out from the bottom, passing through the angle fish-plates. I saw a letter written to one of the tramway managers in the Black Country from one of the authorities, saying that since that joint had been adopted, the claims against them—these claims are very prevalent in the Black Country—although unknown in many places, had been reduced in the Corporation area to a very insignificant sum. Of course, I know many places where, if an accident occurs, they do not come on the tramway company; but Birmingham people seem, for some reason or another, to have been educated by the Vehicular Association formed there, to come down on the tramway company wherever they can. The result of the Victor joint has reduced these expenses very much indeed. It does not interfere with packing, and I think, now that municipal authorities are met together, that if there is any merit in that joint, they should not overlook it. If there is a better joint I should like very much myself to see it. The Birmingham Corporation has spent more money in trying various patents, so as to get the best, than any other Corporation in the kingdom, and I do not think I am wrong in saying that, even in joints, the Corporation must have tried over 50; and now they are perfectly satisfied. This joint has been in use now some years.

Mr. Broome (St. Helen's): I was rather surprised to hear one remark, that is with regard to 6-inch sets being laid tight upon the flange of the rail. I cannot myself think that is a good way. I have always understood these sets upon the rail will eventually become loose, and not make good pavement. With 4-inch cubes and 6-inch concrete underneath, the rails are packed as well as possible. Upon that we lay another 2½ inches concrete, and pave with 4½-inch cubes. With this you get a highly satisfactory tramway, sure to last a considerable time; indeed, repairs may be required to the rails before you are required to repair the sets.

Mr. Brodie: I should like to say a word or two about safety appliances for overhead construction. I will put shortly the present position of Liverpool. As you know, we have had some serious accidents in Liverpool, and as a result the Corporation have entered into negotiations with the people interested in the overhead wires to assist them. As far as the National Telephone Company is concerned, all overhead wires in Liverpool are to-day cabled and suspended, so that there is no possibility of an accident from that source. So far as the telegraph wires are concerned, we have not been able to make the telegraph people move quite so quickly. They are there by Parliamentary authority, and as we had to bear the total cost of putting the wires underground, I think we have gone as far as need be in that direction. With regard to the few—comparatively few—private wires, all these have been removed; and I think there only remain one or two unprotected telephone wires in Liverpool. We made exhaustive experiments both with the guard wire and with the guard strip, and also other arrangements, and I advised the Corporation that neither the guard strip nor the guard wire would afford proper protection. It is possible everything may go right in 99 cases out of 100, but the 100th case will come, and, as you know in the case of Liverpool, it came one very stormy night, when the streets were covered with salt and snow, and, unfortunately, it had fatal results.

Mr. Price: Following on what Mr. Brodie has said, I should like to say that in Birmingham, in connection with the line reconstructed a short time ago, we had the whole of the telephone wires bunched, the private wires insulated, and the Post Office telegraphs agreed to permit their wires being placed underground, and this has been done.

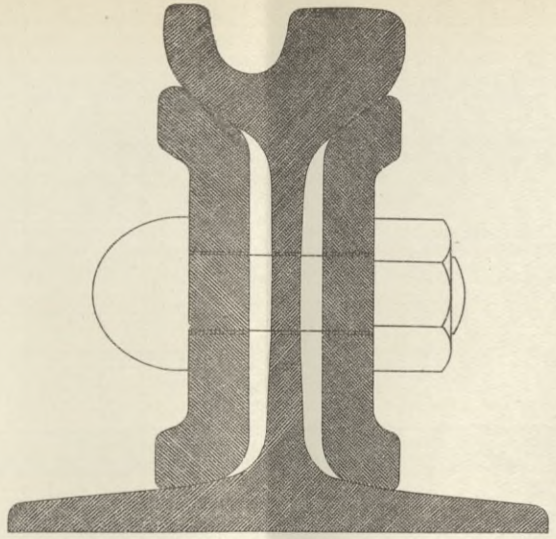
Mr. MORE, in replying, said: Unfortunately I have not heard all that has been said, so if I miss any point you must remind me. With regard to what Mr. Hewson said about the central-groove rail, it is used at Southport and Liverpool. The attractive resistance on that rail is fully 50 per cent. more than the ordinary groove rail. I think that will be understood easily when you consider that for tramway purposes the outer margin of the rail has the least resistance. The one reason why the resistance of the central-groove rail is much greater is, that there is a very small groove first of all, and the flange of the wheel almost fills it. Another reason is obvious in cars with 4 treads on your rail—that is, with trucks with 4 tyres on the rail. If it is a 60-foot car the difference between the inside tread and the outside tread is very considerable, and a most distinct milling action takes place. The resistance is very high indeed. Another point: there is hardly a rail I have seen with the central-groove laid on the curves, so that is literally true. There is difficulty in the ordinary rail; there is more than double the difficulty in curves. With regard to weld joints, I mentioned my own experience. I am very glad to know Mr. Brodie has tried them, and to hear they are satisfactory. I should like to know whether they are real true weld joints or cast weld joints. What are known as cast weld are not a weld at all. One is a good joint electrically; the other is a good joint mechanically, but not electrically.

Mr. BRODIE: The joint I referred to is not a weld joint strictly speaking, but a cast-iron joint which gets a very good hold of the rails, and gives very perfect electrical continuity.

Mr. MORE: It is a very good joint mechanically. Mr. Price referred to a joint Mr. Kenway described. I am sorry to say I never heard of it. There are a great many things I have not heard of, and I do not mean to suggest I have mentioned everything in recent tramway practice. Mr. Price also mentioned, I think, the difference between big and 4-wheeled cars. No doubt big cars are safer for high speed, and there is no doubt whatever a big car is easier upon itself and upon the rail. The permanent way will last longer, and the car itself will last longer. The difficulties of big cars—and I am speaking now of bogie cars—is the want of adhesion on gradients, the weight being distributed. In the maximum traction truck of Messrs. Brill, of Philadelphia, the bolt is moved forward very nearly over the driving wheel, whereby 80 per cent. of the weight-carrying is on the driving wheel. There is another difficulty as regards big cars: they take a great deal of current. On suburban routes I think the big car the right car. You can get high speed, it is much safer, and it is easier on the road. I consider you can work with a big car at a high speed on a lighter rail than you can with an ordinary 4-wheeler. Now I come to Mr. Campbell. He challenged the foundation, and he spoke about evaporation. The returns I quote were got from the various engineers. As regards the laying of the rails, I am sorry I cannot agree with him. I have had 20 years making tramways and maintaining them, and naturally a contractor always tries to make something which costs the least; but I think it impossible to pack a 6-inch bed of concrete in a plastic state. It trembles, and the concrete leaves the rail. I think every practical man will understand what I mean. I quite agree with Mr. Brodie that water is absolutely ruinous. For wood paving you are bound to flood, but I cannot agree with it except in this case. Mr. Harpur follows the same practice as I do. Instead of flooding I put on a cement bed, and I leave the first layer of concrete absolutely rough. The rougher the two faces of concrete the better. I do not quite agree that there should be too much difference between the set and the rail. I think the set ought to touch the flange of the rail. Vibration works the set loose, and there is always a difficulty with sets. Inch sets vary from $\frac{1}{4}$ inch to $1\frac{1}{2}$ inches. I did not quite follow the line Mr. Fowler took.

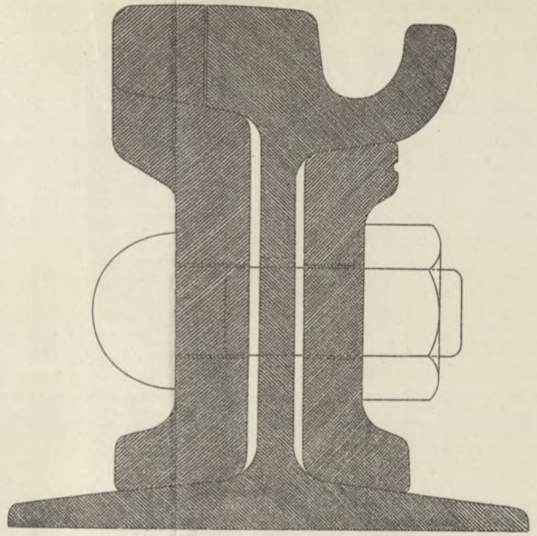
Mr. Fowler: My contention was that the weight should be in the centre of the rail, to get over the vibration.

Mr. More: What Mr. Fowler complains of is more apparent than real. Thus (drawing a section on the board) the weight is carried here, and that is vertical with the centre of the rail flange. As regards Mr. Harpur and pitch grouting, I do not know whether I am right in my geography, but Cardiff I hardly considered a southern town. I referred more particularly to the counties round London. I quite agree with Mr. Harpur that cement grouting is quite unsuitable for wood paving, and



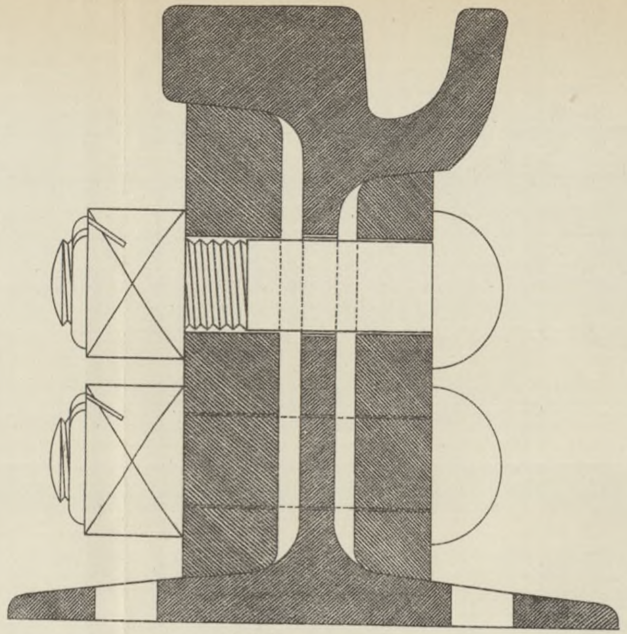
76 lbs per yard

Figure Nº 1



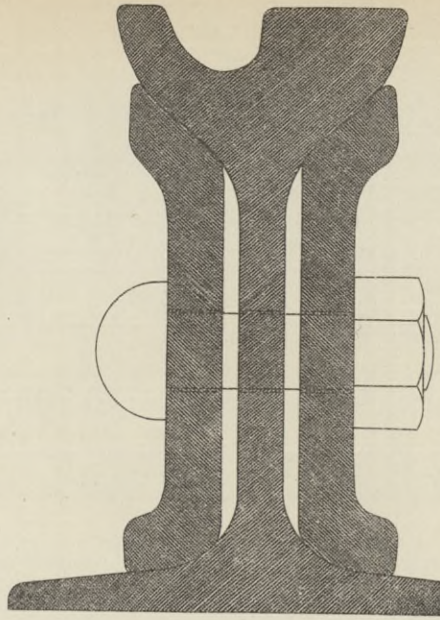
85 lbs per yard

Figure Nº 2



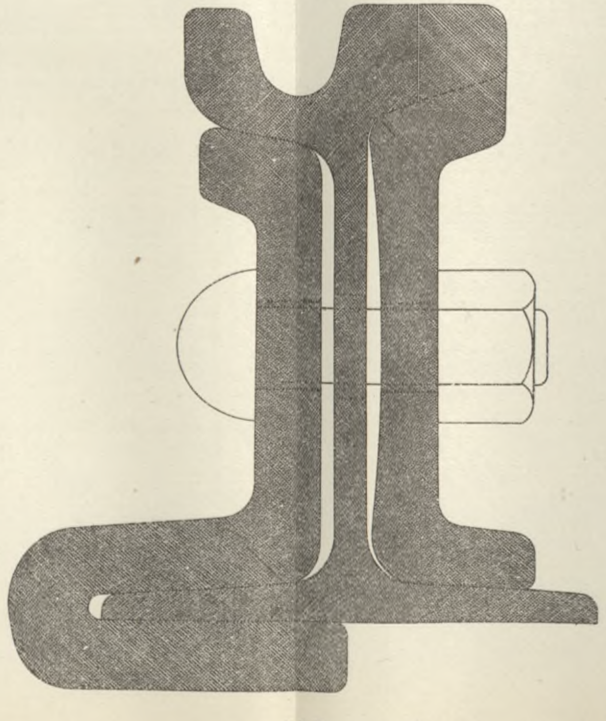
98 lbs per yard

Figure Nº 3



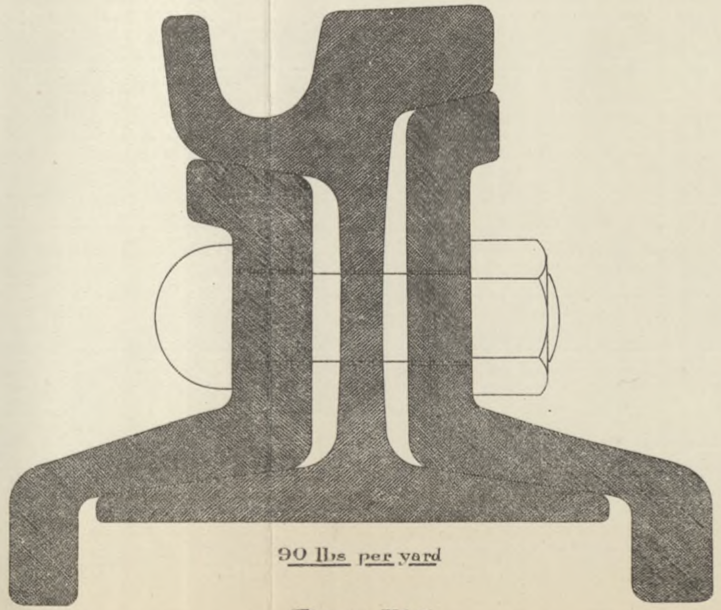
90 lbs per yard

Figure Nº 5



84 lbs per yard

Figure Nº 6

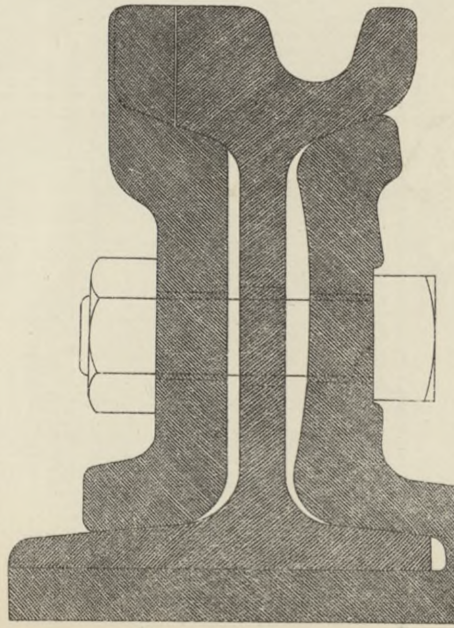


90 lbs per yard

Figure Nº 7

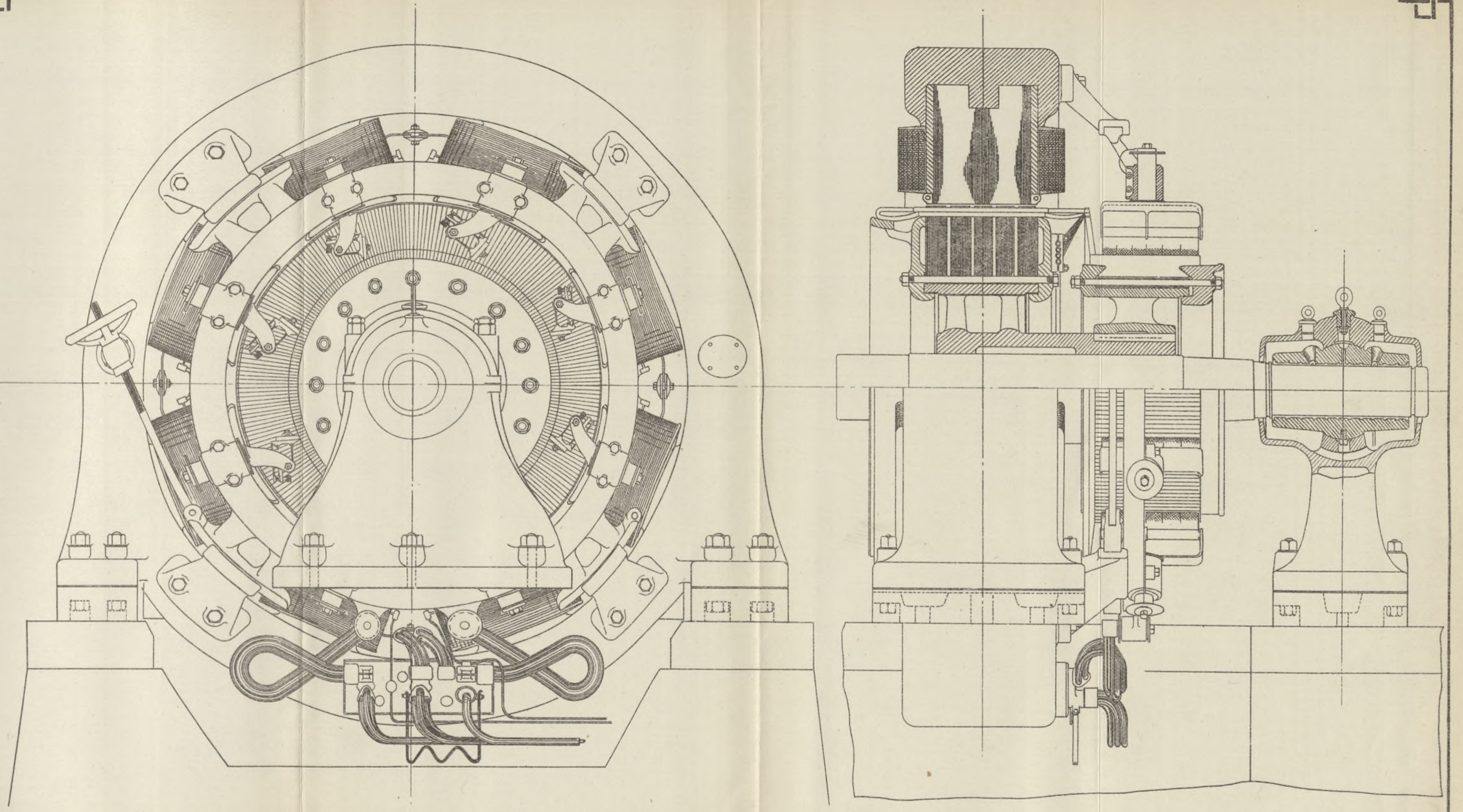
98 lbs per yard

Figure Nº 8



87 lbs per yard

Figure Nº 9



STANDARD GENERATOR CONSTRUCTION

FIGURE No 14

PHOTO-LITHO. SPRAGUE & Co. Ltd. LONDON

CROSS SECTION OF SINGLE TRACK AND DRAW BOX

FOR COUNTRY LINE

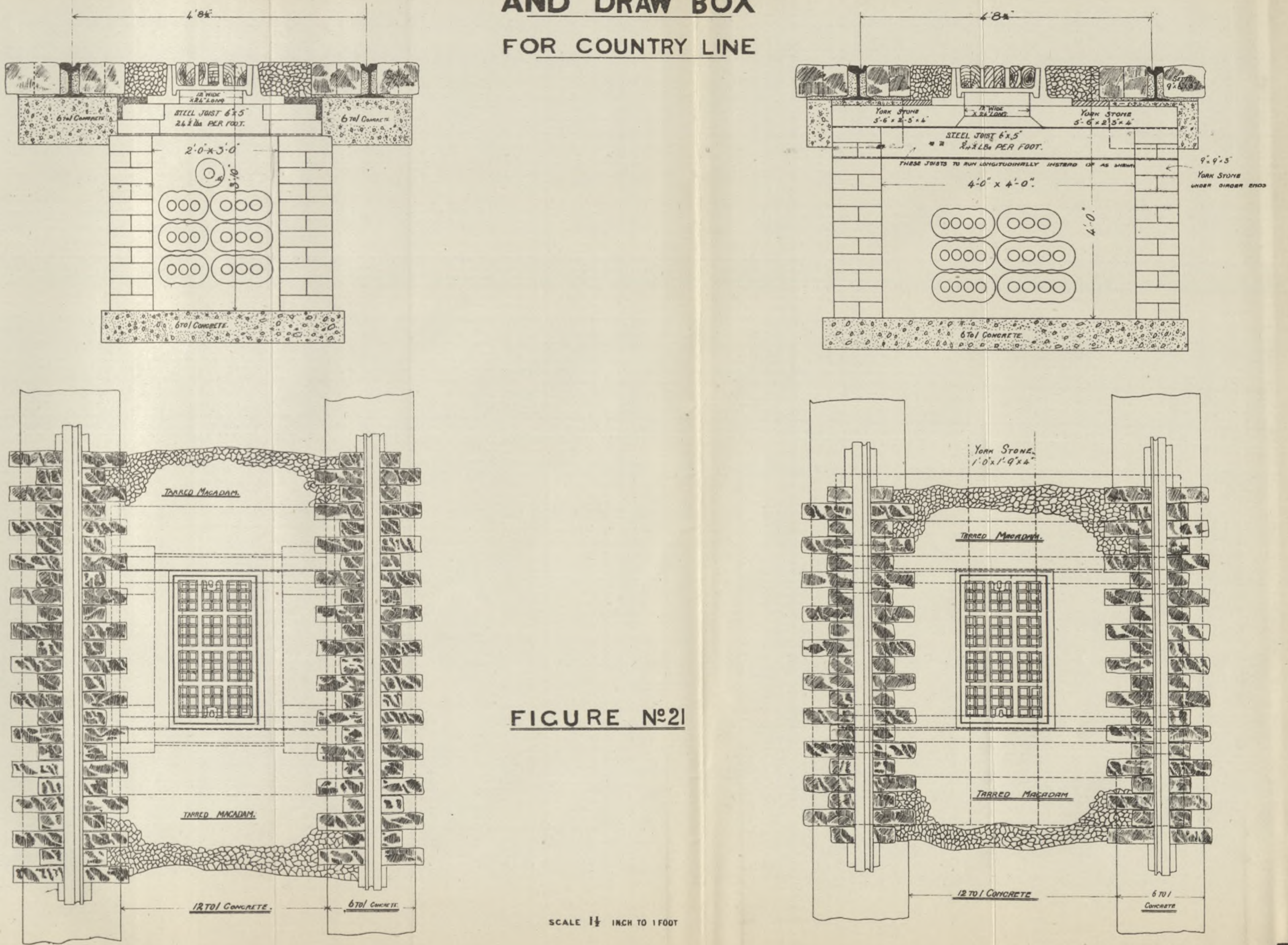


FIGURE No21

SCALE 1½ INCH TO 1 FOOT

PHOTO-LITHO SPRAGUE & Co Ltd LONDON.

FEEDER SWITCH PILLAR

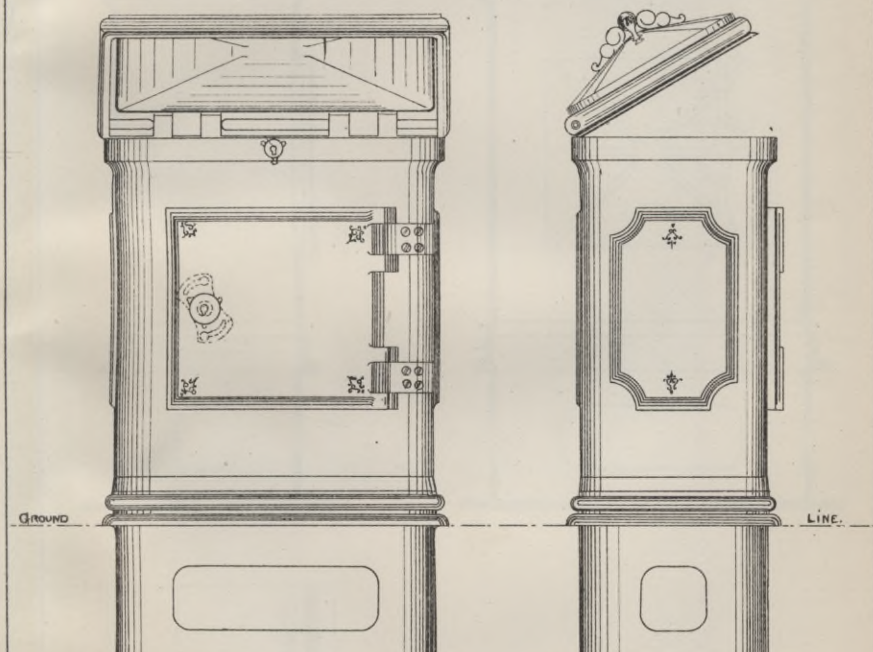


FIGURE N° 22

FEEDER SWITCH PILLAR

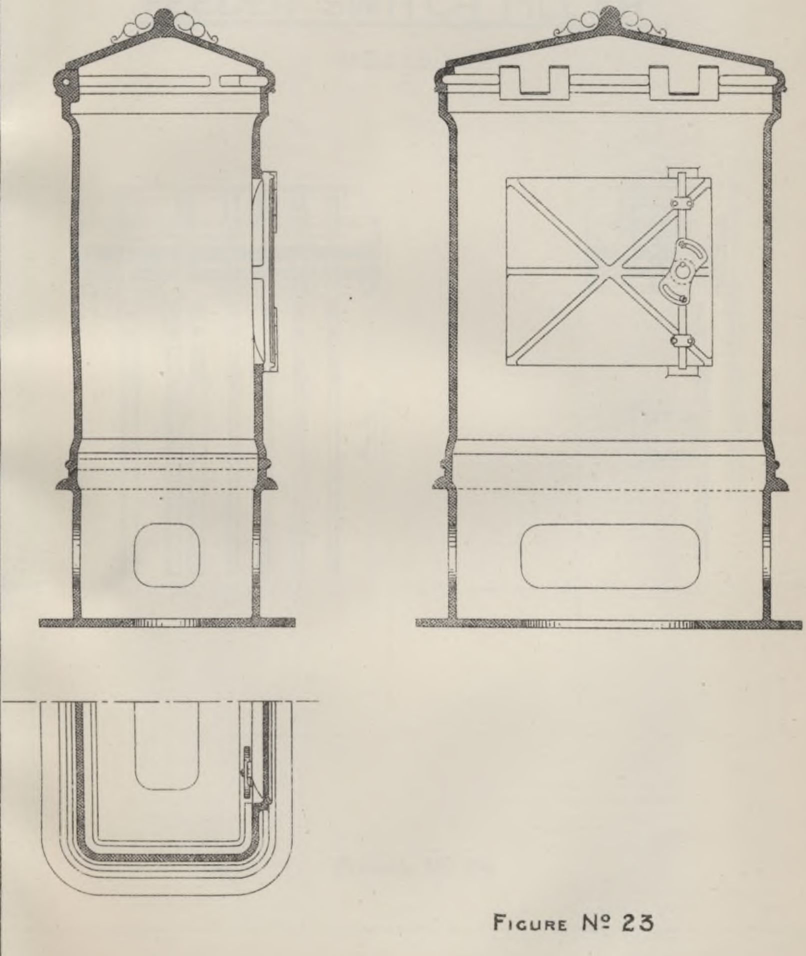


Figure № 23

FEEDER SWITCH PILLAR

SCALE ~ 1½" = 1'-0"

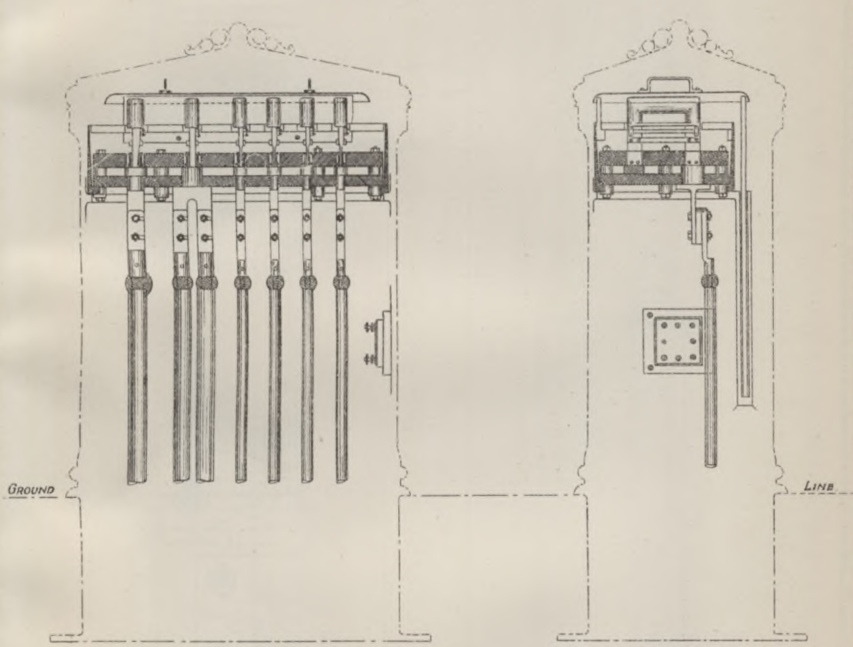
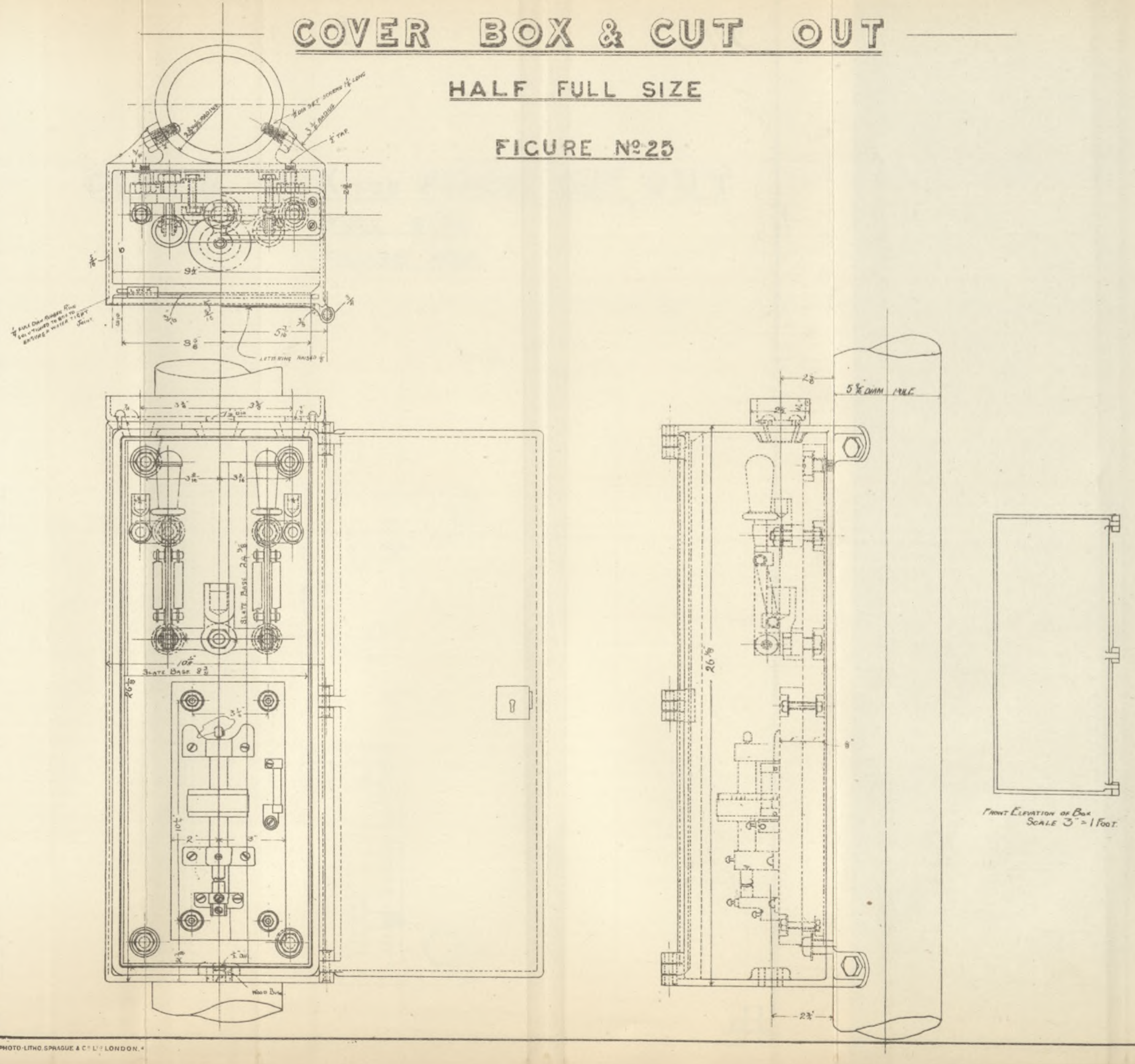


FIGURE № 24

COVER BOX & CUT OUT

HALF FULL SIZE

FIGURE No. 25



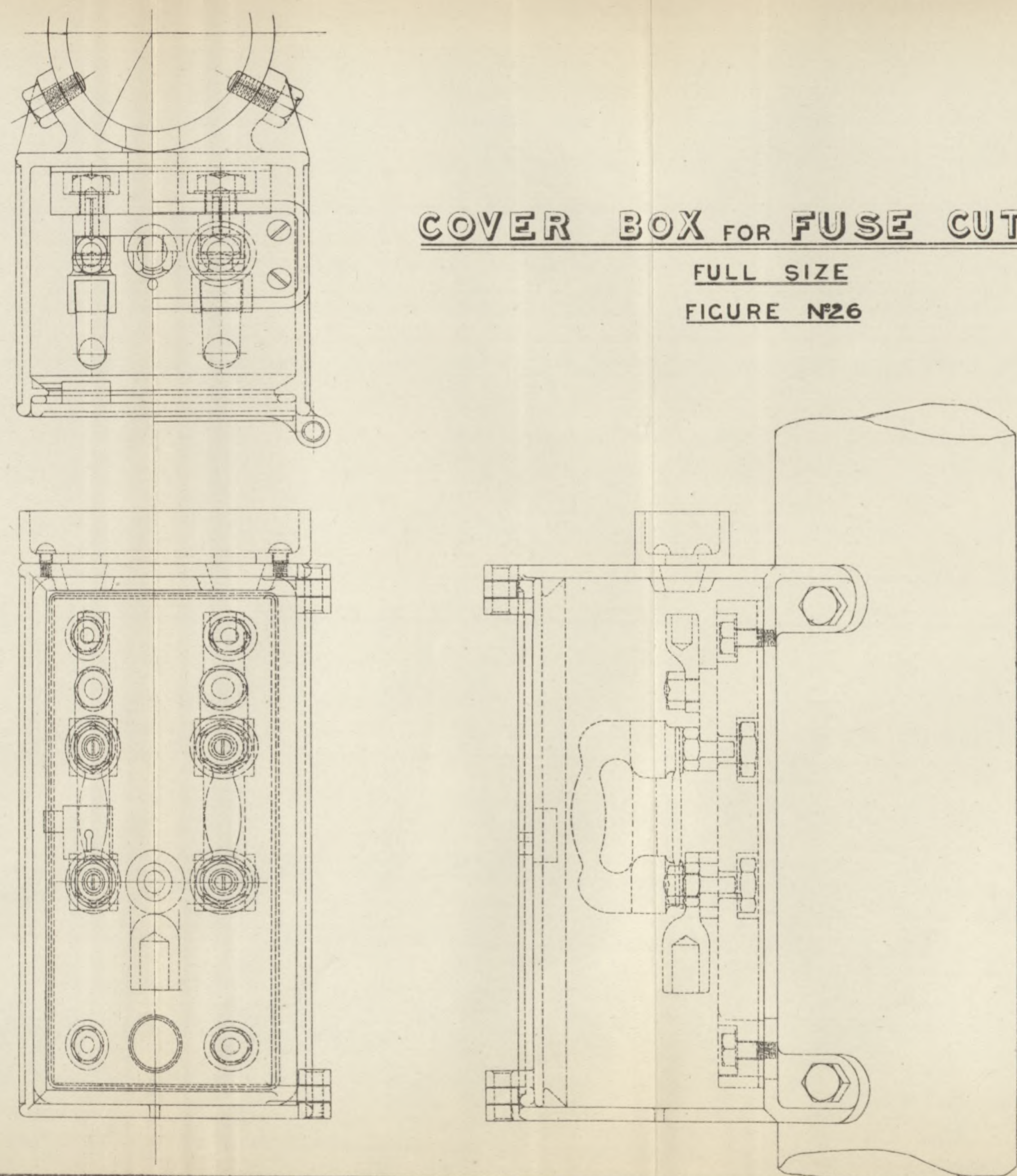
Front Elevation of Box
Scale 3" = 1 Foot.

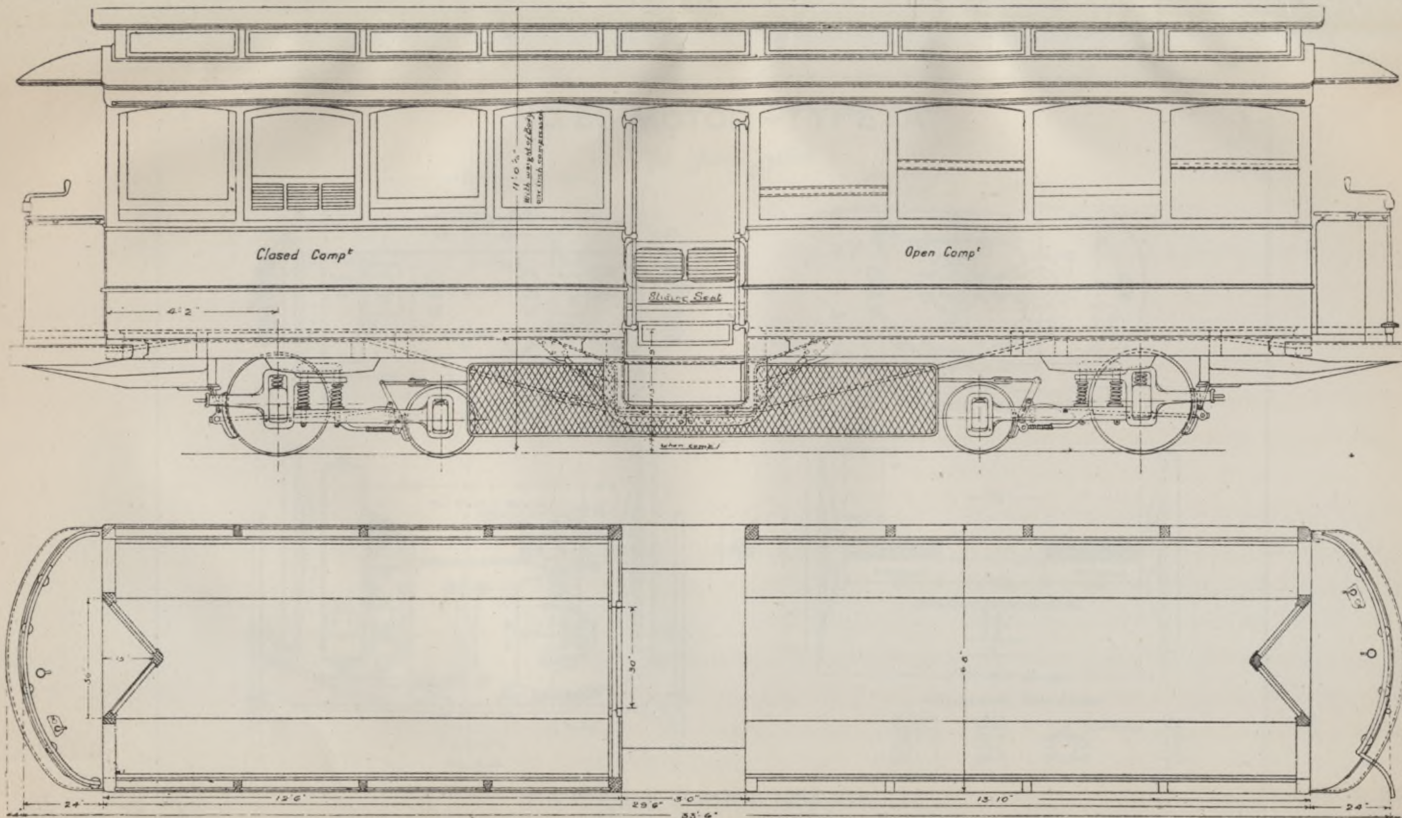
PHOTO-LITHO. SPRAGUE & Co Ltd LONDON.

COVER BOX FOR FUSE CUT OUT

FULL SIZE

FIGURE №26





Plan and Elevation of Double Bogie Car—Liverpool Electric Tramways.

MAXIMUM TRACTION TRUCK

FIGURE No. 27

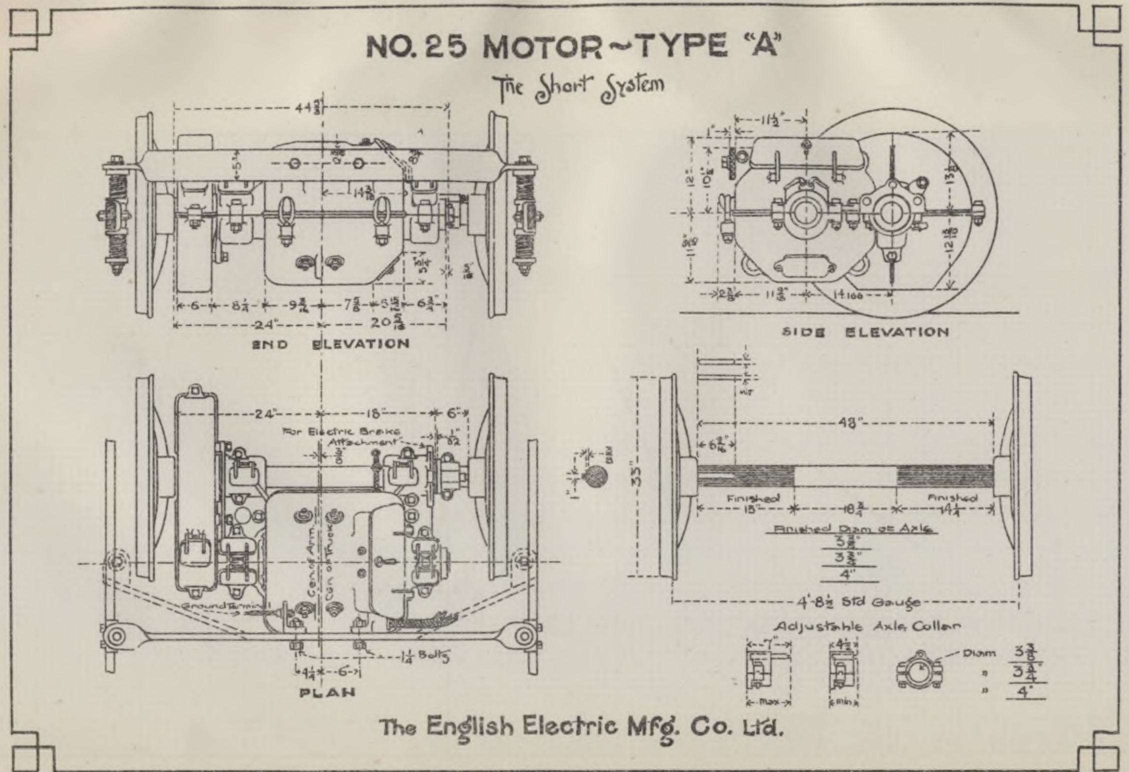

NO. 25 MOTOR ~ TYPE "A"
The Short System
END ELEVATION
SIDE ELEVATION
PLAN
For Electric Brake Attachment
Cen. of Arm.
Cen. of Truck
Ground Terminal
Bolts
48"
35"
Finished 15"
Finished
Finished Diam of Axle
4'-8½ Std Gauge
Adjustable Axle Collar
max
min
Diam
The English Electric Mfg. Co. Ltd.

FIGURE No 28

Figure N° 29

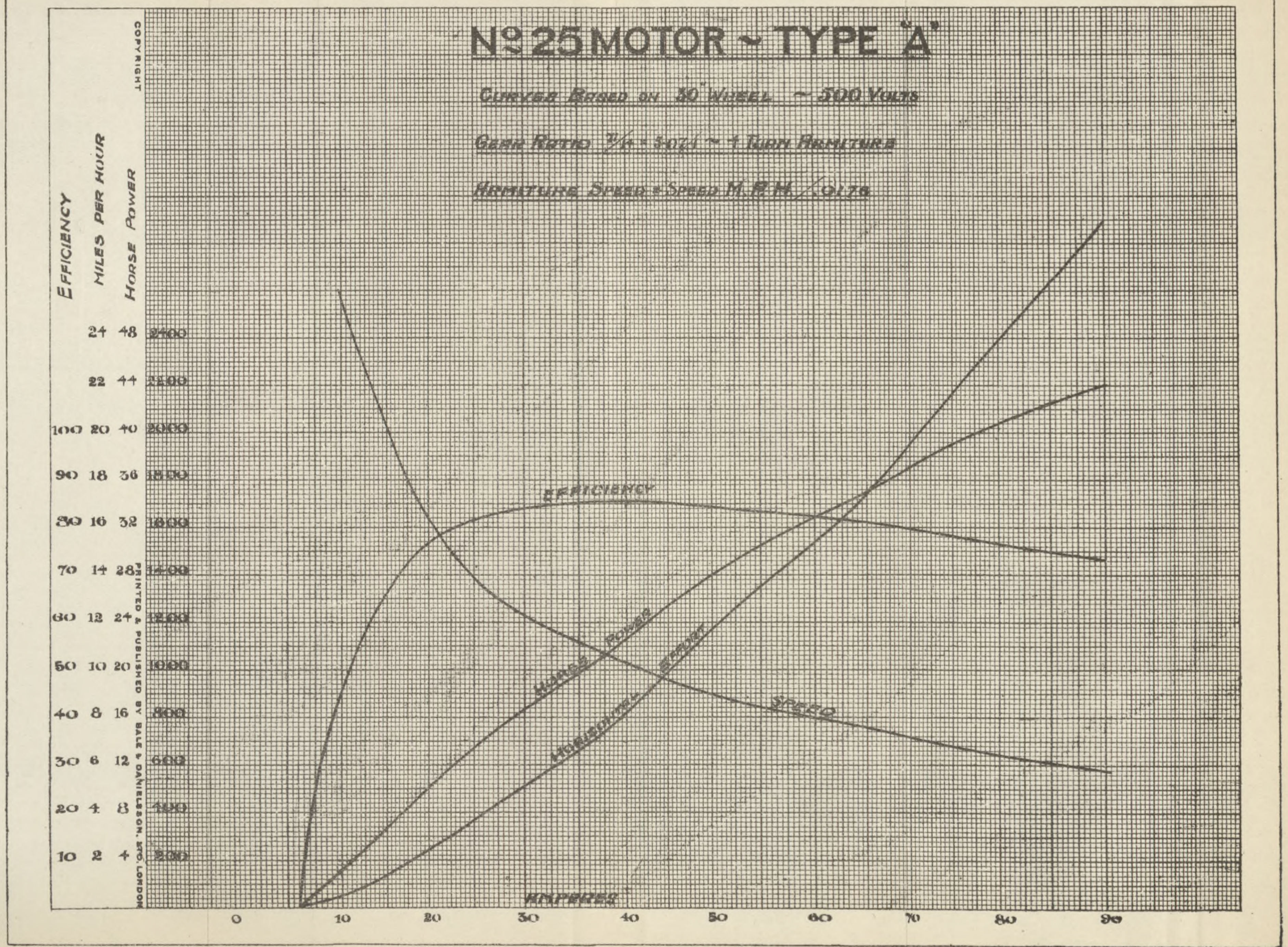


PHOTO-LITHO. SPRAGUE & Co Ltd LONDON.

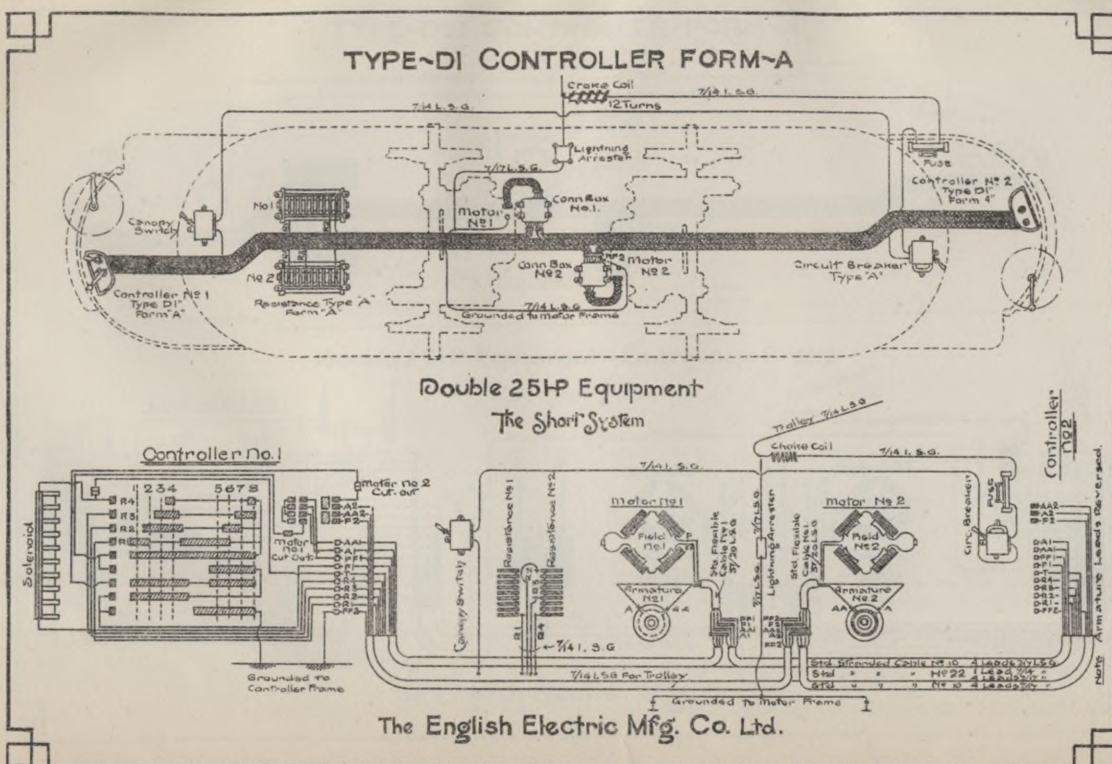
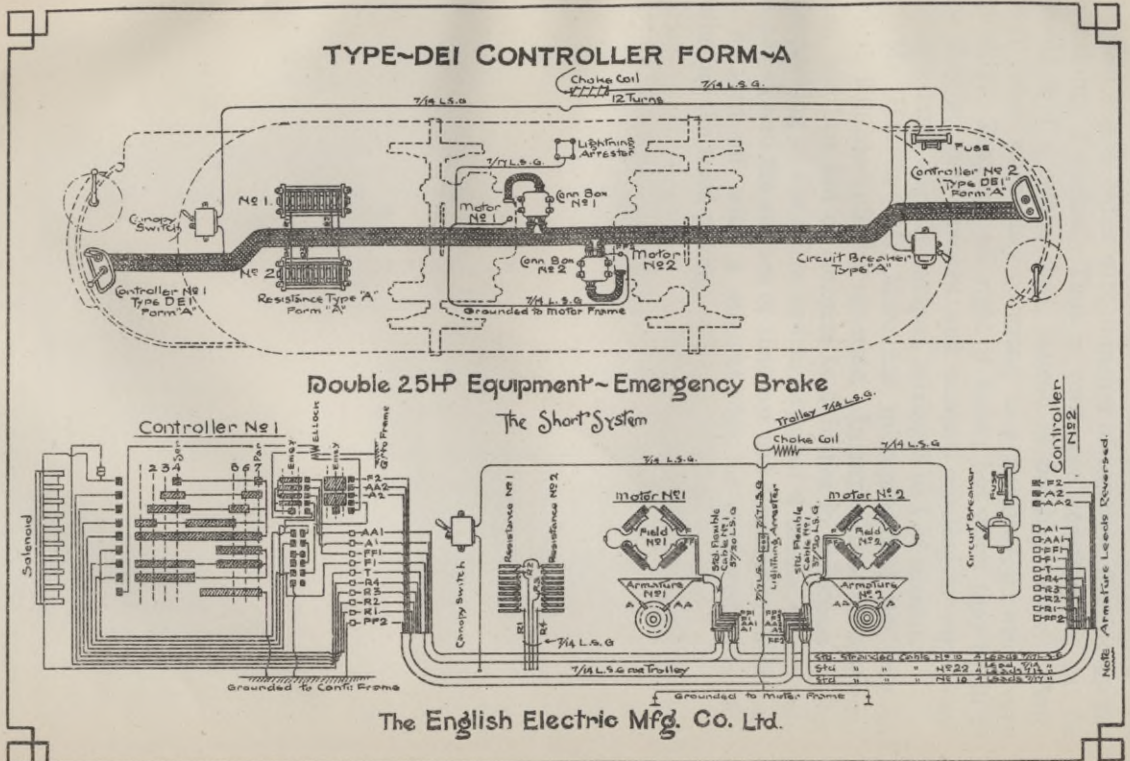

TYPE-DI CONTROLLER FORM-A
Choke Coil
12 Turns
7/14 L.S.G.
Lightning Arrester
Conn Box No. 1
Motor No 1
Conn Box No 2
Motor No 2
Canopy Switch
Resistance Type "A" Form "A"
Controller No 1 Type DI" Form "A"
Controller No 2 Type DI" Form 4"
Fuse
Circuit Breaker Type "A"
Grounded to Motor Frame
Double 25HP Equipment
The Short System
Controller No. 1
Solenoid
Motor No 2 Cut out
Motor No 1 Cut out
Grounded to Controller Frame
Canopy Switch
Resistance No 1
Resistance No 2
Motor No 1
Field No 1
Armature No 1
Motor No 2
Field No 2
Armature No 2
Std. Flexible Cable No 1 37/20 L.S.G.
Lightning Arrester
Trolley 7/14 L.S.G.
Choke Coil
Circ. Breaker
Fuse
Controller No 2
7/14 L.S.G. For Trolley
Grounded to Motor Frame
Note Armature Leads Reversed.
The English Electric Mfg. Co. Ltd.

Figure No 30



TYPE~DEI CONTROLLER FORM~A
Choke Coil
12 Turns
7/14 L.S.G.
Lightning Arrester
Conn Box Nº 1
Conn Box Nº 2
Motor Nº 1
Motor Nº 2
Fuse
Controller Nº 2 Type DEI "Form "A"
Controller Nº 1 Type DEI "Form "A"
Canopy Switch
Nº 1.
Nº 2
Resistance Type "A" Form "A"
Circuit Breaker Type "A"
Grounded to motor Frame
Double 25HP Equipment~Emergency Brake
The Short System
Controller Nº 1
Controller Nº 2
Solenoid
Trolley 7/14 L.S.G.
Choke Coil
Canopy Switch
Resistance Nº 1
Resistance Nº 2
motor Nº 1
motor Nº 2
Field Nº 1
Field Nº 2
Armature Nº 1
Armature Nº 2
Lightning Arrester
Circuit Breaker
Fuse
Std. Flexible Cable Nº 1 37/20 L.S.G.
7/14 L.S.G. for Trolley
Grounded to Cont: Frame
Grounded to Motor Frame
Note Armature Leads Reversed.
The English Electric Mfg. Co. Ltd.

Figure Nº 31

it is unsuitable for tramways. I used pitch grouting in 1872 on the South Staffordshire line. Mr. Broome mentioned that he used 4-inch cubes with 6 inches of concrete, floating up the remaining 2 inches. That is very good construction, but he would find a cement bed, instead of floating, better. Four-inch cubes when they go wrong in a tramway, go wrong very quickly. They are all right if tight; but when they begin to go they go very quickly, and cement grouting is very much better—sand, slightly damped, mixing 3 to 1 of cement.

Mr. Harpur: Mr. More has misrepresented the way in which I finished off the concrete. In my method of construction the last bed of concrete is 4 inches in thickness; after the packing of the rail a bed or layer of 4 inches of concrete is added, and the surface of that last bed 4 inches in thickness, is finished off with a straight-edge, or cambered rule, for relieving the wood paving.

THE PROBLEM OF THE HOUSING OF THE LABOURING CLASSES: WITH SPECIAL REFERENCE TO SUBURBAN DISTRICTS.

BY A. H. CAMPBELL,
ENGINEER AND SURVEYOR, EAST HAM COUNCIL.

THE Standing Orders of Parliament provide for the expression "Labouring Classes" to include "mechanics, artizans, labourers and others working for wages. Hawkers, costermongers, persons not working for wages, but working at some trade or handicraft, without employing others except members of his own family, and persons other than domestic servants whose income *does not exceed an average of* 30*s. per week*, and the families of any such persons as may be residing with them."

The primary aim of the Author in submitting this paper to the Conference is to present certain aspects of this problem which have arisen in the course of his experience as adviser of the East Ham Council.

The district of East Ham, situated in the east of London, growing at the rate of 7000 persons per annum, and those chiefly of the working classes, affords probably as good a field as can be found for experience in the Problem of this paper.

The Council therefore set themselves seriously to tackle the problem of providing, within their district, dwellings of a *suitable class*, and at a *suitable rental* (the two essential, but almost irreconcilable conditions) for the lowest class of wage-earners: that is to say, for those whose employment may be constant, but whose weekly wages are low; or whose work and wages are of the casual class.

The limit of wages which the Author had in mind in the provision his Council are making, is a maximum of 30*s.* per week. In the provinces, no doubt, this rate will be considerably lower.

For the housing of this class, the scheme adopted by the East Ham Council is to provide four- and five-roomed houses, containing 470 superficial feet and 520 superficial feet (*available room-space*) on ground and first floors respectively, at a rental of 5*s.* 9*d.* and 6*s.* 3*d.* per week (*inclusive* of all rates, taxes, water and outgoings).

With this idea, the scheme was matured and received official Government approval, providing for the erection of fully 540 separate houses, which, with land charges, formation of roads and contingencies, made up a total of 120,000*l.*

The outlines of this scheme are illustrated by Drawing (Appendix No. 1).

It was in proceeding to put into practice these proposals that the real difficulties of the problem have been met, and have served to suggest to the Author the facts for this paper.

The problem touches so many departments of life, and involves so many considerations of a moral, material and economic nature, that there is scope for much co-operation.

The Sovereign himself, legislators, local governing authorities, philanthropists, and private enterprise have all joined hands in their efforts to tackle the problem ; but as yet only the fringe seems to have been touched, whilst great masses of our town populations live on in a state only of *existence*, ignorant of the possibilities of life to themselves and their offspring. Reared on improper food, breathing an atmosphere polluted as much by overcrowding as by vice, they fail in the growth of their moral and muscular manhood and womanhood, without which they themselves, Society and the State remain immeasurably the poorer.

It is a true saying, "We are all members one of another" ; hence, if the labour membership of the body politic suffer, so must those whom they serve suffer in turn ; reduced capacity for labour means increased cost of work to the employer, with very obvious results : further, the begetting of poorer and weaker offspring than the parent, involves the gradual decline in physique and in number of the race. Look for an instance of this at London. It is a fact that the native-born Londoner, with rare exceptions, survives only three generations ; and what is true of the Metropolis, is relatively true of other centres of population. Unless those *centres* are supplied with fresh importations from the rural parts of our country, then depopulation (as yet limited to rural districts), must in time extend to the towns—when it may be truthfully affirmed the decadence of the British Isles has begun.

The recent census returns present some most important lessons to us as a nation, lessons bearing materially upon this problem. For instance, the alarming decline of population generally throughout the rural parishes of our country raises the question, "Whence are we to obtain the fresh supplies needed for the loss and waste of town life?"

All these are serious practical questions for our country if we would hold our own; and they evidence the stern necessity there is for the central executive, and the distributed local governing authorities co-operating in united and harmonious efforts to stem these various causes of local and national decline.

Suggestions for the re-populating of our rural parishes, the "Back-to-the-Land" cry of many reformers, whilst these would do much to remedy matters, are rather outside the scope of this paper.

As responsible advisers of municipal authorities in matters of policy as well as *technique*, we have to take the conditions as we now find them, and to prescribe for such conditions, correctives of a sanitary sort, which will make urban life healthy and happy—suitable for *living* as well as for *working* in; and fitted for the production of strong and healthy species to carry on the work and warfare of life.

The social and economic aspects of the problem having been thus briefly alluded to as essentials to the proper study and appreciation of the problem: the considerations of Transport and of Structure, apply probably with more direct application to the membership of this Conference.

TRANSPORT.

By transport is meant the facilities or means of conveyance provided for getting from one's place of labour to the home. As those great circles of population extend outwards, it is the more imperative to provide for rapid transit by road or rail—if not both—from suburbs to centre and conversely.

Unless this is done, an essential part of the problem will have been omitted.

In very many—it might be said in most cases, juxtaposition of railway or tramways and new sites for labour colonies does not exist; it becomes the duty therefore of the housing authority concurrently with the creation of labour townships to provide ample and ready means of communication and at the lowest possible fares. Those fares, however low they may be, are in reality an addition to the rent of the house.

Take the case of a house situated one mile or thereabouts from one's place of work in the provinces, or from a railway station in the outskirts of the metropolis—a very usual and ordinary case. This means—putting it at the very lowest estimate—1*s.* 6*d.* per week for travelling charges, added to or *burdening* the rent of their dwelling.

On this hypothesis of "burden," it might be argued that every single item of charge upon the working-man's treasury is burdensome; yet when the numberless little demands thereon are considered, then it is felt that every reduction even to the fraction of a penny is so much towards the relief of his restricted treasury.

As illustrative of the important part which "transport" plays in the problem of housing the labouring classes, it has been argued by competent writers that this should be the extent of the share of work of municipal authorities in this matter. From this opinion—so limited in its range—the Author entirely dissents, and he is pleased to communicate the fact that the authority he serves is probably the first to acknowledge this dual responsibility of housing and "transport." Concurrently with the execution of the housing scheme, the Council are laying down lines of electric tramway past the sites of their dwellings, communicating with the docks, gas and chemical works in the south; and with the leading railway stations, also Epping Forest on the north (*vide* Drawing No. 2).

If abundant, cheap and ready means of transport into the suburbs are not provided, then the labouring classes will perforce continue to crowd together in the hearts of our cities, with all the heritage of evil consequences dealt with in the opening part of this paper.

Towards the provision of this transport, railway and tramway companies, also the State and the municipal authority could beneficially co-operate: (1) the State, by enlarging and easing the facilities for construction of railways and tramways: (2) the railway companies, in adding to their existing train services from the heart to the outskirts of our cities and towns on a scale *commensurate with the growing demands of population*; (3) the local authorities, by providing the contributory tram services between railways and dwellings.

Whether in this country of built-up cities, *express street railway or tramway services* will ever be a reality, it is not possible to affirm; but failing these, the development of existing systems, and their fullest utilisation, are essential factors in the solution of the problem of housing the labouring classes; and, just because transport is so necessary a factor in this problem, is one amongst many weighty reasons for the *municipalisation of the tramway service of this country.*

Structure.

Under this head of the problem more probably than any other, do the real *difficulties of a practical sort* arise: raising as the structure does, questions of design, ways and means, air-space, finance, rent, and kindred debatable topics.

One of the first thoughts that arises here, is: For what class of the community are we to provide?

If local authorities would make up their minds upon this essential, preliminary to any plans being prepared, a great deal of valuable official time would be saved.

The duty, and, it appears to the Author, the *sole* duty of public municipal bodies in this department of statutory work is to provide dwellings for a class hardly if at all reached by the efforts of private building speculation.

Were such a line of demarcation drawn, there need not arise those fears of interference with private enterprise: there is in this problem opportunity and scope enough to satisfy the ambitions and capacities of all workers.

The class of persons reached by private enterprise are those in receipt of good wages, able to pay rents—in London suburbs—from 7*s.* per week upwards.

This standard varies with the district, its rates of wages, costs of living, etc.; but it may be assumed as a rule that any *inclusive rent, exceeding one shilling a day* becomes burdensome to the class of tenant sought to be catered for by a public authority, in providing dwellings for the labouring classes.

If, then, this rate of 1*s.* a day be adopted as the *maximum* rent which shall be charged, a necessary preliminary to the size and character of house is thus determined.

From a careful investigation by the Author, it has been found that, at the East Ham dwellings (erected at a cost of *under* 5*d. per cube foot*), for each 100 feet of *available* floor space in rooms (excluding lobbies, passages, and closets) a rental of from 1*s.* 4*d.* to 1*s.* 7*d.* per week is required, according to the economy of plan adopted.

Plans are submitted in Appendix illustrating various designs of the Author's, and an analytical table of accommodation and costs ; also rentals needing to be charged so as just to pay their way.

The Author would here observe how very desirable it is, in dealing with comparisons of costs of building, also of rentals and accommodation, that all such comparisons should be reduced to one common standard of rental per week per 100 feet of *available* habitable floor-space.

From inquiries made at different places, the Author has found houses described as 3, 4, or 5-roomed wherein some such rooms are unworthy of the name, being anything but *roomy*, and more fit to be designated "boxes": for instance, a scullery (6 feet by 5 feet) or say a bedroom (8 feet by 6 feet) does not deserve the designation of "room": the plea therefore for a *space-unit* is especially needful at the present time. [*Note.*—The London County Council do not in their dwellings, designate any chamber as a room unless it has 96 superficial feet *clear.*]

The tabular statement submitted in Appendix has been compiled by the Author for comparing the merits and economy of the various alternative plans, and has been found most serviceable for this purpose.

Such statistics when carefully compiled from workers in various towns, would afford a wealth of practical information, helpful in determining the class and size of house according to the rental decided to be charged.

The Author would welcome information from other towns under the headings given in the statistical tables, and would embody such information as a valuable supplement to this paper.

SIZE OF HOUSE.

As the subject under discussion here, is the Housing of the Labouring Classes, it is presumed that it is the *labourer, his wife and family for whom provision is being made.*

The number of persons included in the labouring-class household is, upon an average, five, that is husband, wife and three children. The question of what accommodation—its nature and extent—should be provided for each family is most debatable.

There is the *root idea of "Home"* so dear to the British heart: and there is that other impression or argument that it is not a home we are called upon to provide, but only a *dwelling,* a place of "*lodgment*": it is solely as one chooses to regard this question from one or other standpoint, "*home*" or "*lodgment,*" that the accommodation can be prescribed.

"Home" may be the aim of the theorist; "lodgment" the accepted condition to which the man of practical affairs has to resign himself.

Which of those two ideas one has to interpret by plan, is governed very much by place and circumstance. Thus, if the site of building is *compelled* to be near the heart or in the thick of any great city, where land is dear and every inch of space a consideration, the idea that the house is only a "lodgment" may have to prevail; and, after all, better a well-planned and built family lodging house having its separate family sleeping chambers or cubicles, well appointed and administered in its cleansing, cooking and domestic details, than the wretched, squalid tenements in certain so-called model dwellings of one or even two rooms, wherein families have to herd together almost as do cattle in a common pen.

Call these not homes—say rather abodes of vice, where light is dark, and "darkness visible serves only to discover sights of woe, regions of sorrow, shades where peace and rest of home can never dwell."

Having admitted the *limited* place which the "family lodging house" may play in the housing of the labouring classes, the root idea of the house as a "*Home*" may be examined.

POINTS IN THE DESIGN FOR A WORKING-MAN'S HOME.

In designing the home, one must not be carried away by too fanciful notions, but should approach the plan from the level and standpoint of the intending tenant; omitting all dispensable luxuries, avoiding one's own "fads," paring down extravagances, and providing in lieu of such "fooleries," plenty of space, well lighted and ventilated.

The workman's ideal home should have entrance and exit independent of any other house. To this extent only need it be "self-contained," and should have the following accommodation:

(1) A kitchen, containing at least	144	sup. feet	(net)
(2) Scullery, with small range, copper and bath	70	"	"
(3) Parlour, usable as a bedroom	125	"	"
(4) Bedroom	96	"	"
Total	435	"	"

together with arrangements for coals, water-closet, clothes-closets, and larder, all suitably positioned in plan.

A house giving the above accommodation should be provided in the London suburbs or outskirts at an *inclusive* rental of from 6*s.* to 6*s.* 6*d.* per week, and in the provinces where building-costs, rates and taxes are lower, at a correspondingly lower rental.

It may no doubt be desirable to add one or even two bedrooms to the schedule above given, but the problem before local authorities, and given them by the Legislature to carry out is—*not the creation of municipal villadoms* with their *six* and *seven*-roomed houses, but—the erection of plain substantial cottages for the respectable lowest-wage earning classes, and at rents within their very restricted means. Hence the plea, the strong plea, which the Author desires to emphasise against the ambitious tendency of municipal bodies to compete in accommodation and *show* with the houses provided by private persons for quite another and *better-off* class than was ever intended by the framers of our various Housing Acts.

A well-defined municipal policy as above suggested would bring about a better understanding between public authorities and private persons whose capital is embarked in house property.

In cases known to the Author *in the suburbs of London* there are being provided by local authorities houses 8*s.* 6*d.*, 9*s.* 6*d.*, 10*s.* and up to 12*s.* per week of rental.

Schemes like the above (say rather "*municipal shows*") betray ignorance, or at least misconception of their statutory duty.

The procedure of local authorities, as it appears to the Author, should be to consider the following points in order:

(1) The class for whom they are catering.

(2) The wage earnings of such class, as determining the rent they can pay.

(3) The best space and accommodation available at such prearranged rental.

In such well-defined order as this, then, they are in a position to have plans prepared fairly interpreting this policy of providing houses for a *given class*, at a *given rental*, and of *given accommodation.*

The design of house most nearly satisfying those given conditions is, in the Author's opinion, that known as the *double-tenement* house.

Various alternative plans of the double-tenement house are shown, to illustrate the several points that have been described.

Pursuing such policy, and on plans such as these or of kindred type, there might grow up around the outskirts of our great cities, ranges of plain substantial well appointed labourers' cottages, fulfilling the ideal of homes for the rearing of healthy offspring untainted by evil and squalid surroundings, and well worthy the best efforts of municipal bodies in improving the conditions of life in our towns.

Financial and Legislative.

Repayments of Moneys borrowed for the Housing of Labouring Classes.—On this important detail there is much to be said, the general trend of current opinion being that the term for repayment of the moneys borrowed for such purposes, should be very considerably extended.

Important authorities like the London County Council contend that the land should remain a permanent debt on which interest alone would be paid, whilst for the buildings 100 years should be allowed for repayment, the existing terms being, for land 100 years, and for buildings 60 years.

Between the London County Council's extreme on the one hand, and the Local Government Board's current practice of from 30 to 40 years on the other, some safe and equitable course might be devised.

This part of the problem is more a *financial and legislative* than a *structural* question. It is, therefore, with some misgivings that the Author touches upon it. Having, however, felt where the shoe pinches—in the problem of providing proper houses at suitable rents—he may be pardoned this momentary trespass on the province of others.

The principle governing the terms or period of years allowed for repayment of loans appears to be the Central Board's estimate of *reasonable duration of the permanent work.*

In the metropolis, where the Home Office is the controlling authority, 60 years are allowed for buildings. Outside the metropolis, and subject to the Local Government Board, 30 or at most 40 years are allowed.

For schools, again, the Education Department at Whitehall allow 50 years on the buildings.

Now, why such variety of practice?

The Author, having given some study to this detail, ventures to submit the following digest of points which might be a safe basis determining the period of years to be allowed for the repayment of loans sanctioned for the purpose now under review, and varying according to the necessities of each locality:

1. That for a standard class of dwelling a proper and suitable rent should be decided upon as a *first consideration*; regard being had to the rents and wages prevailing in the district.
2. Thereon should be considered the rate-burdens upon such property in respect of
   - (*a*) Educational charges.
   - (*b*) Poor-law.
   - (*c*) General District Rate.
3. The effect those charges have upon the rent of the house; and varying peculiarly in each district.

Given these three heads or conditions, it now becomes a matter of arithmetic to calculate thereon, with a given capital expenditure, what number of years is required to repay the loan, so as to produce those pre-determined results: and to be approved by the Local Government Board.

There may be complexities, requiring more exhaustive treatment than the compass of such a paper as this permits, but briefly stated, the above appears a fit basis whereby the financial aspect of this problem is assured, free of any loss or charge upon the rates.

A financial re-adjustment in this matter is certainly much required if this struggling enterprise of decently housing our labouring classes is to advance as it ought, and as our social and economic conditions demand.

The lines of readjustment above suggested avoid the extremists' views on both sides; they also have careful regard to all the local conditions as affecting the rent. They would further strengthen the hands and intimacy of the central and local governing authorities, and produce that co-operation which is needed.

Legislative.

The proposal to confer upon local authorities, powers of purchase of land outside of their own district for housing the working classes, will create certain added rate-burdens upon the locality, which it will require fresh legislation to correct; for instance, consider for a moment the effect upon the local rates of say the district of Tottenham by that scheme of the London County Council to speedily plant a population of 40,000 persons within this district. The charge for educating the child-element of this large and sudden importation will so add to the district's local burdens that redress will at once be sought, and such redress points to the necessity for the complete *nationalisation of educational and poor-law burdens.*

Practice of Continental Authorities.

In the Appendix is submitted a digest of the practice of the Prussian Government on this question. This goes far beyond the scope permitted to local authorities in this country; but there is much that might be adopted as a pattern for fresh legislation.

Conclusion.

From a rapid review of this paper—extended beyond the original intention of the Author, yet only touching lightly upon some of the many important points in the problem—it will be seen how great and complex is the subject. Corresponding with its complexity is the satisfaction felt by those who labour in benefiting the lower classes of society: letting the sunlight into their homes; purifying the air they breathe; transporting them from crowded city slums to healthy country-side.

That is the object calling for and needing the united force and co-operation of the Government, municipal authorities, and private housing trusts: it is only by all these forces acting and re-acting upon each other in a sympathetic way that this problem (growing with the rapid growth of cities and towns) will be fairly and seriously tackled; instead of, as heretofore, so much *beating the air, or ploughing the sands.*

Unity of purpose we already have; unity of policy, consolidation of method and of effort, we have *not.*

A new movement will no doubt presently evolve, the result of the universal interest now taken in this problem, and giving birth to some National Housing Council. Such a body, by its weight, could command the ears of Parliament, and acting as an advisory and communicative power, would assist local authorities in their efforts to overtake the arrears of this pressing social and sanitary reform.

APPENDIX.

HOUSING IN PRUSSIA.

Extract from the 'Municipal Journal,' April 12, 1901.

MINISTERIAL RESCRIPT TO LOCAL AUTHORITIES.

The Prussian Government has recently issued to the Civil Governors of the Prussian provinces a memorandum upon the Housing Problem, with the object of meeting the most pressing needs of the moment by administrative action.

In this Government circular, it is pointed out that Municipal and District Councils are required to take the initiative on

HOUSING OF THE LABOURING CLASSES: STATISTICAL TABLE AS TO ACCOMMODATION AND COSTS.

1. Ref. No.	2. Name of Place	3. Single or Double	4. Area of Plot in Square Feet	5. Frontage	6. Depth of Plot in Feet	7. Number of Rooms on each Floor	8. Cube of Building in Feet, estimated at 2 Feet Deep from Ground Floor Level	9. Rate per Cube Foot* for Building only	10. Cost of each Block. (a) Building and Fencing	(b) Land	(c) Roads and Sundries	(d) Total	11. Weekly Rental, Stating whether *Estimated* or *Actual*	12. Rental Reduced to Available Floor Space of Rooms (including Scullery), *per* 100 *Feet Super.*	13. Total Superficial Floor Space of *Rooms only*, including Scullery, but excluding w-c's, Pantries, Lobbies and Landings	14. Detail Schedule of Accommodation, giving the Average Size of each Room, Stating whether Downstairs or Upstairs respectively (a) Parlour	(b) Kitchen	(c) Scullery	(d) Bed Room	(e) Bed Room	(f) Bed Room
				ft. in.	ft. in.			d.	£	£	£ s.	£	s. d.	s. d.	feet	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
	East Ham	Double tenement	1600	20 0	80 0	5 downstairs, 5 upstairs	17,104	4½	321	40	10 0	371	6 3 and 7 0	1 4	476 down 522 up 998 total	10 0 × 12 0 with bay	10 0 × 13 0	8 6 × 6 6	7 0 × 11 0 down	7 0 × 12 0 down	9 0 × 11 0 and 9 0 × 12 0 up
	Ditto	Ditto	1440 equal	18 0	80 0	4 downstairs, 4 upstairs	15,368	4½	288	36	9 0	333	5 6 and 6 0	1 4 and 1 5	422 down 432 up 854 total	12 9 × 9 0 with bay	12 0 × 15 2	8 0 × 8 0	8 3 × 6 0 down	8 0 × 12 0 up with bay	..
	Ditto	Ditto	1280	16 0	80 0	4 downstairs, 5 upstairs	15,822	4½	297	32	8 0	337	5 6 and 6 0	1 4 and 1 5½	422 down 413 up 835 total	12 0 × 11 6 with bay	12 0 × 10 0	6 9 × 6 0	12 0 × 9 0 down	8 6 × 5 6 up	..
	Ditto	Single tenement	1040	13 0	80 0	3 downstairs, 3 upstairs	9,708	4½	182	26	6 10	215	7 6	1 2	649 total	11 0 × 12 3	10 6 × 12 3	7 0 × 7 0	11 0 × 12 3 up	10 6 × 12 3 up	7 0 × 10 6 up
	Richmond	Double tenement	..	17 6	Variable	3 downstairs, 4 upstairs	11,784	6½	324	24	20 0	368	4 6 and 5 6	1 6 and 1 7	293 down 337 up 630 total	living room 10 6 × 11 9		6 10 × 8 6	9 6 × 11 9	5 10 × 7 6 up	..
	Ditto	Single tenement	..	17 6		3 downstairs, 4 upstairs	11,679	5	254	44	20 0	318	7 6	1 2	646 total	10 10 × 11 9 with bay	9 6 × 11 9	6 10 × 8 6	10 10 × 11 9	9 6 × 11 9	8 6 × 6 10 and 5 6 × 7 6 up
	Ditto	Ditto	..	12 6		3 downstairs, 2 upstairs	7,955	6	190	32	14 0	236	6 0	1 3	472 total	11 9 × 8 9	8 10 × 12 0	6 0 × 5 6	11 9 × 9 8	8 10 × 12 0	..
	Preston (Dick Kerr & Co's workmen's houses)	Ditto	..	16 0		2 downstairs, 3 upstairs	12,388	3¼	163	..	..	..	5 6	11	609 total	15 6 × 13 9	15 6 × 13 9	12 6 × 10 0	9 8 × 10 0	5 6 × 10 3	9 8 × 13 9
	Walthamstow. (Warner Estate Co)	Double tenement	..	18 0		5 downstairs, 5 upstairs	19,566	..	..	..	..	..	7 0 and 7 6	1 6 and 1 5	462 down 527 up 989 total	11 0 × 10 6 with bay	11 0 × 11 6	8 0 × 5 0	8 0 × 8 0	11 0 × 10 6	..
	Ditto	Ditto	..	16 0		4 downstairs, 4 upstairs	13,716	..	..	..	..	..	5 9 and 6 0	1 8	342 down 384 up 726 total	10 0 × 11 0	10 0 × 10 0	7 0 × 5 3	9 6 × 10 0	..	..

* Extracted from Mr. A. G. Thompson's book, 'Housing of Working Classes.'

this question, and only in cases where their measures prove inadequate must the State interfere.

It further directs that Municipal and District Councils have the moral obligation to provide all people in their employ with cheap and healthy dwellings, and to promote all endeavours to extend this benefit to the poorer classes in general. For this purpose the Councils can either themselves create building companies or support them. The preliminary condition, however, is that all these companies *shall build small and cheap dwellings.*

FINANCIAL ASSISTANCE TO COMPANIES.

The Government then proceeds to point out how the Councils might best carry out their task.

They are to give financial assistance to building companies, either by subscribing for a considerable number of shares, or by loans at a moderate rate of interest, or, further, by the complete or partial abrogation of the dues for the making of streets and laying of sewers. The building companies to which these facilities are to be granted must not pay a higher dividend per year than 4 per cent., the surplus being used for further investments. In case of the dissolution of the company, the shareholders have only a claim for the nominal value of their shares. The Municipal and District Councils are further, if necessary, to give financial help by lending money on mortgage. Should the towns not have the money themselves, they may raise loans from the savings banks, or from the Imperial Insurance offices, which have an enormous capital accumulated from the contributions to the old age, invalidity, and accident insurance at their disposal. This has to be done in such a way that the Municipal or District Councils are the debtors of the insurance office or savings bank, and the creditors of the building company to which they lend the money at a rate of interest of a quarter of 1 per cent. higher than they have to pay themselves. If circumstances let it appear expedient, the Municipal Councils can stand bail for the companies which borrow the money.

THE TRANSIT QUESTION.

These facilities are also to be granted to individual contractors. All this is, of course, only done on condition that the Municipal Councils have a guarantee in hand that the buildings will afterwards not be used for other purposes. In such case

PLATE I.

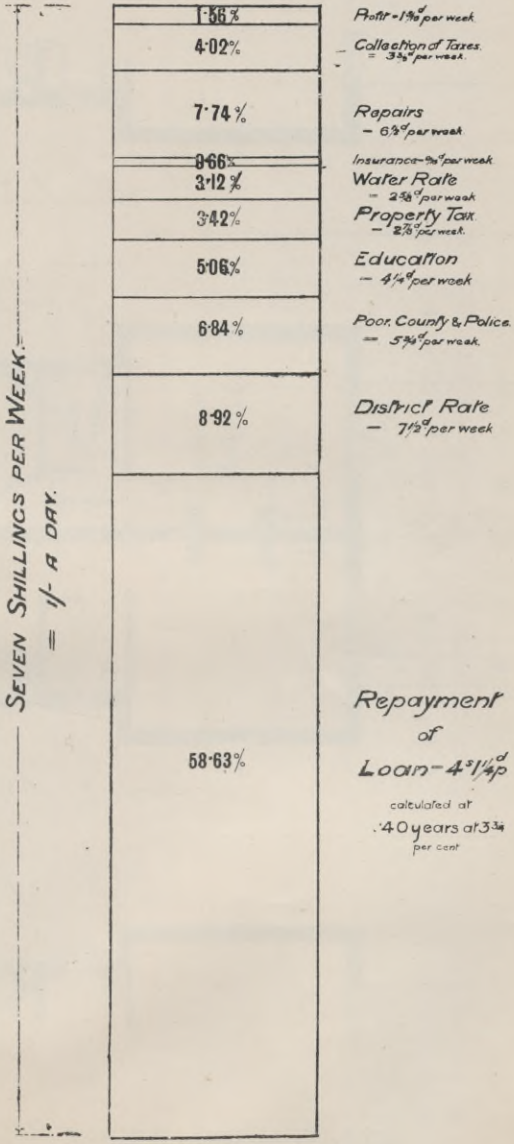
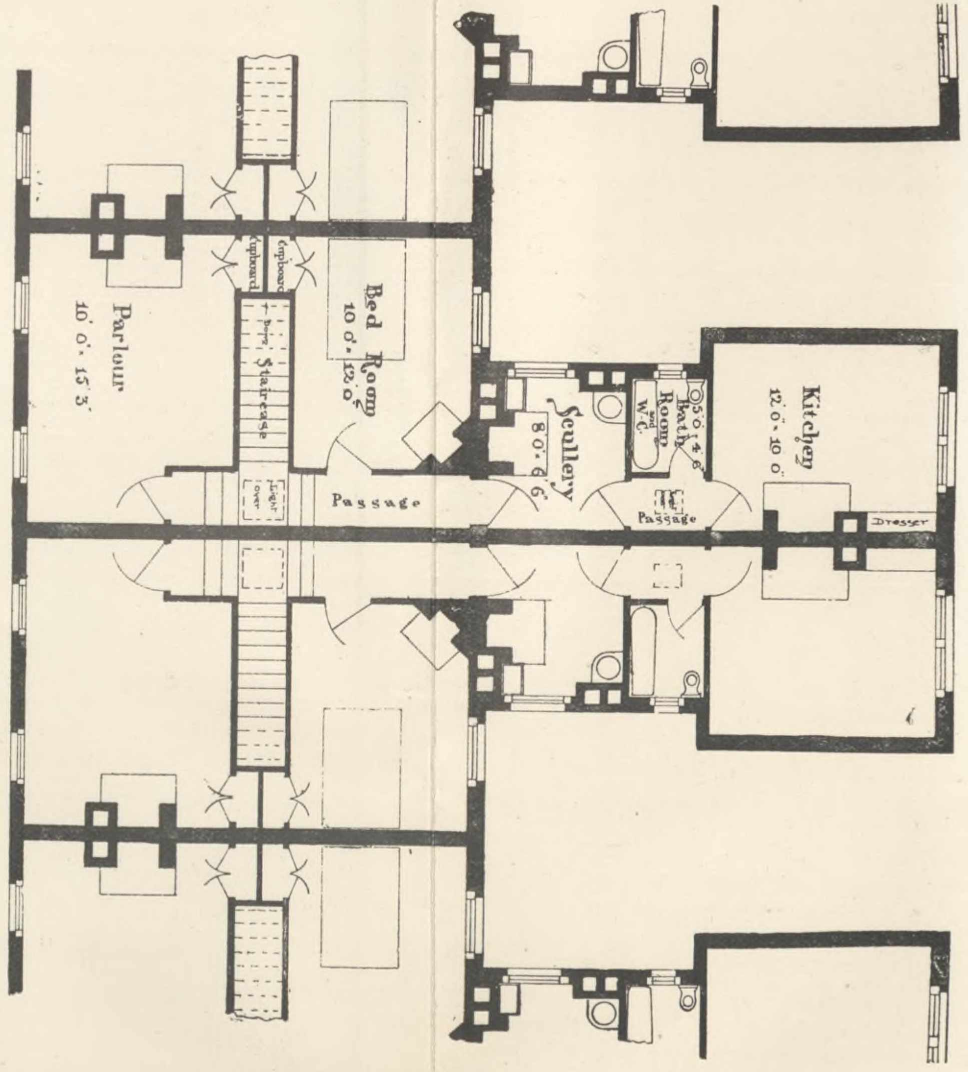
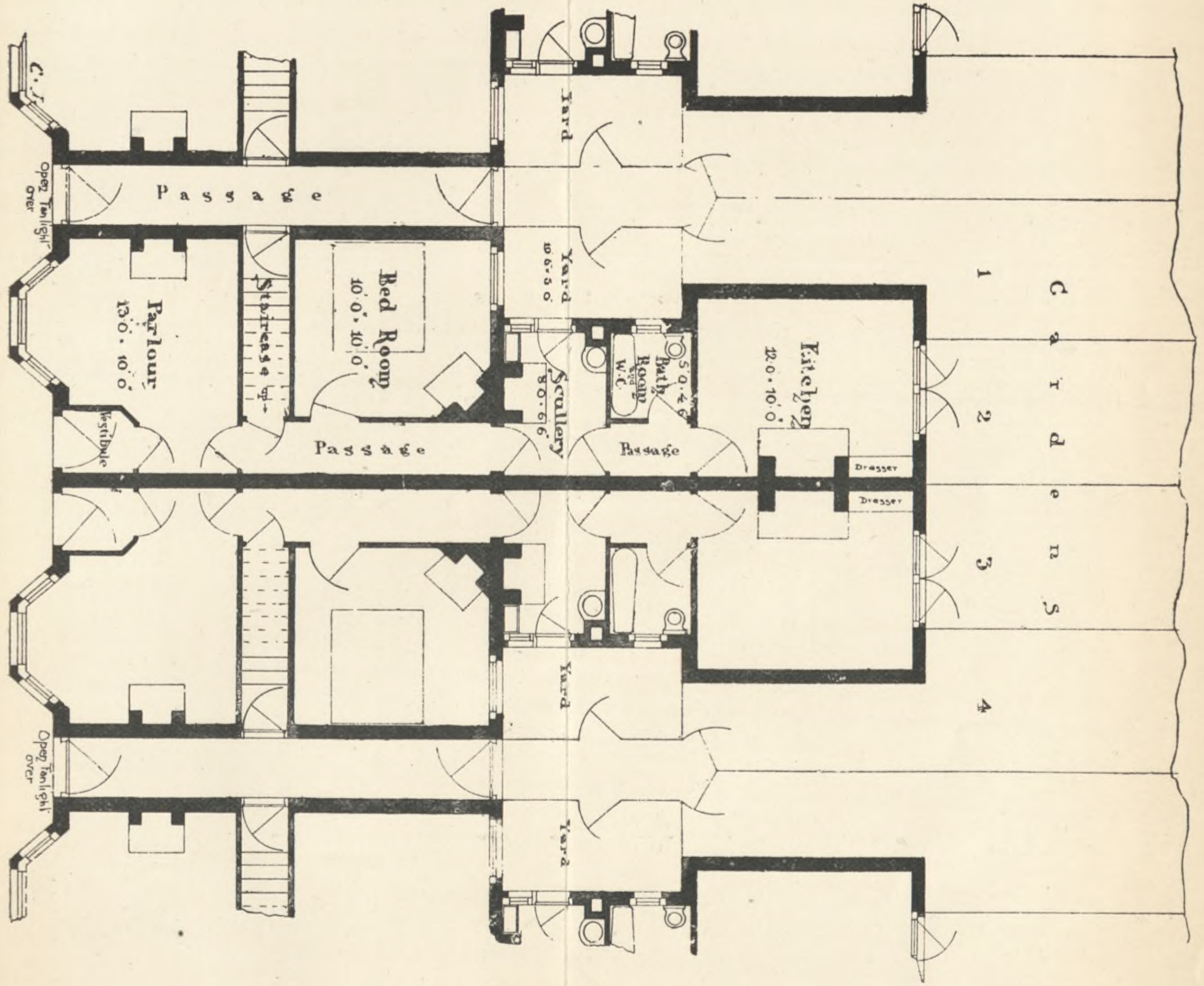


TABLE OF PERCENTAGE YEARLY CHARGED.

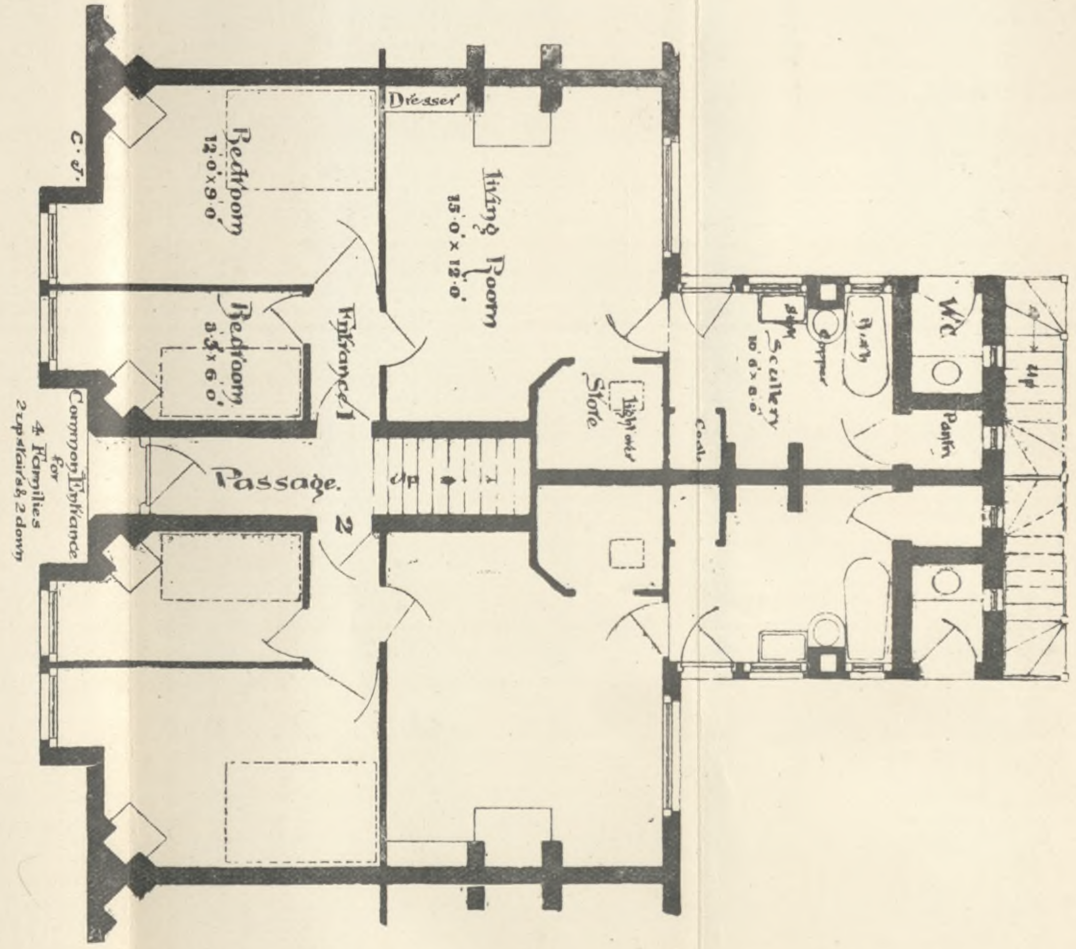
PLATE II.



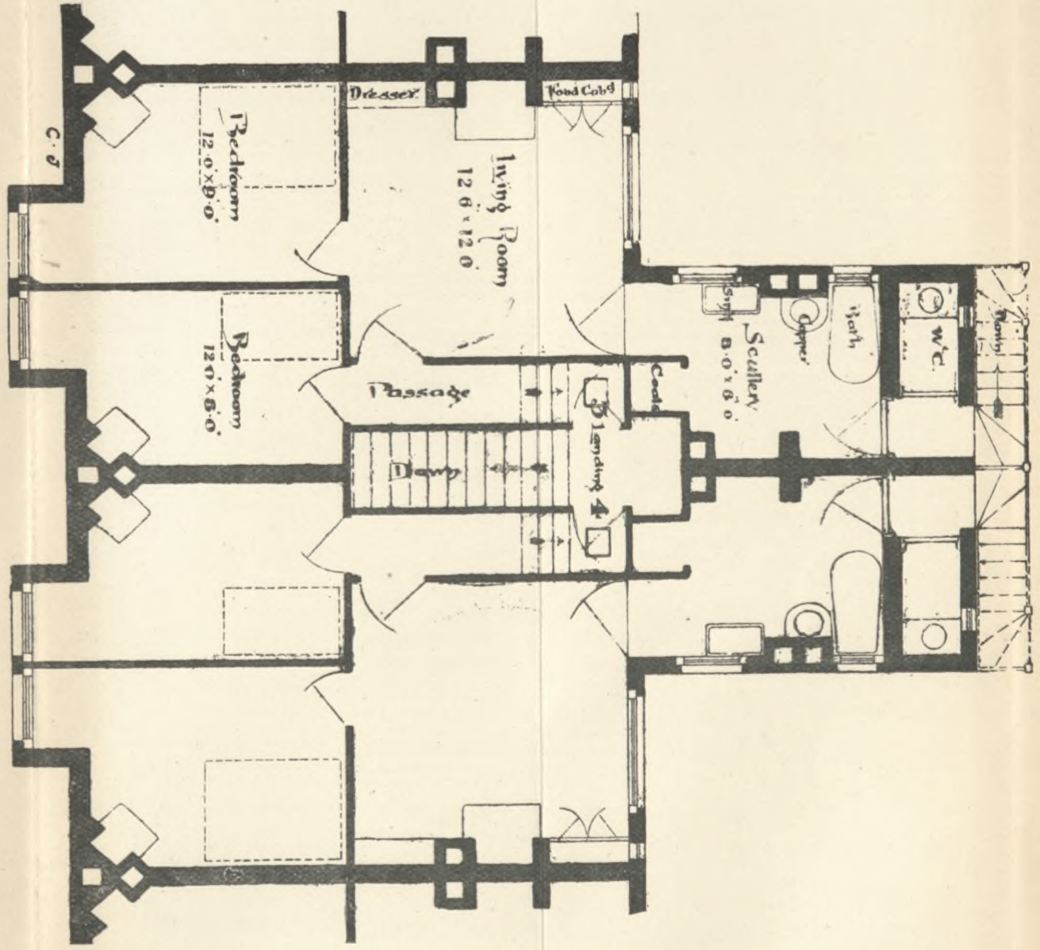
FIRST FLOOR PLAN OF THREE ROOM FLATS.



GROUND FLOOR PLAN OF THREE ROOM FLATS.

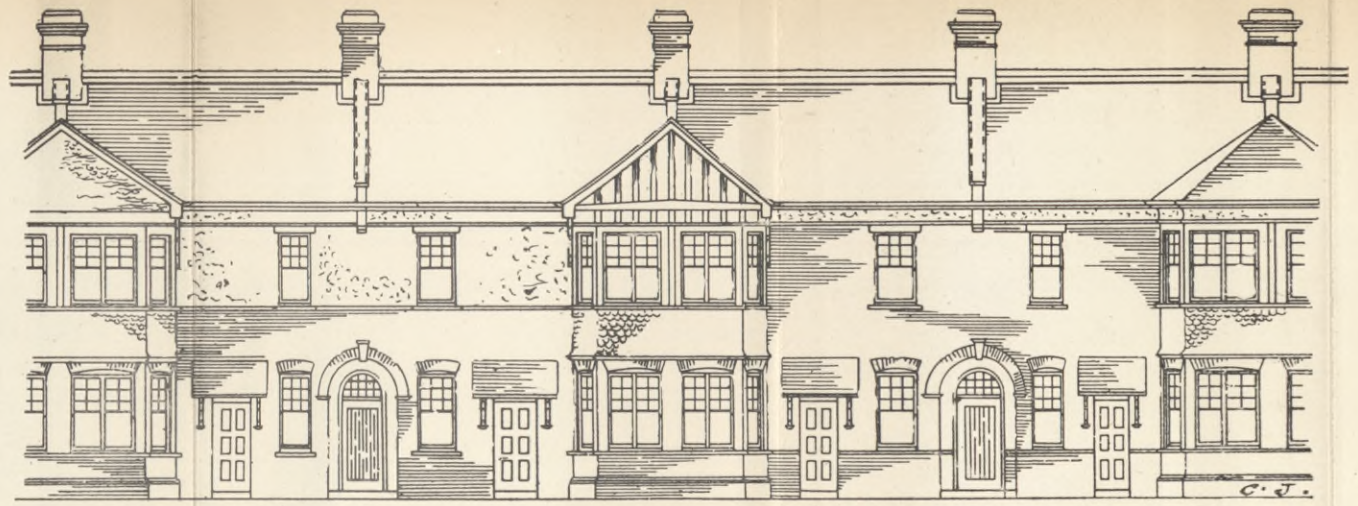


GROUND PLAN OF THREE ROOM FLATS.

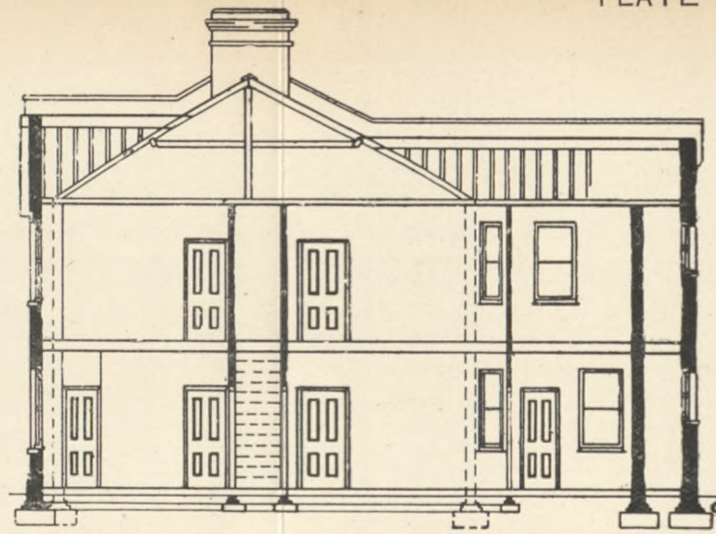


FIRST FLOOR PLAN.

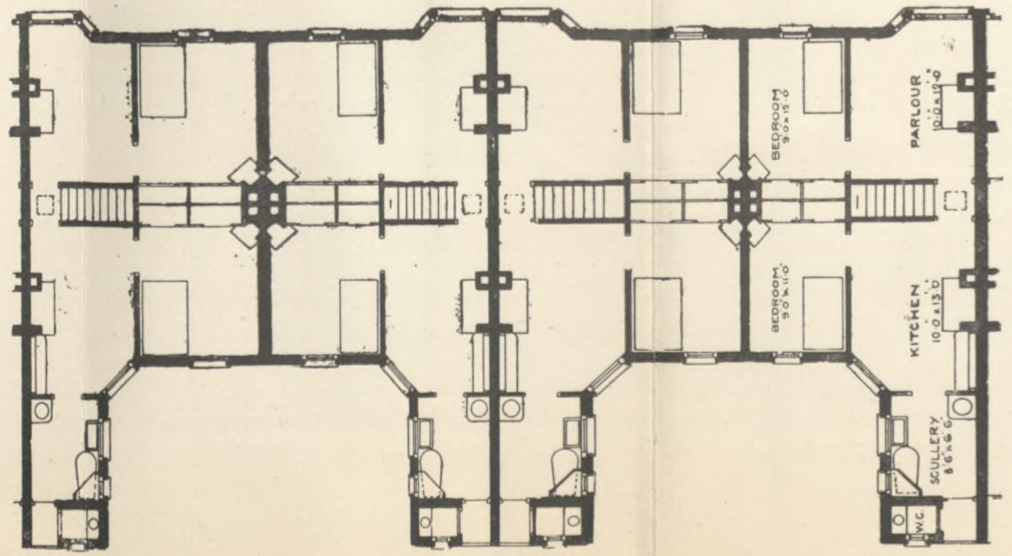
PLATE IV.



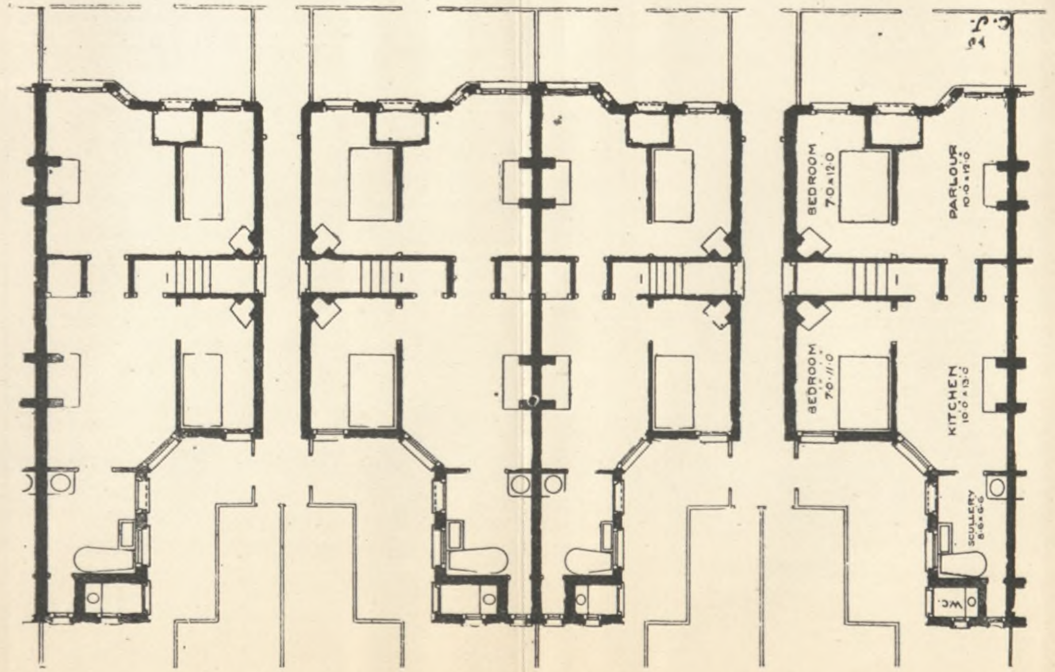
FRONT ELEVATION OF FOUR ROOM FLATS.



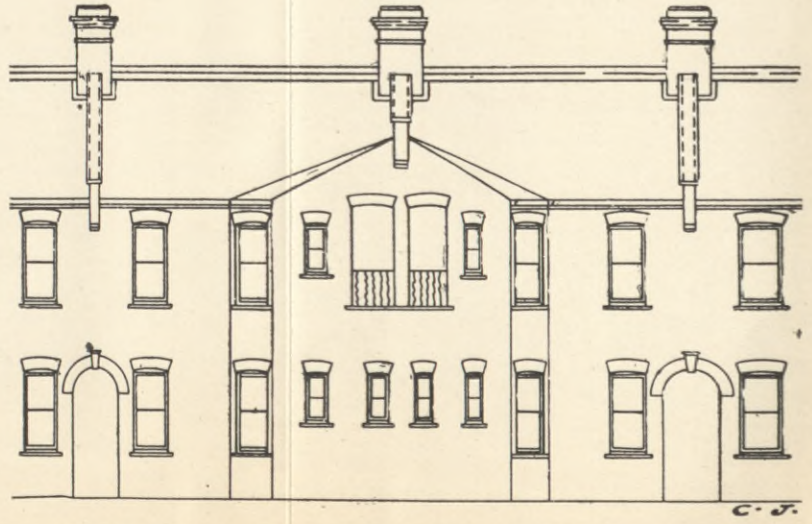
SECTION.



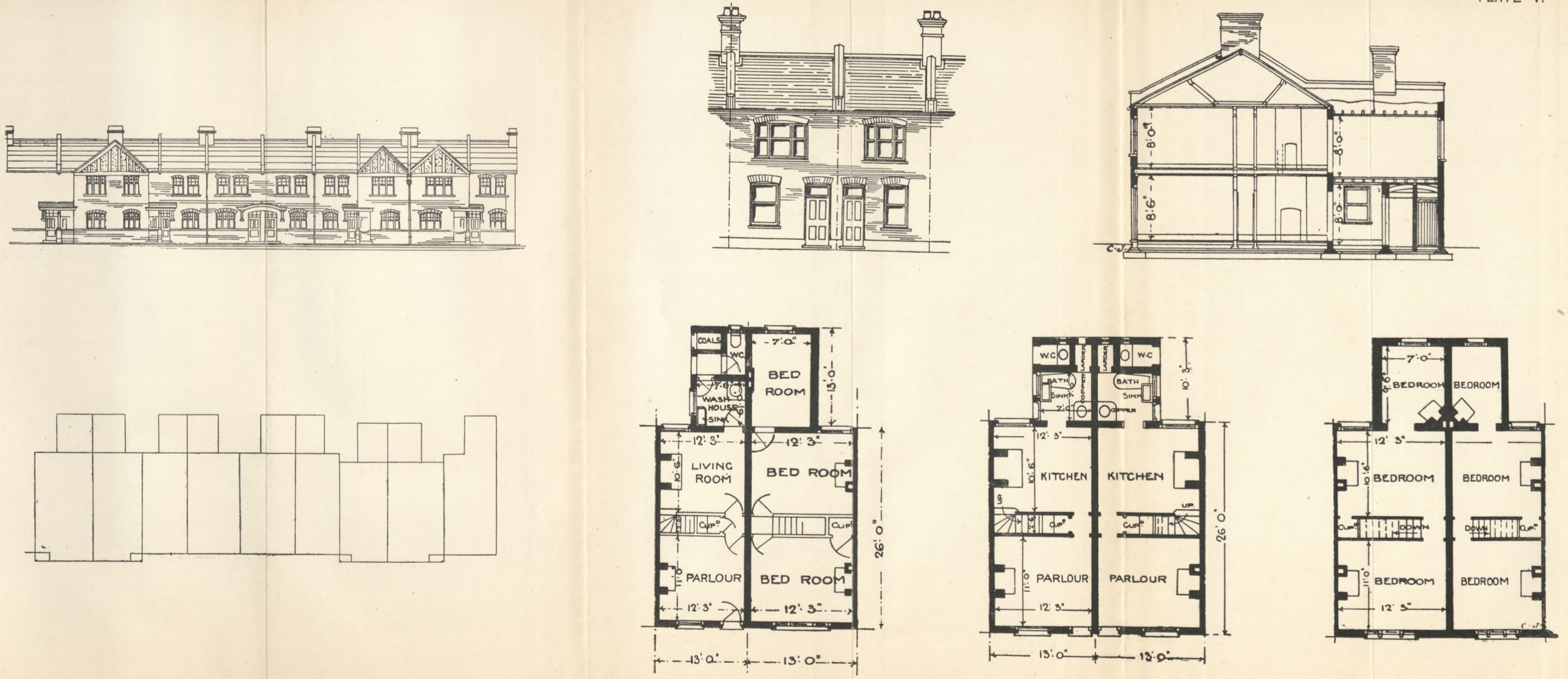
FIRST FLOOR PLAN.



GROUND PLAN OF GROUP OF FOUR ROOM FLATS.



BACK ELEVATION OF FOUR ROOM FLAT.



PLANS AND ELEVATIONS OF FIVE ROOM DWELLINGS.

the Councils have the right of pre-emption at a nominal price. The Municipal Authorities, the ministerial decree says, *ought also to create adequate and cheap means of communication*, so that the working population, and the school children, may be able, without much loss of time, *to live outside the town.*

The building companies are also to have the advice of the building experts employed by the State and Town free of charge, and they have not to pay the different taxes which as a rule are levied on the building of houses. As the present evils are chiefly due to *unhealthy speculation in building land*, this ministerial decree suggests that *the towns ought to buy up as much land in the neighbourhood as they can*, in order to prevent it passing into the hands of speculators. The towns are then to sell the land or houses in their possession with small profit and on convenient terms to contractors who undertake to build *cheap dwellings.* The ministerial decree finally points out that only by a co-operation of all factors concerned in the matter, State, Town and employers, can a satisfactory solution of this most difficult problem be expected. It further suggests the creation of a central office in each province, and the foundation of associations in single districts to be in permanent communication with the central office.

Note.—The Author had hoped for the co-operation of his esteemed predecessor (Mr. W. H. Savage) in the preparation of this Paper: much of the material upon which he is now working having been initiated and designed by Mr. Savage. His illness, however, will deprive the Conference of his valuable contribution on the subject.

DISCUSSION.

The Chairman: We are greatly indebted to Mr. Campbell for the very admirable way in which he has described his undertaking. There is one thing I should like to say. We see some towns giving poor people four rooms. Of course, it is an admirable thing to give a man a nice little house, and I quite agree with it; but is it not a fact that a man earning 25*s.* to 30*s.*

a week cannot pay 7*s.* or 8*s.* a week for this in large towns; and has to take in lodgers, and the house is occupied by two or three families?

Mr. CAMPBELL: Not in our district.

The CHAIRMAN: I am afraid these houses do not serve all the necessities of the case, and it is just a question whether it is not more advisable to leave a few two-roomed tenements with proper sanitary arrangements at a less cost: a couple of rooms about 1*s.* 6*d.* a room. It appears to me that is the great necessity of large cities.

Mr. LOBLEY: I have very great pleasure in moving a vote of thanks to Mr. Campbell for his paper. Mr. Campbell has approached the question no doubt from the point of view of a surveyor in the neighbourhood of London. Of course the conditions existing there are very different indeed to those existing in the Midlands or North of England. There is no doubt that in providing the class of dwellings he shows on the plans, he is providing something not provided by private enterprise, and I take it, that is the point of view from which it should be regarded by the authorities. They are providing something not otherwise provided. Now the difficulty in the case of Midland towns is, that they want to pay a 3*s.* 6*d.* rent for a 7*s.* house. That seems to be the general result of municipal enterprise in the way of artizans' dwellings. Mr. Campbell gave one the impression with regard to East Ham that the increased cost as shown by the diagram, including the rates, etc. would be borne by the occupier. I have been labouring under the idea that the labour interest was so strong in that part of the country, that really it would be at the cost of the ratepayers and not at the cost of the occupier.

Mr. CAMPBELL: No, no.

Mr. LOBLEY: I am quite sure in many Midland towns it would be done at the cost of the ratepayers; and to provide anything like the house for such a rent as that would not mend the difficulty of the position. At Hanley a house can be built, the minimum size, under the bye-laws, with four yards frontage, and twenty yards in depth, including the yard, two rooms down and two up, water-closet and scullery outside, total area 500 square feet, and that can be let at 3*s.* 6*d.* per week. Now to erect any dwelling better than that is to provide for a class who can afford to pay more; to provide less is to break our own bye-laws; and that is a rather awkward thing, so that the difficulty remains. The labouring classes will not hear in our part of anything approaching the flat or tenement system. They want a house entirely in itself. As a matter of fact, the objection to houses built by private enterprise is of course that they are not so well built as by a municipality, and what is wanted is a class of house that will take away people who dwell in the slums or who are living in houses only fit to be pulled down. There are similar houses to those I have described that are being pulled down for various reasons. These houses—it may be for public improvements, it may be the demolition of insanitary districts, it may be the acquisition of land for business premises—are being rapidly demolished. Where are those people to go?—the people who pay 3*s.* 6*d.* per week; the labouring class earning wages of 18*s.* to 22*s.* a week. There is no provision by private enterprise—in fact there cannot be, because the minimum size is the one I have already described. The nearest approach that I have seen was at Edinburgh some few years ago, when I visited some houses erected by the Corporation there. But they had the difficulty of rents there: they are higher than with us. Now to provide houses anything like those on the plans submitted by Mr. Campbell—and they are very nice houses—would be to have a privileged class. The people who live in those houses will be the minority, of course, of the population—at any rate for a great many years, and they will be privileged. They will have a house the market value of which, compared with other houses, will be considerably greater. In other words, the ratepayers will have to supply the difference. That is the view that presents itself to our minds in the Midlands, and the difficulty is to meet that case. With regard to the time for repayment of loans. I quite agree with the idea that a large proportion of the cost of the buildings should be spread over a longer period than the thirty years allowed by the Local Government Board, but there is a limit to that, and the London County Council have certainly gone to too great an extent. It ought not to exceed fifty years.

Mr. Cooper (Wimbledon): I beg to second the resolution. There is one point I would like to speak on—the plan of the cottages. The plan, 20 feet frontage, is a very good one so far as it goes, but there is this great disadvantage: it only provides for two bedrooms. Now two bedrooms are not sufficient for the division of sexes in an ordinary family where there is a man with wife, boys and girls. There is one point which bears on this, and I cannot at all confirm what the Author says. He says, for instance, as regards the size of the rooms, a bedroom 8 feet by 6 feet does not deserve the designation of room. Now we know the size of rooms gentlemen-millionaires who come from the other side of the Atlantic, have to put up with on board ship. If men in positions like that can put up with them I think the size is sufficient for a man earning 20*s.* to 24*s.* a week. There is room for a bed, a washhand-stand, and everything. If these dwellings are going to be a success you must have small bedrooms, and the idea that in the rooms there must be 96 superficial feet is to put a tax on these bedrooms which I consider they ought not to have. The great thing for us in a bedroom is to have ventilation, and if this is arranged 8 feet by 6 feet is quite sufficient, and you can get ample ventilation for one person. Mr. Campbell mentioned that what was wanted in comparing the prices of these dwellings was to take out the superficial area of rooms, thus excluding the passages. If you take that as the standard I am quite willing, but you must remember in the majority of those designs the rooms themselves are made passages. For instance, take the room in the front on the ground floor: you have got to go through there to get to the back; and to get to the back you inconvenience the people using that room.

Mr. Munce (Belfast): A 12 feet house costs 190*l.* I cannot see where the money is spent. We can get in Belfast a first-class workman's house for 80*l.*

Mr. Campbell: Three bedrooms?

Mr. Munce: It will not take 110*l.* to add another room. We let them at 3*s.* to 3*s.* 6*d.* per week.

Mr. Campbell: Are they built by the Corporation?

Mr. Munce: Not by the Corporation: the mistake is made in men more used to designing mansions designing these houses and building them too permanently. As I pointed out at the conference of the Sanitary Institute at Leeds, the proper remedy is to build houses comparatively cheaply. There are 16,000 men employed at the ship yards in Belfast: the bulk of the men live away. The reason is they can travel on the early car for 1*d.* We must build where the people want the houses, and it seems to me we must get rid of our big ideas and build for the people. Many of these do not know how to appreciate elaborate fittings. It is a waste of money, and to use a common expression is "casting pearls before swine." I do not mean anything offensive by that remark, Mr. Chairman. You can build a house to suit a working man for very little money and make 10 per cent. profit on the investment at the ordinary rentals.

Mr. COOPER: It is only right to say that Mr. Munce is speaking of Ireland, not England.

Mr. PRICE (Lytham): There is no doubt houses can be built more cheaply in Ireland. With regard to the plans, I should like to suggest Mr. Campbell might improve them. The bits of green are hardly playgrounds, and I think it would be better if the houses faced each other all down the street, and there are no back streets.

MR. CAMPBELL: Back passages?

Mr. PRICE: I think instead of having to go through this dark passage, it would be an improvement to have the entrances in front, something like those we saw at Brighton.

Mr. CAMPBELL, in replying, said: Mr. Price has spoken of the dark passage. It is not a dark passage; it is quite a light passage. It is left open for air and light; but I may say this, we have erected some sixty dwelling houses with front entrances, but we were only able to get one bedroom on the ground floor, and we found the demand was not for a one-bedroomed house but for two, however small. I say that in reply to Mr. Cooper's observation. Mr. Munce, of Belfast, has spoken of Belfast, not of the Metropolis; and in dealing with this question we have to deal each with his own country. What would do at Preston, Leicester, or any other place would not do in the Metropolis. The Metropolis is a thing in itself. When I asked Mr. Munce whether what he described was Corporation enterprise, he said "No." Well, we know private enterprise is very much cheaper, but not very enduring. They put the most people on the smallest space and get the biggest rent for the least accommodation.

Mr. CAMPBELL: We must approach the question from the tenant's point of view. Progressive and Radical as we are obliged to be, we are not so revolutionary and socialistic as to think of providing the balance at the expense of the ratepayers. Not one penny is thrown on the rates. They would not recognise that for one moment. Mr. Lobley spoke of 3*s.* 6*d.* I should like to know the price of the building, whether the houses were erected by the Corporation, and what they gave for the land. Further, whether the Corporation of Hanley have a loan of sixty years for repayment of capital and interest. That breaks the back of this problem. Mr. Mawbey spoke about 1*s*. 6*d*. per room.

The CHAIRMAN: For a few single and aged people.

Mr. CAMPBELL: We have some rooms for old women and single men, and are able to let them at 3*s*. per week. What we want s reform in the financial and legislative arrangements that will enable us to develop this problem in the way that progress and enterprise demand of us.

COAL-MINING SUBSIDENCES IN RELATION TO SEWERAGE WORKS.

By F. W. MAGER,

SURVEYOR TO THE RURAL DISTRICT COUNCIL OF WALSALL.

THE object of this paper is to direct attention to the anomalous nature of the protection against subsidences, from mining operations, of sewerage works as compared with the protection of the highways, which they underlie, afforded by law.

Alterations in gradients and cross-levels of highways are comparatively of minor importance, and in most cases when they occur they may be easily remedied, yet a subsidence of a highway constitutes technically a public nuisance; against the person causing such subsidence an indictment will lie, and he makes good the subsidence at his own expense.

Alterations in gradients of sewers as a rule virtually terminate the existence of the section affected, and give rise to a very grave actual nuisance, with serious results from a sanitary point of view. That being so, it would be imagined that a similar legal remedy would be provided, but no such remedy is open to the local authority, and reconstruction must be done at their own sole cost.

The Public Health (Support of Sewers) Act, 1883, might be thought from its title to have been framed for the purpose; but in the first place a district could not afford to put the Act into operation, and if it could afford to do so, what might be left of the collieries would not be worth working.

The cost of putting the Act into effective operation depends upon the amount of support considered necessary. In the Author's district it would entail the purchase of seams known as the "yard," the "seven-foot," the "shallow" and the "deep," having a combined thickness of 24 feet. Other coal seams and ironstone bands exist, but are not worked.

The amount of lateral support required is not so readily arrived at. The angle of dip, direction of strike, the nature of the "bottom stone" and depth from the surface, all affect the result; and, unless a sufficient width be provided, the sewer will be "pulled," that is, will subside from insufficient lateral support.

Where the other conditions are favourable, for a mine 300 yards deep a minimum width of 50 yards is requisite.

Thus for each yard run of sewer, minerals possessing a superficial area of 50 square yards and a thickness of 24 feet, equal to about 250 tons weight, would be purchased.

The value of the royalty, adding the usual allowance for interference and compulsory sale on a moderate valuation, would work out at *4l.* to *5l.* per yard run of sewer.

Such a sum is evidently quite prohibitory.

Undue interference with, and a reduction of productive capacity of a vital national industry, would also be fatal objections to the Act, if there was the least likelihood of any Council putting it into effect.

That being the case, the remedy for subsidence is clearly not purchase of support; but its more serious effects may be guarded against by designing the sewerage schemes with regard to the levels which will obtain when subsidence has ultimately taken place, and in such a way that main points of outfall will not be affected.

This having been done, the cost of modifications of level of particular sections consequent upon subsidence posterior to the execution of the works, should by analogy with the law as to highway surfaces, be thrown upon the coal owners.

A reference to works recently designed by the Author and carried out by his own staff will illustrate this.

A certain low lying district which was being entirely undermined had to be sewered, but the sewer had to cross a fault and discharge to works constructed on land beneath the surface of which coal did not exist.

The upper end of the system would consequently subside, while the lower end or outfall would not.

The sewer and the site of the outfall works are shown on Drawing No. 4.

On reaching the outfall the sewage had to be pumped four feet as the levels then stood, and the Author determined to fix the site of the sump on the side of the fault not liable to subsidence, and to put in the floor of sump at such a level that after every seam of mineral had been won, and after the workings had settled down solid, any point of the sewer would still be at a higher level than the inlet to the sump, and thus an adequate fall be still obtained.

On the coal measures side of the fault the workings were in the hands of two separate owners, and were broken up by two minor faults. Subsidences will, as a result, be irregular for some time, and the levels of individual sections of the sewer may have to be modified more than once to avoid fracture of the pipes from movements of the ground; they were shallow socketed and jointed in clay, and, to keep them water-tight should the joints become drawn, they were surrounded with puddle. This method will also allow the pipes to be readily taken up and relaid when modifications of level become necessary. These modifications should evidently, and in spite of the law as it now stands, be carried out at the cost of the coal owners for whose profit the subsidences occurred.

What is required is that the law should be so amended that after such works as the Author has indicated have been carried out, any subsequent modification of level, such as could not be avoided in the original construction of the sewerage system, should be done at the cost of the coal owner.

To call upon a coal owner to provide mineral support at his own cost, and thus maintain sewerage works at their original level, would be to force him to sacrifice valuable property, and to interfere with the working of his mine in such a way as would not be tolerated for a moment, and it has been shown to be unnecessary; but to call upon him to reconstruct public works laid down in public highways which have been damaged by him for his profit, does not appear, to the Author, to be unreasonable, where such reconstruction may be done without excessive cost.

This argument holds good for damage to all public services beneath roads and streets, but obviously not for works constructed by agreement or under powers of a provisional order on private lands; and the Author suggests, in conclusion, that the subject of the foregoing notes is one deserving of more attention than it has hitherto received.

Details of the works alluded to in the foregoing are shown on Drawings Nos. 2, 3 and 5. The special method of construction of the sump was necessary owing to the ground being of a most unstable nature. A driving chain, instead of belting, was adopted for power transmission to economise buildings. This has proved highly satisfactory.

A vote of thanks to the Author for his paper was proposed by the President and carried unanimously.

On Tuesday September 3, *a visit was paid to the Tidal Weir at Glasgow Green. The Members proceeded by special tramcars from the Grand Entrance to the Exhibition, to the Weir.*

This difficult and complicated work, which has been in progress for upwards of three years, is the outcome of the inconsiderate action of the Corporation, who, thirty years ago, decreed the removal of the Old Weir which dammed the river above Hutchesontown Bridge. The consequences of this action, which were foreseen quite clearly by the late Councillor Osborne, the late Mr. Carrick, City Architect, and others, have been disastrous and far-reaching Apart from the dilapidation of the river banks, the repair of which has cost upwards of 30,000*l., the extra dredging of the Harbour entailed by the altered condition of the upstream flow has involved the Trustees of the Clyde Navigation in enormous outlay.*

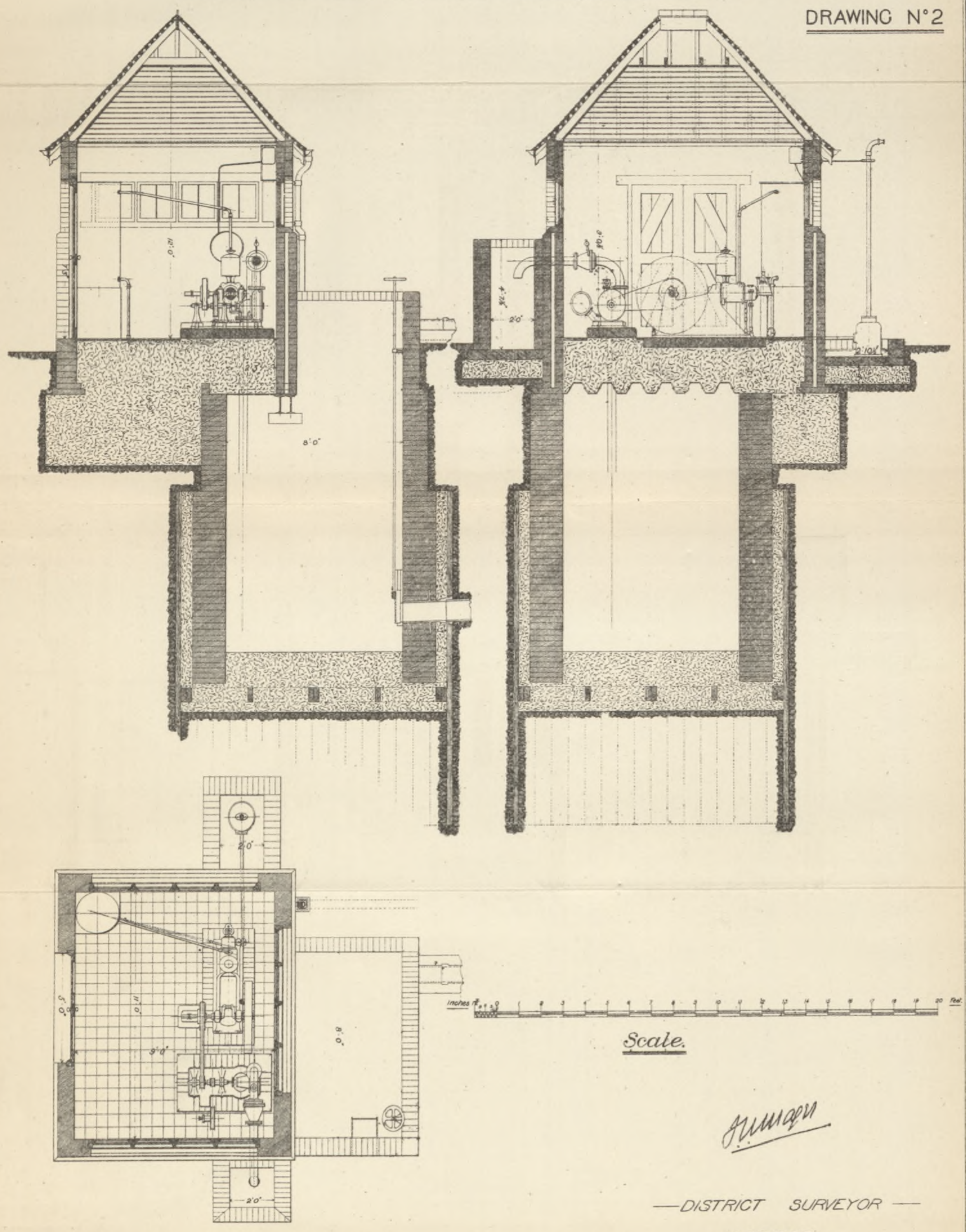
The weir at present in course of construction, in accordance with a plan suggested by Sir Benjamin Baker, K.C.M.G., which will practically maintain perpetual high tide between Glasgow Green and Carmyle Weir, presents an ingenious mechanical arrangement invented by the late Mr. F. G. M. Stoney, M.Inst. C.E. of the firm of Messrs. Ransomes and Rapier, Ipswich, the distinctive principle of which is the movable character of the ponderous gates, 80 *feet wide and* 12 *feet deep, that form the dam. These travel in delicately adjusted guides on roller bearings, under the control of equipoises, which enable each gate to be lifted with the most extraordinary facility. The successful and satisfactory working of this patent is in evidence on the River Thames at Richmond, where a similar weir has done work without interruption for several years.*

The foundations of the Glasgow Weir have been constructed by Messrs. Morrison and Mason, who have encountered great difficulty in carrying down the caissons in which the foundations have been laid under pneumatic pressure; but this most tedious part of the

RURAL DISTRICT COUNCIL OF WALSALL

Stubbers Green Sewerage. Outfall Works

DRAWING N°2



— DISTRICT SURVEYOR —

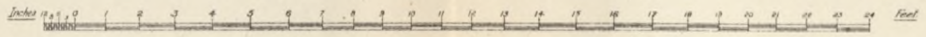
— ALDRIDGE —

PHOTO-LITHO. SPRAGUE & Co. LTD. LONDON.

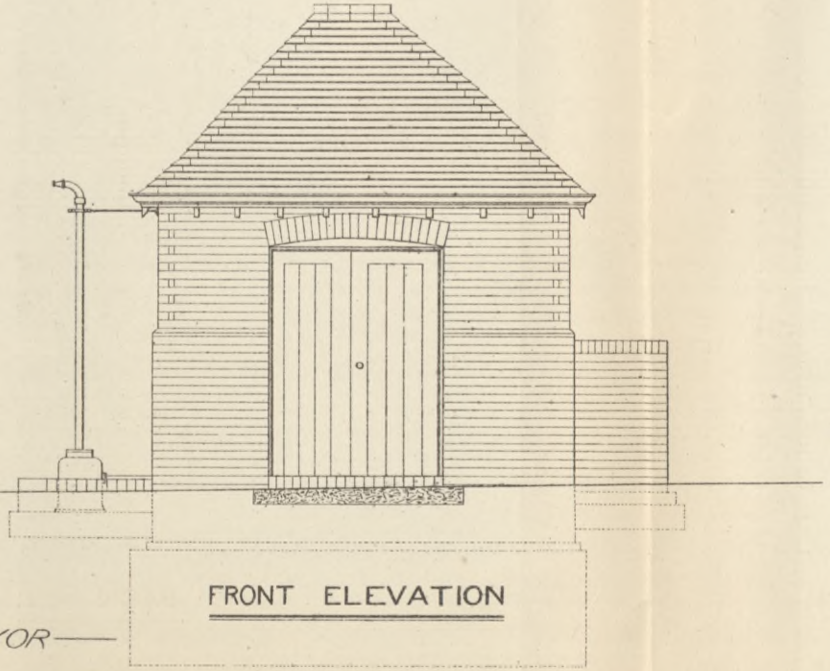
DRAWING N° 3

RURAL DISTRICT COUNCIL OF WALSALL

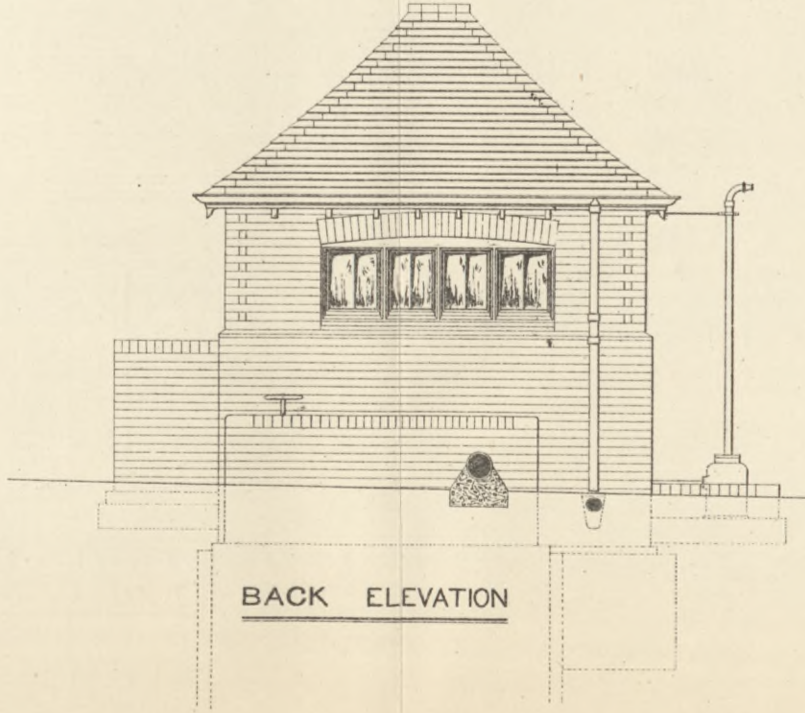
Stubbers Green Sewerage. Outfall Works.



Scale.



FRONT ELEVATION



BACK ELEVATION

DISTRICT SURVEYOR

ALDRIDGE

PHOTO-LITHO. SPRAGUE & Co Ltd LONDON.

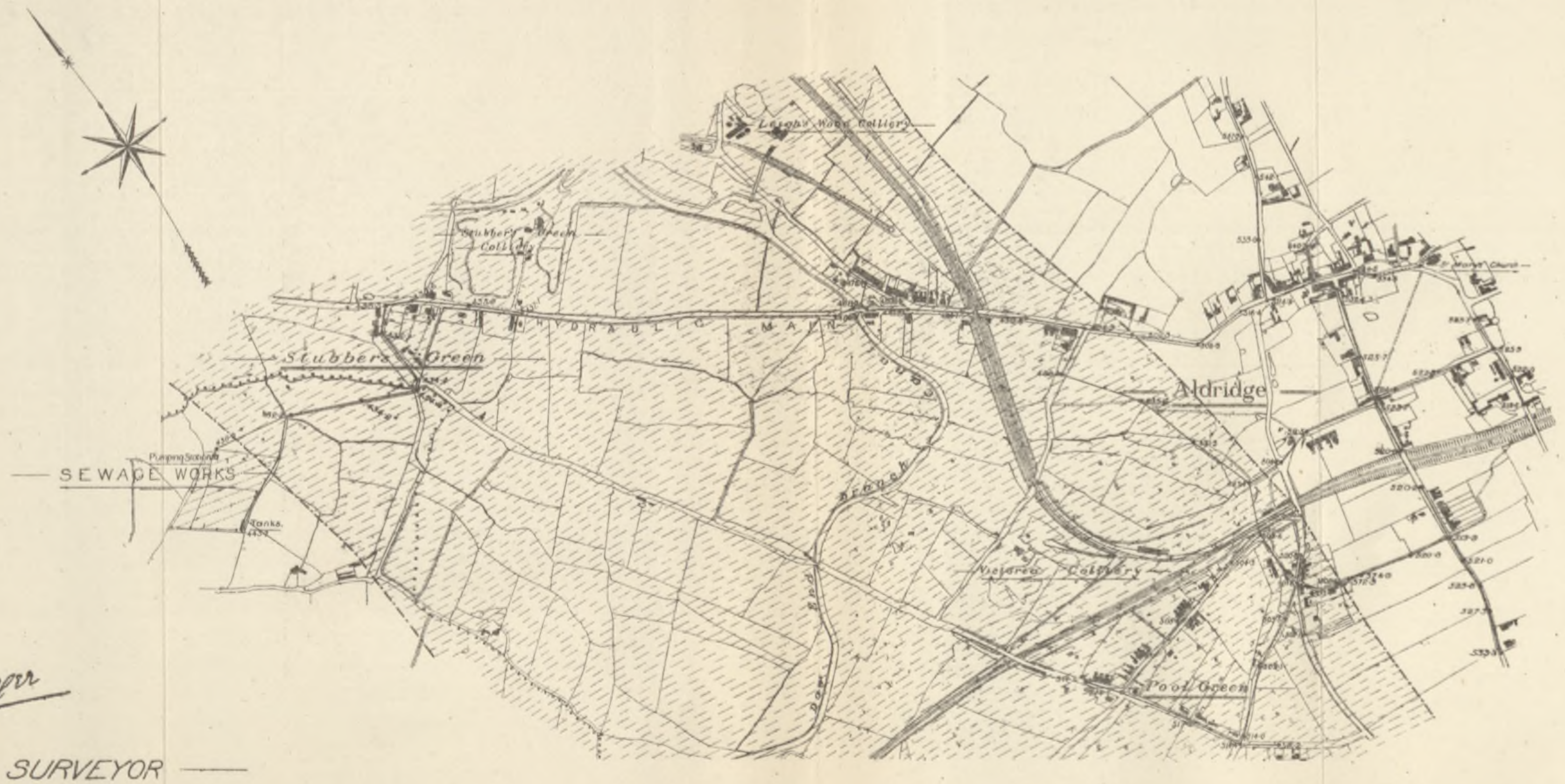
RURAL DISTRICT COUNCIL OF WALSALL

DRAWING N°4

Plan shewing Main Sewer, Aldridge, Walsall.

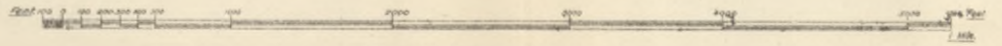
Sewers shewn ———. Figures thus "340·6" refer to surface levels above O.D. Geological faults shewn —·—·—·—·—. Area liable to subsidence

Footpaths ———. Streams ——— . Parish boundary ········



——— DISTRICT SURVEYOR ———

——— ALDRIDGE. ———



Scale.

PHOTO-LITHO SPRAGUE & C° L^TD LONDON.

RURAL DISTRICT COUNCIL OF WALSALL

DRAWING Nº 5

Renolds Patent Silent Driving Chain.

Principle of Gearing

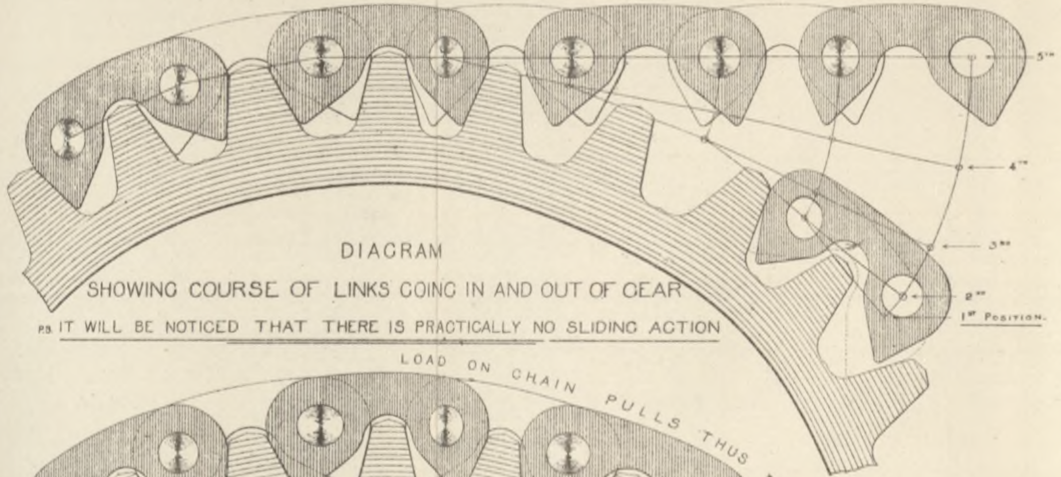
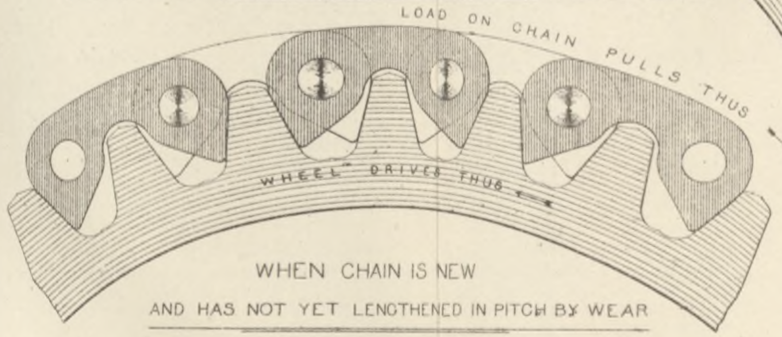
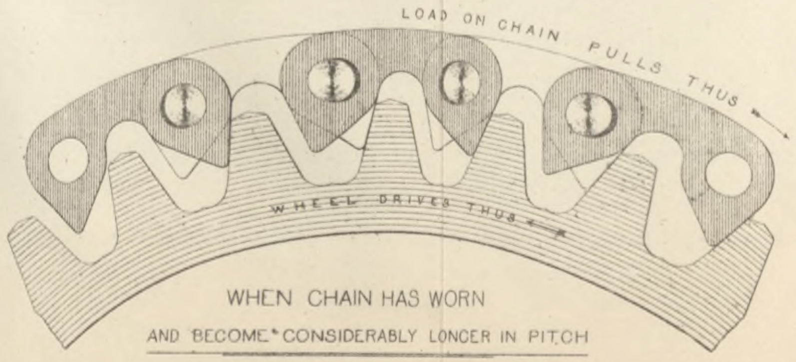


DIAGRAM
SHOWING COURSE OF LINKS GOING IN AND OUT OF GEAR
NB IT WILL BE NOTICED THAT THERE IS PRACTICALLY NO SLIDING ACTION

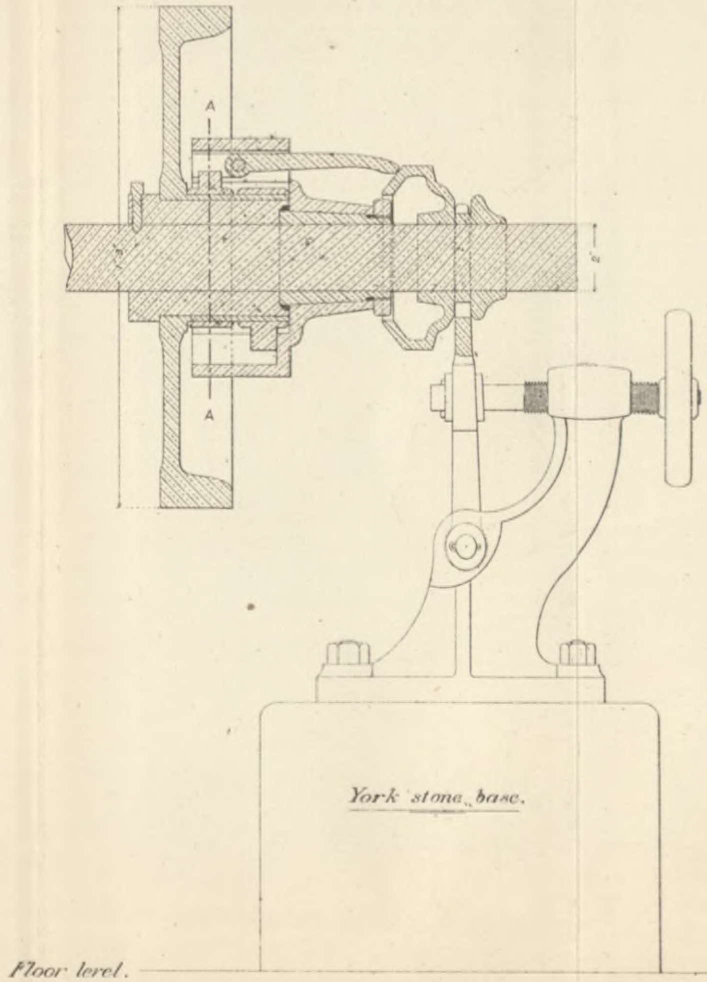


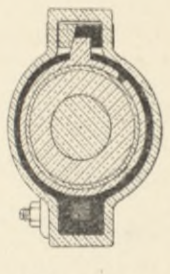
WHEN CHAIN IS NEW
AND HAS NOT YET LENGTHENED IN PITCH BY WEAR



WHEN CHAIN HAS WORN
AND BECOME CONSIDERABLY LONGER IN PITCH

Detail of Clutch.





SECTION A.A

DISTRICT SURVEYOR
ALDRIDGE

PHOTO-LITHO SPRAGUE & Cº LTD LONDON.

work has now been completed, and the last members of the superstructure are being raised by Messrs. Ransomes and Rapier.

The party then visited the Swanston Street Sewage Works.

On Wednesday September 4, *an inspection was made of the Fire Station in Ingram Street, and the Hydraulic Power Station.*

On Thursday September 5, *the Members inspected the Pinkston Tramway Power Station, and the Port Dundas Electric Lighting Station.*

LONDON: PRINTED BY WILLIAM CLOWES AND SONS, LIMITED,
GREAT WINDMILL STREET, W., AND DUKE STREET, STAMFORD STREET, S.E.