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UNDERGROUND RAILWAY OPERATION

HANDLING LONDON'S UNDERGROUND TRAFFIC

By

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*Published by London's Underground
55 Broadway, Westminster, S.W.1*

1928

PRINTED AND MADE IN ENGLAND
AT THE CURWEN PRESS
PLAISTOW, E.13

ENTERED IN DATABASE

X4154.3124.N2

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FOREWORD

IN this book is a record of the various aspects of the problem of handling London's traffic on the Underground railways as they presented themselves to the author in the Spring of 1928. The organization and equipment which is clearly and carefully described in this book was not found ready made. It represents the result of a policy of constant adjustment and improvement spread over some twenty years, in which the author has borne no small or light part. In fact, largely owing to his enterprise and liveliness, the machinery, both human and mechanical, which he describes has been built up and perfected. The book necessarily gives a static impression. It sets out a state of affairs which to the reader may appear as fixed and settled. Yet this is far from being the case. To stay, as it were, the march of progress for a brief while, to survey the position reached, is a convenient and educative step to take. It affords a measure of what has been achieved. Yet, even as I write this brief note of introduction, I know that the position is changing, that progress cannot be checked or thwarted in a living organization, that what is written in the book will need amplification and amendment almost as soon as it is published. To those who know and use the Underground railways, the impression must always be dynamic.

I am driven, therefore, to ask what is the value of this book, and I conceive it to be a groundwork for further advancement. It offers to those who wish to learn about this problem a conspectus of what has been attained to date. They are enabled to share in the experience of the past, so that they may take their places in the machinery promptly and effectively. They may start where those who have toiled at the building have left off. But they must not rest there. They are not required to come into the machinery merely to keep it turning. There is no real education in that. They are expected to continue those adjustments and improvements which will keep it a living organization, growing and developing all the while like a natural creature.

It is easy to say this, difficult to realize it. There is a dreadful inertia about large and complicated machinery. If it slows down or stops, great effort is needed to start it up again. I am thankful that on our Underground system we keep moving. We have a staff trained to watch and act right through the stages of our organization, so that our progress depends not on one here and there, but upon all the members of our organization. That is our strength. It adds to the responsibility of those to whom we must look for the financial resources to continue and expand our work.

This book was started for the benefit of the staff employed. It was intended to assist them to view their work as a whole from the outside, as it were. Then it was felt that a still wider audience might be interested, so it was enlarged and adapted to meet their requirements. Hence the book has grown to be a considerable work. It constitutes a valuable record of present achievement. I hope that it may serve as a groundwork for study and thought so that the next twenty years may show as great a measure of progress as the past twenty years. To save labour, yet to increase efficiency; to give better service to the public, yet to raise the standard of wages; to attract traffic and to bring the Underground railways to prosperity; these are the ultimate aims of the multiplicity of details pursued with care and ingenuity as described in the pages of this book.

FRANK PICK,
Managing Director.

London Underground Railways,
55 Broadway, Westminster, S.W.1.
August 1928.

AUTHOR'S PREFACE

THERE are many books on railway operation, but few that deal with the working of underground electric railways. The want of such literature must necessarily be felt by those who are concerned or interested in rapid-transit undertakings. It is hoped that the present work will fulfil this need, and that it will also form a useful text-book for students of underground railway operation. It deals with the methods adopted in the handling of London's sub-surface system of transport, and pays particular regard to the many innovations for which the London Underground group of companies may claim to be the pioneers. Improvements to secure greater efficiency and economy are constantly under review, and hardly a day passes but that some new instrument or advanced method of working is being tried or introduced. The indulgence of the reader is, therefore, claimed, if, when this book is in circulation, some fresh feature in the operation of the railways may have been observed. It is especially desired to take this opportunity of acknowledging the co-operation of the chiefs of the various sections or departments in the preparation of the original manuscript. Grateful acknowledgment is also due to Mr. D. R. Lamb, the Editor of *Modern Transport*, who has been good enough to edit the work.

J. P. THOMAS,
Operating Manager.

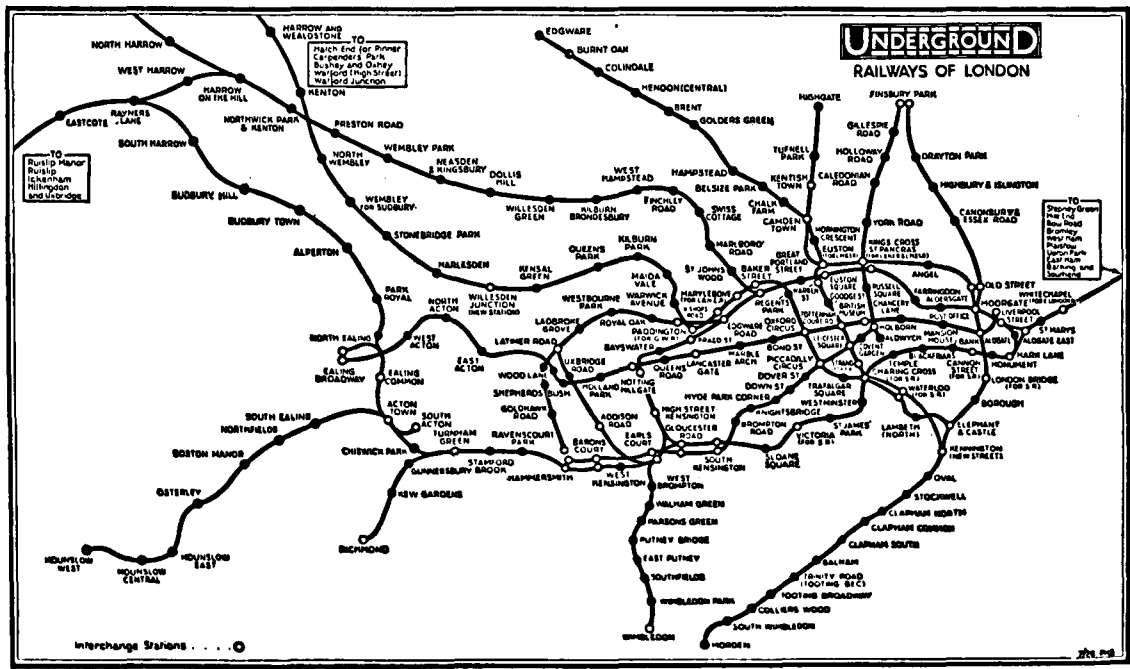
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UNDERGROUND

RAILWAYS OF LONDON



HANDLING LONDON'S UNDERGROUND TRAFFIC

INTRODUCTORY

THE London Underground Group of Companies, engaged as it is in the administration and operation of railway, tramway and omnibus undertakings, embraces the largest urban passenger traffic enterprise in the world. It represents an invested capital of no less than £65,766,288, the whole of this amount having been privately subscribed without contribution from either State or municipality. So extensive are its ramifications, and so many and varied the problems attaching to its administration, that it is by no means surprising that the activities of the London Underground should arouse almost universal interest. The average Londoner, who is proud of his transport system, must occasionally pause to wonder how its comparative efficiency is achieved and maintained, and the same thought must inevitably occur to the visitor from the provinces and from abroad. Many, also, are the requests received by the management from those engaged in the production of transport in other towns and other countries for information on various phases of administration, and it is with a view to enlightening the layman as well as the expert that the present book has been published. In the following pages, therefore, an attempt is made to describe in non-technical language the administrative and operating aspects of the London Underground Railways.

Of the £65,766,288 of capital invested in the various companies comprised in the Underground Group, £54,166,364, or over 82 per cent., is attributable to the railways. The railway system, which is entirely electrified, represents 128 route miles, including the distance covered by running powers exercised over other companies' lines. It embraces 16.18 miles of double track, laid in single cut-and-cover tunnels; 45.73 miles of double track laid in double tunnels built of cast-iron segments and situated at a level considerably lower than the cut-and-cover sections; and 66.16 miles of double track above ground, including considerable stretches of viaduct. From an operating point of view, the London Underground railway system is exceptionally complicated by reason of the fact that the earlier lines were constructed by separate companies without regard to the possibilities of inter-working with other railways and other forms of transport. It has been the task

of the Underground management to co-ordinate all its railways into one system by arranging for exchange facilities at stations common to two or more lines, for through bookings, for easy connection between train and bus, and for the inter-availability of tickets in the event of dislocation of the service on any line. The success of these efforts is indicated by the fact that, during 1927, 79,005,322 car-miles were operated, and 345,403,210 passengers were carried by the railways.

The Underground railways embrace the Metropolitan District (the oldest in the group, but not the first sub-surface railway in London), the first section of which—Kensington High Street to Westminster—was opened for traffic in 1868, the whole railway being electrified between 1903 and 1905; the City and South London, the first Tube railway, which, extending from Stockwell to King William Street, E.C., was opened in 1890 and reconstructed in 1922-24; the Central London, opened in 1900; and the London Electric, comprising the Baker Street and Waterloo, the Great Northern, Piccadilly and Brompton, and the Charing Cross, Euston, and Hampstead Railway—the 'Bakerloo' and Piccadilly lines being opened in 1906 and the Hampstead line in 1907. The companies by whom these several railways are owned, as well as the London General Omnibus Co. Limited, obtained Parliamentary powers in 1915 to enter into what is known as the 'Common Fund' agreement, whereby the balance left after meeting all expenses and fixed charges is pooled and shared out on an agreed basis.

The following brief particulars of the afore-mentioned railways may be of interest:

The Metropolitan District Railway owns or leases a route mileage of 27 miles 66 chains, but its trains are actually operated over 58 miles 56 chains of route, running approximately from west to east—from Hounslow to Barking—the section from Bow Road to Barking being operated by arrangement with the London, Midland and Scottish Railway. It should be mentioned that from Mansion House to Whitechapel the District trains run over the Metropolitan and Metropolitan District (City Lines and Extensions) Railway; from Whitechapel to Bow Road they operate over the Whitechapel and Bow Railway, and from Hammersmith to Turnham Green over the Southern Railway. There are also several branches from the main line: westwards from Acton Town to Ealing Broadway and to South Harrow, and thence over the Metropolitan Railway to Uxbridge; to Putney from Earl's Court and thence to Wimbledon over the Southern Railway; and to Richmond from Turnham Green, also over the Southern Railway. West of Earl's

Court there is a junction with the L.M.S. line to Addison Road and Willesden Junction.

There is also what is known as the Inner Circle service, which is operated in conjunction with the Metropolitan Railway; this extends over the District Railway main line between Mark Lane and South Kensington, thence northwards, and again eastwards over the Metropolitan track, via Baker Street, Great Portland Street, King's Cross and the City, finally turning south to meet the District Railway again at Mark Lane, and thus connecting all the trunk line termini of London north of the Thames. Another service is run over the Metropolitan Railway, via Kensington High Street, from Putney to Edgware Road. There are interchange stations with the Piccadilly line at Hammersmith, Baron's Court, Earl's Court, Gloucester Road and South Kensington; with the Hampstead and Bakerloo lines at Charing Cross, and with the Southern Railway at Victoria, Blackfriars and Cannon Street.

The London Electric Railway :

(a) The Baker Street and Waterloo (known as the 'Bakerloo') section extends from Queen's Park Station in north-west London in a south-easterly direction for 7.03 miles through central London to Elephant and Castle Station. There are interchange stations with the Great Western Railway at Paddington, the Inner Circle and Metropolitan Railway at Baker Street, the Central London Railway at Oxford Circus, the Piccadilly line at Piccadilly Circus, the Metropolitan District Railway and the Hampstead line at Charing Cross, the Hampstead line and the Southern Railway at Waterloo, and the City and South London Railway at Elephant and Castle. At Queen's Park it connects with the London, Midland and Scottish Railway, over which through trains are run to Watford.

(b) The Great Northern, Piccadilly and Brompton (known as the 'Piccadilly') section extends from Baron's Court Station (whence access to Hammersmith is obtained over the District Railway) to the western outskirts of the City, where a small branch is carried from Holborn to Aldwych, a distance of .50 mile. At Holborn the main line turns sharply to the north through King's Cross to Finsbury Park. The total distance from Hammersmith to Finsbury Park is 8.96 miles. There are interchange stations with the Metropolitan District Railway at Hammersmith, Baron's Court, Earl's Court, Gloucester Road and South Kensington; with the Bakerloo line at Piccadilly Circus; with the Hampstead line at Leicester Square; with the City and South London, Metropolitan and London and North Eastern Railways at King's Cross,

and with the London and North Eastern Railway and Metropolitan Railway (G.N. and City Section) at Finsbury Park.

(c) The Charing Cross, Euston and Hampstead (known as the 'Hampstead') section extends for 15.6 miles from Kennington in the south through Charing Cross and Camden Town, where it branches to Edgware and to Highgate. At Euston it connects with the City and South London Railway. The line has also a junction at Kennington with the same railway, over which its trains run to Morden. There are interchange stations with the Central London Railway at Tottenham Court Road, the Piccadilly line at Leicester Square, the Metropolitan District Railway and the Bakerloo line at Charing Cross, and the Bakerloo line at Waterloo. There are also interchange stations with the Southern Railway at Waterloo and Strand, and with the London, Midland and Scottish at Euston.

The City and South London Railway (known as the 'City' railway) extends from Euston in the north, where it connects with the Hampstead line, and where there is an interchange station with the L.M.S.R., through Islington to the City, which it enters at Moorgate. It then turns southwards, passing below the Metropolitan Railway at Moorgate and the Central London Railway at the Bank, where there is an interchange station. Thence it bears south-westwards below the Thames, meeting the Bakerloo line at Elephant and Castle, where there is an interchange station, and, connecting with the Hampstead line at Kennington, continues as far as Morden in the south-west, a total distance of 12.6 miles. There are also interchange stations with the L.N.E.R. at King's Cross, with the Metropolitan (G.N. & City Section) at Old Street and Moorgate, and with the Southern at London Bridge.

The Central London Railway stretches from east to west—from Liverpool Street to Wood Lane—a distance of 6.9 miles, roughly parallel with, and two miles to the north of, the District Railway. It connects with the Great Western Railway track from Wood Lane to Ealing, over which its trains are operated. There are interchange stations with the Hampstead line at Tottenham Court Road, the Bakerloo line at Oxford Circus, the City and South London Railway at the Bank, and with the London and North Eastern at Liverpool Street.

The greater portion of the tunnelling has been excavated through the London Clay, the name given to the stiff tertiary loam, sometimes grey-green but tending to yellow in the later deposits, which was laid down on top of the chalk and sand of what was once a sea bed. The tunnels are

driven under the shallow beds of gravel and river drift which form the successive terraces laid down over the clay by the Thames and its tributaries. North of a line represented roughly by the Euston Road the London Clay comes to the surface and stretches as far as the chalk of the Chiltern Hills, with occasional outcrops of sand or glacial deposits. Examples of these outcrops which occur on the Underground are the Claygate and Bagshot beds of Hampstead Heath and the glacial gravel of Hendon Hill, which are encountered on the Hampstead line. Pockets of sand and gravel, sometimes holding water, are found locally in the hollows of the clay in the central and southern districts below a considerable layer of 'made ground' formed by the foundations of older Londons—amounting to 24 feet in depth in Farringdon Street. The chalk rises to within a foot of sea level at Tottenham Court Road Station, but is elsewhere covered with a thick layer of London Clay of anything up to 450 feet in depth, and providing a stodgy, but more or less homogeneous and workable tunnelling medium for an undertaking that would have been more than Herculean in the rock of New York or the peaty swamps of Leningrad.

In conclusion, it may be mentioned that, in addition to the facilities of the railway, tramway and omnibus undertakings of the Underground Group, services are provided in Greater London by the Metropolitan Railway Company, the first Underground railway in London, which opened its first section from Farringdon Street to Bishop's Road, Paddington, in 1863; by the Waterloo and City Railway, a short Tube railway from Waterloo to the Bank operated by the Southern Railway; by the tramway services of the London County Council and other local authorities, and on the suburban lines of the trunk railway companies, many miles of which have been, or are in process of being, converted from steam to electric traction.

Chapter I

ORGANIZATION OF THE OPERATING DEPARTMENT

THE organization of any business must be framed with a two-fold object, first, of ensuring that the work of the various departments is performed and co-ordinated to secure efficiency, and, secondly, of encouraging goodwill and the maximum of effort on the part of the staff. Certain routine work is unavoidable, but it should not hamper the executive, whose efforts must at all times be directed towards improving the service rendered. This may be done by the examination, and, where advisable, the adoption of new methods and devices, which will tend to cultivate public interest and goodwill, and to develop a cordial relationship between the management and the staff. These are, or should be, the objects of every public utility undertaking; they certainly are the qualities which characterize the incessant endeavours of the London Underground group of companies.

Of all the departments embraced by this important organization it is to be assumed that none is likely to attract greater public interest than the operating department, which is responsible for the conduct of the immense traffic that daily passes over the Underground railways. Its staff is the largest of any department, and its wages bill alone accounts for an expenditure of nearly £1,000,000 per annum. By reference to the chart in Fig. 1 it will be seen that the staff of the operating department is divided into two sections—outdoor and indoor—each being under the control of an assistant to the superintendent of the line, who, in turn, is responsible to the operating manager.

OUTDOOR STAFF

Broadly speaking, the outdoor staff is grouped into four divisions comprising, respectively, the Metropolitan District, Piccadilly, Bakerloo and Central London, and Hampstead and City Railways. Each of these divisions is under the immediate control of a divisional traffic superintendent, who reports to the outdoor assistant to the superintendent of the line. The divisional traffic superintendent is entirely responsible for the working of his own division, and for the conduct of all employees engaged in the movement of traffic, including the clerical staff in the booking-offices. His duties include:

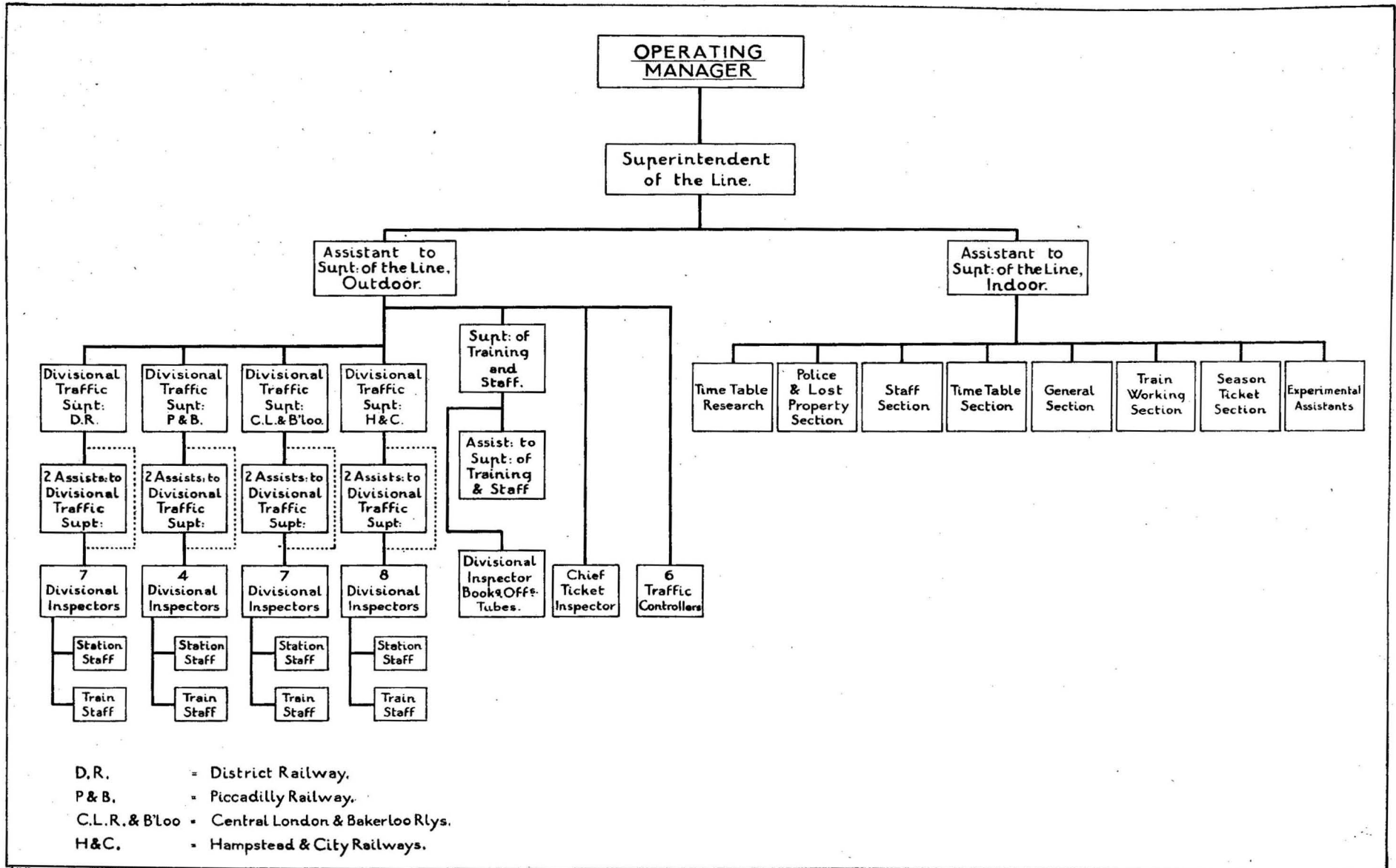


Fig. 1. Chart showing organization of the operating department of the London Underground Railways.

- (a) The enforcement of the company's rules and regulations.
- (b) The control of all traffic movements.
- (c) The efficiency of the staff.
- (d) The checking of the ticket system.
- (e) The consideration of improvements in the working.
- (f) A constant interest in the welfare of the staff.

Officials holding these positions must necessarily possess special qualifications, and not only is a technical knowledge of electric railway operation obligatory, but they must also be able to exercise judgment and discretion in dealing with the public and the staff.

PERSONNEL

There are approximately 1,200 employees on the operating staff of the Metropolitan District Railway, and 3,500 on that of the three tube railways. They are sub-divided into grades, as in the following table, which shows the number in each grade and the average weekly wage for week ended October 8th, 1927:

TABLE SHOWING NUMBER OF STAFF IN OPERATING DEPARTMENT FOR WEEK ENDED OCTOBER 8th, 1927

Grade	M.D.R.	L.E.R.		Total	Average wage per week		
		C.S.L.R.	C.L.R.		£	s.	d.
Control Staff	13	50		63	5	7	0
Motormen	247	557		804	5	3	3
Guards	280	827		1,107	3	17	11
Gate-men	2	561		563	2	15	2
Stationmasters and Inspectors	43	96		139	5	19	3
Booking Clerks	152	364		516	3	16	3
Telephone Operators	2	5		7	3	2	11
Travelling Ticket Inspectors	16	18		34	4	19	5
Station Foremen	50	30		80	4	5	0
Signalmen	56	59		115	4	10	7
Ticket Collectors	102	122		224	3	7	9
Porters	169	342		511	2	15	11
Liftmen	—	259		259	3	11	5
Lift Porters	—	50		50	3	5	2
Lavatory and Waiting Room Attendants	18	26		44	1	9	4
Miscellaneous	20	44		64	3	15	10

It may be mentioned that the selection and training of the personnel is the responsibility of a special department in charge of the superintendent of training and staff, who reports to the outdoor assistant to the

superintendent of the line. Their initial training having been completed, the employees come automatically under the complete control of the respective divisional superintendents. The routine of the company's employment bureau and training school is described in the next chapter.

ARRANGEMENT OF SUPERVISION

There are two assistants to each divisional superintendent, except in the case of the Piccadilly Railway, where only one is employed. The two assistants in each division take early and late turns of duty alternately. In this way each division is at all times under the immediate control of a responsible official—from the first train at 5.0 a.m. until the last train at 1.30 the following morning.

Under the control of each assistant to divisional superintendent are a number of divisional inspectors, each in charge of the working over a particular section of the line, whilst reporting to the latter are the yard (or depot) masters, whose duties are as follows:

1. The control of all trainmen engaged at the respective depots.
2. The marshalling of trains to conform with the time schedules.
3. The prompt dispatch of trains and the time-keeping of the staff.
4. The responsibility for seeing that all trains are in proper condition for passenger service.
5. The efficiency of the train staff.
6. Dealing with breakdowns affecting running lines.

YARDMASTERS AND STATIONMASTERS

The yardmaster usually has a staff of about 500 men, and controls approximately 300 cars. Amongst his other duties he must see that the reliefs of the men are duly arranged, and largely upon his shoulders rests the responsibility for the efficiency of the service. A full knowledge of the operation and running of the trains is his essential qualification. He must, therefore, have been passed as competent to perform the duties of driver, guard and shunter, and be able to instruct and examine the staff under his control as to their fitness for their respective duties. As a rule, yardmasters are promoted from the train staff after having served as stationmasters at various points of the system, and been accustomed to the control and management of large staffs.

The stationmaster is responsible to the divisional inspector for the working of the station, or stations, under his control, and for this purpose the railway is again sub-divided into sections. Except for the six most important stations, such as Victoria, with its 21,000,000

passengers per annum, or Piccadilly Circus, with its 25,000,000, the stations are grouped on the basis of the volume of traffic handled. In some instances a stationmaster may have five stations under his control, in which case he is the master of a section of the line rather than master of a single station. This system of widening the scope of the work promotes efficiency, particularly in the assignment of duties and the consumption of stores, whilst affording opportunity for ability and initiative and the employment of a better type of man with a view to promotion. Originally, a separate stationmaster was allotted to each station, but the restrictions of service and monotony of occupation were found to be in the interests neither of the staff nor the working of the stations.

Under the present organization a stationmaster has complete control of the area assigned to him, including the booking-office work in detail, and the banking of daily cash receipts, and is also responsible for the general conduct of all workmen on the station premises, whether servants of the company or contractors. Stationmasters are promoted from grades such as motormen, station foremen, signalmen, guards, and booking-clerks, and experience proves that it is often difficult to find the right type of man for the position. The company's training school, therefore, specializes in the instruction of this grade; applicants must be certified as being acquainted with practically every phase of railway operation and, in addition, afford evidence of the possession of the necessary tact and discretion needful in dealing with the travelling public.

CADETSHIPS

Shortly after the war the company introduced a scheme of cadetships in order, on the one hand, to afford special opportunity for those of its employees who had shown particular aptitude whilst on war service and had proved their fitness for greater responsibility, and, on the other, to attract to its staff young men of individuality and exceptional educational qualifications. Selected candidates for cadetships are required to undergo a six-months' probationary period. At its conclusion those who have failed to justify themselves revert to their former grades, or, if they are new entrants, are informed that their services are no longer required. The curriculum of a cadet includes a brief period in each of the following sections:

1. The training and employment school, where he follows the ordinary training of new employees and obtains an insight into the type of men required and an idea of the work of each of the grades.

2. The traffic controller's office.
3. The time-table and duty-schedule sections, where he has an opportunity of studying the system upon which the time-tables are drawn up and the duties of the men arranged.
4. Depots or yards, where the trains are stabled, and where he is afforded an opportunity of studying train marshalling.
5. Signal boxes, where he learns the principles of signalling.
6. Divisional traffic superintendent's office, where he may assist in the general work of the office and in the analysis and investigation of operating problems.
7. Experience in the engineering and other departments is also arranged according to the trend of ability.

The chief of each of the sections watches the progress and reports from time to time on the work of each cadet, and furnishes a final and comprehensive report at the conclusion of the period of training in the section. On completion of the tour through the various sections, the reports of the sectional heads are received, and the future of the cadet considered with the chief of the particular section in which he is employed, special regard being paid to powers of observation, initiative, application, keenness and a natural bent for transport work.

INDOOR ORGANIZATION

The outdoor work of a railway organism, such as that described, has its counterpart in skilful administration at headquarters. A monopoly of brain power is by no means possessed by the indoor staff, but it were unreasonable to refrain from alluding to the importance of the work of those whose duty it is to compile train working time-tables in consonance with the requirements of the eight-hour day. The preparation of a modern electric railway time-table, such as that which, with its appendices, concerns the working of the District or the Hampstead and City lines, is no haphazard undertaking. From start to finish it is a carefully considered, if not scientific, production, based on closely analysed facts. No phase of railway work entails the application of more intensive thought than this, and to it a separate chapter is devoted.

A new section of the indoor work, known as the time-table research section, probably marks an innovation in railway routine. Its functions are to carry out research and investigation into all phases of time-table work, such as analysis of train working times and loads, junction and terminal facilities, and performance of rolling stock. For this purpose the section has authority to consult with indoor and outdoor staff, to examine the working in the signal boxes, to consider junction, station

and depot lay-outs, and to co-ordinate the work of the outdoor staff with that of head office, both on existing and proposed new works.

POLICE AND LOST PROPERTY SECTION

This section is a necessary evil in railway work. It exists to cater for those troublesome people who are a nuisance to the public and the company, and it takes care of the property left in the trains by careless and oft-times irresponsible travellers. Some 300 passengers or trespassers have to be prosecuted annually, their fines and costs amounting to £700, whilst 35,000 people leave property on the railway, each article having to be forwarded to the lost property department, fully recorded, and handed to the owner if and when he comes forward. Only 35 per cent. claim their belongings. The remaining property is sold every six months, and, after warehousing expenses have been defrayed, the balance is devoted to staff welfare work, as, for example, the provision of pavilions for sports grounds. It may be of interest to mention that in one year 12,000 umbrellas, 500 walking-sticks, 1,000 articles of jewellery, 2,400 attaché cases, and 10,000 pairs of spectacles were left in Underground trains and in cloak rooms, as also were twelve sets of false teeth, six perambulators and mail carts, and six bicycles.

The actual work of the police department on the railway is comparatively insignificant when it is considered that 345,403,210 passenger journeys are made annually, but the presence of the police, particularly on the occasion of race meetings and popular processions, during the return theatre traffic, and on football days and similarly crowded events, undoubtedly has a steadying effect on those who are inclined to rowdiness, picking pockets, and bag-snatching. Besides reassuring the public, the police, during busy periods, can be of real assistance to the station staff in the regulation of traffic, and in ensuring the preservation of general good behaviour.

STAFF SECTION

The staff section is the repository for complete records of the services performed by each member of the staff from the date of appointment, particulars of conduct, timekeeping, commendation and disciplinary action being tabulated on a card index. This work must be performed with accuracy, for a member of the staff may at any time demand to see his record, and the company considers he has a perfect right to do so. The section is also responsible for advising the accountant of any changes in the pay roll or in grade. The working out of the annual

leave rosters of the staff is done under the supervision of the chief staff clerk, who also examines the daily time cards before wages are paid. The secretarial work of the sectional committees of the Railway Staff Council is the duty of this section, as also are the compilation of statistics relative to the conditions of service and wages of staff, and the preparation of information required in negotiations with the trade union officials.

One of the most important duties of the chief staff clerk is to ensure that, before filing staff appointment papers, the company's regulations have been rigorously carried out in regard to references and medical examination, the details of which are dealt with in the next chapter. The chief staff clerk reports to the indoor assistant to the superintendent of the line, but has direct access to the superintendent.

GENERAL OFFICE SECTION

The function of this section may be described as that of tying up the loose ends of the administrative section—the scrutiny of questions which may overlap the indoor and outdoor sections. A passenger's suggestion or complaint may, for example, refer to a dozen different matters, and as a thorough investigation is made of each and every complaint, it may be necessary to refer it to several heads of sections; this must be done with dispatch, otherwise the reply to the passenger may be neither correct nor timely. Letters received from passengers and dealt with mainly by the general section number 5,000 per annum, and relate to every possible phase of operation. The letter may be one in which a personal call by a company's official is necessary, and usually this duty is carried out by the divisional superintendent of the line concerned, or his assistant.

Included in the general section are the checking of requisitions, invoices, and general statistical work. The scrutiny of booking-office furniture and equipment is provided for in this section, as also are records of the development of ticket-printing and ticket-issuing machines, a subject which is more fully dealt with in a subsequent chapter.

Supervision of the sale of season tickets is carried out in this section. Latterly, season tickets of ordinary issue have been purchasable at all booking-offices. This has been found to stimulate sales and, manifestly, is a convenience to the public, who previously were required to write or visit either head office or one of the few season-ticket sub-offices. The annual value of season tickets issued on the Underground railways is £652,117, representing 865,066 tickets.

In concluding this chapter, it may be remarked that the general scheme of organization is continually under review by the management, and is revised as may be necessary to ensure that present-day needs are fulfilled. Probably in every organization mental processes are apt to become mechanical, and mechanization tends to monotony. Too much monotony thwarts ambition, and, in time, may subdue keenness and enthusiasm. Interest, however, may be sustained and executive ability encouraged by careful and opportune adjustment of routine and procedure.

Chapter II

STAFF EDUCATION AND CONTROL

IN the selection of staff for the London Underground Railways, the greatest care is exercised. It is not considered sufficient that the candidate should be able merely to fulfil the requirements of the vacant position: there must also be evidence of his general fitness for the eventual filling of a higher post. Every porter is a potential guard, driver, inspector, or superintendent, and each member of the staff is made to realize that he has the opportunity to qualify for the highest position in the service. Each prospective employee must initially appear before the superintendent of employment and, before being passed finally into the service, is also interviewed by the superintendent of the line.

The following are the salient requirements which are taken into account in the selection of candidates for employment:

1. *Medical fitness*: The company's medical officer is held responsible for the physical fitness of all new employees, and a clean bill of health is imperative. No person can be passed into the service unless the medical officer has filled in and signed the authorized medical examination form.
2. *Previous record*: References are taken up by personal interview as well as by correspondence. The applicant's referees are interviewed personally by an official of the company and the result of the interview reported, after which a decision is arrived at as to whether the applicant is suitable for employment. By this procedure the company obtains the fullest information concerning its prospective staff and assures itself, as far as possible, that the best type of man is engaged.
3. *Height*: The minimum height has been fixed at 5 ft. 7 in., as men of shorter stature are at a disadvantage in dealing with crowds.
4. *General education*: This is also a subject for attention, as also are matters of personal cleanliness and address.

Applicants for employment are interviewed at the company's training school as and when required, and those who appear to be suitable are registered. In the first instance, subject to satisfactory references and medical examination, a new employee remains for five or six days at the school. During this time he is occupied in studying the geography of the system, the interchange points, and the connecting facilities between train, tram and bus. He is also handed a book of rules and regulations for the working of the railways, and is impressed with the importance of learning the rules, as ignorance in this respect is regarded as an obstacle to advancement in the service.

MEDICAL EXAMINATION

The medical examination of prospective employees of the London Underground Railways is very thoroughly carried out, a high standard of health and general fitness being required in the interests of public safety. Before new applicants appear before the doctor they have already undergone a preliminary examination as to sight and general external appearance at the hands of an official of the employment bureau. For example, a man having obvious signs of varicose veins is told at the outset that it is of no use his waiting to see the doctor. In this way a good deal of time and trouble is avoided. Thus, during 1926, out of 810 candidates examined by the doctor, 617, or 76 per cent., were finally appointed. (Fig. 2.)



Fig. 2. An applicant for employment undergoing medical test.

Of the men rejected, failure in the sight tests accounted for 10 per cent.

These tests are made with the greatest possible care and consist of:

(a) The vision test, in which the candidate is required to read with rapidity and certainty letters of varying size and style of printing (Fig. 3).

(b) The colour test, an important factor in railway operation, consisting of a black drum-shaped apparatus with a small aperture at the top through which coloured lights are shown, the colours corresponding to those of the Underground signals.

As will be seen from Fig. 4, the effect on an examinee in the latter test is not unlike looking through a Tube railway tunnel and watching for the signals. The lights shown are so focussed that at 20 feet they have the same appearance as a signal 440 yards away. The instrument has also an arrangement whereby the lights can be 'fogged', to give an effect similar to that of heavy rain.



Fig. 3. Vision Test.



Fig. 4. Colour test.



Fig. 5. Further colour test with mixed strands of wool.

Should the doctor have any doubt after these tests as to a man's ability to distinguish colours, a still further test is made. In this a quantity of mixed strands of wool in knots of various colours are handed to the applicant, who is required to sort them out and place them on a card having corresponding squares of the same hues (Fig. 5). This process leaves no doubt as to a man's sense of colour. Clearness of utterance is another factor to which the doctor devotes careful attention.

Further medical examinations take place on an individual's promotion to other grades. After being absent from duty through illness, employees have again to pass the doctor before they are allowed to resume work.

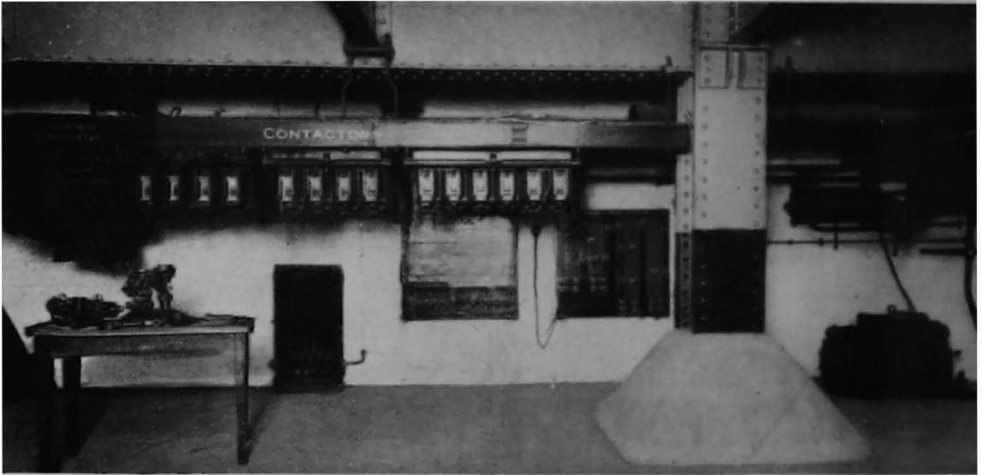


Fig. 6. A corner of the training school, showing multiple unit electrical equipment.

Furthermore, all employees, after having attained a certain age, are periodically examined, and if, for instance, their sight is below a certain standard, that must receive consideration in relation to the duties they have to perform.

It is worthy of note that during 1926 the number of cases of sickness and incapacity throughout the staff was only 2.7 per cent., a figure which may be regarded as evidence of the care that is taken to pass into the service only those who are in every way medically fit.

TRAINING SCHOOL

A central employment bureau and training school for the instruction of the staff was established in 1920 to secure uniformity of practice throughout the system. The school is situated at Lambeth (North) Station, and consists of medical officer's rooms, a cinema and lecture hall, and various classrooms. The school is equipped on a comprehensive scale for tuition in the various phases of railway operation. The installation includes complete multiple unit train equipments, except that for demonstration purposes banks of lamps are used instead of motors in order to demonstrate the action of the control apparatus, whilst wiring diagrams and other information are provided in detail, as indicated in Figs. 6 and 7. It is a sound axiom in railway work that it is more important to know how to stop a train than to start one, and

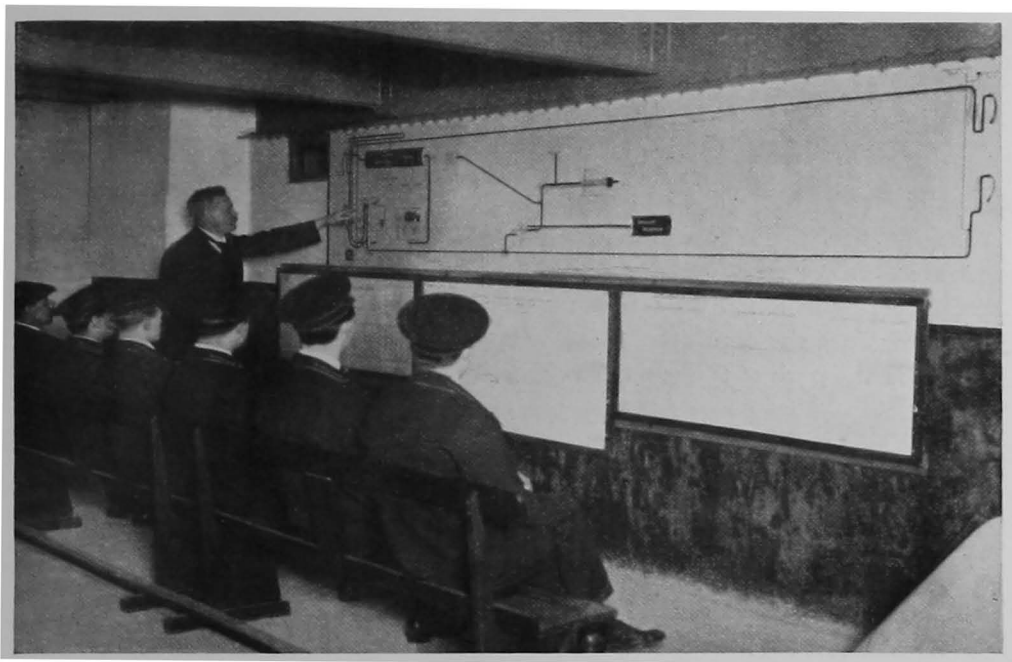


Fig. 7. A lecture on the working of the Westinghouse brake.

an insight is provided into every detail of the Westinghouse brake equipment. By means of diagrams the action of the air may be traced from the time it enters the compressor right through each stage until it is finally exhausted to atmosphere. Other instructional equipment, such as that for dealing with emergency devices for cutting off current in case of short circuits, air-door engines, and snow-fighting equipment, are also provided.

For the instruction of liftmen a complete lift control board is available, tuition in the method of winding lifts up or down by hand and in other similar operations being given in one of the actual lift machine rooms. An excellently appointed signalling school has also recently been provided wherein by means of a detailed installation of the actual apparatus the staff are instructed in the use and maintenance of the various types of power installation on the company's system.

EXAMINATION PAPERS

Throughout their studies in the training school, the staff are set a number of standard questions bearing on the rules and regulations, and

the methods of procedure in the various grades. These papers have proved very helpful to the staff, the drivers' question paper, for instance, dealing with no fewer than eighty-two items, and the guards' paper with ninety. Examples of these questions are given below:

Drivers :

1. What is the sequence of duties of a motorman in preparing a train for service ?
2. Describe in detail the test you would make of the Westinghouse brake.
3. How does the conductor test the brake, and why ?
4. Give the path of the current on first notch of controller, including reverser circuit.
5. If motors were working O.K. in series but dropped out in parallel, what points in the control circuits would you examine ?
6. Why is it that the current is cut off by releasing the 'Dead Man's' handle ?

Guards :

1. What must your full equipment be when taking charge of a train ?
2. Explain in detail the method of testing the Westinghouse brake.
3. What is an automatic signal—semi-automatic signal—repeater signal—fog repeater signal—calling-on signal ?
4. If for any reason the trip isolating cock at the front of the train is closed, what must you do ?
5. Wrong line working: what precautions are taken if it is necessary to work the traffic in both directions over a single line ?
6. Give a detailed explanation of the working of the Westinghouse brake.

OPPORTUNITIES FOR PROMOTION

There are liberal chances for the staff to advance. Instructional classes, to which all the staff are invited, are regularly held, qualified instructors being detailed to give the lectures. An excellent opportunity is thus afforded for members of the staff to prepare themselves for promotion and to be in readiness to step into a higher position when a vacancy occurs. Promotion from one grade to another, whatever the grade may be, involves an examination and the issue of certificates of proficiency signed by a responsible official of the company. The following is a copy of the driver's certificate. Certificates for other grades are framed in similar terms:

_____ Railway

MOTORMAN'S PROFICIENCY CERTIFICATE

Learner's Name..... Grade..... Depot.....

To the Superintendent of the Line,

I have received instruction in, and understand the electric motor car system of traction on the above railway, the Westinghouse air brake, the hand brakes, the connections of the main feeders in the tunnels and depots, and the operation of the emergency telephones and lighting.

I have made myself acquainted with the rules and regulations for the safe working of the railways and feel competent to drive a train in passenger service.

Signed.....

Date.....192....

_____ Railway

TRAINING SCHOOL CERTIFICATE

Name.....attended the Training School from
.....192...., to192...., and
received instruction in the electric motor car system on the above railway, the Westinghouse air brake, the hand brake, the emergency telephone and lighting, and the rules and regulations for the safe working of the railways. I have examined him as to his knowledge of these subjects and consider him competent to drive a train in passenger service.

Total hours at School..... Total hours on train.....

Signed.....

Date.....192....

—————Railway

YARDMASTER'S CERTIFICATE

Name.....has been instructed in the driving of a train in passenger service and as to the main feeders in the tunnels and depots, and, having seen him drive a train the whole length of the above railway on several occasions, I consider him competent to drive a train in passenger service.

Signed.....

Date.....192....

PERIOD OF TRAINING

Time occupied in the final training of staff for the respective positions varies a good deal according to the higher grade in view and also according to the aptitude of the pupil. A limit is, however, put upon the final number of days' training for which the company pays wages. For instance, a guard, in order to qualify for the position of emergency driver, is allowed twelve days, and unless able to pass out in that time is put back (Fig. 8). An emergency driver, to become a full-time driver, is allowed a further eight days' training. The days of training are divided between the school and operating on the line concerned. A driver must not only become fully acquainted with his train but, what is of equal importance, the contour of the line, sub-stations, speed restrictions, signalling, emergency devices, correct stopping points at the stations, and many other items. His certificate of proficiency includes references to the equipment of the road.

The question may be asked, is the cost of the training establishment justified since the expense incurred, for instance, in passing out a guard to the post of driver amounts to £15. The answer is to be found very largely in the efficiency with which the railways are run. A staff qualified to deal, not only with operation when things are normal, but also in time of abnormality, such as may be occasioned by breakdown, is an invaluable asset, and the record of delays shows clearly that when a breakdown occurs the staff are, as a general rule, competent to deal with it with safety and in the shortest time possible.

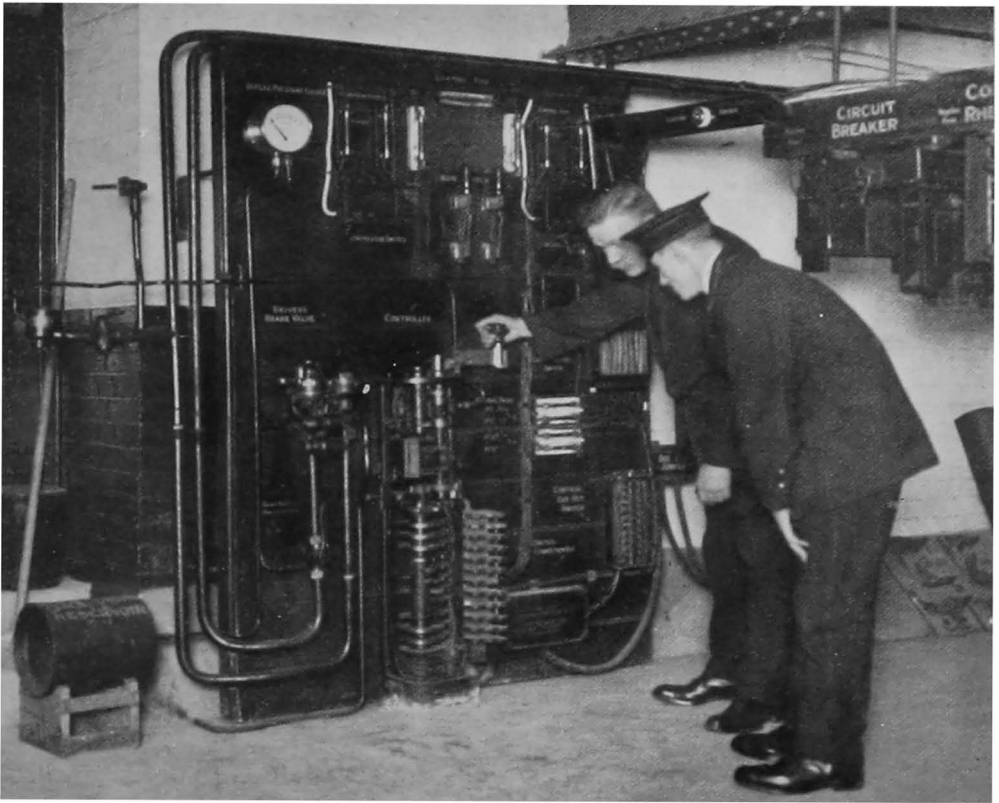


Fig. 8. Instruction in driving.

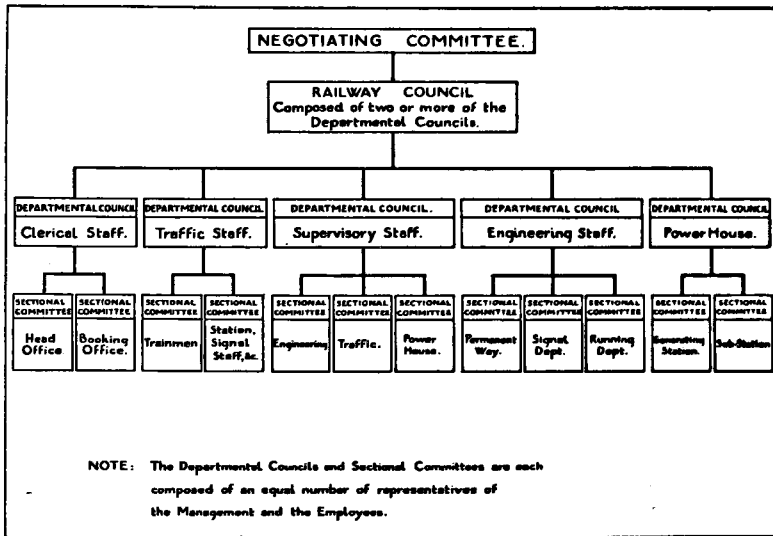
The following figures relating to the staff who in a recent year received technical training and were examined at the training school may be of interest:

	<i>Passed</i>	<i>Failed</i>	<i>Per cent Failed</i>
Stationmasters	52	16	23
Motormen	81	43	34
Emergency Motormen	43	12	26
Guards	242	97	28
Gatemen	344	—	<i>nil</i>
Liftmen	222	29	11
Foremen Ticket Collectors	19	22	53
Foremen	4	7	63
Signalmen	74	9	10
Booking-Clerks Test for Lifts (op.)	77	9	10
Total	<u>1,158</u>	<u>244</u>	<u>17</u>

Attendance at Voluntary Classes 752

RATES OF PAY AND CONDITIONS OF SERVICE

In essential particulars the company has followed the Railway National Agreement, which should be referred to for details. As a means of negotiating matters which may arise between the company and its staff, a system of Railway Councils, representing all manipulative grades of the service, is established. No matter may be brought forward that has not had the opportunity of adjustment through the usual channels of the organization, and no question may be passed forward from one committee or council to another unless referred to the management with a view to adjustment. The appended chart shows the outline of the constitution which has been in operation for six years and worked satisfactorily to all concerned, no fewer than 1,100 matters brought forward having been dealt with.



ESPRIT DE CORPS

The quality of *esprit de corps* is one which cannot be instilled deliberately into a large staff in the same way as a knowledge of their duties. The fact that it is of almost equal importance in securing the best results is acknowledged by every progressive employer and employee. It is the

constant endeavour of the Underground Company to promote this spirit. The means to this end, from both an educational and recreational point of view, are many and varied, and may be said to commence from the day the employee enters the service. The company firmly believes in the policy of obtaining the co-operation of the staff. The broadening of outlook, the development of resource and initiative, the fostering of the spirit of *camaraderie*, are essentials to success. The company has instituted for its administrative staff a superannuation fund and for the non-administrative staff a pension scheme, and a benevolent fund, known as the T.O.T. Fund, to which each member of the staff may voluntarily contribute one penny per week, a like amount being subscribed by the company.

It is necessary, of course, to establish a definite disciplinary system. Each employee's record of service contains a complete history of his conduct. Items of default as well as of commendation are included in the record, and all such items are entered on a form which is forwarded to the employee and the receipt of which he is required to acknowledge. In this way each employee is—as he should be—kept informed of all material entries on his record, and he has the right of appeal to a higher official in respect of any entry. The disciplinary clause of the National Agreement has been accepted by the Underground Railway and is as follows:

'Men charged with misconduct, neglect of duty, or other breaches of discipline will be permitted to state their defence, to call witnesses, and to advance any extenuating circumstances before their officers, prior to a final decision being arrived at. At such interview the man may be accompanied by an advocate. In all cases a man shall be informed in writing of the nature of his offence and the punishment it is proposed to inflict. Where doubts arise, or where serious results to men are likely to follow, the cases should be placed before the higher officials of the company. Appeals after punishment lead to a difficult position, and the necessity for them should be avoided. If, after such investigation of a charge against an employee, he is adjudged guilty and is to be punished for the offence, he shall have the right of appeal to a superior officer for a reconsideration of his case, provided that such right of appeal shall not extend to cases of a trivial character. Any such appeal must be made in writing, within seven days. If the employee so desires, he may be heard in person, and, in that case also, he may be accompanied at the interview with the superior officer by a spokesman, who may be either a fellow-workman or a representative nominated by the man's trade union.'

Chapter III

ARRANGING THE SERVICE

THE train service provided by a railway company may be regarded as a marketable commodity which must be produced economically and scientifically. It must be of a nature which will create an ever-increasing demand and must pay regard to local circumstances. In sparsely populated districts, for instance, the service must not consist of long trains. They will be only partially filled, and revenue will be lowered by the cost of many useless car miles; little or no return will be obtained on the capital invested in the railway, rates will have to be maintained at a high level to cover even the working expenses, and social and industrial development will in consequence be restricted. Furthermore, too meagre or irregular a service will discourage the casual passenger who, being uncertain of getting a train quickly, will travel by bus or tram.

It is apparent that a rapid-transit railway, while embodying some of the principles of trunk-line operation, must provide an entirely different type of service, and the agreements governing the working conditions of the trainmen must vary accordingly, but not necessarily in respect of hours and wages.

The design and provision of an intensive electric service may be divided into three stages:

1. *Demand*: How the demand for such a service arises and how its extent is gauged.
2. *Production*: The methods adopted in compiling and adjusting time-tables and duty sheets.
3. *Operation*: Conditions tending to the efficient conduct and maintenance of the service.

These stages will be reviewed in this and succeeding chapters.

STAGE I.—DEMAND

The circumstances which, although comparatively rare, cause the most fundamental changes in a train service are, of course, extensions of the line, such as that which occurred when the City and South London Railway was extended from Clapham Common to Morden. New issues of time-tables are, however, necessitated more frequently, though less permanently, by seasonal holiday and other special variations of traffic. Every year sees the issue of a summer and a winter time-table, a heavier service being run in the winter to allow for football and theatre traffic

and to accommodate the additional passengers resulting from the increased popularity of the buses in wet weather. Additionally, the regular re-issue of the time-table enables such minor alterations to be made as appear necessary following complaints and suggestions from the travelling public, as well as those changes which are dictated by operating considerations.

The requirements in connection with holiday and other special occasions are gauged by the staff of the train-working department, who base their recommendations on a study of the traffic reports rendered by stationmasters and traffic superintendents on the results of the service provided for the same (or similar) event of the previous year. The reports are summarized into a précis, in which, on reference to last year's time-table, suggested alterations are made. The complete recommendations for all lines are then entered on a 'Broad Sheet', with a statement of the number of extra cars and car-miles required by the service.

On Good Friday a Sunday service is worked throughout the day, but trains are started an hour earlier to make provision for the appreciably heavy workmen's traffic caused by the redecoration of stores, hotels and apartment houses, which generally commences in London on Good Fridays.

Easter Monday, Whit Monday, and August Bank Holiday are provided with comparatively close-interval services all day on the Hampstead, Edgware, Morden, and Watford lines, as to these points large crowds resort, and likewise, but in a less degree, to Richmond, Harrow, Uxbridge, and Hounslow. On purely City and West End services, such as those on the Central London and Piccadilly lines, the normal Sunday service, with the addition of long trains at sundown, meets the requirements.

Christmas Day is provided with a Sunday morning service, though much slacker between 3.0 p.m. and 9.0 p.m., after which the traffic increases again as people go home from their parties.

Such occasions as Armistice Day, the Lord Mayor's Show, and the Football Cup Final, have to be dealt with in the same way, namely, by reviewing the adequacy or otherwise of last year's arrangements.

TRAIN CHECKERS

Another method of gauging traffic requirements is by means of the reports and charts of specially appointed 'train checkers'. These officials operate under orders from the train-working department; they are stationed at various points throughout the Underground system,

and take the loadings of each train as it passes. Figs. 9 and 10 show how the results of these observations are charted. In Fig. 9 is indicated the morning east-bound City peak at South Kensington, the dotted line showing how the trains had emptied by the time Holborn was reached. The thick black line represents the seating accommodation available, and its sudden drop after the 10.26 a.m. from South Kensington marks the point where trains began to be uncoupled. It will be noted that this occurs almost exactly at the point at which the peak traffic falls off suddenly, demonstrating very clearly the value of such readings, without which the most favourable moment for uncoupling could never have been determined. The second chart (Fig. 10) shows the loadings for the same period on the east-bound road at Sloane Square. Here again the increase to eight-car trains coincides with the beginning of the heavy traffic. The excess of passengers over accommodation between 8.30 and 9.30 indicates the number of passengers standing—up to twelve per car, or 100 in all. As it is impossible for the checkers to gauge figures accurately beyond this, any further excess is called 'heavy' or 'packed'.

The train checkers work round all the lines on a roster of stations, except when special requirements call for concentrated observations. In the normal routine work they generally cover only the heaviest direction of traffic, i.e. the up road in the morning and the down road at night, trains being regarded as 'up' trains when they are running in either direction towards the City, as on the District Railway. Special seasonal loadings are also taken all day at selected points on each line once in February, May, and November, and on one Sunday in summer and winter. The examples shown in Figs. 9 and 10, already referred to, were taken from the result of one of these special seasonal loadings, and from them it will be seen how easy it is to judge whether the service is adequate or too liberal for traffic requirements, bearing in mind that, wherever possible, there should be a slight margin of seating capacity to allow for emergency rushes caused by a serious surface traffic hold-up or a sudden storm.

THE 'BLACK LIST'

A further device by which the train-working department is enabled to criticize the working of the service is that known as the 'Black List'. Every day the pile of signal-box reports, guards' journals, and clock-dial charts are brought in for examination. The clock dial registers the interval headway between each train as it passes: its working is explained in a subsequent chapter. If, on examination, this shows, say,

TRAIN LOADING DIAGRAM.

ARRIVAL OR DEPARTURE

No 14

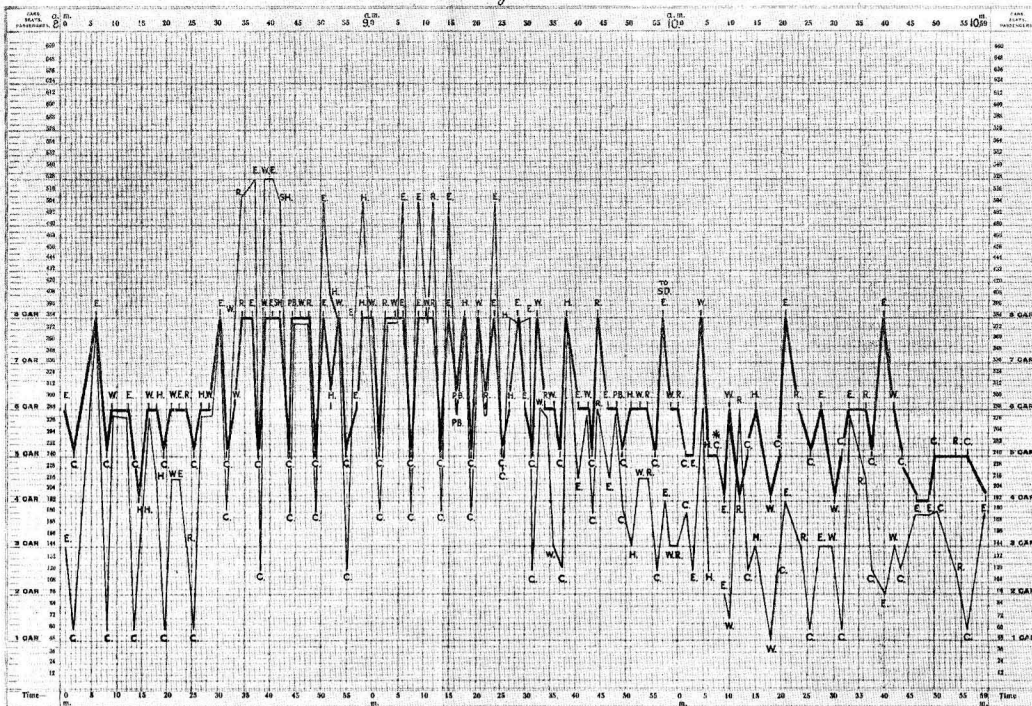
TAKEN AT Sloane Square

BOUND ROAD on departure

District RAILWAY.

DATE Tues DAY 6th May 1927.

WEATHER Fine



The thick line indicates the number of Cars on the Train. G. S. L. R. 50 seats per Car, unless otherwise stated.
 The thin line indicates the number of Passengers in the Train at Sloane Square.
 The horizontal line indicates the number of Passengers in the Train at Sloane Square.
 The vertical scales indicate time at train. Times are indicated on Sloane Square lines.

GENERAL NOVEL 50 1510

<p>D.R.:</p> <p>A: Arrive Train</p> <p>B: Depart Road</p> <p>C: Leave</p> <p>E: Enter Train</p> <p>H: Leave Train</p> <p>M: Leave Train</p> <p>R: Leave Train</p> <p>W: Leave Train</p>	<p>DEPARTURE: STARTING POINT:</p> <p>A: Arrive Train</p> <p>B: Depart Road</p> <p>C: Leave</p> <p>E: Enter Train</p> <p>H: Leave Train</p> <p>M: Leave Train</p> <p>R: Leave Train</p> <p>W: Leave Train</p>	<p>BLOCK W: Without</p> <p>C: With</p> <p>H: With</p> <p>M: With</p> <p>R: With</p> <p>W: With</p> <p>INSTEAD: (C) (H) (M) (R) (W)</p> <p>G.L.R. E: Filling</p>	<p>* (Cancelled, defective,</p>
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District Railway Train Loading Diagram (1927-28) B-10

Fig. 10. Diagram showing the loading of east-bound trains passing through Sloane Square between 8.0 and 11.0 a.m. on May 6, 1927

a $2\frac{1}{2}$ -minute headway instead of one of $1\frac{1}{2}$ minutes the signal-box reports and guards' journals are turned up. The signal-box report shows the time each train passed the cabin, together with the remarks of the signalman as to why the train was late. The guard's journal is a form, showing starting and finishing times of each trip and the time some central station (e.g. Victoria, on the District Railway) was passed. If any train is delayed in a station or checked in a tunnel the guard must produce a reason, such as 'Signal on', 'Traffic unduly heavy', etc. A list is kept of the trips of every train, and whenever a train is over half a minute late the lost time is marked down against it: any time over three minutes is written in red. From this list the regular offenders can readily be singled out, and in each case it is possible to determine whether the lateness is due to inadequate timing, or to its having been set back by the late running of the train or trains in advance. A succession of red entries against a particular train indicates that something is radically wrong with its timing, and the matter is taken up with the time-table department.

TRAIN-RUNNING SUMMARY

Another record which indicates the adequacy or otherwise of a time-table is the 'Summary of Train Running'. This is produced approximately at fortnightly intervals and shows the percentage of trains running up to time or a few minutes late. The following figures give typical readings for the District and Piccadilly Railways:

SUMMARY OF RUNNING—DISTRICT & PICCADILLY RAILWAYS. WEEKDAYS

Date	Place	Right time and not exceeding 1 minute late		$1\frac{1}{2}$ to 3 minutes late		Over 3 minutes late	
		W. B.	E. B.	W. B.	E. B.	W. B.	E. B.
DISTRICT RAILWAY:							
Mar. 15, 1928	Mansion House	%	%	%	%	%	%
" 21 "	" "	93	86½	6	11½	1	2
Apr. 18 "	" "	95	84	4½	14	½	2
" 25 "	" "	92	82	7	13	1	5
May 7 "	" "	89	86	9	9½	2	4½
		92½	90	7	9½	½	½
PICCADILLY LINE:							
May 12, 1928	Piccadilly Circus	96	89	3½	11	—	—
" 26 "	" "	99	96	1	4	—	—
Apr. 2 "	" "	99	97	1	3	—	—
" 24 "	" "	99½	97	½	3	—	—
May 10 "	" "	100	98	—	2	—	—
" 30 "	" "	100	99	—	1	—	—

In addition to these regular sources of information as to the efficiency of the train service, reports are sent in from time to time by the divisional traffic superintendents and district inspectors, embodying suggestions and remarks pertinent to the service. These are considered by the train-working department and noted for inclusion, if suitable and not urgent, in the next revision of the time-table.

A good example of how the Underground meets the demands of the public as a result of the observations of the staff occurred at Kennington on the City and South London Railway, when, although junction facilities had been installed in the reconstruction work, trains were not run through very frequently from the Edgware line via Charing Cross. It was noticed that there was a heavy interchange traffic from the Charing Cross trains that terminated at Kennington, to the City trains that ran through Tooting and the south. Recommendations were made which resulted in a through service being installed from both branches. Similarly, many letters are received through the public letters section containing suggestions and complaints from passengers which may lead to an increase or modification in the service.

Suggestions also emanate from local administrative bodies. These may be of the extravagant and impracticable type suggesting a four-track lay-out to serve some scantily populated area, or they may be of a reasonable nature and likely to prove advantageous to the railway. In such instances the nature of the existing travelling facilities and the possibilities of extension are considered and assessed by the train-working department.

CONNECTIONS WITH OTHER RAILWAYS

Connections with foreign railway companies also materially affect the compilation of the train service. Physical connections, for example, occur at the junctions of the District Railway with the Southern at Turnham Green Junction and at Putney; with the London, Midland and Scottish between Earl's Court and Addison Road; with the Metropolitan at South Harrow, South Kensington, and Kensington High Street; and with the Metropolitan and District Joint Railway at Mansion House. Similarly, the 'Bakerloo' line of the London Electric Railway connects with the London, Midland and Scottish at Queen's Park, and the Central London Railway joins the Great Western at Wood Lane. These physical connections impose restrictions on working, since outgoing Underground trains must fit in with the time-table of the foreign company concerned. An alteration in the Underground time-table may

not suit that of the foreign company, whilst the revision of the latter's time-table may necessitate an alteration of the Underground time-table. In consequence, an understanding generally exists between the companies that new time-tables shall be agreed and issued simultaneously.

A different type of connection occurs where the Underground line crosses under or over, but does not physically connect with, another Underground or foreign railway line. This may necessitate (as it does at Charing Cross, the interchange point of District, Hampstead and Bakerloo trains) the synchronization of the times of the first and last trains each day, and this is always carefully carried out.

A third type of connection is concerned in certain not infrequent cases where the Underground is bound by some long-standing agreement. The obligation may be to allow another company to operate so many trains over District metals each day, or it may be, as is actually the case on one of the lines, that only certain passed trainmen may operate trains over the other company's line. Such limitations imposed on the service must, of course, be kept in view when alterations are being made.

Apart from these compulsory requirements, foreign companies frequently furnish suggestions which prove of considerable value in facilitating an operation such as the coupling of trains, or in improving inter-connecting times.

As soon as the various suggestions of the public and the staff have been sorted and collated in the train-working department they are ready for consideration in connection with the compilation of the time-table—the second, or production, stage connected with the train service.

STAGE II.—PRODUCTION

The schedules office, in the department of the superintendent of the line, is informed of the type of interval service that is to be operated over a particular line, at the busy and slack hours of the day, and of the number of trains that are available for the service. Fig. 11, for example, is the route diagram of a railway over which it might be required to run a six-minute service of trains from A to D, and a six-minute service from B to E, giving one of

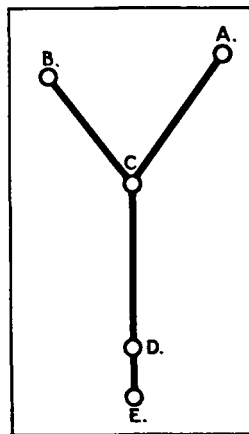


Fig. 11. Route diagram illustrating train service requirements.

three-minute intervals between C and D. Two alternative arrangements will give the required intervals. A 'self-contained' service may be run from A to D and another from B to E, or one 'inter-worked' service may be installed for the whole system, trains running A-D-B-E-A.

Of the two possibilities the first, i.e., two self-contained services, is the easier to arrange and will give less trouble in the coupling and uncoupling of trains. Moreover, if a delay occurs on one service which necessitates the reorganization of trains, it is possible that only one set of crews will have to be rearranged, instead of the whole staff of the line. On the other hand, in spite of the changes arranged by duty rosters, there is a tendency in a self-contained service to restrict the trainmen to working over the one section of the line, with the result that when in emergency they are put on to another section they are unfamiliar with the road and bad running may result.

From the point of view of the duty compiler, a self-contained service causes more waste of time in booking men to take over a train after their relief, owing to the fact that they are compelled to await the arrival of a train that is working on their particular service. This difficulty may be avoided by working the rolling stock on the self-contained service, but booking the men to work on different services after relief wherever possible. The inter-worked service may also allow a slight economy in 'lay-over' time at terminals, and thus make it possible to dispense with a train and its crew.¹ So unless a self-contained service is actually required, the time-table department endeavours to make all services inter-work consistent with schedule efficiency and economy. The self-contained service is of more value to the compiler of a special service such as that run on Bank Holidays, when a certain number of staff must be employed under the 'guaranteed' week clause of the National Agreement. As there are then plenty of trainmen for the service to be operated, time is of little account, and a much simpler temporary time-table can be arranged than would be possible with an inter-worked service.

LAY-OVER TIMES

In any definite interval service the sum of the time taken for a round trip and the 'lay-over' times at each end is equal to the product of the number of trains required to run the service and the headway interval

¹ The 'lay-over' is the time spent at a terminal before starting on the return trip. During this period the motorman must cut out his controls, change ends, cut in at the other end and pump up his brake reservoirs: meanwhile the guard changes destination boards, non-stop boards, and tail lamp.

between trains. Now, running time and headway interval are fixed data, so far as the compiler is concerned, and the number of trains must be the smallest whole number obtainable; so the only figures with which any degree of freedom is possible are the 'lay-over' times. These must, of course, be chosen so that trains entering or leaving the terminus by means of a cross-over road do not foul one another, and, as has been explained, they must be arranged to make the round trip time a multiple of the headway interval. In inter-worked services there are naturally more lay-over times to adjust—in the example in Fig. 11 there would be four—and consequently they provide a greater degree of freedom.

For example, suppose two six-minute services are to be run on a certain line, the end to end running times of each being 16 and 25 minutes respectively. Then, applying the above formula:

$(2 \times 16 + L_1) \div 6 =$ number of trains required to operate on one service where L_1 is the total time available for the 'lay-over' at both ends of the service; and

$(2 \times 25 + L_2) \div 6 =$ number of trains required to operate on the second service, L_2 being the corresponding 'lay-over' figure.

Supposing the terminals are equipped with only two roads and a scissors cross-over: with trains arriving every six minutes, it is clear that trains cannot spend more than $10\frac{1}{2}$ minutes at the terminal, nor can they leave between $4\frac{1}{2}$ and 6 minutes after their arrival, if $1\frac{1}{2}$ minutes have to be allowed for the next train to clear the cross-over and for the points to be reversed. This clearance allowance depends on the position of the cross-over relative to the platform; sometimes one minute will be sufficient if the cross-over is near enough.

The only figure that fulfils all these conditions for L_1 and L_2 is 10 in each case, 4 minutes being manifestly insufficient for two 'lay-overs'.

Thus, $(2 \times 16) + 10 = 42$; on a 6-minute headway this would require 7 trains, giving a 'lay-over' of 6 minutes at one terminus and 4 minutes at the other (5 minutes at each end having been shown to be impracticable);

Also, $(2 \times 25) + 10 = 60$, which gives similar 'lay-overs' of 6 and 4 minutes and requires a further 10 trains, or 17 in all.

In the inter-worked service, however, we have $(2 \times 16) + (2 \times 25) + L$ as the total round trip and 'lay-over' time, where L is the total of all 'lay-over' times. If L is 14, this total figure is 96, giving 'lay-overs' of 4 and 3 minutes at each end and requiring only 16 trains for identically the same service.

Considerable latitude can be obtained by 'staggering' the regular 6-minute interval into a 4- and an 8-minute or 5- and 7-minute service, but 3 minutes is found to be the practicable minimum time in which a crew can be expected to change ends and prepare a train for reversing.

All trains, it may be mentioned, are given a number, which they carry throughout the day or until they are re-formed by coupling or uncoupling or by an emergency alteration of service.

'RUSH' HOURS

The next consideration is as to how long the rush-hour service shall be in operation. It is clearly wasteful to continue running a close service of seven- and eight-car trains throughout the day, but local conditions must decide when and where are the rush hours. In London there is a generally heavy workmen's traffic from the opening of the lines, at about 5 o'clock, till the closing of the period of availability of the cheap workmen's tickets at 7.30 a.m. Traffic then slackens down for nearly an hour before the City rush begins at about 8.20. By 10.30 the trains are again running with light loads until 4.50 p.m. The homeward rush then starts and, while it lasts, is more concentrated than the morning peak traffic, because all the traffic starts from the small confines of the City to disperse over Greater London. Traffic is again quiet by 6.45, but at 7.30 the dinner and theatre traffic becomes evident in the West End. Between 8.30 p.m. and 10.45 p.m. occurs the slackest period of the day. The home-going traffic then begins and continues until the closing of the lines between 12.30 and 1.0 a.m.

There are two ways of reducing the components needed for a rush-hour service to those requisite for a slack service. The first is to reduce the number of trains by stabling some of them, thus lengthening the headway; and the second is to uncouple the trains and so, while reducing the number of cars, to keep the headway still comparatively short. No hard and fast rule can be laid down as to which of these is the more efficient from the operating point of view. Stabling whole trains and portions of trains saves current, wear and tear to stock, and trainmen's wages; it is improbable, however, that any of the remaining long trains left in service would ever pick up a full load in the normal slack hours unless the headway were increased so enormously that it would tend to drive the traffic off the railway to other means of transport.

INFLUENCE OF TRAIN LENGTH

Running short trains is probably less economical in operating costs, since a three-car uses more than half the current taken by a six-car

train; it causes as much wear and tear to signal plant, and the economy in staff is diminished compared with that effected by stabling whole trains. On the District Railway, for instance, except in the case of an eight-car train, which would lose one guard in uncoupling, there would be no reduction of staff at all. Fig. 12 shows how the trainmen's wages cost per car mile is affected by reducing or increasing the number of cars on a train: from this it will be seen that, except where a guard can be saved as between a seven- and six-car train on the District Railway, the cost per car mile is now higher when the number of cars is reduced.

As a result of experience, the tendency in the slack hours on the Underground is to run short trains at short (and sometimes shorter than rush-hour) intervals in the central areas, and short trains at longer intervals in the outer districts.

On the Central London Railway, from Liverpool Street to Wood Lane, bills advertise 'Every hour a rush hour' and actually the $2\frac{7}{7}$ -minute rush-hour headway of long trains is altered to a $1\frac{1}{8}$ -minute service of three-car trains in the slack hours, while on the District Railway, the $1\frac{1}{2}$ -minute interval on the main line from Sloane Square to Mansion House is only widened to 2 minutes in the slack periods.

'NON-STOPS'

During the rush-hour periods, by way of speeding up the service, trains are run through certain of the less important stations, and some remarks are called for on the effect of 'non-stops' on the compilation of a time-table. To avoid any misunderstanding caused by visions of the famous 'Limiteds' of trunk-line companies, it should be stated that without a four-track lay-out a 'non-stop' is not an express train in the generally accepted sense of the term. Very little time can be saved on ordinary booked running times, and it is improbable that the average passenger notices that 3 minutes have been knocked off a journey of 32 minutes. Nevertheless, 'non-stops' are a valuable facility to the time-table and operating departments, besides the economy they effect in rolling stock and current consumption. The time saved by passing one station may not be apparent in the time-table, which is only written to the nearest half-minute or minute. But if the small benefit afforded by non-stopping is utilized, a timing can be arranged elsewhere on the run that would otherwise have been too tight. Where trains leave the main line and go on to a branch line, thus leaving a longer interval on the main line ahead, the following main line train may be given one or more stations to 'non-stop' and so be enabled to reduce the headway from, say, $4\frac{1}{2}$ to 2 minutes.

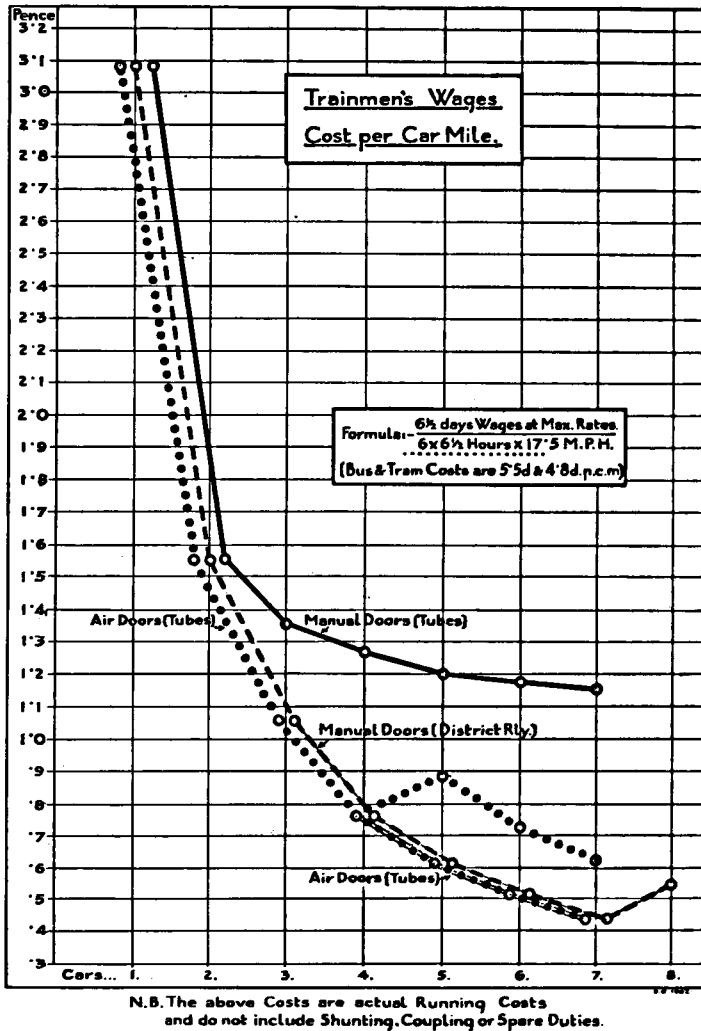


Fig. 12. Diagram illustrating the influence of train composition on wages costs per car mile.

'Non-stops' also provide an excellent margin above normal running for sudden spasms of overcrowding and for slight delays. Again, on the District Railway, where certain through trains are run over trunk lines, these may be composed of different and less easily handled cars than ordinary District cars. Such trains are made to pass a number of stations in order to save the time otherwise employed in shutting doors and enabling passengers to alight from corridor coaches with no central doors.

FIRST AND LAST TRAINS

However often a time-table is altered, an effort is always made to keep the working of the first and last trains exactly the same; this practice avoids inconvenience to early and late workers and to the heavy night 'amusement' traffic. Obviously, arrangements are made to avoid 'empty' or waste mileage, but it is not always possible to book a train to carry passengers at the first station after it leaves its depot. This, of course, occurs frequently in the early services before the arrival of the staff at intermediate stations, special trains being booked to carry the staff to and from their stations before the first, and after the last, passenger train. As has been explained, first and last trains must make adequate connections with the trains of other lines, and it must be remembered that the most efficient schedule is one that enables current to be taken off at the earliest moment after the public service has terminated, thus saving money at the power-house and enabling the repair and maintenance men of the permanent way and signal departments to work as long as possible before the commencement of the morning service.

Chapter IV

PROVIDING THE SERVICE

THE various steps in the compilation of the time-table have now been discussed. It should consist of a complete week-day's working, together with a 'yard' page showing starting, coupling, and stabling times. Modifications, of course, will have to be made for the slack traffic of Sundays, and for the fact that on Saturdays the homeward rush starts at 12 p.m. instead of 4.50 p.m. Included in the tables will also be a list of inter-station running times, and a table of non-stop codes, electric current switching 'on' and 'off' arrangements, speed restrictions and connecting services. The next consideration is as to how all this information is to be set out. 'Who', it may be asked, 'is going to read it?' A complicated publication with its small print, asterisks, and footnotes, can easily be followed by the clerk in the travel bureau, but not by the outdoor railwayman, for whose instruction and information the Underground time-table is primarily intended. It is, in fact, a working time-table.

The type must, therefore, be large and uniform, and important stations may be distinctively shown. Indenting helps to distinguish main line stations from those on branch lines, and it will generally be found advisable to include the whole system on one page to save the continual turning over of pages to look for connections and destinations. This, of course, cannot be done if the system is too large, but it is quite comprehensible as arranged, for instance, for the fifty-nine route miles of the District Railway. Only important or junction stations are listed, as the running time is assumed to be constant between the remainder. A typical page of the District Railway time-table is shown in Fig. 13, and the same principles of legibility and simplicity apply with equal, if not greater force, to the yard pages, one of which is shown in Fig. 14.

DUTY SHEETS

The duty-sheets section of the schedules office is worthy of special notice as it is rather an unusual feature of railway organization. Its work consists in fitting in the duties of the train crews, as required by the already completed time-table, with the minimum of waste time and, consequently, of expense to the company. In this task, which could never be a sinecure, complications are increased by the existence of many local agreements and undertakings embodying terms additional

ROLLING STOCK WORKING. TIMES OF STARTING, COUPLING, UNCOUPLING AND STABLING OF TRAINS.

MARKING.						SATURDAYS EXCEPTED.						
START OF COUPLE UP.		UNCOUPLE OR STABLE.				START OF COUPLE UP.		UNCOUPLE OR STABLE.				
Main Portion	S.E. Portion	No. of Cars	Start.	Time.	S.E. Portion	Main Portion	No. of Cars	Start.	Time.	S.E. Portion	Main Portion	
No. of Cars	No. of Cars	S.E. Portion	Start.	Time.	S.E. Portion	Main Portion	No. of Cars	Start.	Time.	S.E. Portion	Main Portion	
1	1	50	8:40	8:40	12	1	50	8:40	8:40	12	1	50
7	7	17	8:49	8:49	10	7	17	8:49	8:49	10	7	17
13	13	15	8:58	8:58	12	13	15	8:58	8:58	12	13	15
...
71	71	10	10:14	10:14	13	71	10	10:14	10:14	13	71	10

ROLLING STOCK WORKING. TIMES OF STARTING, COUPLING, UNCOUPLING AND STABLING OF TRAINS.

MARKING.						SATURDAYS EXCEPTED.						
START OF COUPLE UP.		UNCOUPLE OR STABLE.				START OF COUPLE UP.		UNCOUPLE OR STABLE.				
Main Portion	S.E. Portion	No. of Cars	Start.	Time.	S.E. Portion	Main Portion	No. of Cars	Start.	Time.	S.E. Portion	Main Portion	
No. of Cars	No. of Cars	S.E. Portion	Start.	Time.	S.E. Portion	Main Portion	No. of Cars	Start.	Time.	S.E. Portion	Main Portion	
1	1	50	8:40	8:40	12	1	50	8:40	8:40	12	1	50
7	7	17	8:49	8:49	10	7	17	8:49	8:49	10	7	17
13	13	15	8:58	8:58	12	13	15	8:58	8:58	12	13	15
...
71	71	10	10:14	10:14	13	71	10	10:14	10:14	13	71	10

ROLLING STOCK WORKING. TIMES OF STARTING, COUPLING, UNCOUPLING AND STABLING OF TRAINS.

MARKING.						SATURDAYS EXCEPTED.						
START OF COUPLE UP.		UNCOUPLE OR STABLE.				START OF COUPLE UP.		UNCOUPLE OR STABLE.				
Main Portion	S.E. Portion	No. of Cars	Start.	Time.	S.E. Portion	Main Portion	No. of Cars	Start.	Time.	S.E. Portion	Main Portion	
No. of Cars	No. of Cars	S.E. Portion	Start.	Time.	S.E. Portion	Main Portion	No. of Cars	Start.	Time.	S.E. Portion	Main Portion	
1	1	50	8:40	8:40	12	1	50	8:40	8:40	12	1	50
7	7	17	8:49	8:49	10	7	17	8:49	8:49	10	7	17
13	13	15	8:58	8:58	12	13	15	8:58	8:58	12	13	15
...
71	71	10	10:14	10:14	13	71	10	10:14	10:14	13	71	10

ROLLING STOCK WORKING. TIMES OF STARTING, COUPLING, UNCOUPLING AND STABLING OF TRAINS.

MARKING.						SATURDAYS EXCEPTED.						
START OF COUPLE UP.		UNCOUPLE OR STABLE.				START OF COUPLE UP.		UNCOUPLE OR STABLE.				
Main Portion	S.E. Portion	No. of Cars	Start.	Time.	S.E. Portion	Main Portion	No. of Cars	Start.	Time.	S.E. Portion	Main Portion	
No. of Cars	No. of Cars	S.E. Portion	Start.	Time.	S.E. Portion	Main Portion	No. of Cars	Start.	Time.	S.E. Portion	Main Portion	
1	1	50	8:40	8:40	12	1	50	8:40	8:40	12	1	50
7	7	17	8:49	8:49	10	7	17	8:49	8:49	10	7	17
13	13	15	8:58	8:58	12	13	15	8:58	8:58	12	13	15
...
71	71	10	10:14	10:14	13	71	10	10:14	10:14	13	71	10

EAST HAN DEPOT (LITTLE ELFORD SIDING). SATURDAYS EXCEPTED.

Time	Loc.	Loc.	Loc.	Loc.
8:25	1	1	1	1
8:35	1	1	1	1
8:45	1	1	1	1
8:55	1	1	1	1
9:05	1	1	1	1
9:15	1	1	1	1
9:25	1	1	1	1
9:35	1	1	1	1
9:45	1	1	1	1
9:55	1	1	1	1
10:05	1	1	1	1
10:15	1	1	1	1
10:25	1	1	1	1
10:35	1	1	1	1
10:45	1	1	1	1
10:55	1	1	1	1
11:05	1	1	1	1
11:15	1	1	1	1
11:25	1	1	1	1
11:35	1	1	1	1
11:45	1	1	1	1
11:55	1	1	1	1

Fig. 14. A page from the yard, or train formation, section of the District Railway time-table.

to those concerned in the National Agreement of 1919, and the eight-hour day. When a new time-table is compiled the first step of the duty-sheet department is to ascertain the approximate number of duties that will be required to work it. This figure is obtained by dividing the number of train-hours by eight, representing the number of hours in a theoretical working day, the result being in terms of 'crew-hours'. Then, if the average crew consists of a motorman and a guard, twice the crew-hours will give an approximation to the minimum number of duties required to staff the schedule.

Each trainman is registered as belonging to a particular depot, and can only be booked on and off at that depot, or thereabouts. Where possible, depots are situated at, or near, one end of each line, in order to minimize empty mileage incurred in running trains from the depot to the nearest terminus preparatory to going into traffic and back again at the end of the day. On the District Railway, owing to the longer route mileage served—fifty-nine miles as compared with the nine miles of the Piccadilly line—in addition to the outlying depots at Ealing, Parsons Green, and East Ham, there is a central depot at Cromwell Curve, and a meal relief station at Sloane Square. The first train in the morning—the 'coach', as the staff train to Barking is called—leaves Ealing Common depot at 4.36 a.m. and the last train, the 'up staff' from Hounslow West, stables at Ealing Common depot at 1.41 a.m. This implies that under the present District Railway time-table trains are running and must be staffed for twenty-one hours five minutes out of the twenty-four.

'STRAIGHT' AND 'SPLIT' TURNS

The duty-sheet compiler can arrange the duties in what are known as 'straight' and 'split' turns. A minimum of eight hours for six days a week has to be paid for, and, in view of the guaranteed wage, it is the compiler's task to ensure that, as nearly as possible, the period of duty in each case is actually worked. In the matter of cost, any time booked to be worked over the eight hours must be paid for at the overtime rate of 'time and a quarter', except between 10.0 p.m. and 4.0 a.m., when the rate is 'time and a half'; Sunday work (either ordinary or overtime) is also paid at 'time and a half'. This rate applies also to Christmas Day and Good Friday, other Bank Holidays being paid for at the ordinary rate. Any ordinary time (i.e. not overtime) worked after 10 p.m. is paid for at the rate of 'time and a quarter'.

'Split' turns—i.e. turns in which the period of duty is interrupted by an interval of rest—must fit in with the regulations governing 'reliefs'

and 'spread-overs'; the latter expression is used to denote the total time, from the commencement of duty in the morning to the finish of the last duty at night. No overtime may be booked on a 'split' turn consisting of seven and a half hours' work, which, with no further meal relief, is paid for as eight hours; and only 10 per cent. of the motormen and guards, and 60 per cent. of the gatemen on each line may be booked for 'split' turns. All employees must have twelve hours' rest¹, the total 'spread-over' thus being limited to twelve hours. A 'straight' turn, i.e., a turn that is not divided as above, may not exceed eight and a half hours for 35 per cent., and eight and three-quarter hours for a further 5 per cent. of the staff of each line, time in excess of eight hours being paid for at the overtime rates quoted above. A minimum meal relief of thirty minutes between the third and fifth hours of the duty must be allowed and paid for as working time. This meal relief is sometimes locally augmented, and to it has to be added a varying number of minutes' 'walking' allowance, according to the distance of the mess-room from the station.

No useful rules can possibly be laid down for the production of a duty sheet. It is a matter purely of experience and ingenuity, no two time-tables ever bearing the least resemblance to one another in the matter of staffing. It is, however, the practice to adopt a general method which facilitates the actual fitting in of the duty times.

A TYPICAL DUTY SHEET

Fig. 15 is an example of a duty sheet containing two early turn duties, two late turn, and two 'split' turn or 'spread-over' duties. The starting times of trains from the depot are entered in chronological order, the early turn men being booked on at their respective depots to take out these trains. Twenty minutes must be allowed for the examination and preparation of trains for service, in addition to any local walking allowance. A note is then made of the times, between the third and fifth hours of duty, at which the trains pass relief stations where messrooms are provided. At these points the trains are handed over to the relieving crews, who are probably working a 'split' turn, for it is bad policy to book on fresh 'straight' turn crews at 8.0 or 9.0 a.m., in view of the fact that the services, and consequently the crews, will all have to be reduced at about 10.0 a.m. After their thirty minutes' relief, the early turn men are available for the relief of the other early turn men, who are now

¹ Except when duties are changed over (i.e., from late to early turn) at week ends by the operation of the trainmen's rosters (see Fig. 16).

HAMPSTEAD & CITY RAILWAY														
DUTY SHEET IN OPERATION FROM 4TH NOVEMBER 1922														
POSITIONS <u>MOTORMEN & GUARDS</u> DEPOT <u>GOLDERS GREEN</u>														
SERVICE <u>SATURDAYS EXCEPTED.</u>														
DUTY NO	REPORT AT		WORK				FINISH AT		TIME WORKED		RELIEF		SPREAD OVER	
	TIME	PLACE	SET NO	FROM		TO		TIME	PLACE	STRETCHER OF	TOTAL	STRETCHER OF		TOTAL
				TIME	PLACE	TIME	PLACE							
6	A.M.													
	5.7	GG	26	5.35	Dt	9.11	CT4			4.4				
	9.41	CT	47 5	10.8 12.47	Hg CT1	12.35 12.57	CT3 GGN	1.7	GG	3.26	7.30		3U	8.0
9	5.18	GG	27	5.46	Dt	9.28	M	9.30	M	4.12				
	10.0	M	88 59 96	10.6 11.48 1.0	M K4 CT1	11.38 12.44 1.11	K4 CT1 GG	1.18	GG	3.18	7.30		3U	8.0
	25 S	7.32 2.0	GG GG	19 15	8.0 2.7	Dt GGS	10.0 6.28	DtGG GGS	10.26 6.36	GG GG	2.54 4.36	7.30		3.34	11.4
29 S	8.9	GG	53	8.37	Dt	9.36	DtM							
	4.3	GG	66 72 52	10.19 4.52 5.35	T Dm DtGG DtGG	11.15 4.58 7.35	DtGG GGN DtGG	11.41 8.1	GG GG	3.32 3.58	7.30		4.22	11.52
	P.M.													
55	4.47	GG	2	5.5	GGN	5.28	GGS							
	8.21	K	3 79	5.37 8.24	GGS K3	7.37 12.21	K1 Dt	7.51 12.47	K GG	3.4 4.26	7.30		30	8.0
	5.0	GG	16 6	5.9 7.13	GGS K2	7.4 8.29	K2 CT2			3.29				
59	8.59	CT	12	9.7	CT2	12.34	Dt	1.0	GG	4.1	7.30		30	8.0
<u>LIST OF ABBREVIATIONS</u>														
			GG	=	Golders Green station.									
			GGN	=	Golders Green North Bound platform.									
			GGS	=	Golders Green South Bound platform.									
			Hg	=	Highgate station.									
			CT	=	Camden Town station.									
			CT1	=	Camden Town North Bound platform to Golders Green.									
			CT2	=	Camden Town South Bound platform from Golders Green.									
			CT3	=	Camden Town North Bound platform to Highgate.									
			CT4	=	Camden Town South Bound platform from Highgate.									
			K	=	Kennington station.									
			K1	=	Kennington North Bound platform via Charing Cross.									
			K2	=	Kennington South Bound platform via Charing Cross.									
			K3	=	Kennington North Bound platform via Bark.									
			K4	=	Kennington South Bound platform via Bark.									
			T Dm	=	Footing "Down" platform.									
			Dt	=	Morden station.									
			S	=	Depot.									
					In duty No. column signifies "Split" duty.									

Fig. 15. A specimen duty sheet.

nearing their fifth hour of duty. It should be noted that all men must be relieved after the third and before the fifth hour; if they were relieved before the third hour, the relief would not count as such, and another spell would have to be granted later.

BOOKING OFF

Provision must now be made to ensure that the early turn men will be passing their home depot at about eight hours after they booked on. If, after their meal relief, the train they have taken on will be too far away and so necessitate their travelling back at the company's expense to their home depot, they must be changed over and given charge of a train on the other road which will enable them to reach home at the correct time, seven minutes being then allowed for booking off. This change-over affords opportunity for relief to be given to the original crew, who may be either a 'split' turn crew booking off from their first spell of duty until later in the evening, or a 'straight' turn crew who can be given meal relief.

The late turn men 'take over' from the early turn crews, who finish between 1.0 and 3.30 p.m., the 'split' turn men entering on their last spell of duty in time to build up for the evening peak service, and to provide meal relief for the late turn. A little forethought is now necessary to enable these 'split' turn men to take over trains that are booked to stable early after the evening peak—between 6.30 and 9.0 p.m.—and are not required to be used again for the theatre and homeward bound amusement traffic. These early stabling trains enable the 'split' turn men, who, as already stated, brought out of the depot the last trains before the morning peak, to be booked for the 11- or 12-hour spread-over. The late turn men then finish out the day and stable the last trains, eighteen minutes being allowed for the purpose of stabling a train and booking off, in addition to local 'walking' allowances.

SIX MONTHS' ROSTER

On the completion of a set of duty sheets, the compiler makes out a roster of duties to cover six months' rotation. No names are affixed, but it is decided, perhaps, that duty 53 shall follow duty 27, 16 follow 53 then 5, 33, 35, 17, 4, 11, etc., as seems fairest to the men, by varying the successive duties as 'early', 'split', or 'late' turns. The men's representatives are then afforded an opportunity of scrutinizing both the rosters and the duty sheets. A new set of duties having been compiled, the yardmasters enter a name against each duty, and the men



HAMPSTEAD AND CITY RAILWAY.

ROTATION OF DUTIES MOTORMEN'S GRADE.

SCHEDULES No 132 DATE 6th December 1928 DEPOT GOLDER'S GREEN

WEEKLY DUTY NO	SUNDAYS				MONDAYS TO FRIDAYS				SATURDAYS			
	DAILY DUTY NO	REPORT	FINISH	TIME OFF DUTY	DAILY DUTY NO.	REPORT	FINISH	TIME OFF DUTY	DAILY DUTY NO.	REPORT.	FINISH.	TIME OFF DUTY
1		DAY OFF			1	4.55	12.55	16.0	1	4.55	12.65	18.23
2	1	7.18	3.18	25.18	44	4.36	12.36	15.49	44	4.25	12.25	
3		DAY OFF			21	6.28	2.28	16.16	21	6.44	2.44	25.11
4	19	3.55	11.43	13.32	33	1.25	9.25	15.45	33	1.10	9.10	14.36
5	11	11.45	4.19	13.55	20	6.14	2.14	16.0	20	6.14	2.14	25.51
6	25	4.5	12.2	13.58	68	2.0	10.0	16.0	68	2.0	10.0	
7		DAY OFF			11	5.22	1.22	16.0	11	5.22	1.22	26.43
8	23	4.5	11.57	13.53	35	1.50	9.50	15.35	35	1.25	9.25	
9		DAY OFF			24	6.45	5.39	14.22	24	8.1	4.1	15.51
10	5	7.52	3.52	25.40	57	5.32	1.32	16.0	57	5.32	1.32	18.58
11	40	7.30	12.0	13.24	32	1.24	9.24	15.42	32	1.6	9.6	
12		DAY OFF			19	5.59	2.13	15.46	19	5.59	1.59	

Fig. 16. Example of a duty roster.

thereafter change duties mechanically according to roster. Fig. 16 shows a duty roster for the Hampstead and City Railway.

It should be mentioned that, before the duty sheets are made available for scrutiny by the men's representatives, the compiler must satisfy himself that none of the duties entails an infringement of the mileage clause, which limits to 124½ the daily mileage that can be operated by one man, any excess having to be remunerated at the rate of fifteen miles to an hour's pay. This, incidentally, is another of the disadvantages of a self-contained service, for if it has to be operated and staffed over outlying branch lines, such as those to Harrow and Uxbridge, the greater distance between stations results in an increase in the over-all average speed, so that it is quite possible for a man to travel 140 miles during his turn of duty.

SIX DIVISIONS

It will thus be seen that the trainmen's working day falls into six divisions:

- 1 Net revenue-earning work.
- 2 Booking on and off time.
- 3 Meal relief.
- 4 Walking allowance and other local
- 5 Waste. [alleviations.]
- 6 Overtime.

Of these, (1) and part of (6) are the only sections which are remunerative to the company. Since the wages bill absorbs the major portion of railway operating expenditure, it is essential that the first item should be entirely profitable. Items (2), (3) and (4) are definitely wasteful so far as the company is concerned, except in respect of that part of the booking-on time spent in testing the train preparatory to service; the only scope for the duty-schedule compiler is to minimize further waste by fitting in these items, if possible, exactly with train-running times. Items (5) and (6) are the only ones which can be reduced by the compiler's ingenuity. The waste under (5) is entirely attributable to the compulsory adoption of a guaranteed eight-hour day. From the very nature of transport work, it follows that any day of a guaranteed number of hours will give inefficiency and waste in duty compilation, since duties rotate weekly according to rosters made out by the duty-sheet compiler, and different duties on different trips entail varying numbers of miles to be run, all of which duties must be paid for at the rate of eight hours' work and none of which may exceed eight hours. Since, then, after the booking-on time in the morning, every minute of the day has to be paid for (except in the case of 'split' turns whose limitations have already been described), it is obvious that any gap between meal relief or change-over and an available connecting train entails a loss to the company.

WASTE TIME

Men need not be booked on till the agreed time before each train has to be started from the depot, so no loss need occur at this period of the compilation; but the following examples show how waste time does occur, and to what extent it is unavoidable. The obligatory thirty minutes' meal relief time, included in the eight hours and paid for by the company, may mean a man's missing, at about his booking-off time, a train which it was desirable he should take over owing to its stabling at, or passing, his home depot. This occurs particularly on the Bakerloo line, where men from Watford depot, who may only be booked to work Watford, and not local, trains, on the completion of their thirty-four minutes' relief and walking time at Queen's Park, just miss the next Watford train, a service which has a fifteen-minute headway. They are, therefore, booked to take over a train on the opposite road, where trains arrive on the fifteen-minute headway *from* Watford, say, seven and a half minutes after trains have left *to* Watford; the unavoidable waste is thus minimized, but not eliminated.

Again, it may not be possible to book every man to start work on a

train stabling at, or passing, his home depot near his booking-off time, and in such cases one of three arrangements may be made, each of which must inevitably result in a certain amount of waste:

1. The man may be booked to continue on the train and be taken off it at some other relieving station, whence sufficient time is allowed him to travel home as a passenger in the next train to his home depot, where he is booked off.

2. He may be taken off the train in question as it passes his home depot on the trip nearest his booking-off time: any further time between his being relieved from the train and the expiration of his eight hours must then be accounted as waste, unless, during an emergency reorganization of service, his yardmaster can utilize his services to give half an hour's meal relief to another man and return to the depot on a short trip, such as Parsons Green to Wimbledon and back.

3. The compiler may take him off the train and book him to take over, from another crew on the opposite road, a train which will be stabling at, or passing, his home depot at the expiration of his eight hours' duty. Any waste time between his leaving the first train and the arrival of the second train is unavoidable according to the time-table, but none the less real.

Fig. 17 shows the proportion of each item of the working day of the train crews on the five lines of the London Underground. This indicates concisely the relative and actual efficiency of each line and discloses which of the waste items has the preponderating effect on each figure. An example of endeavour by the compiler to use up this waste time can be seen on reference to the chart relating to the District Railway.

INSTRUCTIONAL TIME

It is thought desirable, from the point of view of the company as well as of the men, that all guards at least once a month should run one or two trips over the line as drivers to give themselves confidence and to keep them familiar with the road, in case, in an emergency, such as the sudden illness of the driver, they were actually called upon to move the train. In order that such instructional time shall not represent extra expense to the company, while a man is driving under the supervision of his own motorman his place is taken by a rear guard whose normal services have been dispensed with through the uncoupling of his eight-car train after the morning peak.

PROGRAMME OF DUTIES

Another task which devolves on the time-schedules department is that of providing the train crews with a programme of their duties from start to finish to save constant reference to the time-table itself. There

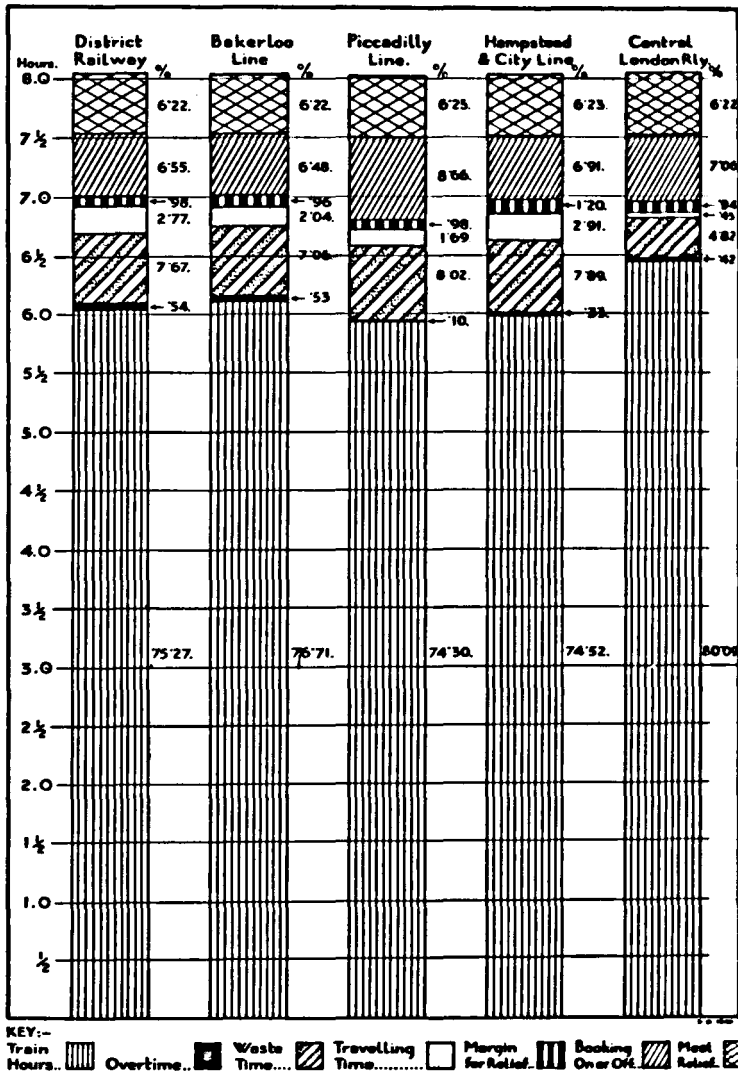


Fig. 17. Diagram indicating how the hours of duty of trainmen are spent on the various Underground railways.

are two systems of arranging these programmes. On the District Railway a form is used as in Fig. 18. This is officially known as the motorman's train-running schedule and familiarly as 'the board'. The form is pasted on to a board on the back of which is fixed a slip bearing the non-stop code. The example in Fig. 18 shows the working of set 56 in the 'Saturdays Excepted' District Railway time-table commencing July 11th, 1927.

The train, composed of eight cars, starts at 5.40 a.m. from Ealing Common depot and runs empty to Ealing Broadway, where it arrives at 5.45, to pick up its day's working. As a 'BB' non-stop it passes West Ham, arriving at Barking, the eastern terminus of electric trains, at 6.57. Passing Plaistow, West Ham, Mile End, St. Mary's, Stamford Brook and Turnham Green, it arrives back at Ealing at 8.16. The eastward trip is an 'AA, B' non-stop, passing four stations, Ravenscourt Park, Baron's Court, South Kensington, and St. Mary's, arriving at Barking at 9.29. On the return trip, it arrives at Ealing 10.48, calling at all stations, and is then uncoupled (see diamond at foot of Fig. 18), three cars remaining in service, the five-car portion being worked from Ealing to Ealing Common depot at a convenient time.

The three-car portion leaves Ealing at 10.58, calling at all stations to Barking, arriving at 12.2, and returns to Ealing, calling at all stations, arriving at 1.13. Leaving Ealing at 1.18, it arrives Barking at 2.22, calling at all stations. Departs Barking 2.28 for Ealing, where it arrives 3.33, again calling at all stations, and then couples up to eight cars (see circle, foot of Fig. 18), the five-car portion having been previously worked from Ealing Common depot for the purpose. This then forms the 3.40 from Ealing, calling at all stations to Whitechapel, arriving there at 4.26. On the westward journey it departs Whitechapel 4.31, non-stopping St. Mary's, and arrives at Wimbledon 5.15. Leaving Wimbledon at 5.24, it arrives at East Ham 6.22, after non-stopping Walham Green, West Brompton, Gloucester Road, South Kensington, Stepney Green, and West Ham, indicated by 'U,E,DD'. It then proceeds to East Ham depot, stabling there at 6.27 p.m.

These 'boards' are left in the train whose set number they bear, and are given to the motorman in the morning and returned by him with his tools to the yardmaster on completion of the day's work. A duplicate of each 'board' is kept at the relief depot at Sloane Square. In the event of the service becoming disorganized, owing to a train defect or overcrowding as a result of bad weather, a train may have to be 're-formed' into the running of another train in order to get back to time-table working. In this event the set number is changed, and the motorman,

DATE 11th July 1927
Subway Receipt

METROPOLITAN DISTRICT RAILWAY.

START AT P.N. GBR

TRAIN STARTING FROM Barking Cannon DEPÔT S. 40 Ann SET No. 56

STATIONS	M	S	M	S	M	S	Code	Stations Non-stopped	Code	Stations Non-stopped
EALING	(7.44)	5.52	8.26	10.08	11.17	3.40				
HOUNSLOW WEST	(11.54)									
ACTON TOWN	(5.78)	5.57	8.21	11.3	1.23	3.46	U E			
RICHMOND	(7.78)									
HAMMERSMITH	(8.18)	6.6	8.40	11.12	1.22	3.46				
WIMBLEDON	(7.21)	A.B.	AA							
PUTNEY BRIDGE	(8.04)									
PARSONS GREEN	(8.18)									
EARLS COURT	(1.08)	6.8	8.46	11.17	1.27	3.52				
EDGWARE ROAD	(4.3)									
SLOANE SQUARE	(8.04)	6.17	8.47	11.23	1.43	4.6				
MANBION HOUSE	(8.04)	6.29	8.58	11.26	1.50	4.17				
WHITECHAPEL	(8.10)	6.38	9.10	11.23	2.3	4.26				
BOW ROAD	(8.61)	6.48	9.21	11.28	2.8	4.4				
PLAISTOW	(8.88)	6.49	9.21	11.52	2.46	6.17				
EAST HAM	(10.81)	6.59	9.28	11.59	2.59	6.22				
BARKING	(11.58)	6.57	9.29	12.2	3.22					
BARKING		7.15	9.42	12.8	2.28					
EAST HAM		7.42	9.44	12.4	2.42					
PLAISTOW		7.59	9.47	12.17	2.57	AA				
BOW ROAD		7.26	9.47	12.23	2.40					
WHITECHAPEL		7.21	10.2	12.28	2.48					
MANBION HOUSE		7.20	10.8	12.57	2.57					
SLOANE SQUARE		7.52	10.23	12.28	2.8	AA				
EDGWARE ROAD		7.58	10.29	12.26	2.46					
EARLS COURT										
PARSONS GREEN										
PUTNEY BRIDGE										
WIMBLEDON										
HAMMERSMITH										
RICHMOND										
ACTON TOWN										
HOUNSLOW WEST										
EALING		8.57	8.4	10.23	1.2	2.22				

NON-STOP CODES		NON-STOP CODES	
FOR STATIONS WEST OF ALDGATE EAST	FOR USE IN EITHER DIRECTION	FOR STATIONS EAST OF ALDGATE EAST	FOR USE IN EITHER DIRECTION
Code	Stations Non-stopped	Code	Stations Non-stopped
A	Stanford Brook, West Kensington, Earl's Court and Gloucester Road	AA	St. Mary's
B	Ravenscourt Park, Barons Court and South Kensington	BB	West Ham
C	Parson's Green, Wilham Green and West Brampton	CC	St. Mary's and Bromley
D	Parson's Green and West Brampton	DD	Stepney Green and West Ham
E	Gloucester Road and South Kensington	EE	St. Mary's and Bow Road
F	Earl's Court and Gloucester Road	FF	St. Mary's, Mile End and Bromley
G	Ravenscourt Park and Barons Court	GG	Stepney Green, Bow Road and West Ham
H	Turnham Green and Stamford Brook	HH	Bromley and West Ham
I	Manusman, Westminster and Sloane Square	II	West Ham, Bromley, Bow Road, and Mile End
J	Putney Bridge, Parson's Green, West Brampton and South Kensington	JJ	Planton, West Ham, Bromley, and Mile End
K	Stanford Brook and West Kensington	KK	East Ham, Planton, Bromley, Bow Road, and Stepney Green
L	Parson's Green, Wilham Green, West Brampton and Gloucester Road	LL	Bromley, Bow Road, and Stepney Green
M	Stanford Brook, West Kensington and Gloucester Road	MM	Upton Park, West Ham, Bow Road, and Stepney Green
N	Queery and Brompton Mauer	NN	Planton, Bromley, Mile End, and St. Mary's
O	Park Royal	OO	Planton, West Ham, Bromley, Bow Road, and Stepney Green
P	Acton Town, Turnham Green, Stamford Brook, Ravenscourt Park, Barons Court, West Kensington, Earl's Court, Gloucester Road and South Kensington	PP	Planton, West Ham, Mile End, and St. Mary's
Q	Queery and Brompton Mauer	QQ	Planton, Bromley, Bow Road, and Stepney Green
R	Queery and Brompton Mauer	RR	Non-stop between Barking and Aldgate East, except Whitechapel
S	Queery and Brompton Mauer	SS	East Ham, Planton, West Ham, Bromley, Bow Road, and Stepney Green
T	Turnham Green	TT	East Ham, Planton, West Ham, Mile End, and St. Mary's
U	Wilham Green and West Brampton	UU	West Ham, Bow Road, and St. Mary's
V	Stanford Brook, Ravenscourt Park and Barons Court	VV	West Ham, Bromley, and Mile End
W	West Brampton	WW	Non-stop between Barking and Aldgate East, except Mile End
X	Stanford Brook, Earl's Court and Gloucester Road	XX	West Ham, Bromley, Bow Road, and Stepney Green
Y	Stanford Brook and Ravenscourt Park	YY	Upton Park, West Ham, Bromley, Bow Road, Mile End, Stepney Green, and St. Mary's
Z		ZZ	Upton Park, Planton, West Ham, Bromley, Mile End, Stepney Green, and St. Mary's

TRAIN TO FROM AT 6.27 pm

LONDON & N.E. Railway's Train Running Schedule. (1927-28.)

Fig. 18. A specimen motorman's train-running schedule, District Railway.

HAMPSTEAD & C. & S.L. RAILWAYS.

DUTY NO. _____ SCHEDULE NO. _____ DAYS _____

REPORT ON DUTY (TIME) _____ (PLACE)

TRAIN NO.	NON-STOP CODE.	REPORT ON DUTY (TIME)										(PLACE)												
		EDG. DEP.	COL. DEP.	G.G. DEP.	HO. DEP.	C.T. DEP.	EUR. (OFF) DEP.	EUR. (OFF) DEP.	C.X. DEP.	KENN. DEP.	TGOT. INC. DEP.	ARR.	MORDEN NON-STOP CODE.	DEP.	TGOT. INC. DEP.	KENN. DEP.	C.X. DEP.	EDG. DEP.	C.T. DEP.	HO. ARR.	G.G. ARR.	COL. ARR.	EDG. ARR.	

When trains are being reformed Train Staff must refer and work to the Time Table until such time as they are put on their booked working.

331-4117 B. Trainmen's Duty Card. (Hampstead & C. & S.L.R.) 1-20-22.

BOOK OFF DUTY (TIME) _____ (PLACE)

Fig. 19. Trainmen's duty card, as used on the Hampstead and City & South London Railways.

on arriving at Sloane Square, takes out the board of his new set number and gives up his old one. Guards on the District Railway obtain their information directly from the time-table, and their booking on and off times from the yard roster.

On the Tubes, however, where there is a less confusing number of destinations and possible routes, 'trainmen's duty cards' are employed. These are thin cardboard slips, as in Fig. 19, on which are noted the men's duties, times of booking on and off, relief and change-overs. These cards differ from the 'boards' of the District Railway in that they follow the men and not the trains. Each man (motorman and guard) keeps his card for a week, when it passes by roster to another man. Fragmentary working of several trains may occur on one card, but only one duty.

TIME-TABLE ALTERATIONS

Perhaps the commonest form of special time-table alteration is that designed to meet the pressure of crowds attracted by important League football matches. Three big League teams have grounds near Underground stations—West Ham at Upton Park, and Chelsea at Walham

Green, on the District Railway, and Arsenal at Gillespie Road on the Piccadilly line. Smaller matches are disregarded, except that station staffs may be temporarily strengthened. As there is a first-class match at Walham Green or Upton Park every Saturday during the football season, the District Railway services are always strengthened in the 'Saturdays only' winter time-table as a standard basis, extra trains or cars only being added on each Saturday to suit the time of the kick-off, which varies between 2.0 and 3.30 p.m.

The extra car and train miles entailed by any special alteration are totalled up by the train-working department, wherein a record is kept of all alterations to train services.

On the Piccadilly line a big match at Gillespie Road necessitates a completely new time-table; its general form is fixed, but times of commencement and finish vary with the time of the kick-off, the ordinary Saturday working, and, subsequently, week-day working, being brought into operation again as soon as possible after the ground has been cleared.

SPECIAL EVENTS

Other special events are similarly provided for by time-table alterations, the service requirements being worked out, as has been explained, by the train-working department. But as an example of how far-reaching an apparently simple alteration can be, Fig. 20 shows one page of the 146 in a set of District Railway time-tables altered and ready to be set up in type. These alterations were caused by reducing the Inner Circle service from a 6- to a $7\frac{1}{2}$ -minute interval, and extending a number of Putney Bridge trains that terminated at High Street, Kensington, as far as Edgware Road.

Another type of special or extraordinary traffic arranged for through the time-schedules department, is that concerned with summer time, school treats, and military movements. Applications are made for the privilege of using a cheap rate—for over-twelve adults in the party. The advice is then passed to the time-schedule department, which determines whether the suggested times of travelling are convenient. A large party may necessitate the strengthening of one or more trains or, perhaps—especially in the case of large bodies of troops, as during the war—the addition of a special train. Advice is then given to the stationmaster to enable him to staff his station accordingly. For very large parties, such as political association outings, it may be possible for the time-table department to arrange for an extra train, without holding up the regular service, to be run non-stopping all intermediate stations.

WEST TO EAST AND INNER RAIL.													SATURDAYS EXCEPTED												
RET. NO. ...	30	65	80	Met.	1st	99	52	09	23	Met.	70	73	57	Met.	19	24	20	67	20	Met.					
No. of Cars ...	6	6	3	6	5	6	8	6	6 (8)	6	6	6	6	5	6	3	3	6	18	6					
Non-stop Code ...	D-D	E-E													A										
HALEND BROADWAY ...	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.					
UXBRIDGE & HARROW ...	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45					
BOUSLOW WEST ...	5 50	5 50	5 50	5 50	5 50	5 50	5 50	5 50	5 50	5 50	5 50	5 50	5 50	5 50	5 50	5 50	5 50	5 50	5 50	5 50					
ACTON TOWN ...	5 55	5 55	5 55	5 55	5 55	5 55	5 55	5 55	5 55	5 55	5 55	5 55	5 55	5 55	5 55	5 55	5 55	5 55	5 55	5 55					
RICHMOND ...	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58					
WIMBLEDON ...	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58					
ALDGATE EAST ...	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58					
WHITECHAPEL ...	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58					
BOW ROAD ...	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58					
EAST HAM ...	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58					
BARKING ...	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58	5 58					
To Form ...	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45	5 45					

Fig. 20. Indicating the time-table amendments needed in consequence of a slight alteration in the service on the District Railway.

TIME-TABLE DISTRIBUTION

The completed time-table is distributed to the staff by the train-working department. This department is also responsible for arranging with the various depots for any further special train-running during traffic hours, such as empty stock being worked to Acton Town repair depot—this may be Bakerloo stock worked round via Willesden and Addison Road—or test runs on new equipment. These special runnings can only, of course, be inserted where suitable gaps, made for the purpose, have been left in the time-table.

All alterations to train services must pass through the aforementioned channels, in which adequate records are kept to ensure a fair distribution of charges and revenue. In emergency, however, the traffic controller, whose functions are described in detail in Chapter VI, or the traffic superintendents and district inspectors acting with the knowledge of the traffic controller, may cancel the running of any train or reverse a train short of its destination in order to relieve the service. In the same way, although one train may be booked to pass in front of another train at a junction, it lies at the discretion of the signalmen to allow the second train to pass in front of the first if the latter is running late and if the holding up of the second train will cause delays to the rest of the service.

Chapter V

PROBLEMS OF OPERATION

IN the previous two chapters we have considered the first two stages—demand and production—concerned in the design and provision of an intensive electric service. We now come to the third and equally interesting stage, namely, that which involves its operation. Four of the important items that affect the nature and capacity of a close interval service are:

- 1 The length of station stops,
- 2 The position of signals,
- 3 The lay-out of tracks, and
- 4 Gradients and curves.

1. *The length of station stops.* Apart from such considerations as the rate of acceleration and deceleration, maximum speed and the lay-out of the track, the duration of station stops and their frequency very largely determine the possible capacity of the line, and the effective speed of the service. Fig. 21 gives a direct reading of the fall in speed due to stops of varying lengths and frequency. On the basis of an average speed of 25 m.p.h., a stop of 60 seconds per half mile, for example, reduces the average speed to 14.4 m.p.h. and increases the running time for four miles from 9.6 minutes to 16.6 minutes. Fig. 22 shows the percentage drop in speed at one, two, and four stops a mile.

Fig. 23 has been prepared to indicate how prolonged station stops will hold up the following trains and produce a cumulative delay. For convenience, a section of line has been taken with an assumed capacity of sixty trains per hour, allowing for a station stop of 20 seconds at stations 'A' and 'B'. At station 'A' the 20-second station stop is not exceeded, but at 'B' it is prolonged from 20 to 40 seconds. The effect of No. 1 train absorbing 20 seconds over its normal time at 'B' causes No. 2 to slacken at the outer home signal, and this is shown by a slight 'lag' in the normal direction of the curve, the signal coming 'off' before the train actually stopped. This is more pronounced in the case of No. 4 train, owing to its having to come to a standstill and start again. The delay is increased with each succeeding train, until the holding of No. 7 at 'B' outer home signal has the effect of stopping No. 8 at 'A' advance starting signal. The delays at these two signals are repeated until No. 11 train is held at station 'A' awaiting the starting signal. The progressive result is that the running time (i.e. the time between the

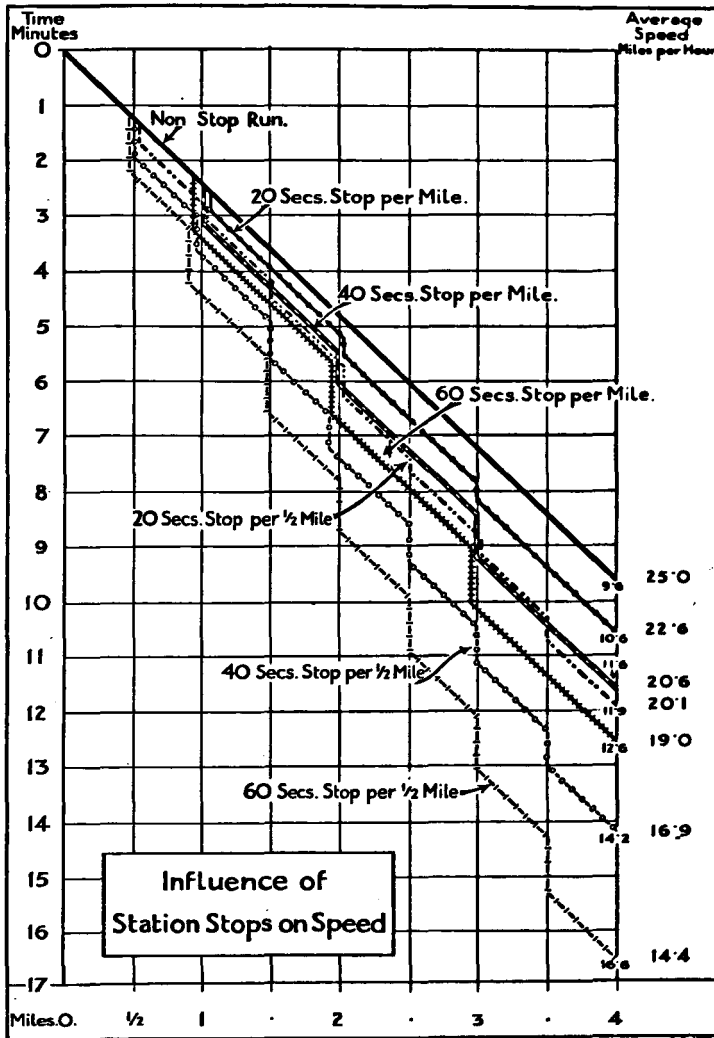


Fig. 21. Diagram indicating the decline in speed owing to station stops.

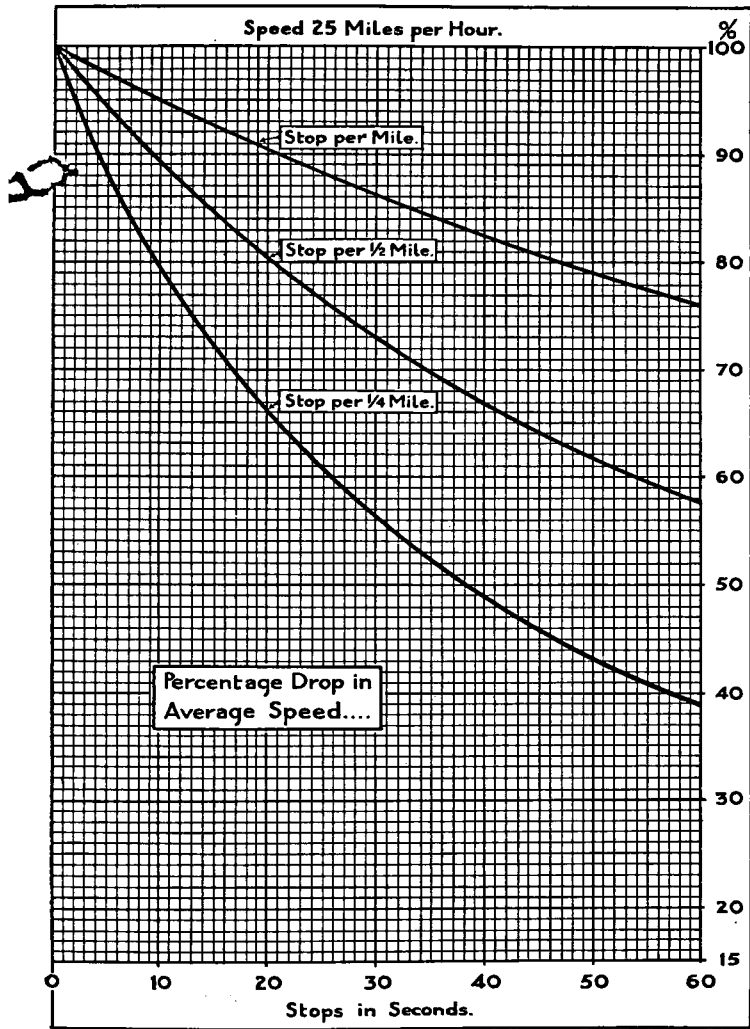


Fig. 22. Chart showing the percentage drop in speed at one, two and four stops a mile.

moment when each train is ready to start from 'A' and the moment when it arrives at 'B') increases from 75 seconds in the case of the first train to 168 seconds in that of the twelfth train.

2. *The position of signals.* The position of signals and the length of their 'overlaps' have an important influence on the capacity and efficiency of a train service. Briefly, the fewer the signals, the fewer the trains. Each section of road must be protected by a stop signal, whether automatic or controlled from a signal cabin, and the longer the sections the longer must be the time interval before the section and its 'overlap' are clear and the protecting signal comes off for the next train. It should be explained that the 'overlap' is the distance beyond the stop signal (usually 400 ft. of ordinary road) which must be left clear in case the following train runs past the signal and has to be pulled up by the action of the 'trip cock'.

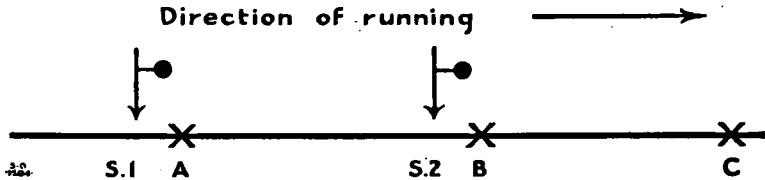


Fig. 24. Diagram illustrating the principle of track circuiting as applied to automatic signalling.

Fig. 24 is a diagram of an imaginary section of road. S.1 and S.2 are automatic stop signals, and 'A', 'B' and 'C' block joints dividing the sections. S.1 goes to 'danger' as soon as 'A-B' track relay is broken down by the action of the leading bogie of the train in 'shorting' the relay circuit across the running rails; S.2 similarly assumes the danger position as soon as 'B-C' track relay is broken down. Signal S.1 does not clear when S.2 goes to 'danger', as if a train developed a defect just on reaching track 'B-C' the next train might over-run S.2 and not be pulled up by the emergency opening of the trip cock in time to avoid a collision with the first train. S.1, therefore, does not clear until 'B-C' track relay 'picks up', which will occur when the last bogie is clear of 'C', and the relay is once more energized through the running rails of 'B-C'.

If the distance from S.1 to 'C' is long, the following train will have to draw up at S.1 and so waste time, current, and consequently money, in braking and then accelerating from rest. But 'B-C' for an ordinary section of running road, or for a section near a station where trains may

be 'non-stopped' at high speed, is a fixed distance to ensure a safety margin. Between certain City stations of the District Railway, where no trains are non-stopped, the 'overlap' on starting signals may be considerably reduced, because the motorman has to stop at the station in any case, and will have begun to apply his brake before he looks to see whether the starting signal is 'on' or 'off'. Consequently, the portion 'A-B', lying between the signal block joints, must be kept as short as possible.

The tendency in modern practice is to close up the distances between the 'home' signals, while keeping longer intervals between the 'starting' and 'advance starting' signals, these being the first two signals encountered beyond the station. This arrangement enables a longer clear run on leaving the station and ensures that if the following train must be held up it is detained in the station, where it may be of some use, rather than in the tunnel 300 ft. or so beyond the station. This theory, however, must be applied with circumspection, otherwise delays may result. For instance, two trains may be following one another, and if the distance between 'starter' and 'advance' is too great, the second train will be held so long in the station that the first is well beyond the next station before the motorman of the second comes within sighting distance of the closed up 'home' signal system. In such an event the latter, far from being an advantage, will be an impediment, because, owing to the long gap between following trains, the capacity of the track will be decreased instead of increased. It is, therefore, essential that the timetable compiler, besides being conversant with running times, should also be aware of the position of signals and be familiar with track and terminal lay-outs.

3. *The lay-out of tracks.* Track lay-out may be considered from the point of view of (a) terminals, (b) intermediate stations, and (c) junctions. With regard to terminals the simplest and usual lay-out on the Underground is one consisting of two dead-ends with one scissors cross-over at the entrance to the platform lines. This type occurs in 50 per cent. of Underground termini; but the three-road type, as recently installed at Hounslow West and Morden, gives considerably greater scope for service operation. Terminal loops are used at Wood Lane and Kennington.

The ultimate capacity of a system of railway lines depends on the capacity of the weakest section. This 'weakest section' may be at an intermediate station owing to a prolonged station stop, as already indicated, or it may occur at terminals where, by reason of limited lay-out

measurements, difficulty is experienced in reversing a train off the running road in time to admit the next, or it may occur at a junction. Both in design and operation, these sections call for the utmost care and attention.

TERMINAL CAPACITY

The capacity of a terminal depends both on the lay-out and on the measurements, and, in the simple scissors cross-over type of terminal, the position of the cross-over in relation to the platform regulates the clearance time of trains using the cross-over; thus, within reasonable limits, it may be said that the nearer the cross-over is to the platform the greater the capacity of the terminal.

It is now possible to imagine the design of the ideal terminal, assuming absolute efficiency of operation to the nearest second, and thus

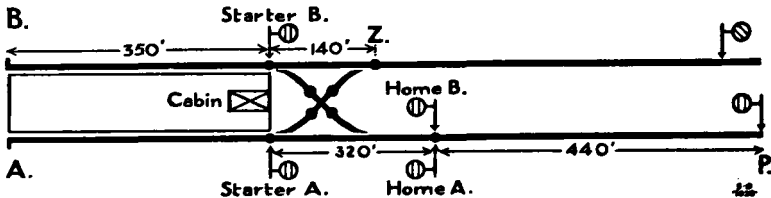


Fig. 25. Diagram of a typical double cross-over terminal designed for Tube railway operation. The above dimensions are general, and will vary according to the lay-out.

dispensing with the above described 'margin' of safety and error, but allowing the minimum safety distances between signals. The example given in Fig. 25 is intended to serve as an indication of the limit in this respect beyond which no terminal of this type can be expected to cope with a service. It will be seen that the platforms are 350 ft. long, i.e. just sufficient to accommodate the trains, which are assumed to be 350 ft. in length. The block joints for the overlap on the home signal, the starting signals, and the cross-over switches are made to coincide with the end of this 350 ft. platform. The overlap on the home signal is 320 ft., which is just enough to allow the emergency brakes to stop a train, passing the home signal at 'danger' at 30 m.p.h., in time to prevent its running into a train standing at the platform.

For simplicity's sake, the 'home repeater' is placed approximately 440 ft. in the rear of the home signal, and it is assumed that if the repeater does not come 'off' before the driver passes it at 30 m.p.h. he will immediately start a service application of his brakes, which would draw

the train up at the 'home'. If, however, the 'repeater' comes 'off' before he reaches it, the driver will brake only sufficiently to bring his train to a complete stop at the platform, and a 15 m.p.h. speed limit must be observed in moving over the cross-over either in or out. Acceleration is taken at 1 m.p.h. per second, normal retardation at 1.5 m.p.h. per second, and emergency retardation of about 3 m.p.h. per second.

'P' indicates the position of the 'repeater' and 'Z' the block joint clearing the overlap on either 'starter'. From passing 'P' at 30 m.p.h. to coming to rest in 'A' platform occupies 33 seconds, and in 'B' 42 seconds. Starting from 'A' to clearing 'Z' takes 30 seconds, and starting from 'B' to clearing 'Z' 26 seconds, whilst 15 seconds is allowed for each series of lever movements to reverse the cross-over.

If, to give the heaviest possible service, a spare change-over crew is waiting, then, allowing 72 seconds in 'A' and 67 seconds in 'B' for cutting-in the train and changing over, a 1½-minute service of trains can, *on paper*, be reversed at the above station, giving a capacity of forty-eight trains per hour. It may be of interest to note that, whilst allowing adequate safety margins for human or mechanical errors, the Underground has actually maintained on this system of change-over crews an hourly service of forty-two trains of either three, four, or five cars, and not over 250 ft. in length. This was accomplished at the former terminus of the Hampstead and Highgate Railway at Strand Station (then known as Charing Cross) before the construction of the Charing Cross loop, which has recently been removed.

If, however, the crew have to change ends and the absolute minimum of 2½ minutes is allowed for this purpose, a 1⅞-minute service can be worked, giving sixty-three trains in two hours. The nearest approach to this in practice on the Underground is the 2-minute service of thirty trains an hour regularly worked at certain periods of the day in and out of Elephant and Castle Station on the Bakerloo line.

The following table, indicating the working of a 2-minute service with a 3-minute 'lay-over' and a 1-minute clearance, shows how the time-table compiler arranged the road working of his trains, allowing 1-minute or 1½-minutes' clearance time, according to the position of the cross-over:

<i>No. 1 Road</i>		<i>No. 2 Road</i>	
<i>Arr.</i>	<i>Dept.</i>	<i>Arr.</i>	<i>Dept.</i>
4.30	4.33	4.32	4.35
4.34	4.37	4.36	4.39
4.38	4.41	4.40	4.43
4.42	4.45	4.44	4.47
4.46	4.49	4.48	4.51

DOUBLE CROSS-OVER ROADS

The 1 $\frac{3}{4}$ -minute slack hour service on the Central London Railway should not be confused with the above theoretical service, since at Wood Lane the loop terminal has as great a capacity as any of the running lines, whilst, in addition, one train out of every three goes straight through to Ealing without reversing. At the other end of the



Fig. 26. Liverpool Street, Central London Railway, an example of a terminal with a cross-over at each end of an island platform.

line—at Liverpool Street—the terminus is equipped with a cross-over at each end of the station as in Fig. 26, an arrangement which naturally provides greater scope than the single cross-over.

The method of working is as follows: Platform 'A' is used for arrivals, and 'B' for departures only. All trains, then, arrive at platform 'A' and, dropping their passengers, pick up a spare crew, with motorman in the rear and guard in the front car, and proceed into the dead-end at 'A'; the spare crew 'cut in' the train for reversing, and the points are re-set; the train moves into 'B' platform, takes up its passengers, and proceeds on its journey. One dead-end only is employed, unless two trains arrive on a very short headway, when the second dead-end may be used to avoid holding a third train at the home signal in the tunnel. This extra movement into the dead-end occupies about three minutes' more running time, and actually entails the employment of an extra train and crew to maintain the service. The cross-over at the approach end of the station is only used if a train arrives on a long headway with another close behind it, for it enables the first to be sent straight away from platform 'A' without going into the dead-end, and, although the second train may be held at the home signal, the interval is thereby levelled out.

The reasons for the greater capacity of this lay-out are apparent. First, a train can stand at the platform unloading passengers without delaying a following train; secondly, as only one dead-end is normally used there is no crossing over of trains or fouling of both roads, and thus, without diminishing the degree of safety, less margin is necessary to allow for this crossing over. Queen's Park (Fig. 33) possesses a similar arrangement to that noted above, and so did Shepherd's Bush when it was the terminus of the Central London Railway.

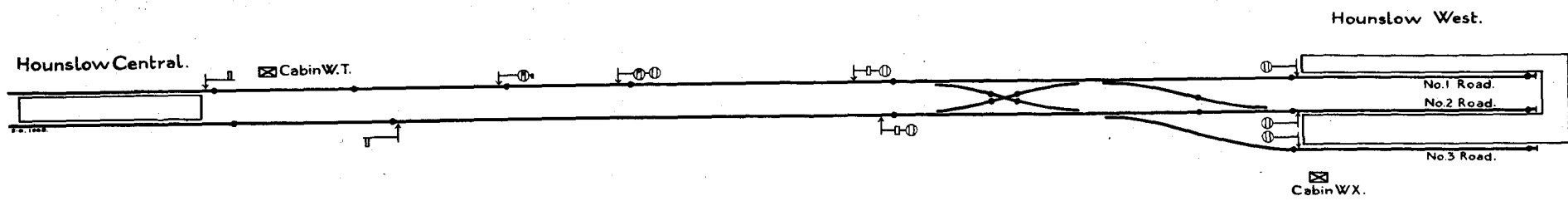


Fig. 27. The lay-out at Hounslow Central and Hounslow West, the latter a terminal of the three-bay type.

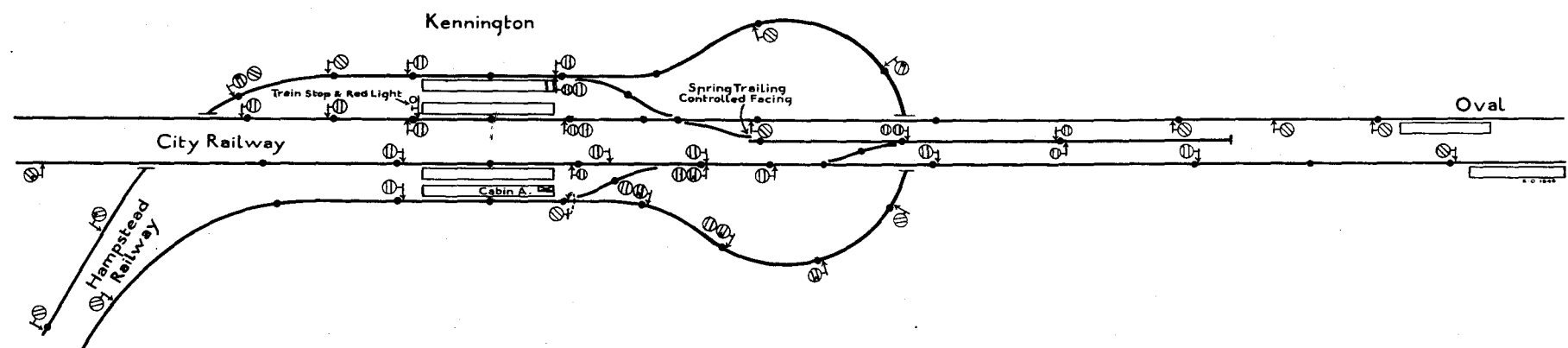


Fig. 28. The lay-out at Kennington, showing terminal loop line, central bay road, and through roads of the City Railway.

THREE-BAY LAY-OUT

Another type of simple terminal lay-out is that consisting of three bay roads, as at Hounslow West, Morden, and Ealing Broadway. In these cases trains may be worked from the down road to any of the bays and from any of the bays on to the up road. Fig. 27 shows the lay-out at Hounslow West, where, in practice, forty trains an hour could be worked if the traffic demanded such a service, as is actually the case at Morden during certain periods of the day. The following table shows how the compiler 'roughs' out the road working for a three-bay road lay-out:

MORDEN: EVENING PEAK WORKING

<i>No. 1 Road</i>		<i>No. 2 Road</i>		<i>No. 3 Road</i>	
<i>Arr.</i>	<i>Dept.</i>	<i>Arr.</i>	<i>Dept.</i>	<i>Arr.</i>	<i>Dept.</i>
—	—	—	—	4.56½	5.6
4.58	5.1	4.59½	5.3½	—	—
5.4	5.9	5.5½	5.17	5.7	5.11
5.11	5.15	—	—	5.13	5.18½
5.16	5.26	5.18	5.22½	5.20½	5.24½
—	—	5.24	5.34	5.25½	5.29½
5.28	5.31½	—	—	5.32	5.36
5.33½	5.46½	5.35	5.39	5.39	5.43

LOOP LINES

The third type of simple terminal lay-out—the loop—is the subject of some controversy. Such lay-outs exist on the Underground system at Wood Lane and Kennington, and one has been lately removed from Charing Cross as it is no longer a terminus. Briefly, the advantages of these single-track loops are:

1. No lay-over is necessary,
2. The crew need not change ends,
3. Points, cross-overs, signal installation and staff are dispensed with,
4. Trains need not hold one another up by crossing over from down to up roads,
5. Only one platform need be constructed.

The following are disadvantages of single-track loops:

1. As there is no lay-over there is no margin with which to correct late running,
2. The sharp curve imposes a severe speed limit,

3. The one platform may lead to congestion,
4. A defective train may hold up the whole service, as there is no alternative bay road,
5. Great care must be taken to provide that trains run round the loop a correct number of times to enable them to couple up with other stock for the evening peak traffic.

At Kennington (Fig. 28) there has been provided a central bay road which may be used for reversing trains without turning them round, or for stabling a defective train; trains may also go straight through from the Charing Cross line towards Morden.

The preference for terminal loops, both in elevated and surface operation, is very pronounced in several American cities—Boston and Philadelphia, for example—whilst at the Gare du Lyon, on the Paris Metropolitan Railway, there is an interesting four-platform loop equipment which allows great freedom of train and passenger movement; this is shown in Fig. 29.

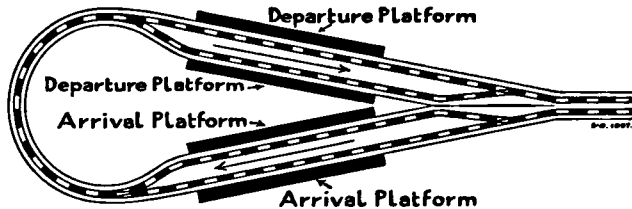


Fig. 29. Arrangement of terminal loop lines at Gare du Lyon, Paris Metropolitan Railway.

INTERMEDIATE STATIONS

Intermediate stations may be equipped with a central or side-bay road for reversing trains, or, as at Mansion House on the District Railway, with both central and side-bay roads. Fig. 30 shows the lay-out at Colindale, where trains are allowed a period of five minutes from arrival at the down platform to departure from the up platform. These central bays, which enable trains to be reversed without fouling either running road, occur also at Tooting and Putney Bridge, and are a feature of the big lay-outs at Acton Town, Earl's Court, and Golder's Green. The side-bay road is less satisfactory to operate, since trains running out of or into it must foul the main roads.

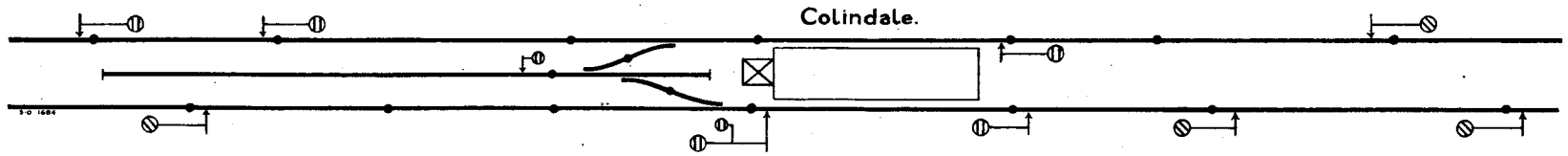


Fig. 30. Colindale, showing central bay road.

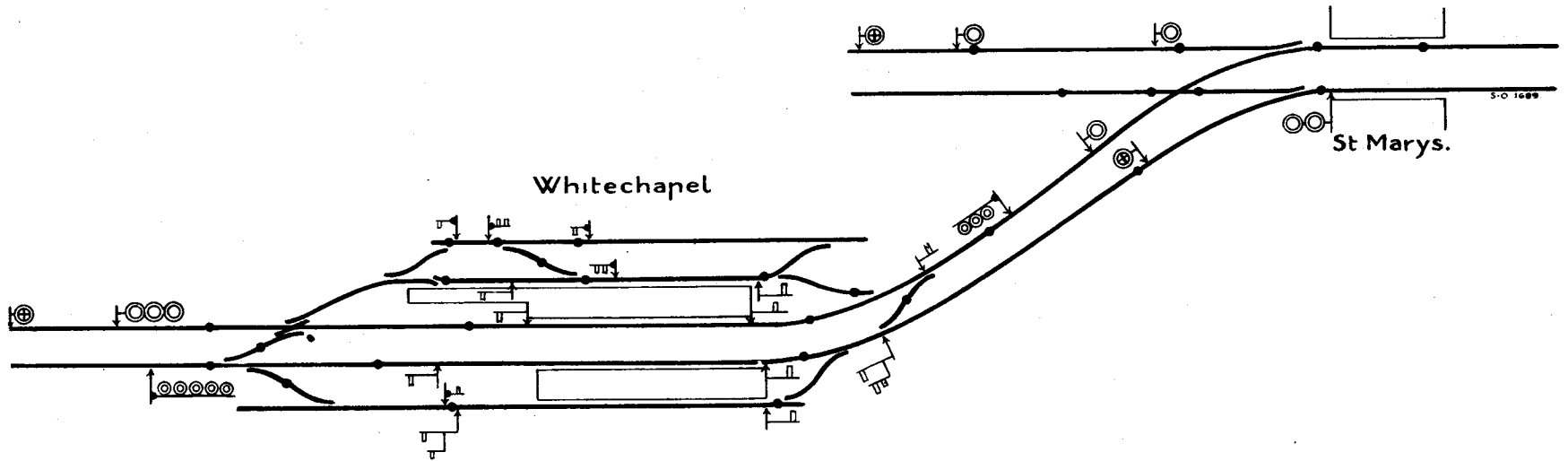


Fig. 31. The well-designed lay-out at Whitechapel.

Another feature of intermediate station lay-out is the relief loops such as those which occur simply at Hammersmith on the District Railway and Brent on the Hampstead line, and are also embodied in the larger systems at Whitechapel and Golder's Green. Fig. 31 shows the lay-out at Whitechapel, an exceptionally well-designed station. It will be seen that a train can be moved from either of the three loop roads and placed at either of the four platforms with only one shunting movement.

At Golder's Green (Fig. 32) there are two very useful relief loops. If a City train is being reversed in No. 2 road and held for a connection from Hendon, expected in No. 3 road, and if, owing to the re-forming of some train, another comes from Hampstead to be reversed at Golder's Green, it need not hold up trains in the rear, because it can be run into the loop and held there while following trains pass on the through track via No. 1 road. The following table shows the road working of Golder's Green in the evening peak:

GOLDER'S GREEN.—EVENING PEAK

<i>No. 1 Road, through North-bound</i>	<i>No. 2 Road</i>		<i>No. 3 Road, through South-bound</i>
	<i>Arr.</i>	<i>Dept.</i>	
5.5½	—	—	5.4½
5.8	—	—	5.9
5.10	—	—	5.13½
—	5.12½	5.15½	5.17
5.14½	—	—	5.19
5.17½	—	—	5.20½
5.19½	—	—	5.23
—	5.21½	5.25½	—
5.24	—	—	5.28
—	5.26½	5.29½	—
5.28½	—	—	5.32½
—	5.31	5.34½	—
5.33	—	—	5.37
5.36	—	—	5.39
5.38	—	—	5.41½
—	5.40½	5.43½	—
5.42½	—	—	5.46
5.45½	—	—	5.48
5.47	—	—	5.51
—	5.49½	5.53	—
5.52	—	—	5.56

While on the subject of special lay-outs, attention should be drawn to

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the complicated system at Queen's Park (Bakerloo), which is illustrated in Fig. 33, the working being shown below:

QUEEN'S PARK.—EVENING PEAK

North-bound Platform Arr.	No. 1 Road Watford (through) N. B.	No. 2 Shed Road		No. 3 Shed Road		No. 4 Road Watford (through) S. B.	South-bound Platform Dept.
		Arr.	Dept.	Arr.	Dept.		
5.0	5.1	—	—	—	—	—	—
5.1½	—	5.2½	5.4½	—	—	—	5.5½
—	—	—	—	—	—	5.7	5.8
5.4½	—	—	—	5.6	5.9	—	5.10
5.7	—	5.8	5.11½	—	—	—	5.13
5.9½	—	—	—	5.11	5.14½	—	5.15½
5.12	—	5.13	5.16½	—	—	—	5.18
5.15	5.16	—	—	—	—	—	—
—	—	—	—	—	—	5.19	5.20
5.16½	—	—	—	5.18	5.21	—	5.22
5.18½	—	5.19½	5.23	—	—	—	5.25

RUNNING ROADS

Single track, it is hardly necessary to say, is inadequate for a rapid-transit service. On the District Railway the last mile or so of the Hounslow branch, from Hounslow Central to Hounslow West, was, until November 1926, a single line. This restricted the service interval to the sum of the running times from the Central to the West station and back, and the necessary time for the crew to change ends and cut-in their controls.

With the exception of the Aldwych branch of the Piccadilly line, which is worked by a single-line shuttle service to and from Holborn, the whole of the Underground system is provided with double track. This, as has been stated previously, does not permit of express trains being run to any extent. A scheme has, however, been proposed for doubling the District Railway track between Hammersmith and Acton Town by utilizing the disused Southern Railway viaduct adjoining.

JUNCTION LAY-OUTS

Both 'flat' and 'flying' junctions are to be found on the Underground. Examples of the old-fashioned 'flat' junction may be seen at Hanger Lane, South Kensington, and the Minories; Fig. 34 illustrates the flat junction at the Minories where outer-rail Circle trains from Aldgate,

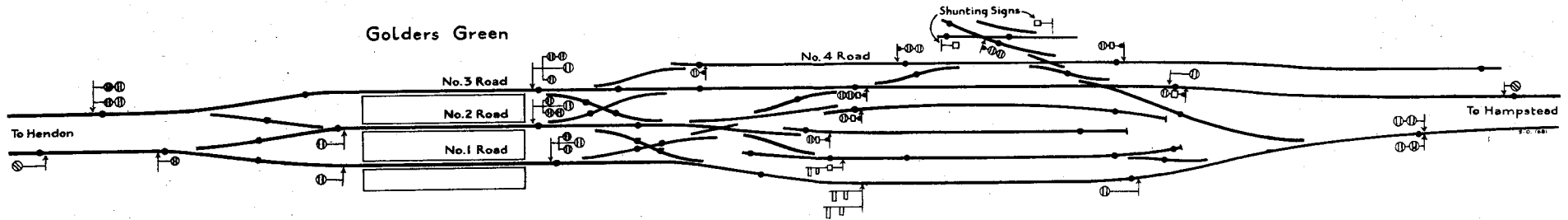


Fig. 32. Golder's Green station lay-out, showing provision for terminal and through working.

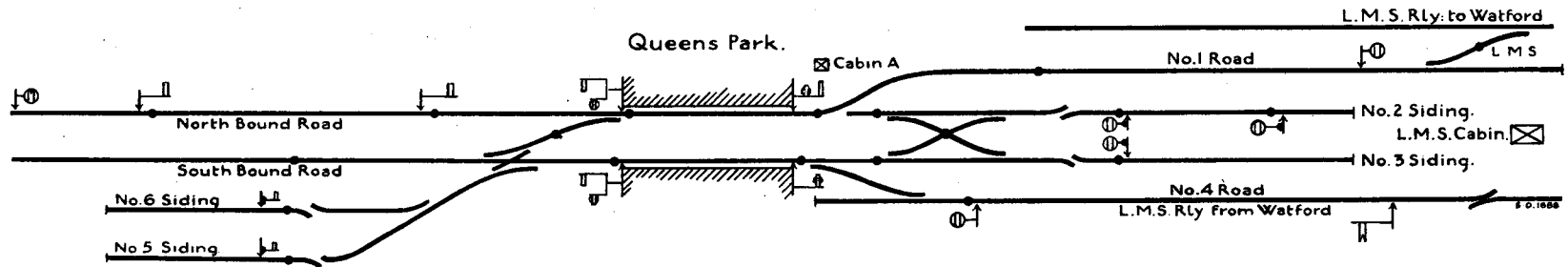


Fig. 33. Queen's Park, the junction with the L.M.S. for the Bakerloo—Watford services.



Fig. 34. The 'flat' junction at the Minories.

running westwards to Mansion House, foul the District down main line to Whitechapel. The elimination of certain of the 'flat' junctions on the District Railway has increased the capacity of the line by 18 per cent., the trains on the main line from South Kensington to Mansion House having increased from thirty-four to forty per hour. The flying junctions at Earl's Court necessitated the provision, at a cost of over £80,000, of fly-under as well as fly-over tunnels through the grounds of Earl's Court Exhibition; the permanent improvement in the service has more than justified the outlay.

Flying junctions have also replaced 'flat' junctions at Acton Town and Turnham Green, and between Earl's Court and High Street, Kensington. At the new burrowing junction at Camden Town no fewer than eight different tracks converge and join without fouling one another. One hundred and ten trains are worked in both directions through Camden Town in one hour, necessitating 1,184 lever movements per hour in the signal cabin. Further reference to Camden Town burrowing junction will be made in a subsequent chapter.

4. *Gradients and Curves.* We have now dealt with three of the main items—station stops, position of signals, and track lay-out—which affect the service. The fourth is concerned in the physical limitations, such as gradients and curves, which impose speed restrictions. Such are, of course, allowed for in the running times. A train on the Hampstead



Fig. 35. 'Flying' junction west of Turnham Green, looking west.



Fig. 36. 'Flying' junction at Turnham Green, looking east, showing the 'up' Richmond line passing under the main line.

line, for example, must not be scheduled to pass at full speed another standing at Brent Station platform, because the gradient and curve of the loop, which was only intended for stabling trains, would not permit of express running.

On 'fly-under' roads the speed acquired by running down the slope is counteracted by climbing the succeeding gradient, e.g. in the case of the 'fly-under' between High Street, Kensington, and Earl's Court, where the road 'passes under' the main lines, the gradient into Earl's Court is 1 in 40 up.

On 'fly-over' roads the steep incline which has to be negotiated is, of course, followed by a falling gradient, but it is not always possible to take advantage of it. At Acton Town, where the Ealing line passes over the 'up' and 'down' Hounslow lines, the steep bank up to the bridge naturally limits the speed out of Acton Town and advantage cannot be taken of the run down, since the train must be steadied, if not (as in most cases) stopped at Ealing Common Station just at the bottom of the bank.

It is worthy of note that the steepest gradient on the London Underground Railways occurs between Shepherd's Bush and Wood Lane, where the rise is 1 in 25, whilst the sharpest curve (4.87 chains) occurs north of Trafalgar Square.

Chapter VI

CONTROL OF THE TRAFFIC

ALTHOUGH trains are worked on most railway systems in accordance with a pre-arranged schedule, such as that outlined in previous chapters, the volume of the traffic and the diversity of the conditions by which it is apt to be affected hour by hour may necessitate constant modification in the working arrangements. Additionally, precautions may have to be taken to ensure that both scheduled and special workings are being efficiently performed. Hence the need for a central control office connected by telephone with all stations and strategical points on a given section of line or even throughout an entire system of railways.

It is a point of interest that a form of centralized control for railway working was first put into operation in 1905 on the District Railway. Traffic control was soon after adopted on certain sections of the British trunk railways for facilitating the working of freight trains, and the former Midland Railway is generally regarded as having been the first trunk line administration in Great Britain to institute a scheme designed to supervise traffic working all over the line through the medium of a central control.

CONTROL ON THE DISTRICT

In the early steam days of the District Railway, delays were comparatively rare. In cases of emergency, however, notification thereof was given to the telegraph office at Earl's Court, whence the train booking-office on the west-bound platform was advised, and the booking-boy there was responsible for sending for the necessary repair-men. These were stationed at certain points along the line. Signal fitters, for example, were available at Aldgate East for the eastern joint stations; linesmen were on call at Victoria for dealing with electric (as opposed to mechanical) failures of the Sykes indicator and signal interlocking and of the Spagnoletti system, which was installed at the eastern and western joint stations; a carriage examiner was stationed at Hammersmith and handle-oiling boys at Whitechapel. Additionally, there were locomotive foremen, who also took care of the steam-worked air-pumping engines at Temple, Victoria, Sloane Square, South Kensington, and Warwick Road, whilst a chief inspector, responsible for train working throughout the system, was stationed at Earl's Court.

Electrification, which was effected in 1905, necessitated a closer measure of control over traffic working. Consequently, private telephone lines were laid to the important termini, such as Whitechapel, Putney Bridge, and Ealing Broadway, and to the depot at Lillie Bridge. At the general offices and the main points on the route, including Mansion House, Charing Cross, Victoria, Hammersmith, and Acton Town, plug-in telephones were provided. Thus, if the traffic controller wished to call up Charing Cross, he would use the telegraph to transmit by code a signal implying 'Come to the telephone'. The stationmaster or foreman would then plug-in on the telephone line and gain direct communication with the controller; this procedure, however, would temporarily cut out all stations on the line beyond Charing Cross. The controller could speak to any of the termini by simply plugging-in on his board, but if two stations on either side of Earl's Court, e.g. Acton Town and Victoria, wished to converse, they could summon one another to the 'phone by telegraph, and then the traffic controller would have to take out his own plug and plug-in a connecting wire between the Ealing and the Whitechapel lines.

The limitations and drawbacks to such a system were, of course, obvious, but it was not until 1912 that the present control board of forty-five lines was erected in the controller's office, and recently a still later type of board of 500 lines has been introduced.

In 1890 the City and South London Tube was opened, and on its being extended to Euston a local control office was opened at Moorgate Street. The Central London Railway—the old 'Twopenny Tube'—followed in 1900, with its control office at Wood Lane. The original control office of the Bakerloo was at London Road, and that of the Piccadilly Railway at Leicester Square. When the Hampstead Railway, which was opened in 1907, had been running for two years, a joint control office for the Bakerloo, Piccadilly, and Hampstead lines (constituting the London Electric Railway) was formed at Leicester Square, and this has now been considerably enlarged.

TRAFFIC CONTROLLERS

At Earl's Court, where the District Railway control office is still situated (Fig. 37), there are three controllers working eight-hour shifts daily, and one assistant controller. The assistant controller works on a split turn from 7.0 to 10.30 a.m. and from 3.0 to 7.30 p.m. to enable extra supervision during peak hours when the staff are changing round and



Fig. 37. District Railway control office, Earl's Court.

the trains are coupling and uncoupling. At Leicester Square (Fig. 38) there are also three Tube controllers, who work eight-hour shifts. During the day two assistant controllers are also on duty; they work nine-hour shifts Monday to Friday and three hours on Saturday. The controller on night duty works alone. These two offices at Earl's Court and Leicester Square are the concentration points for the entire control of traffic working over the London Underground Railways.

It is the duty of the traffic controller to see that the working is performed to schedule. It is equally his duty to effect such temporary alteration in the normal working as may be necessitated by prevailing circumstances. For instance, he must be watchful for any tightness in the schedule, and must remedy delays by reversing trains short of their destinations or by cancelling them altogether. In his task the controller relies on the co-operation of all other grades. If a breakdown occurs it is the duty of the man on the spot, whatever his grade, to devise and put into effect, if possible, the immediate physical remedy. Also, by prompt telephonic advice to the controller, he enables the latter to deal with the emergency

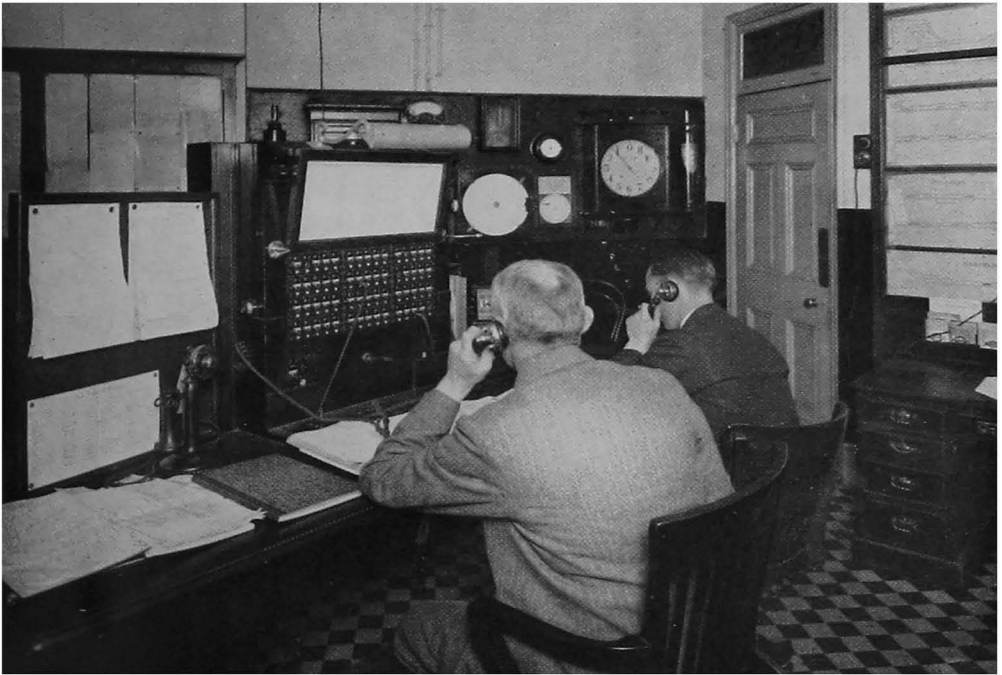


Fig. 38. The control office for the Tube railways at Leicester Square.

from the general service standpoint; for the controller is in a position to restore the service to normal as quickly as possible and thus inflict a minimum of inconvenience on passengers other than those immediately affected by the breakdown.

It is of some interest to note that delays on the London Underground Railways may be attributed in the proportion of 39 per cent. to rolling stock, 13 per cent. to signals and permanent way, 1 per cent. to current, 17 per cent. to delinquencies on the part of the staff, 15 per cent. to other railway companies, and the remaining 15 per cent. to miscellaneous causes. Delays, however, are happily of rare occurrence; in fact, there are less than three delays exceeding three minutes each per 100,000 car-miles run.

The problems which a traffic controller is called upon to solve fall under three headings: (1) Inequality of performance and nature of stock and track; (2) branch-line operation, involving connections and through cars, and (3) collection of information.

PROBLEMS OF STOCK AND TRACK

If an eight-car train is taken out of service in the morning owing to a rolling-stock defect, the controller will transfer the crew to the first available train at the nearest depot. This, however, may be a six-car train, and so, when it is stabled for the slack hours, the odd two-car unit off the first train must be worked back to avoid depleting the evening service. If, on the other hand, the two trains are composed of different types of stock, such a procedure may be impossible, and considerable shuffling will be necessary to restore the balance. Or again, the relieving train may be of old stock incapable of the speed of the new train taken out of service; this would mean lost time on the journey, which must be avoided by a still more elaborate transfer arrangement. Another possibility is that the staff may be insufficient or superfluous after a change-over, and care must be taken that as little overtime as possible is incurred in re-forming the service.

Track capabilities have also an important bearing on the emergency control of a service. Altogether, there are sixty-two stations equipped with one or more cross-over or run-round loop roads, giving an average of one per 1·17 route miles under the controller's authority. Sidings, depots or dead-ends are also provided at thirty-eight stations, allowing one per 1·91 route miles for the stabling of disabled trains.

The frequent installation of cross-over roads on a line enables the service to be maintained, in emergency, close up to the point of breakdown, but it should be borne in mind that a simple tube cross-over like that at Hyde Park Corner costs £17,500, given favourable working conditions. Moreover, the frequent appearance of cross-overs may add considerably to the running time from terminal to terminal owing to the need for imposing speed restrictions over the facing points, as at Hampstead, 20 m.p.h.; Lambeth (North), 20 m.p.h., and Piccadilly Circus (Bakerloo), 15 m.p.h.

PROBLEMS OF BRANCH-LINE CONTROL

Throughout the various routes covered by the trains of the District Railway there are ten branches. A train may be delayed at Wimbledon, for instance, owing either to unsuitable fog-signalling arrangements or overcrowding, and by the time it reaches Earl's Court it has missed its path and has to be sandwiched in at the wrong place. This may mean that it fouls the working of a Circle train at South Kensington, causing trains to block back on the bottle neck on a tight 1½-minute headway.

Signal to signal checking then occurs, and from an initial 2-minute delay on the branch line an accumulated delay of 10 or 12 minutes may be set up.

At some stations communication with the station staff can only be obtained through the signalman, and it is in such cases that the controller sometimes experiences difficulty, especially in the event of delays or other occurrences likely to affect the working. He is, of course, advised of minor delays and defects through the medium of the guards' journals, which are compiled and handed in by the guards after their period of duty, and forwarded to the controller. He is thus enabled to ascertain the reason for any material delays and, if necessary, to recommend alterations in service arrangements to head office. At the principal stations special breakdown bells have been installed to warn the staff and passengers of the delays to the service.

The extensions to our railways, heavier services, and increases in traffic density, necessitated a higher standard of control. The system of telephonic communication from the controller's office to the numerous depots and officials concerned with the operation of the services does not in itself meet present-day requirements. More precise means of giving details of failures and detentions quickly to those responsible for remedying them are necessary, and have been obtained by adopting the message transmitting system, such as is used by newspaper offices and clubs. The installation consists of eighteen tape-machines and one operating key-board in Leicester Square Control Office, which covers also the District Railway Control Office at Earl's Court; the tape-machines are installed at the general offices, control offices, rolling stock depots, power stations, etc. Every delay exceeding two or three minutes, and any serious occurrence, is immediately telegraphed to the responsible offices concerned, the cause, so far as is known, being stated at the time of transmission.

BREAKDOWN ARRANGEMENTS

Immediately the controller is advised of a breakdown or other defect, he summons by telephone the necessary emergency repair-man or orders out the breakdown lorries complete with personnel and equipment. In the event of lift or lift-gate failures the man on the spot summons the lift fitter and then advises the controller. Should a breakdown preclude the continuance of through working, the most frequent service possible ($3\frac{1}{2}$ or 4 minutes' headway) is maintained by utilizing the nearest cross-over to reverse trains. If feasible, single-line working will be scheduled

UNDERGROUND

RAILWAY.

FORM REFERRED TO IN RULE 229, RULES AND REGULATIONS BOOK.

Single Line Working during Repairs or Obstruction.

(This Form must be filled up and used whenever it is temporarily necessary to work the traffic of a Double Line over a Single Line.)

..... Station, 19.....

The..... Line being blocked between.....
and..... all Traffic will pass between those two places
on the..... Line.

..... will act as Pilotman, and no Train must be allowed
to pass on to the Single Line unless he is present and personally orders the Train to start.

Block Telegraph Working must be suspended, { *Delete if Automatic Signalling is normally in operation.*

Automatic Signalling is normally in operation and } *Delete if Automatic Signalling is not normally in operation.*
arrangements have been made in accordance with Rules. }

This Order is to remain in force until withdrawn by the Pilotman.

Catch Points exist at....., and arrangements have
been made for working as directed in Rule 236. *(If no Catch Points exist, erase this clause.)*

(Signed).....

To.....

TIME

H. M.

*Noted by..... at.....	:	.....	m.
*Noted by..... at.....	:	.....	m.
*Noted by..... at.....	:	.....	m.
*Noted by..... at.....	:	.....	m.
*Noted by..... at.....	:	.....	m.
*Noted by..... at.....	:	.....	m.

Noted by..... Pilotman.

** These signatures must only be made on the copy held by the Pilotman.*

Twelve of these Forms must be kept in a convenient place at each Station, and at every Signal-box where there is a Crossover-road, so as to be available at any moment, night or day.

Before Single Line Working is commenced, a copy of this Form must be signed by the Signaller and person in charge at each end of the Single Line, and at each intermediate Signal-box or Station, and be kept by the Pilotman, who must see that each of the men signing the Form retains a copy for himself.

In the event of a Station-Master or Station-Inspector himself acting as Pilotman, he must address and give a copy of the Form to the person he leaves in charge of his Station.

Station-Masters or Station-Inspectors and persons in charge receiving this Form will be held responsible that the Inspectors, Foremen, Signallers and others concerned at their Station are immediately made acquainted with the circumstances, and are instructed in their necessary duties.

Fig. 39. Specimen Pilotman's form which is used for the institution of single line working during repairs or temporary obstruction of the facing road.

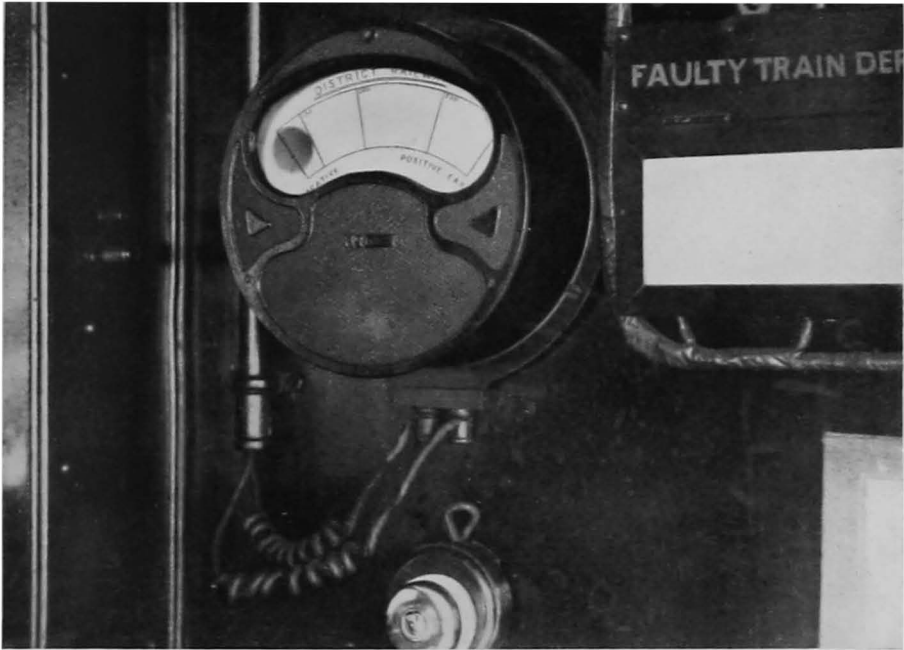


Fig. 40. The indicator which is used to detect leakage of electrical current.

by the controller, who will advise other lines of the Underground as to any necessary diversion of traffic or fresh availability of tickets. Incidentally, a reciprocal agreement, dated 1919, exists between the Underground and the Southern Railway Companies whereby, in the event of a breakdown between either Wimbledon, Richmond and Charing Cross (District) or Wimbledon, Richmond and Waterloo (Southern), both ordinary and season tickets will be honoured on the line which is unaffected. Similar reciprocal arrangements exist between the Underground and the Great Western, Metropolitan, and London and North Eastern Railway Companies. The arrangements, of course, do not apply in the case of temporary delays such as those caused by fog.

In the event of single-line working becoming necessary on a double track, owing to reconstruction or obstruction during traffic hours, the signalman signs the pilotman's 'single-line form' (Fig. 39) and the pilotman signs a similar one kept by the signalman. No train may pass over the single line unless the pilotman is in the motorman's cab. The signalman, also, must be in complete control of the operation, unless automatic signalling is installed between the two cross-over roads, in

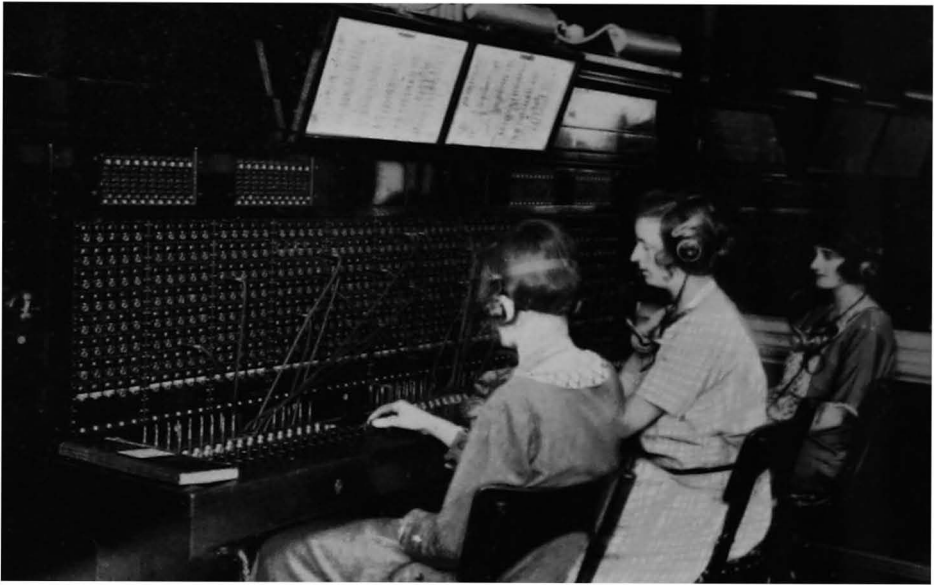


Fig. 41. London Underground private telephone exchange.

which case the signaller will work the cross-over signals, and hand-signalmen will be stationed at each automatic signal.

CONTROL-OFFICE EQUIPMENT

The telephone board in the controller's office is in communication with all signal cabins and important passenger stations, yards and power stations. When any particular line is plugged-in it is automatically disconnected from the exchange, and cut off from any conflicting call. The board is equipped with the visual system, a red disc appearing above the numbered plugging-in hole when the line is calling the controller, while a small lamp next to the disc is illuminated if the line is engaged. On an average a call is made in or out of the controller's office at Leicester Square every two minutes and at Earl's Court every three minutes twenty seconds. The office is also equipped with a headway clock and an 'interval recorder', both of which are described in a later chapter. They can be switched by the controller on to either road at several stations.

An innovation in equipment is the 'leak' indicator (Fig. 40), which

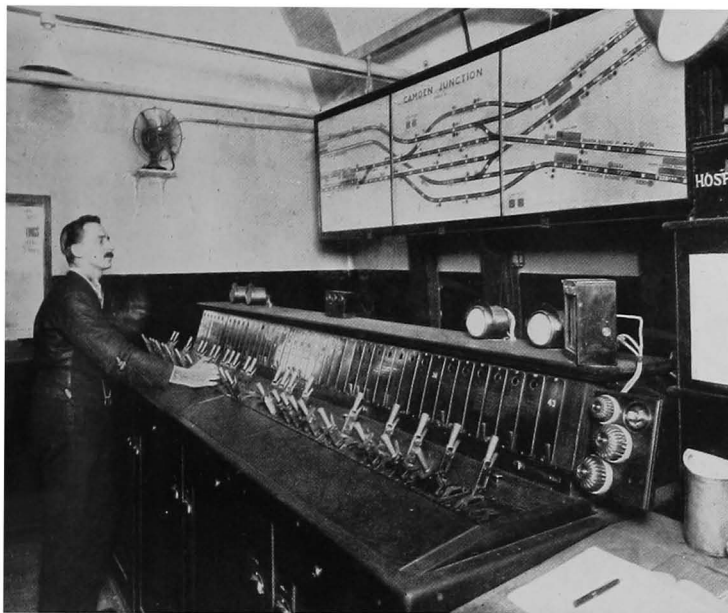


Fig. 42. Power signal-box at Camden Town, showing all-electric lever frame and illuminated track indicator.

has proved of great value in detecting leakage of current either on the track or the trains. It consists of a red disc on a needle, which fluctuates according to the leakage in the low-tension system measured by a train passing over a selected length of current rail. There are also one or more Post Office telephones which can be connected through the private exchange (Fig. 41) with any other points on the system that are not on the control board, or through the private exchange to the Post Office exchange. A barometer is provided to warn the controller of any sudden change in the weather, to enable him to make arrangements for dealing with 'rush' traffic brought in by a sudden storm; a thermometer also warns him when he should give instructions for the car-heating switches to be turned on or off.

Included in the equipment of each control office are a number of important maps and diagrams, which are vital to the controller in emergency situations. All the Tube lines are charted in showcases

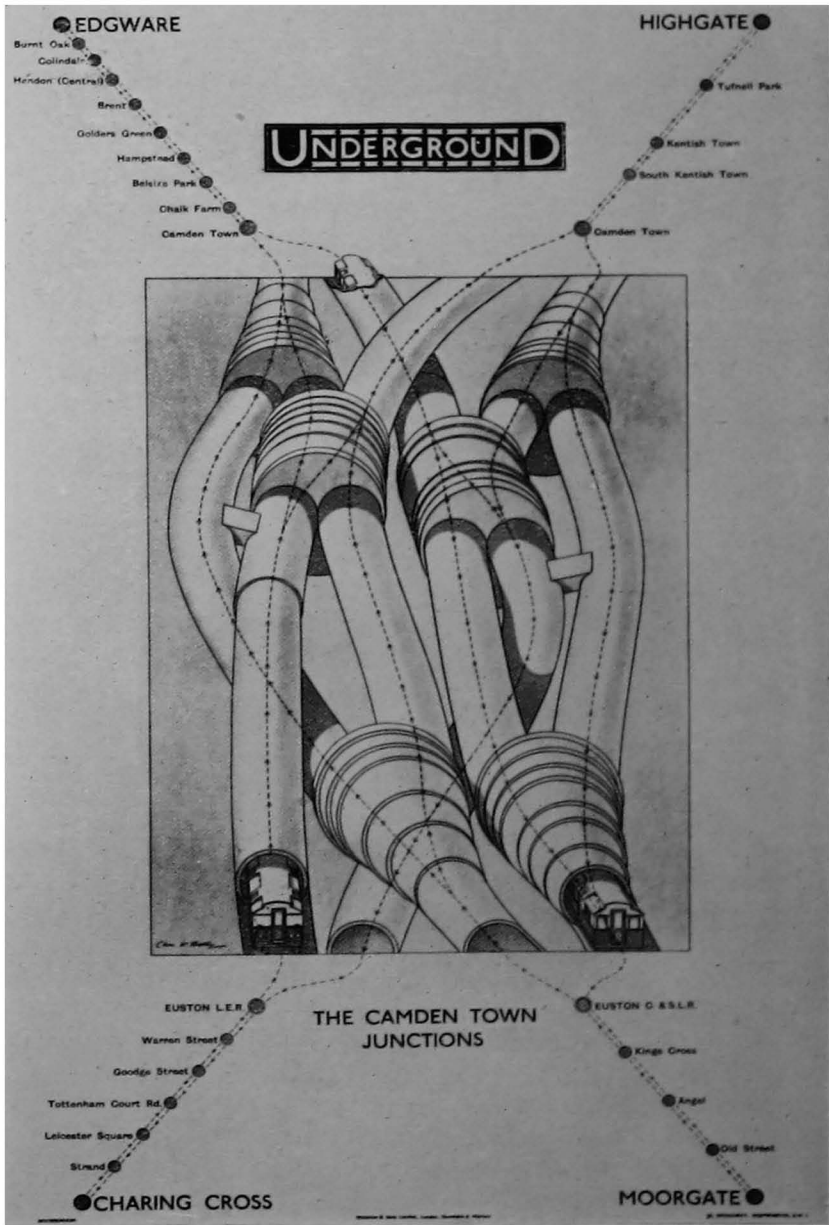


Fig. 43. Diagram of the Tube junctions at Camden Town.

at Leicester Square, whilst at Earl's Court there is a large book of the different sections of the District Railway. Another series of diagrams shows the position and nature of all lifts and escalator feeds, together with the local wiring of the trunk and selector switches at each station and their relation to the sub-stations. In the event of a lift-current failure the controller can see at a glance whether the pushing home of a selector switch (i.e. cutting out the trunk switch circuit) will isolate the point of trouble and enable the intermediate stations to be fed from the sub-station on the other side, or whether, as at some terminal stations such as Aldwych, the track selector switch must be used to take the lift-current from the track.

The signal cabins throughout the system may be regarded as the local centres of control, and it is to these that orders are transmitted from the control offices. There are thirty-nine signal cabins on the London Underground Railways, in charge of 120 signalmen, who, although taking their emergency orders from the controller, are expected to be able to deal with such minor points as the regulation of headways, when the latter become ragged, and the ordinary time-table working of a terminal station. The busiest signal cabin on the London Underground is that at Camden Town, which contains an all-electric power signal frame, as illustrated in Fig. 42. This box controls the working through a complicated system of tunnels comprising an extensive burrowing junction, as shown in the diagram Fig. 43, which enables the operation of an intensive service.

Signalling, however, is of sufficient importance to form the subject of a separate chapter and will thus be dealt with.

Chapter VII

SIGNALLING

POWER signalling is installed on all the lines constituting the London Underground railway system. All lines are track-circuited throughout, the single-rail type being used in all cases, except on the Central London Railway, where both running rails are used for traction current return, and, therefore, double-rail track circuits with impedance bonds are used. The original track circuits for all lines (except the Central London Railway) were direct current, each having two polarized track relays. Alternating current track circuits were first adopted on the Central London Railway, using single element vane relays. With various new works and developments, different types of A.C. track circuits and relays have been used, until at the present day the standard track relay is of the two-element vane type, the track circuit being of the direct condenser fed type.

CABINS AT JUNCTIONS ONLY

All signals are power-worked and cabins are only provided at places where there are junctions or points; most of the locking frames are for power operation and are fitted with miniature levers. The signals worked from the frames are of the semi-automatic type, being replaced to 'danger' when a train passes them, independently of the position of the lever. In most cases they are termed 'disengaged', that is, after being put to 'danger' they will not return to the 'clear' position until the lever controlling them has been replaced to the normal position in the power frame, and again reversed. This is accomplished by using what is known as a 'stick' relay. The back-locking circuits for the electric lock on the signal lever are also taken through this relay, and perform the following functions:

- (1) If a train has approached to within a certain distance of the signal, and the signal has been 'pulled off', the lever cannot be put back to normal until the train has passed beyond the clearing point of the junction, thus preventing a signalman putting back his lever and re-setting the road.
- (2) If, however, the lever is in the 'reversed' position, but the signal is at 'danger', due to the stick relay not having been picked up, and a train approaches the signal, it is possible for the lever to be put normal,

and pulled off again, owing to the back-lock circuit through the bottom contact on the stick relay.

To save employment of signalmen in the event of the temporary closing of the station or siding controlled from a particular cabin, many of the signal-boxes have been provided with 'king' levers. When pulled over, the king lever locks the signal levers for the straight through roads in the reverse position and thus enables the controlled section to be worked automatically; e.g., the cabins at the Angel and Stockwell on the City Railway are normally closed and the king levers pulled over, except when the sidings at these points are required for stabling trains.

GENERAL ARRANGEMENT

Signals between controlled areas work automatically and are normally 'clear', being placed to 'danger' when the section is occupied and returning to the 'clear' position when the train has cleared the section. Stop signals for passenger moves are provided with train stops. Points, operated from power frames, and all signals and train stops are worked by compressed air at approximately 60 lb. to the sq. in. controlled by electrically operated valves, with the exception of the signalling between Golder's Green and Edgware, which is all-electric, A.C. No block working is in operation on these lines, as all signals are controlled by track circuits, and information as to which track circuits in his control area are occupied is conveyed to the signalman by means of an illuminated diagram. These diagrams are provided in all signal cabins; they have proved extremely useful to the signalmen, especially in foggy weather, and make it much easier for new men to pick up the working of the cabin.

All signals on the Underground system are of the two-position type. They are considered the most suitable for a railway such as the Underground, where the headway is very close and the majority of the trains run at practically the same speed and the acceleration and deceleration are about the same. In the open sections signals are generally of the semaphore type, but recently signals of the day-colour light type (Fig. 44) have been adopted. These are brilliant lights shining through powerful prismatic lenses, and, shrouded by deep hoods, are capable of giving an extremely long range of visibility by day and night, and even in bright sunshine. All track relays, transformers, condensers, etc., for an automatic signal location are arranged at the signal position. It has been found that this makes the best arrangement for both construction and maintenance purposes.



Fig. 44. Two-position day colour light signal.



Fig. 45. A typical fog-repeater signal.

Although fog does not directly interfere with the operation of the tunnel sections of the Underground, any irregularity due to this cause on the open sections of line has its effect on the service throughout the system, and steps must therefore be taken to minimize delays owing to fog. What is known as a fog repeater signal has been found of considerable assistance in this respect. This consists of a short signal standard (Fig. 45), placed by the side of the running track, at the height of the train driver's eyes, and bearing two coloured lamps which repeat the ordinary signal ahead. This device is found to be a great improvement upon the old percussion fog signal still employed on the trunk railways, and it eliminates the human factor in the shape of the fogman.

'Automatic stop' signals are controlled entirely by the passage of trains: they are distinguishable from semi-automatic or manually controlled signals by having a white line (if 'semaphore') painted lengthwise along the face of the arm, and by having the letter 'S' prefixed to the station number of the signal.

As each signal is put to danger by the passage of a train and only released to the 'off' position when the train passes and puts to danger

the next signal, the block system common to trunk line operation is not observed on the Underground railways. The sections, i.e. the distance from one stop signal to the next, are considerably shorter than the 2 to 2½ mile block sections of a main line railway. The tendency latterly has been to increase the number of home signals on busy stretches of line, as this helps to counteract the effect of long station stops and to save the checking of trains at intermediate signals. The following have been recognized as interval headways (not including station stops), but should not be regarded as of general application:

One-home-signal equipment, 67 secs.

Two-home-signal equipment, known as 'home' and 'outer home', 59 secs.

Three-home-signal equipment, known as 'home', 'outer home', and 'inner home', 56 sec.

Four-home-signal equipment, known as 'home', 'outer home', 'inner home', and 'innermost home', 54 secs.

The saving of time between the three- and four-signal equipment is only two seconds; two seconds saved at a congested station may, however, afford essential relief in the operation of services of considerable density.

With a 30-seconds' stop the four-home-signal equipment on the District Railway tunnel section has enabled the operation of forty-two trains of six- and eight-car lengths per hour, whilst one-home-signal equipment allows of thirty-seven trains per hour only. The installation of a fifth home signal, which might at first sight seem indicated, would bring some of the home signals within station limits, entailing complication and expense not justified by the slight saving in time.

The maximum number of automatic home signals in operation in this country is four. On the Interborough Line in New York as many as seven sections are employed, but on an entirely different system known as 'speed control'.

STEPS TO INCREASE TRAIN DENSITY

Owing to the considerable growth of traffic on the Underground lines, the difficulty of coping with it in the congested areas in the centre of London has steadily increased, and as an alternative to new Tube construction, the signalling has been laid out to facilitate traffic operation. Thus, particular care has been displayed in the location of signals to maintain as far as possible an even time spacing between trains, retaining overlaps on all signals. An endeavour is also made to prevent trains being stopped in the tunnels, as passengers dislike this experience.

Additional home signals have also been installed to enable following trains to approach a station as soon as the preceding train commences to move out. As it is necessary to provide for a 90-seconds' service on many parts of the line—with a 30-seconds' station stop—it will be appreciated that the lay-outs of these signals must be carefully arranged. In one of the worst cases four home signals were installed, and during a special traffic test it was found that 30 trains passed through the station in 41 minutes 32 seconds, being at the rate of 83 seconds' headway, or over 43 trains per hour on one road. The maximum number of trains per hour operated on the New York lines over stretches exceeding two or three miles is thirty-four.

To maintain such a service as that on the Underground, it is essential that the 'station stop' should not exceed 30 seconds, and to help in this respect at certain busy stations a siren is sounded when the train has been at rest for that period or some other predetermined period. This siren was originally hand-operated, but subsequently the signal department was asked to work it automatically. This is now done by means of a special mechanism, which is brought into action by the breaking down of the platform track circuit, and after a definite time the siren is sounded provided the starting signal is 'off' and the train has not started-up. The circuit is taken through a contact made when the signal is at 'clear'; the siren, therefore, does not operate if the signal is at 'danger'. The siren is automatically prevented from sounding after a train has started-up.

On the Underground all 'stop' signals governing passenger train movements are provided with a train-stopping device, which consists of an arm which engages with a trip-handle on an air cock on the train, and applies the brakes in the event of a train attempting to pass a signal at 'danger'. In view of the great importance attached to this device, it was considered advisable in the latest signalling installations to provide detection of the position of the train-stop arm, to make sure that it was functioning correctly, and that the head had not been broken off. This has been effected by providing a circuit-breaker box which is operated from the head of the train-stop arm.

TRAIN DESCRIBERS

When block working was dispensed with it became very necessary to give signalmen controlling junctions, etc., an indication of the destination of approaching trains, and this destination is also shown on platform signs, for the information of passengers, by means of 'train describers'. The signalman at the end of the line or section sends a

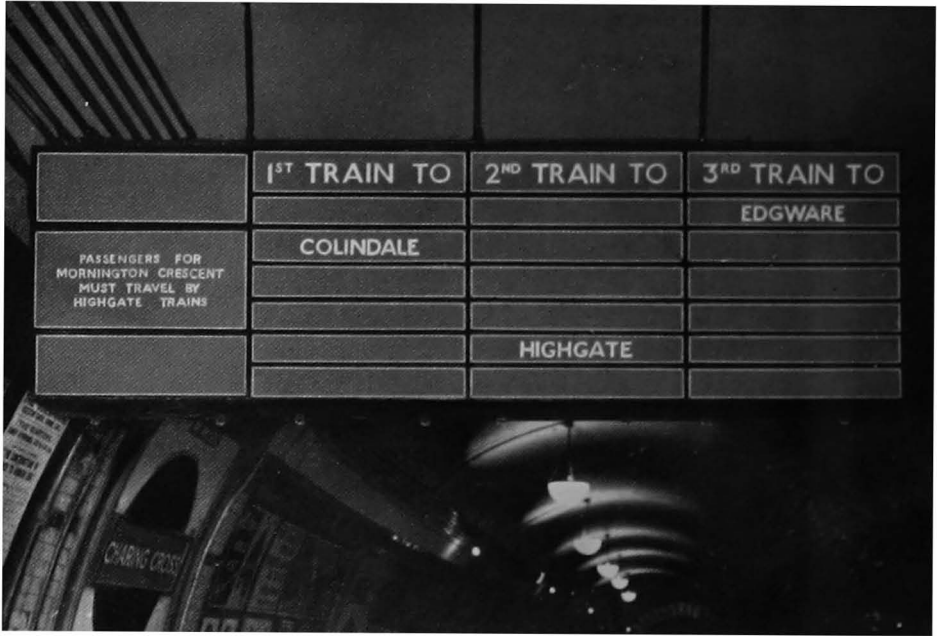


Fig. 46. Illuminated platform train indicator, Charing Cross (Hampstead Line).

description of each train as it leaves him. These descriptions are received and stored up electrically at each station throughout the section and in the signal cabin at the end thereof, and are shown up on signs in their correct order. As each train passes out of a station or section, the description applying to that train is automatically cancelled and that of the following train is revealed in its place. Typical platform indicators are shown in Figs. 46 and 47.

In sending out the train descriptions the departure station signalman operates a transmitter, consisting of an ebonite disc, on the face of which are a number of brass segments. The disc is free to revolve and it is fitted with a handle and pointer. Four contact springs, one connected to each line, are arranged so as to press on the face of the disc, and as the disc revolves, the springs come into contact with the brass segments at various parts of the revolution. On one side is a lever which, when pulled, operates a switch and transmits current to the brass segments on the disc and then on to any springs which may be touching the segments. The signalman turns the handle until the pointer is opposite the description he wishes to send, and, by pulling the lever, puts current on to the combination of lines that corresponds to this description.



Fig. 47. Another type of platform train indicator (District Line).

At each station there is an instrument which receives and stores up the description until required (Fig. 48). It consists of a metal drum which revolves in its bearings. Around the periphery of the drum are a large number of studs. These are arranged in four rows, and below them are four electrically operated hammers—one connected to each line. When the hammers are energized they strike the studs above them, knocking them inwards. They remain in this position until released, the drum revolving round a step in order to bring another set of studs above the hammers. Inside the drum are four springs, so arranged that they make contact on those studs which have been driven in.

From these collector-springs current is taken to the combinator, and it is here that the combinations are sorted out into their various descriptions. The combinator is an arrangement of four coils, each with an armature fitted with a large number of contacts and circuits, and so arranged that through these contacts, according to the combination of coils energized and de-energized, the description is sorted out and the appropriate sign illuminated. When the train leaves the station the collector-springs are moved on to the next set of studs, and the cancelled studs are released. On the busier stations the receivers are fitted

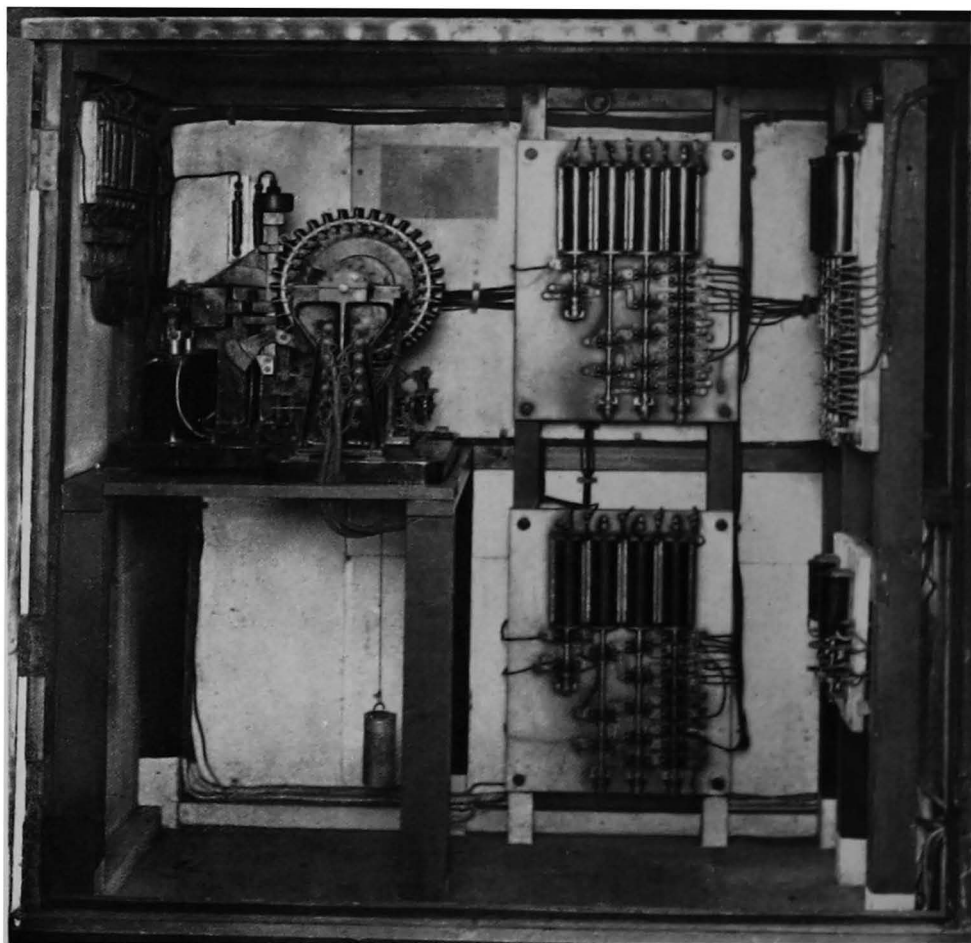


Fig. 48. The instrument which receives and stores up train descriptions transmitted to it from the station in the rear.

with three sets of collector-springs and three combiners, thus enabling the destinations of the next three approaching trains to be given.

FOLLOWING-UP SIGNAL FAILURES

It will readily be appreciated that where traffic is worked at the rate of 35 to 40 trains per hour—and in some cases up to 43 trains per hour on one road—a signal or point failure will very quickly disorganize the

system; if a train is held up for only a few minutes the following trains will be checked for a considerable distance in the rear, and should this failure remain on for any length of time, practically the whole service comes to a standstill. The system of tabulating and investigating signal failures on the Underground railways is, therefore, fairly elaborate. A signal report failure form is made out by the signal lineman for every reported failure of the apparatus to operate correctly. The reports of the failures of the previous day are dispatched from the various depots to the signal engineer's office by 8 o'clock each morning. At the same time a report is received from the traffic controllers regarding all signal failures reported to them, together with the delay caused in each case. These sheets, together with the reports from the linemen, are perused by the signal inspector, and are then examined personally by the chief signal engineer.

At the end of each half-month all the signal reports are classified under about twelve main headings, from which a curve is drawn showing the number of failures up to date. This gives an early visible indication of any sudden increase in the average number of failures. At the same time they are also classified under the various maintenance sections, and at the end of each month particulars of the number of failures on all sections of the line are sent out to each lineman's depot. This information stimulates interest in the men who are directly concerned in the maintenance of the signalling apparatus. In addition to the main headings referred to, for office purposes the failures are again split up into a much larger number of causes of failure, this analysis being principally used to find out the weak parts of the signal system. At the end of each year this analysis sheet is examined very carefully and compared with the results of the previous year, when some idea can be gathered as to the type of failure which has given the most trouble during the year, and also as to whether any new arrangement for reducing failures has been successful.

On an average, over a period of two years, the failures of automatic signals on the whole of the Underground represent 1 in 213,857 movements, each of which implies the movement of the signal and train-stop to 'danger' and the subsequent resumption of the 'clear' indication. The failures referred to, whilst not in any way endangering the service, are the cause of momentary delay due to the signals remaining in the 'danger' position when they were due to be in the 'clear' position. Causes of such failures may be a blown fuse or a temporary bridging of insulated block-points by brake-block dust, to which the delicate apparatus is highly susceptible.

Chapter VIII

EMERGENCY DEVICES

IN railway operation efforts must at all times be directed towards the institution of safeguards against mechanical or other defects and against failure on the part of the human element; an intensive passenger service necessarily demands the closest consideration from this point of view. The main precautionary measures comprised in modern signalling have been reviewed in previous chapters, and it now remains to discuss the more important emergency and other control devices which are employed on the London Underground Railways. The density of the service and the limited space in which the trains are operated render imperative the adoption of the most efficient appliances to ensure that traffic operation shall be conducted in safety and without delay. In view of the peculiar requirements of underground railway working, many hitherto unknown expedients have had to be adopted by the administration; consequently, in the introduction and use of many safety appliances the London Underground Group have been the pioneers, and many interesting and ingenious devices are in use; these will now be briefly reviewed.

TUNNEL TELEPHONE

In the event of a failure of electric insulation in the tunnels of the Underground, either in the cables, the conductor rails, or the train equipment, the results are liable to be of a more serious nature than those on an open track, for, although there is an almost entire absence of combustible material in the car and tunnel equipment, the fumes from arcing caused by burning insulation, having no outlet to the open air, spread rapidly through the tunnels and may alarm the passengers. In such an emergency it is essential that the current should be cut off with the least possible delay. Two bare telephone wires are, therefore, suspended along the sides of the tunnels throughout the Tube Railway, and each driver is provided with a portable telephone set, which, when hooked upon the bare wires, as shown in Fig. 49, places him at once in communication with the sub-station.

The driver need not leave his cab, as the telephone wires are within easy reach. Conversation, however, is apt to be interrupted by the noise of passing trains and of the machinery in the sub-stations. Moreover, there must be a disadvantage if the driver alone is able to communicate with the sub-station attendant. Hence, it was decided that any member



Fig. 49. A driver using his portable telephone set. By hooking the terminals to the bare wires in the tunnels he is enabled to communicate with the sub-station.



Fig. 50. The action of pinching the wires in the tunnel, as shown, enables the train-man, in emergency, automatically to operate the sub-station cut-out.

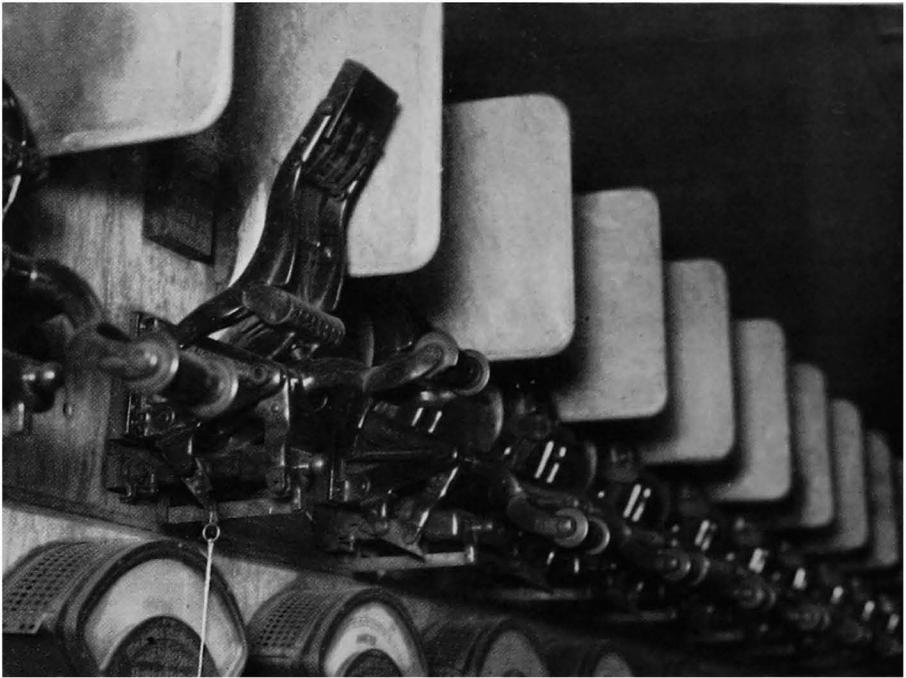


Fig. 51. Automatic operation of sub-station cut-out consequent on the pinching of the wires in the tunnels.

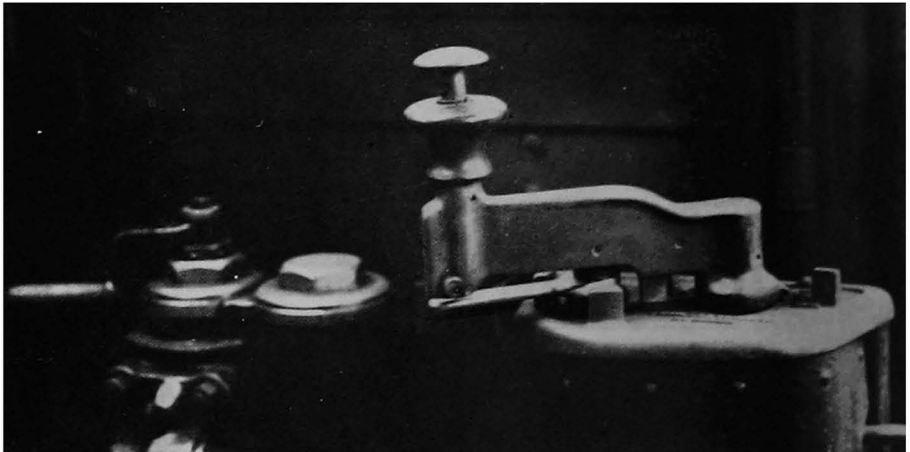


Fig. 52. The 'dead man's handle'. It consists of a knob, superimposed on the knob of the controller handle. If the driver should release his pressure on it the train is brought to a standstill by the automatic application of the Westinghouse brake.

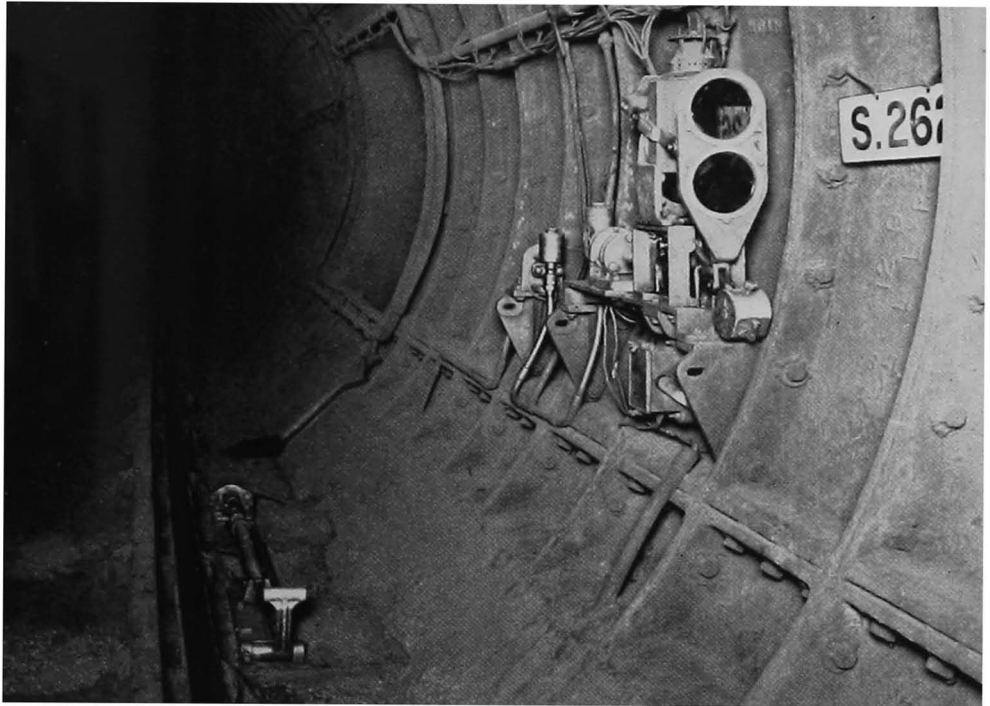


Fig. 53. The trip cock, by means of which a train is brought to a standstill should the signal be passed in the danger position.

of the train crew, without leaving his post, should give the signal to the sub-station attendant to cut off the power by merely pinching the telephone wires together with his fingers, as in Fig. 50.

The need for saving seconds, however, impelled the company to go a step further and to arrange so that the action of pinching the telephone wires should automatically operate the sub-station cut-out (Fig. 51) without the intervention of the attendant. Cutting off the main current from the conductor rail immediately reduces the danger from smoke, and enables the passengers, if necessary, to walk with safety along the permanent way to the nearest station. In this they are assisted by the lights in the train and also by electric lamps in the tunnels, which are switched on by the same operation that cuts off the main current.

'DEAD MAN'S HANDLE'

If, in the event of the driver being disabled, it were possible for a train to run uncontrolled, it would be brought to a standstill at the next stop

signal by the operation of the trip cock. It is desirable, however, that a train should be pulled up immediately control over it is relaxed, and for this purpose a device called the 'dead man's handle' is used on all the trains of the Underground. This appliance consists of a flat knob, superimposed on the knob of the controller handle and supported by a spring weak enough to be held down without effort by the driver's hand when operating the controller handle, as shown in Fig. 52. So long as this knob is depressed the normal operation of the controller can proceed, but if the pressure is released or the hand removed, power is at once cut off and the brakes are applied.

The 'dead man's handle' ensures the safety of the passengers if the driver is suddenly incapacitated. Provision, however, is also made for any momentary absent-mindedness, which might otherwise result in a signal being passed at 'danger', by the use of a trip cock. This appliance (Fig. 53) consists of a short lever fixed on the permanent way and connected with the signal.

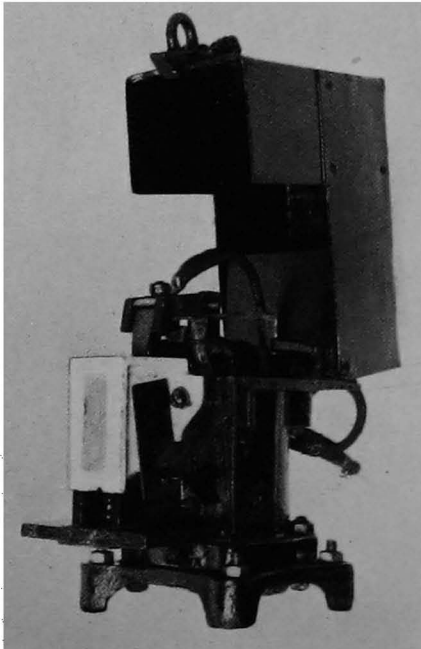


Fig. 54. The brake governor, which prevents a driver from starting his train unless the requisite air pressure exists in the Westinghouse brake system.

When the signal is 'off' the lever is depressed clear of the train, but when the signal is set to 'danger' the lever rises to a vertical position in the path of an arm on the train attached to the air brakes, putting them full on and bringing the train to a standstill within its own length.

Another check on the human element consists of a device called the 'brake governor', which prevents a driver from starting his train unless the air pressure in the Westinghouse brake system is up to the required standard. This is an electro-pneumatic device (Fig. 54) which prevents the passage of current to the train motors if the air pressure in the braking system is below 50 lbs.

HEADWAY CLOCKS AND CHARTS

In order that a train driver may not unconsciously be following the

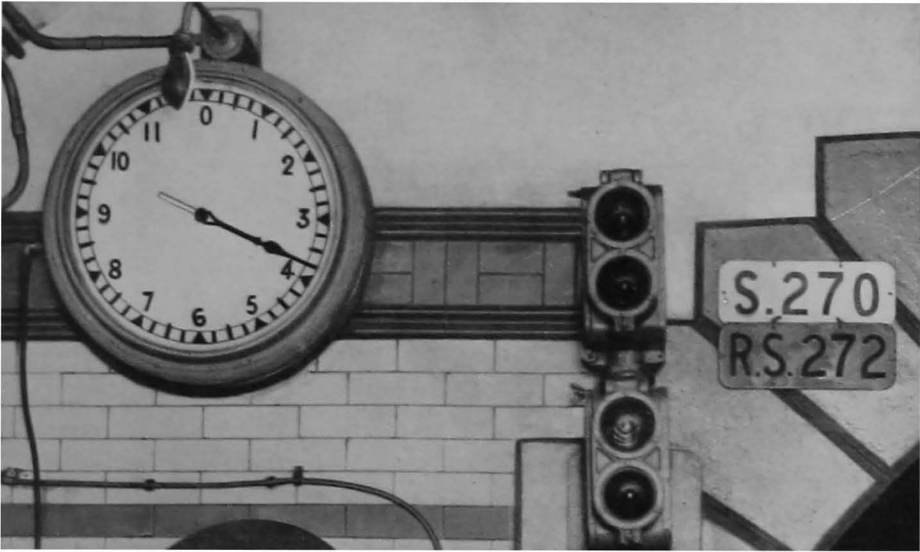


Fig. 55. The headway clock, which indicates to the driver the distance ahead of the preceding train.

train ahead at too close an interval, headway clocks are installed at many stations where a close service is in operation. The headway clock (Fig. 55) works automatically. It is set automatically to zero by the passage of a train out of the station, and from that instant begins to record the seconds as they elapse until it is again set to zero by the passing of the next train. Both driver and guard are thus given a warning as to the proximity of the train in front, and can take the necessary measures for the restoration of a proper headway.

The headway clock warning is invaluable for the maintenance of a proper service interval, and at first sight one would imagine that its record was a transient one. This is not so, however, for attached to the mechanism is a circular paper chart divided into hourly spaces (Fig. 56). During that period the chart revolves, and as each train passes out of the station an electrical contact causes a hammer to descend on to an inking ribbon, stamping a short line against the exact time on the chart. A permanent record of the headways of trains throughout the service is thus to hand daily; this may be compared with the scheduled times and any discrepancy investigated. A further indication of train running is given to the driver at Earl's Court Station, District Railway, where, by means of illuminated signs (Fig. 57), he is advised the number of minutes his train is running before or behind schedule time.

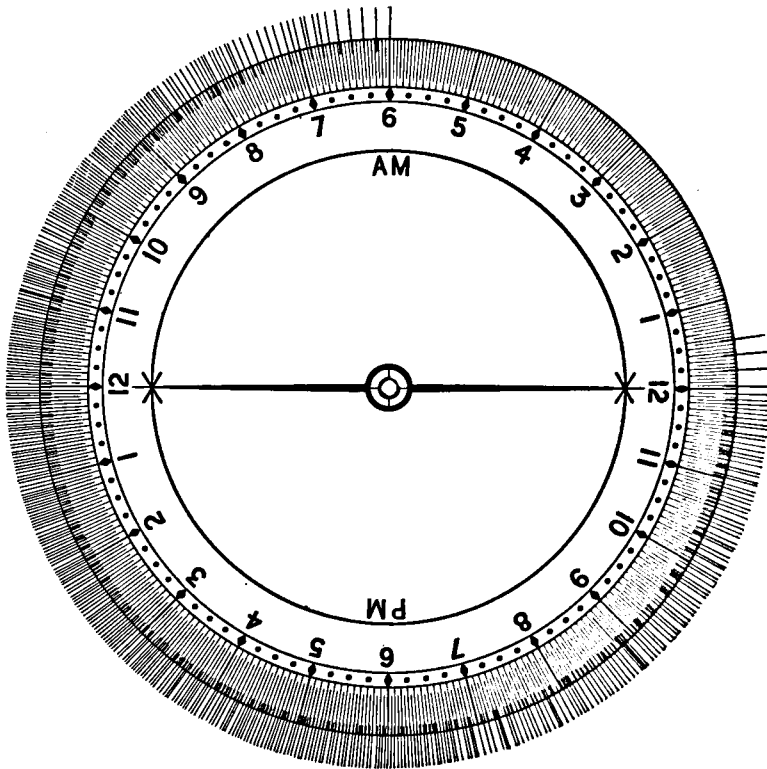


Fig. 56. The headway chart which, working in conjunction with the headway clock, records the passage of trains throughout the day.

Recently six recording clocks have been installed in the entrance hall to the Underground general offices at 55 Broadway, Westminster, and in the controllers' offices, as well as at certain stations for the information of the public. Separate clocks are provided for each railway (District, Bakerloo, Piccadilly, Hampstead, Central London, and City), as shown in Fig. 58. The faces of these clocks are similar to the headway clocks described above. They consist of paper dials covering the twenty-four hours, and they are connected up electrically with a contact lever on the track. The passage of an individual train past a given point makes an electrical contact, which causes a small inked hammer to strike the fringe



Fig. 57. Illuminated train-running indicator at Earl's Court.

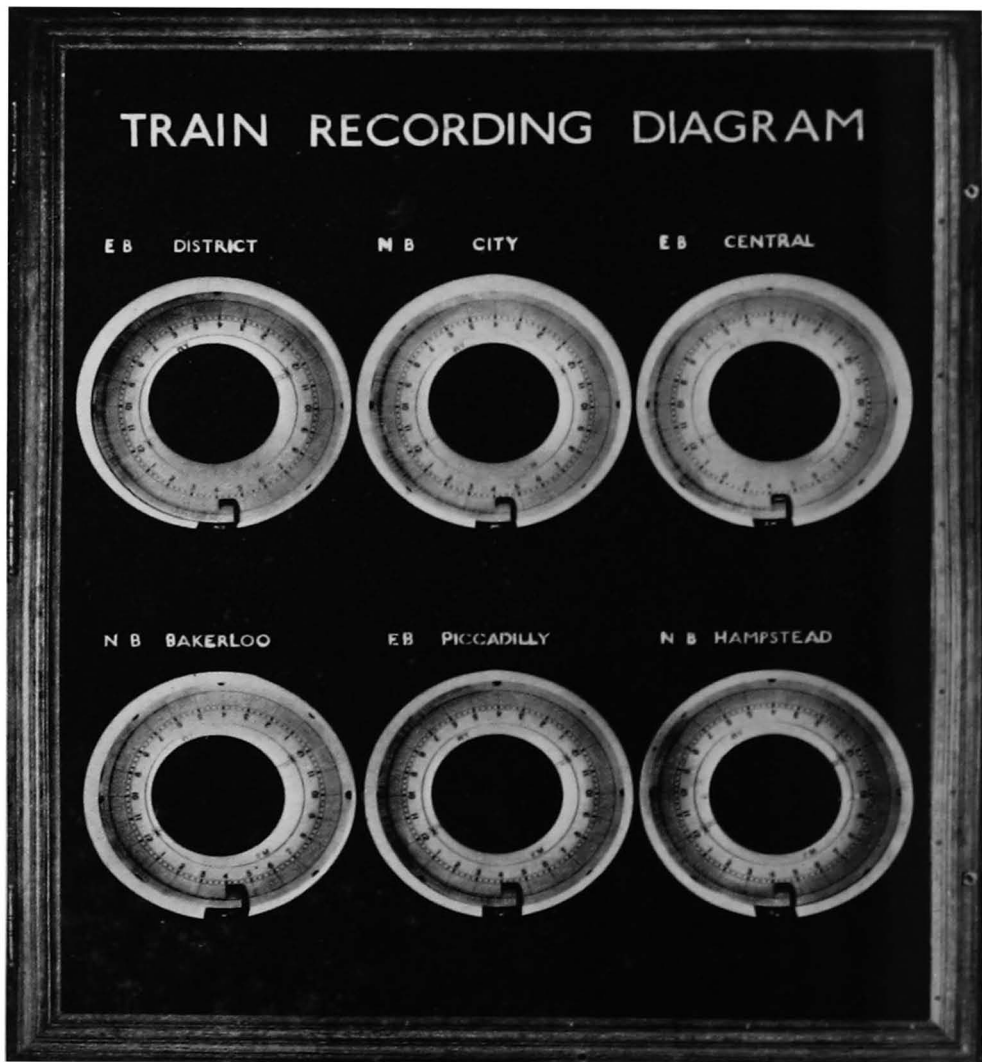


Fig. 58. Automatic train recording clocks, as installed in the controllers' offices and at headquarters.

of the dial. The dial itself rotates at the equivalent speed of a clock, and as the hours go by, the periphery reveals a number of fine markings. These, if equidistantly spaced, show that the trains are running to schedule. The dial makes a complete revolution in the nineteen hours of traffic, and a record of the day's working is thus obtained. If, however, the service is not working smoothly, gaps appear upon the dial.

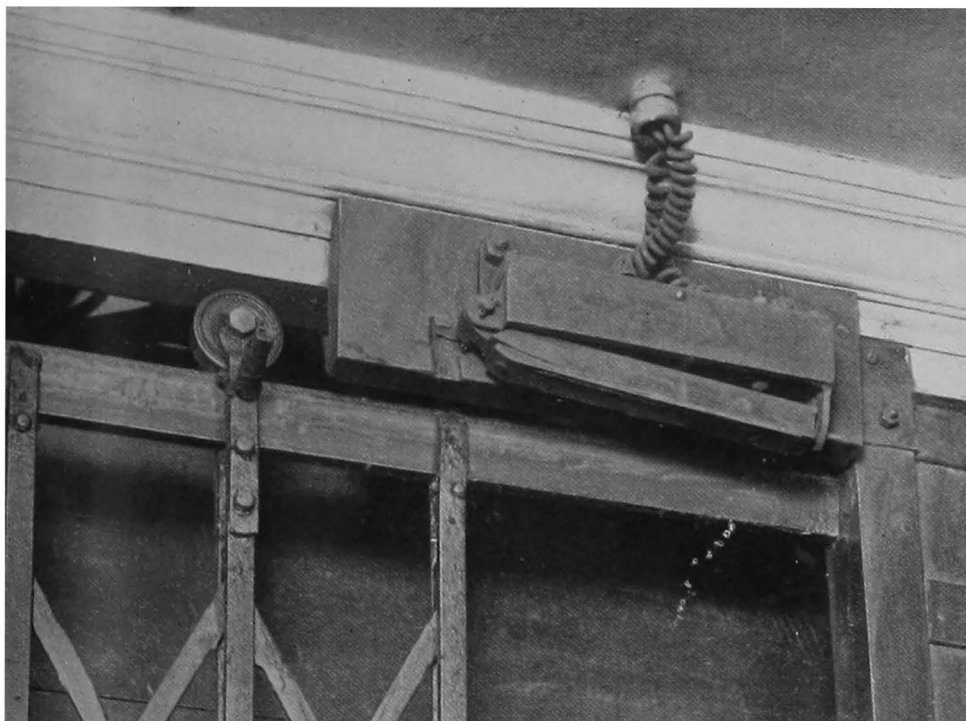


Fig. 59. The safety catch, which prevents a lift being started before the gates are closed.

The dial itself affords no explanation of what has occurred. There is, therefore, installed in conjunction with the clock a machine which will set out particulars of the incident causing the derangement, when such occurs, stating the locality and what changes are necessary to correct it. As mentioned in Chapter VI, these news-recording instruments will be installed at all the depots, so that the engineering and operating staff will be advised at once, and simultaneously, of the occurrence. They will be operated from the controllers' offices at Leicester Square for the Tube railways, and at Earl's Court for the District Railway. By this means it is hoped to minimise any delay which may follow from a mishap and further to improve the standard of operation upon the railways as a whole.

LIFT SAFETY DEVICES

As with the trains, so with the lifts: mechanical control is used, wherever possible, in preference to, or as a check upon, human control. To

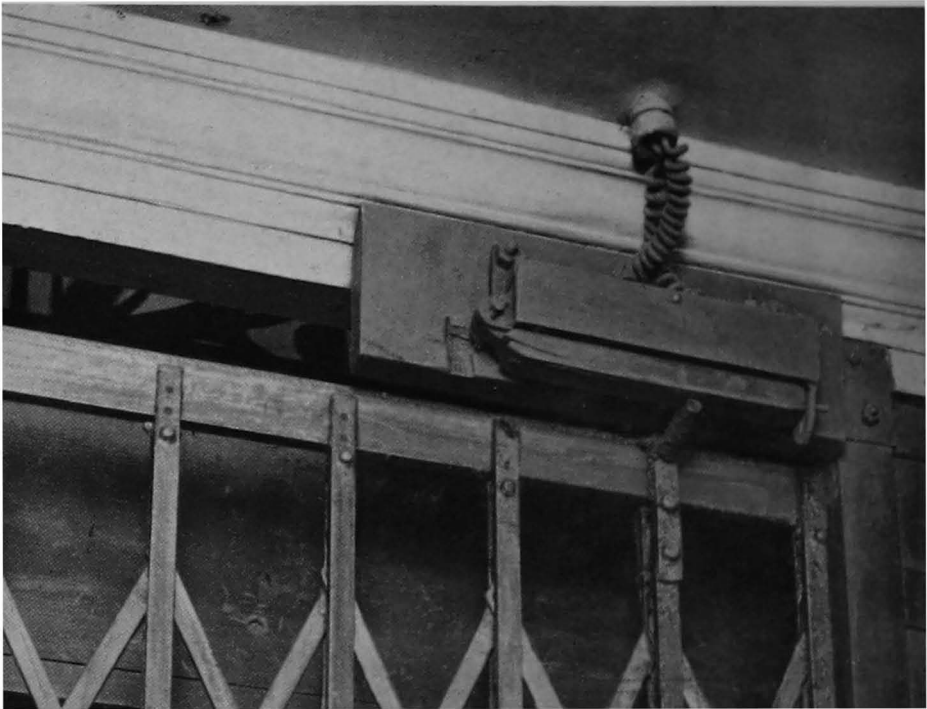


Fig. 60. Another view of the lift safety catch. It is here shown in the closed position, having been put out of action by the closing of the gate.

guard against the possibility of a lift starting before the gates are closed, a device known as the safety catch is used. (Figs. 59 and 60.) This is a switch fixed in the path of the folding gate and held in an open position by a spring whilst the gate is open. In this position no current can pass to the lift controller, and the lift is immovable, and it is not until the closing gate overcomes the resistance of the spring, and the switch is closed, that the lift may be started.

A further safety device, called a lift governor (Fig. 61), regulates the speed of the lift, which might otherwise be allowed, under human control, to exceed the safety limit and endanger the occupants. It is in the form, familiar to engineers, of two metal balls held by arms to a vertical shaft and free both to revolve and to move in a vertical direction by centrifugal force: when the speed of the lift becomes excessive the governor actuates a powerful brake, which brings the lift to a standstill.

Recent developments in mechanical control enable lifts to be operated without an attendant travelling in them. Known as 'landing control',

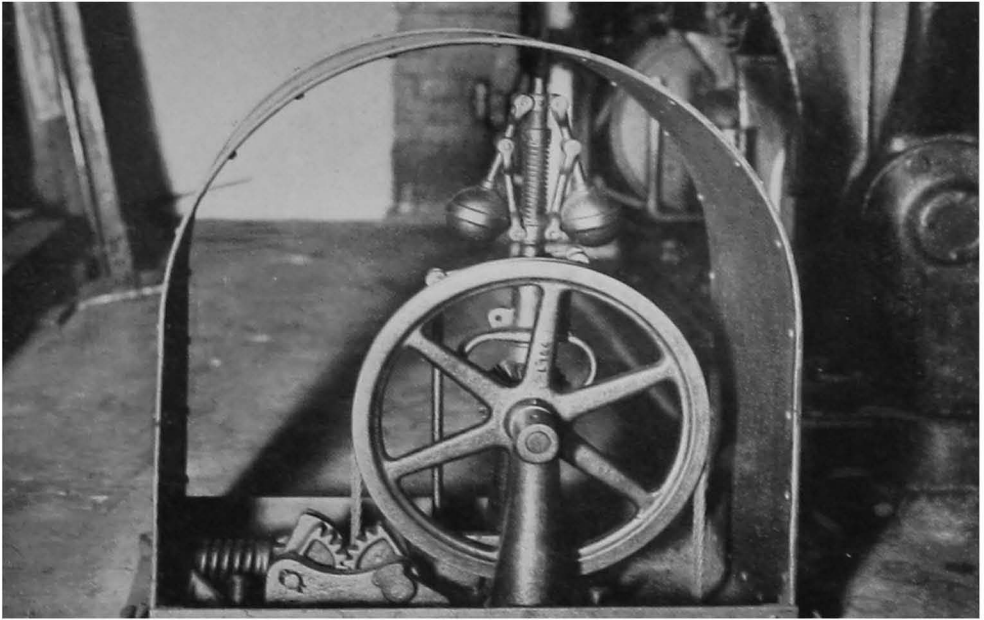


Fig. 61. The governor, by which the speed of the lift is regulated.



Fig. 62. A lift being manipulated by means of the landing control equipment.



Fig. 63. The emergency door, by means of which passengers in a disabled lift can gain access to an adjacent one and thus continue their journey.

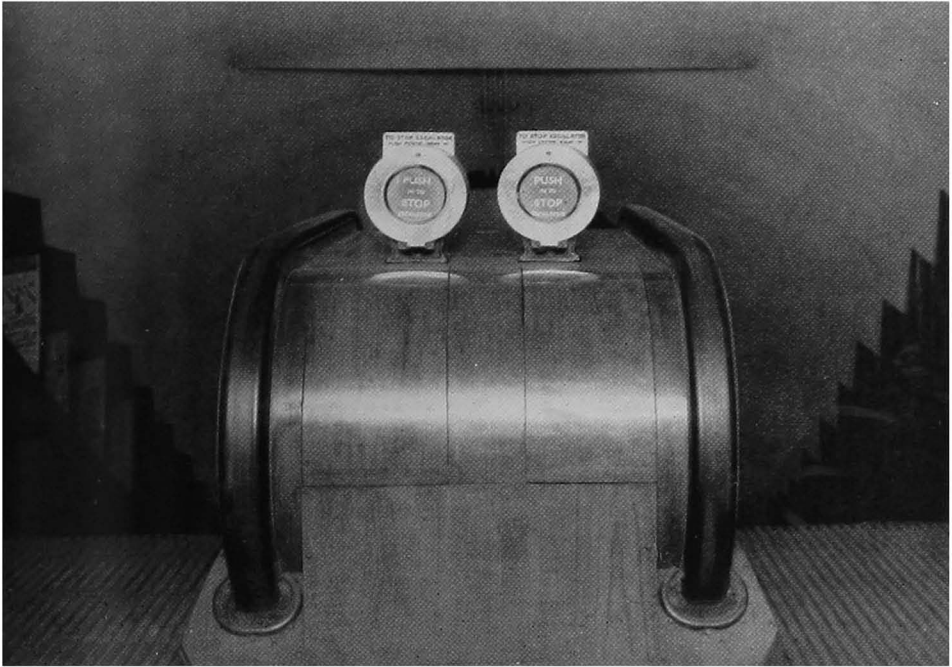


Fig. 64. The device for stopping escalators in emergency.

this is an almost completely automatic system of operation (Fig. 62). The control on the part of the attendant consists in supervising the entry and exit of passengers and closing the gates, all other movements, including acceleration and deceleration, being performed automatically. By this system, with the attendant permanently stationed on the landing and several lifts under his control, a more regular service can be given and the waiting time of the passenger curtailed, while there is a resultant economy in staff.

Lifts are generally installed in pairs in the same shaft. If a defect in the controlling mechanism should cause a lift to stop midway in the shaft, an emergency outlet for passengers can be arranged by bringing the other lift to the level of the disabled one. A door in each (Fig. 63) can then be opened and the passengers may step from the one to the other and be brought to either landing. These doors are normally unnoticeable, being hidden by the advertisement frames, which swing with them. In the event of the complete breaking down of a lift, special hand-winding gear is provided by which it can be raised to the top of the shaft in a few minutes. Such an occurrence as this, however, is rare and



Fig. 65. A car equipped with the end doors that have now been superseded.

has not occurred more than a dozen times altogether since the railways started.

The latest method of transport on the Underground—the escalator—is so simple and safe that the only emergency device considered necessary is one that enables the staff and/or passengers to stop its movement. This is in the form of a small metal drum (Fig. 64) having a paper diaphragm, beneath which are two bare wires. When an emergency arises the paper diaphragm is broken and the wires pinched together with the fingers, thus operating an automatic cut-out controlling the escalator current. The escalator equipment is, of course, fully protected against any contingency that might arise through mechanical or electrical defect.



Fig. 66. A car with the new type of air-controlled doors.

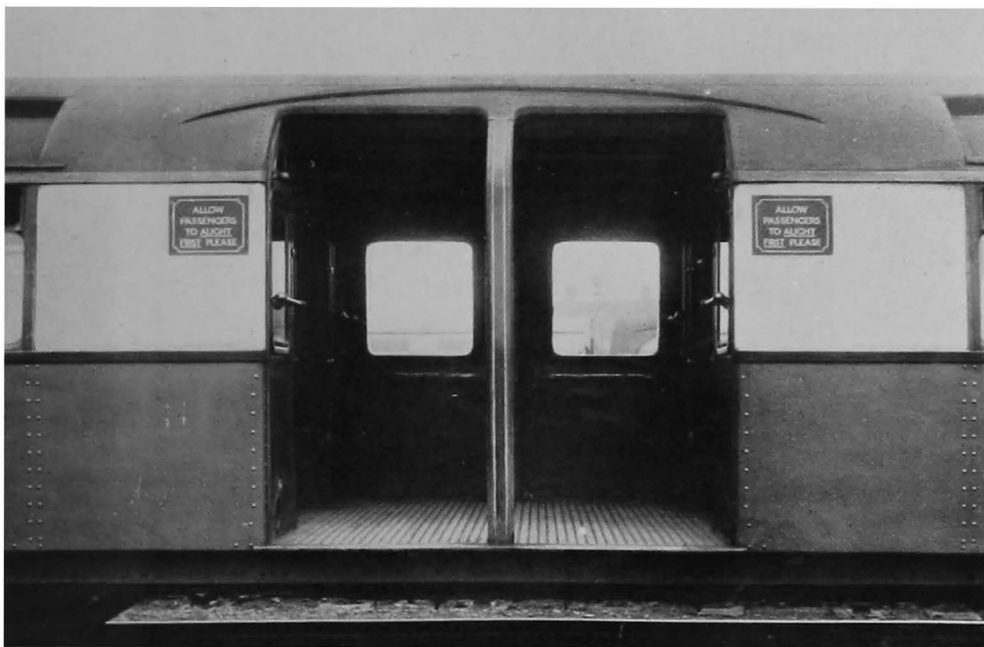


Fig. 67. A near view of a pair of pneumatically-controlled doors. Automatic retardation of the movement of the doors prevents any possibility of injury to passengers.

AIR-CONTROLLED DOORS

Pneumatically, controlled doors were introduced on Underground rolling stock in 1921. The innovation has met with unreserved public approval and this type is rapidly superseding that worked by hand, the new doors being controlled and operated by the guard. Nearly 700 cars of the new type are in daily service. On a six-car train the door service is nearly doubled. The great objection to the old type of car is the inadequate door service, whilst the new type provides a spaciousness which adds to the comfort and speed of the user, particularly the short distance passenger, who needs to be in a position to get out quickly without having to pass to the centre of the car. The advantages of the new over the old type of car may be seen by reference to Figs. 65 and 66, while a near view of a pair of doors is shown in Fig. 67. It may be mentioned that stop-watch observations have shown that at crowded stations the time occupied in the loading of individual trains has been reduced from 45 to 22 seconds, a saving of 100 per cent.; at slack stations, however, the stop is about the same with both types of train.



Fig. 68. This equipment includes a signal light which appears only when all doors are closed. Until then the guard cannot operate the bell signal to the driver to start.



Fig. 69. A driver telephoning to the guard on one of the new trains; notice the loud-speaker just behind the driver's head and in line with his left ear.

Safety devices are provided to prevent the trains from starting unless all doors are closed. When every door is closed the driver receives a bell signal which can be operated by the guard only when all is clear. (Fig. 68.) It should be noted that the air pressure of the doors is retarded to a great extent during the last five inches of the stroke, so that the doors can easily be held open by the hand; in addition, soft rubber-cushioned edges are provided and physical injury cannot possibly be inflicted by the closing of doors.

TELEPHONE COMMUNICATION ON TRAINS

It is the policy of the company to reduce to a minimum all forms of automatic or routine manual work, such work being monotonous and



Fig. 70. A guard in telephonic communication with his driver, the loud-speaker in this case being fixed in the roof.

often wasteful, and the aim has been to develop and perfect such devices as will enable electric railway operation to be carried out by a limited but skilled staff. Originally each six-car train on the Tube railways required the services of six men—a driver, a guard, and four gatemen—but the pneumatic system of door control has enabled even a seven-car train to be operated efficiently merely by a driver and a guard. To provide direct communication between these two officials, which may



Fig. 71. The plunger can be operated by the platform staff for the purpose of closing air-controlled doors in the front part of the train.

at times be necessary, a microphone and loud-speaker have been installed in the driver's cab and on the guard's platform on the rear car. Figs. 69 and 70 show these instruments in use, the loud-speaker being by the driver's left ear.

The device is of advantage in many ways; for example, the guard may receive special instructions regarding non-stopping, or, in the event of a breakdown, say, on the Hampstead and City line, he may have a slip handed to him containing particulars of alteration in route. By means of the microphone he can inform his driver of the facts without confusion or delay.

To meet the circumstance of a driver over-running a station to the extent, say, of half a car's length, resulting in the front doors being within the tunnel, he can operate a switch in his cab which will keep the front doors closed; passengers are thus prevented from leaving that portion of the train which is not at the platform. Another device on the new trains consists of a plunger (Fig. 71), which may be operated by the platform staff to relieve congestion at the front part of the train and assist in its getting away to schedule. A porter in the centre of the plat-

form has a better view than the guard of the passengers entering the forward doors, and can watch his opportunity for closing the doors at a favourable moment. This he does by the simple expedient of pushing in the plunger.

It is largely by the adoption of such devices as those described that the passenger by Underground can be conveyed at a higher speed and with greater safety than upon the roads. Whereas the average speed on the Underground railways, including station stops, is approximately 18 m.p.h., that of surface transport is between 9 and 10 m.p.h., whilst, according to official statistics, the number of accidents to passengers on the Underground averages .3 per million carried as against 2.3 per million in the case of passengers by omnibus and tramcar. And, be it noted, no passenger has so far received fatal injury as the result of any train accident on the London Underground Railways.

Chapter IX

ABNORMAL TRAFFIC MOVEMENTS

ABILITY to handle large crowds is an indispensable condition in the operation of every large passenger-carrying company. The public on these occasions expects to be conveyed with speed and comfort—reasonable comfort, at any rate—and whilst the resources of the transport undertaking concerned may be taxed to the utmost, the arrangements are not infrequently the subject of criticism. It is, therefore, particularly necessary that all concerned in the operation of abnormal flows of traffic should co-ordinate their endeavours to ensure efficiency. This is invariably the aim of the staff of the Underground railways.

Seasonal events, such as the Oxford and Cambridge Universities' Boat Race, the Football Association Cup Ties, the opening of Parliament, the Lord Mayor's Show, the Wimbledon Tennis Tournaments, Cricket at Lord's and the Oval, Exhibitions at Olympia and the Agricultural Hall, Bank Holidays at Hampstead Heath and Hampton Court, and Chestnut Sunday at Bushey, draw approximately the same crowds year by year. The Bank Holiday travel habit, however, is always undergoing some change or other. The volume of traffic to Hampstead Heath, Hampton Court, and the Boat Race is definitely less than twenty years ago. This, no doubt, is attributable to the amazing increase in the use of road motor-vehicles; it is also due to the general and obvious desire of the populace to get into the country and away from the drab monotony of bricks and mortar.

The number of people visiting Hampstead Heath on Bank Holidays has fallen by possibly 20 per cent., whilst the number to be found, on such occasions, in the fields and woods on the outer fringes of London is noticeably increasing. Nevertheless, there still remain all those who have to be conveyed to the local amusement resorts, and for whom careful preparation must be made, and usually every vehicle which can reasonably be worked is pressed into service, and additional and supplementary staff appointed. The service to be provided is measured by the flow of traffic on the previous year or occasion—a fair guide in view of the slight variation in consecutive periods.

The results of inclement weather must be guarded against. Usually on public holidays the world and his wife wear their best attire and hesitate to take with them either waterproof or umbrella. It only needs a shadow over the sun to remind them of the Underground, and a storm

will bring them back post haste to its shelter. The services of the railway staff and police must then be used to the utmost, and the special barriers, which are generally erected to meet such an emergency, prove their utility, for the rate at which passengers are allowed to flow into the stations and trains must be carefully regulated. At Hampstead Heath Station, for instance, the official deputed to control the platform indicates by an electric bell code to the booking-hall controller when the latter must 'ease up' or 'stop' the flow, and thus avoid over-congestion on the platforms and subways, and invariably the passengers have the good sense to submit unhesitatingly to the behests of the police and the traffic officers.

FOOTBALL CROWDS

Football crowds are probably the most difficult to deal with, for the reason that the forward and return traffics constitute two exceedingly heavy peaks separated by a comparatively short period of an hour and a half. The peak loads present themselves suddenly and cease just as abruptly. There is no spreading out, as at a cricket match or tennis tournament, where the traffic is on the move almost throughout the hours of play. At Gillespie Road—the station adjoining the Woolwich Arsenal Football Ground—the Piccadilly line is called upon to deal with 20,000 passengers, and this it does during the brief period of fifty minutes before and again fifty minutes after the match (Fig. 72). Football enthusiasts are inclined to be excitable and need firmer methods of control than usual. On these occasions, in particular, the closest co-operation between the Metropolitan Police, the railway officials, and the ground authorities ensures uniform safeguard against disturbance of any kind. The police officers command authority and respect, and the moral effect of the mounted police, who usually attend as a precautionary measure, is particularly apparent.

Difficult conditions prevail at Gillespie Road as, by reason of the close proximity of the football ground to the station, there is no gathering space in which to marshal the outgoing passengers. However, by careful attention to the design of barriers, to the assignment of staff, to the ticket-issuing arrangements, and to the use of outside police, it is possible to maintain a steady and unbroken flow of people right from the ground on to the station platforms.

Another point at which football crowds congregate is Walham Green, the station for the Chelsea Ground, which on several occasions has accommodated as many as 75,000 people. The only railway serving this ground is the District, but transport is undertaken also by the omnibuses

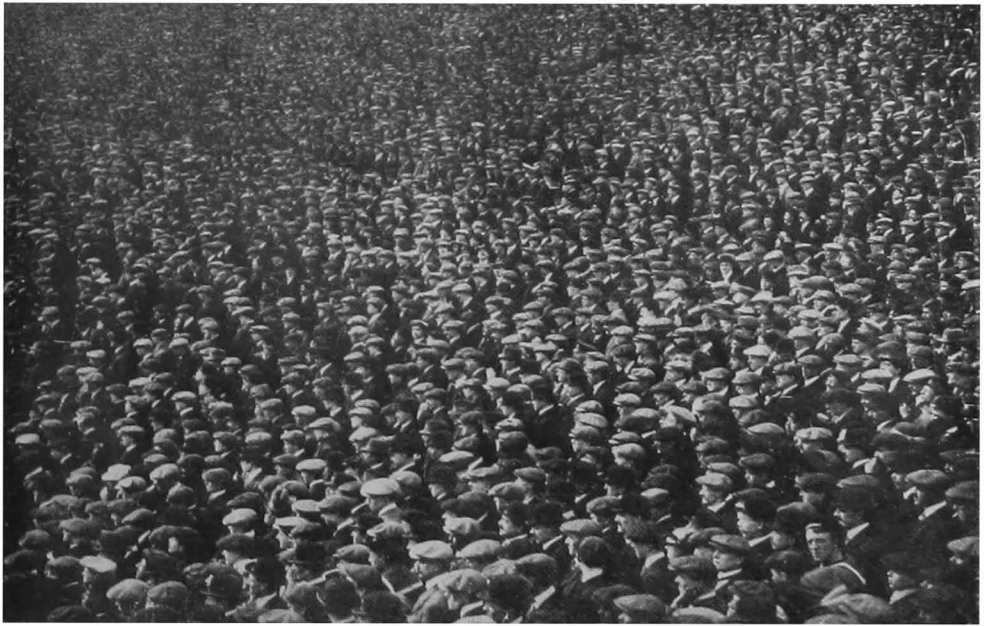


Fig. 72. A football crowd on the Woolwich Arsenal Ground, a large portion of whom use Gillespie Road Station on the Piccadilly line.

which serve Walham Green and Fulham from all parts of London. The railway, however, is required to deal with the major portion of the traffic, and this it does efficiently by means of eight-car trains, which each hold a thousand passengers. The station platforms and stairways also are of ample dimensions, and no fewer than 30,000 people are handled on arrival and departure by the railway on such occasions. The problem is less acute than at Gillespie Road, because the ground is 100 yards away from the station. The station platforms are also closer to the booking-hall, and from a bridge the station controller is presented with a bird's-eye view of the whole position, being thus able to exercise positive control over the booking-hall, train and platform accommodation. Here, as at Gillespie Road, there is the closest liaison between the Metropolitan Police and the railway officials.

AIR PAGEANTS

Fifty per cent. of the 80,000 people who attend the Royal Air Force Pageant, which is held annually at Colindale, are conveyed over the



Fig. 73. A section of the crowd passing into Colindale Station after a Royal Air Force Pageant at Hendon.

Tube railway extension. Colindale Station is a quarter of a mile from the flying ground, a fortunate circumstance from an operating point of view, because it enables the traffic flow to be more easily regulated (Fig. 73). The fact that the meeting is held on a Saturday creates a difficult problem, because the forward traffic has to be handled at the same time as the normal home-bound peak. Incidentally, the modern Tube rolling stock, with the wide centre-doors, is found to be specially useful in dealing with these crowds. The ample means of ingress and egress serve to eliminate the extended delays and congestion at stations common to the old type of stock with its narrow hand-worked end gateways. Records taken at Colindale show that the new type of train, carrying 750 passengers, can be unloaded in 20 seconds as against the 75 seconds occupied with the older stock. Between 12.30 and 2.30 p.m. 28,000 people arrived at Colindale Station for the 1927 Air Pageant, while a total of 38,000 passengers arrived and 36,000 departed during the day. The discrepancy between the numbers arriving

and departing is usual on such occasions and is due to the action of certain people in availing themselves of other means of finding their way home. Before such events, meetings between the railway officials, the police and the ground authorities are invariably held on the site in order to decide and prepare the best means of dealing with the crowds.

EXCEPTIONAL EVENTS

The transport arrangements which have to be made in connection with events which are not seasonal are of added complexity because of the lack of precedent upon which to base calculations, and the characteristics of the traffic are likely to be entirely different from anything that previous experience might indicate. Every possible phase of movement must be thought out, and nothing left to chance, whilst provision must be made for contingencies and alterations in programme. These variations, unless previously studied and to some extent rehearsed, will be most difficult, if not impossible, to institute when the time comes. Events of this nature comprise such occurrences as coronations, royal weddings and funerals, peace celebrations, visits of royal and other notable personages, election results, and the opening of exhibitions and railway extensions.

One of the greatest crowds on record assembled in the City on the return of the City Imperial Volunteers from the Boer War in 1900, and there was a dense mass of people in front of the Mansion House for twenty-four hours. The Central London Railway, which at that time extended from Shepherd's Bush to the Bank, conveyed 200,000 passengers—possibly a record in numbers carried over a double-track system in one day. The year 1919 was an outstanding one in connection with the conveyance of abnormal volumes of traffic, for on no fewer than eleven occasions were there celebrations of some description associated with the successful conclusion of hostilities.

OPENING OF NEW LINES

The opening day of a new Tube railway or extension necessarily arouses great public interest. When the Hampstead Railway was opened in June, 1907, the company sought to popularize the line by allowing every one to travel free on that one day, a privilege of which full advantage was taken by both children and adults. A similar step was taken on the opening of the City Railway extension to Morden in September, 1926. Four hundred guests attended the official ceremony, and from 3.0 p.m., when the line was opened to traffic, to just after midnight,

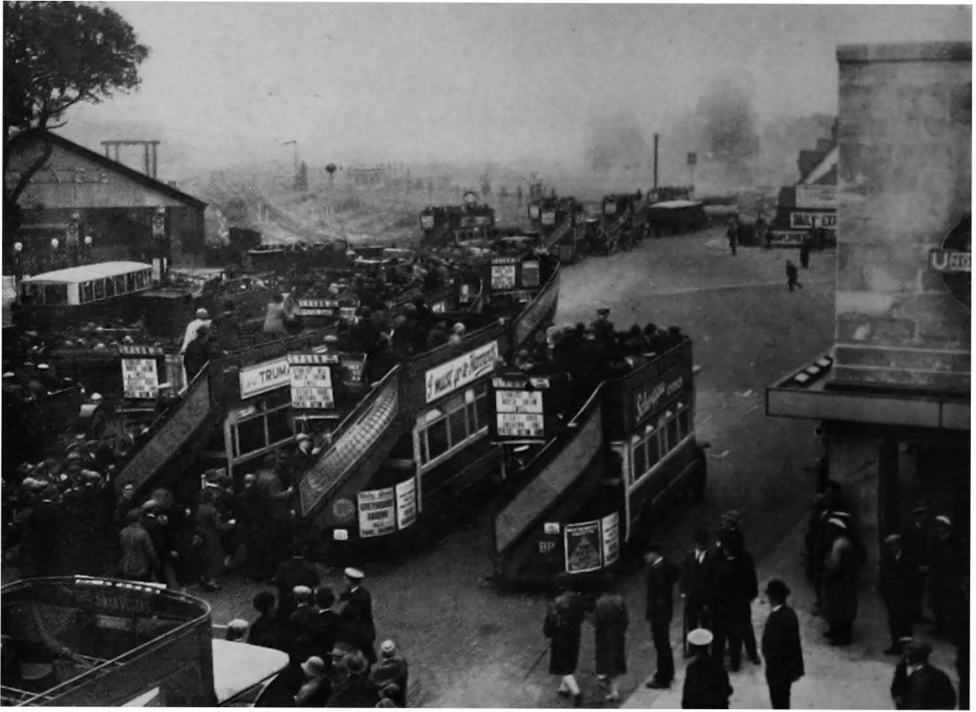


Fig. 74. Passengers joining omnibuses at Morden Station en route to the Derby.

when it closed, no fewer than 35,000 people used the railway. Since that date traffic over this railway has steadily increased, and already a service of forty trains per hour is being operated. Morden is now a most popular point for joining the buses which run to Epsom, Dorking, Sutton, Worcester Park and other points in Surrey. On June 6th, 1928, on the occasion of the Derby, 53,000 people used the station, six- and seven-car trains at three-minute intervals being heavily loaded in both directions. Incidentally, for this event the London General Omnibus Company put into service 115 special omnibuses, and a bus left the station for the racecourse every 45 seconds (Fig. 74).

STAFF AND EQUIPMENT

A variety of circumstances—and not least the weather—may affect the volume of traffic on special occasions, and the time and manner in which it will flow can rarely be gauged with any accuracy. The provision of staff and equipment to meet contingencies is generally, therefore, a

source of expense and difficulty, for it is to be noted that trains cannot be shot on to or off a Tube railway at a moment's notice. The base from which the trains are worked is usually at an outlying point, and so it is necessary to run trains for longer periods than the actual traffic warrants in order that the service may be at full strength at the required moment. Likewise, after the traffic has been dealt with, a good deal of superfluous working has to be resorted to in the return of the additional trains to their depot; on the District Railway, for instance, this process, occupying a period of two hours, involves considerable waste car mileage.

At the power station, also, a certain amount of wasteful expenditure must be incurred during the raising of steam, the standing by for the load, and, after the traffic, the drawing of fires. During these periods of intensity it is interesting to observe the switchboards at the power station, because they are a sure reflection of the work being done on the railway. The additional passengers tend to lengthen the station halts, whilst the driver tries to neutralize the time so spent by faster running. In these efforts he is not assisted by the weight of his train, for it is invariably full and is, therefore, 50 tons heavier than when empty.

In conclusion, it may be said that, when regard is paid to all relevant factors, little profit accrues from the conveyance of abnormal volumes of traffic on Tube railways. The only advantage arising is the public goodwill which must inevitably result from the expeditious handling of crowds in reasonable comfort, and it can confidently be asserted that, in this regard, it is the practice of the London Underground to spare neither trouble nor expense.

Chapter X

ROLLING STOCK

COMFORTABLE, well-built rolling stock is the key to a satisfactory train service; without it the service must suffer both in time-keeping and in public patronage. The number, position and means of operation of the carriage doors, for instance, affect station working and have an immediate bearing upon the time schedule, whilst the method of illumination, particularly of Tube rolling stock, is a matter of prime importance in view of the amount of reading done by passengers, especially in the rush-hour periods. To these and many other aspects of rolling-stock design and equipment have the Underground administration paid constant and particular attention, and so interesting is the subject that it is proposed, in this and the succeeding chapter, to review briefly the evolution of locomotives and rolling stock on the London Underground Railways since the opening of the District Railway over fifty years ago.

EARLY DISTRICT STOCK

The original rolling stock of the District Railway consisted of 24 steam locomotives and 152 coaches, a portion of a train being shown in Fig. 75. The locomotives were designed by Sir John Fowler and built by Beyer, Peacock & Co. Limited, of Gorton Foundry, Manchester. They had four coupled wheels of 5 ft. 9 in. diameter, truck wheels of 3 ft. diameter, and outside cylinders of 17 in. diameter by 24 in. stroke. The boilers were of wrought iron, designed for a working pressure of 130 lb. per sq. in., the heating surface of the firebox being 103 sq. ft. and of the tubes 909 sq. ft.; the grate area was 19 sq. ft. The engines weighed 46½ tons, of which 18 and 17½ tons were on the driving and trailing axles, respectively. Subsequently, boilers that had been tested to 160 lb. per sq. in. (reduced later to 150 lb.) were fitted to the engines, together with stronger link motion, steel axles instead of faggoted iron, and girder section coupling rods instead of the flat-bar type originally fitted.

Including the first delivery, which was made in 1871, fifty-four engines, based on the original design, were supplied at intervals by the same builders, as follows:

Nos.	1-24	.	.	1871	Nos.	37-42	.	.	1883
"	25-30	.	.	1876	"	43-48	.	.	1884
"	31-36	.	.	1881	"	49-54	.	.	1886



Fig. 75. A portion of an early steam train on the District Railway.

Nos. 1-24 had a leading Bissel radial swivelling four-wheel truck, but the remainder were equipped with Adams bogies, Nos. 1-24 being so fitted subsequently. The original twenty-four also had a small vertical pipe on each water tank to enable surplus steam to escape when condensing, but ultimately all the engines were fitted with bridge pipes, with neat bell-mouthed outlets, which carried the steam above the enginemens' heads. Nos. 24-30, when new, were provided with cabs which encompassed the whole of the footplate and the coal bunker, but as these proved very unpopular with the drivers and firemen they were later removed. The earlier engines had a plain rounded weather-board, but later they all carried a larger weather-plate, the top of which was bent back, and carried a rack for spare destination boards. As a protection when running bunker first, the back-plate of the coal bunker was carried up 15 inches or so. The first thirty-six engines were originally fitted with brass bell-mouthed dome covers with spring-balance safety valves over the domes; engines 37-54 had round-topped closed-in dome covers, 'Ramsbottom' safety valves being placed over the fireboxes. The polished brass dome covers, invariably placed on



Fig. 76. One of the earliest coaches to be used on the District Railway.

the front ring of the boiler immediately behind the funnel, gave the engines a smart appearance, in spite of the smoke-laden tunnels through which they were operated. The locomotives were painted olive green, and all the fifty-four were still in traffic in 1905, when electrification was accomplished.

EARLY TRAINS ON THE DISTRICT

The first trains on the District Railway were composed of eight four-wheeled coaches—two first class, two second and four third (Fig. 76). The classes were distinguished by large numerals painted on the compartment doors. The trains were at first lighted by coal gas supplied from mains at Mansion House and Kensington High Street, the gas being carried in flexible longitudinal holders, or 'bags', arranged along the centres of the roofs. In 1878 this very primitive arrangement gave place to the use of compressed oil gas. The first-class coaches had four compartments, the others five, and each compartment seated ten passengers. The first-class compartments were, of course, roomier than



Fig. 77. Type of coach introduced when the District Railway was electrified in June, 1903.

the second and third, otherwise the class distinctions of the Victorian era—as to-day—were only reflected in the varying quality and comfort of the upholstery.

New trains placed in service as extensions were inaugurated were composed of nine coaches, including an additional second class, and the nine-coach trains became the standard so far as the City services were concerned. Smoking compartments were not at first provided, both the District and the Metropolitan Companies having obtained special exemption from the clause of the Railway Regulation Act of 1868 which decreed that smoking compartments should be provided on all trains. They were, however, introduced on the District Railway in 1874.

During the later period of steam traction on the District, a 'next station' indicator was installed in the trains. It was fixed in an aperture cut in the upper part of the partitions between compartments and was operated by the guard, who, by pulling a string, brought into view a tablet bearing the name of the next station. It was also worked automatically by a treadle on the track and a lever on the engine. This rather



Fig. 78. District Railway coach, in service immediately after electrification.

primitive device frequently became deranged, to the considerable inconvenience of casual passengers.

DISTRICT RAILWAY ELECTRIFICATION

The closing years of the nineteenth century were anxious ones for the District Railway Company. The opening of the Central London Railway and the development of electric tramways in the western suburbs caused considerable diminution in traffic, and it was decided to electrify the line. At the outset, a comparative test was made between Kensington High Street and Earl's Court. A temporary power station was built at Earl's Court, the line between the two stations electrified, and an experimental electric train constructed. In February, 1900, trials were held between a standard steam locomotive and an electric motor car, the latter being controlled by a large wheel, not unlike a ship's steering wheel; needless to say, the electric train won easily, and the doom of steam locomotion was sealed. **Electrification of the line**

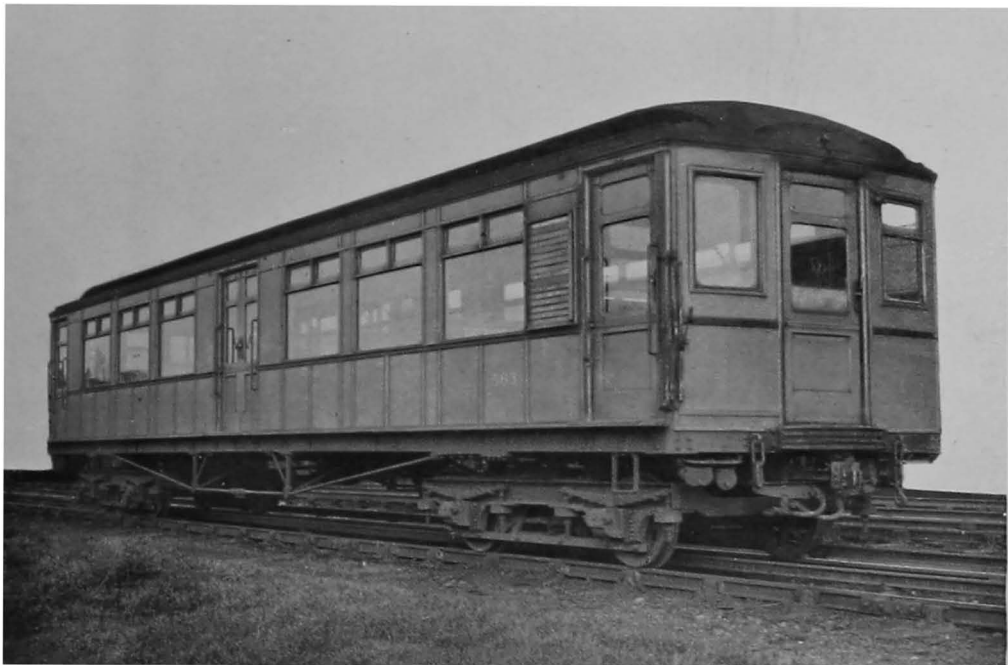


Fig. 79. Another type of coach in service on the District Railway shortly after electrification.

was at once begun and was continued in stages for several years, the last of the steam trains being withdrawn on November 5th, 1905.

The first electric trains were operated in June, 1903, between South Harrow and Ealing. The cars were manufactured by the Brush Electrical Engineering Co. Limited, of Loughborough, and were of American design, being constructed under the supervision of a prominent Chicago 'rapid transit' engineer. Externally the trains were painted a bright yellow, and the seats extended longitudinally along the sides, with a broad corridor down the middle. The cars were 50 ft. long, seating capacity for thirty-six passengers being provided in the motor cars, forty-eight in control trailers, and fifty-two in the trailers. Both end and side doors were provided. Over 400 cars were ultimately acquired, embodying improvements which experience had proved to be advantageous. Examples of these and the earliest types of car are given in Figs. 77, 78 and 79.

Towards the end of 1920 there was put into service the first of 100 new steel cars designed with the object of increasing the eight-car train

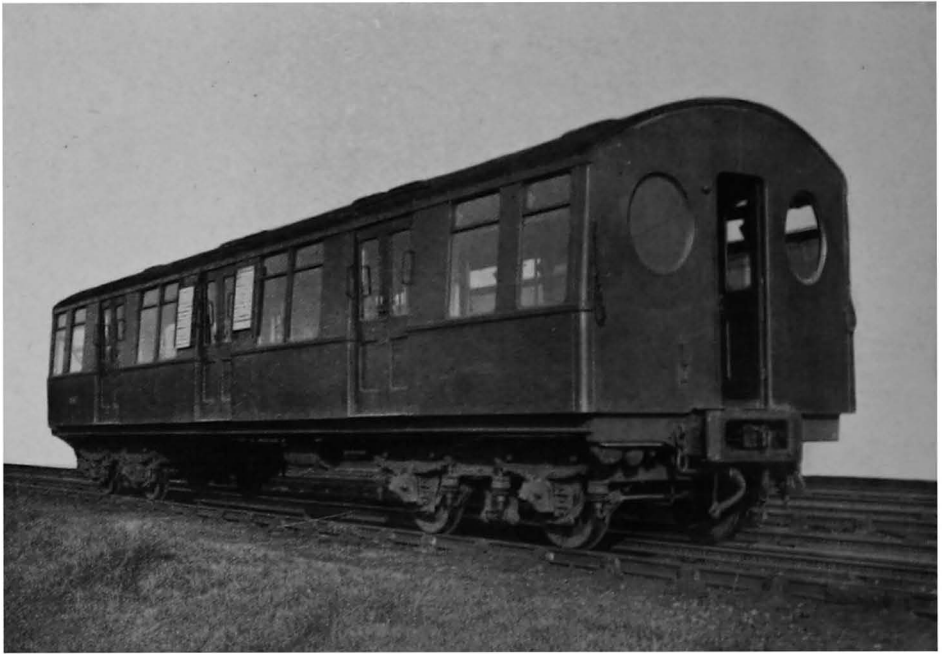


Fig. 80. District Railway all-steel coach, put into service in 1920.

service on the over-pressed sections of the District Railway. These cars (Fig. 80), which were built by the Metropolitan Carriage, Wagon & Finance Co. Limited, of Birmingham, differed in many ways from the older ones. They were wider by 11 in. (9 ft. 7 in. as against 8 ft. 8 in.), the body width being extended almost to the limit of the step-board of the earlier type. The sides of the new cars were slightly curved instead of straight, and were some 8 in. longer—49 ft. 8 in. overall. Improved springing ensured easy riding, and the large bogies, with which the trailer cars were fitted, made for silence and smooth running. The new motor cars were of higher power than the older ones. The new trains were capable of 45 miles per hour on non-stop runs, whilst the increased power also considerably assisted acceleration on starting; improved braking equipment was also fitted to secure quicker and more even stopping. These are all points of great importance on Underground lines, as the problem of getting more trains through the tunnel sections depends not only on the time taken between stations or at stations, but also upon the time taken in stopping and starting.

DISTRICT CAR DETAILS (1920 Steel Stock)

The general dimensions of the cars now in operation on the District Railway are as follows:

	<i>feet inches</i>	
Length over head-stocks . . .	49	8½
Width over sole-bars . . .	9	6¾
Height from rail level . . .	11	11½
Distance between bogie centres . . .	34	0
Bogie wheelbase (motor cars) . . .	7	10
" " (trailer cars) . . .	7	3
	<i>Total weight</i>	<i>Weight of each bogie</i>
	<i>tons cwt.</i>	<i>tons cwt.</i>
Motor cars . . .	44 10	11 18
Trailer cars . . .	24 10	5 3
Control trailers . . .	25 17	5 8

The illustrations give a general idea of the difference in the general design of the cars. The old type had vestibule end doors and double centre-doors, whilst the new have three double side-doors of sliding pattern, working on ball-bearing runners. On an eight-car train there is thus the equivalent of forty-eight single doors. A complete eight-car train is made up as follows, the seating capacity of a motor car being 40, of a control trailer 44, and of a trailer 48:

1	2	3	4	5	6	7	8
<i>Mtr.</i>	<i>Trlr.</i>	<i>Con.</i>	<i>Mtr.</i>	<i>Trlr.</i>	<i>Trlr.</i>	<i>Trlr.</i>	<i>Mtr.</i>
		<i>Trlr.</i>					

The motor cars are generally each equipped with four G.E.260 motors and are of the interpole tapped field self-ventilated type, and rated at 198 h.p. for one hour and 182 amperes continuously. They are fitted with 19-tooth pinion gearing with 64-toothed gear wheels, and are provided with bolted-type axle cups and dust shields for the axles. The suspension-bearing brasses are keyed to prevent rotation. Each pair of motors with its control gear constitutes a complete unit equipment. The control gear, mounted under the car, consists of circuit breaker, main switch fuses, reverser, fifteen contactors, resistances, and tapped field relay. The contactors are of an improved type, the contact tips being provided with arching horns and a moulded arc shoot. The interlocks are of the disc type and are mounted on the back of the contactor.

The contactor box, with all contactors and resistances, is a unit complete with wiring, and has its own terminal base. The reverser, connected to the motor fields, is of a drum type, operated by a pair of opposed solenoid coils. Other apparatus is substantially the same as



Fig. 81. Interior of one of the steel District Railway cars.

was provided on the older stock. Master controllers of an improved type have been fitted at each end of the motor cars and at one end of the control trailers, together with the necessary control and compressor switches, circuit-breaker switches, fuses and control cut-out switch. The control is non-automatic, except that the motor field is weakened automatically by the tapped field relay on the current decreasing on the last controller pointing parallel. The eight-car train has an acceleration of $1\frac{1}{2}$ miles per hour per second and a balancing speed of 45 miles per hour attained after a mile on the level.

The cars are fitted with Westinghouse brakes on the standard type double-block system, provided with automatic adjustment for taking up the slack. The cylinder pressure with full application is 50 lb. to the sq. in., and the leverage 4.4 to 1. A handbrake is fitted to all motor cars and control trailers, and there are main reservoirs on each motor car. The underframes are constructed entirely of steel, 6 in. by 3 in. by $\frac{3}{8}$ in. Angles untrussed, but cambered up, form the sole-bars, which are 8 ft. 6 in. apart, and the centre longitudinals are of rolled steel channel sections, 8 in. by $3\frac{1}{2}$ in. by $\frac{7}{16}$ in., spaced 2 ft. 3 in.



Fig. 82. Another interior view of a modern District Railway car.

apart and extending along the frame between the bogie centres, where they are brought 1 ft. 4 in. apart. The extension to head-stocks again diverges and is made up of pressed steel channel sections $7\frac{3}{4}$ in. by 4 in. by $\frac{7}{16}$ in., deepened at head-stocks end. The cross-bearers at the bogies are pressed steel sections $\frac{1}{2}$ in. by $7\frac{3}{4}$ in. plate, deep at the centre and tapering to 6 in. at the sides, with flanges of 3 in. stiffened by $\frac{3}{4}$ in. plate above and $\frac{3}{8}$ in. plate below. Floor plates are stiffened with short angles and pressing across from sole-bars to centre longitudinals, the whole being stiffened up with four gusset plates between the bogie centres.

Each motor bogie is equipped with two motors, which are hung on the axles and supported by brackets extending from housing plates. The driving wheels are 36 in. in diameter. The motor bogie side-frames are of channel section, 12 in. by $3\frac{1}{2}$ in. by $\frac{1}{2}$ in., extending for 13 ft. to the head-stocks, but are cut away on the bottom flange to receive the axle boxes. The head-stocks are 8 in. by 3 in. by $\frac{3}{8}$ in. channels with $\frac{3}{8}$ in. gusset plates at each corner. The bolster housing plates are 5 ft. by $3\frac{1}{2}$ in. by $\frac{1}{2}$ in. channels stiffened with double gussets at each side. The bolsters are built up of 8 in. by 3 in. channels, $5\frac{1}{2}$ in. apart and

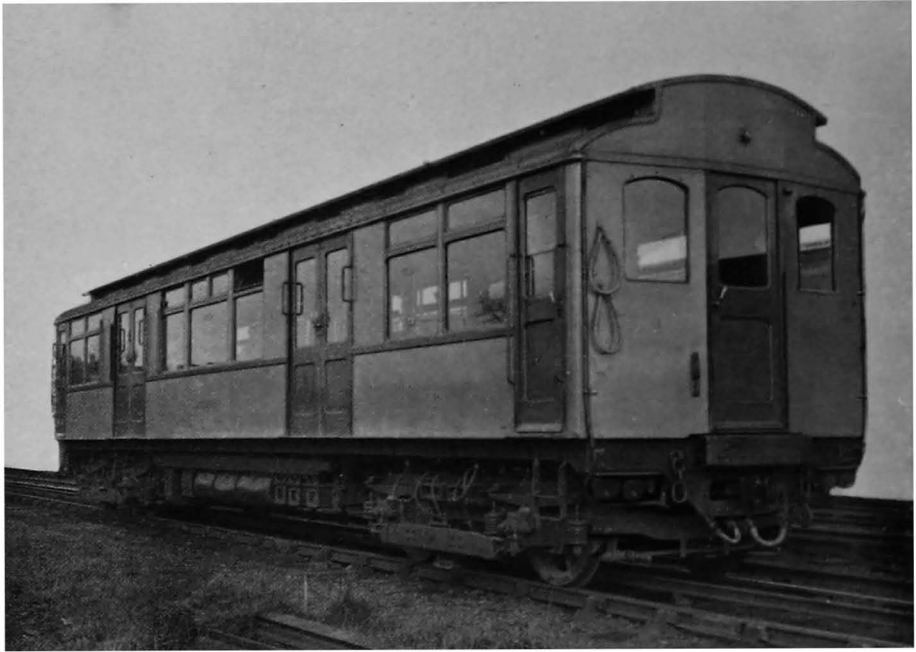


Fig. 83. District Railway car, introduced in 1923.

stiffened, top and bottom, with $\frac{5}{16}$ in. plates. These are supported on nests of concentric coil springs mounted on the spring plate, which is a channel pressing of 11 in. by 4 in. by $\frac{1}{2}$ in. plate, and the upper end is turned over to form a flange of $2\frac{1}{2}$ in.; this, in turn, is supported by heavy steel forgings pivoted to cast-iron brackets fastened to the housing plates. The centre bearing is of the ball-bearing type. The journals measure 9 in. by $5\frac{1}{2}$ in., and the boxes, which slide on cast-iron horn guides $4\frac{1}{2}$ in. wide, are also of heavy cast steel, bearing on laminated springs comprised of seven plates $\frac{5}{16}$ in. thick. Eye bolts take up the load through auxiliary rubber springs through steel eye-bolt brackets riveted to the side-frame channels. Trailer bogies follow the same design but are of lighter construction.

DISTRICT RAILWAY CARS—INTERIOR

The interior fittings of the new cars are worthy of mention (Figs. 81 and 82). The sides are slightly sloped and the roof arched, enhancing their general appearance. The windows are of polished English $\frac{1}{4}$ in.

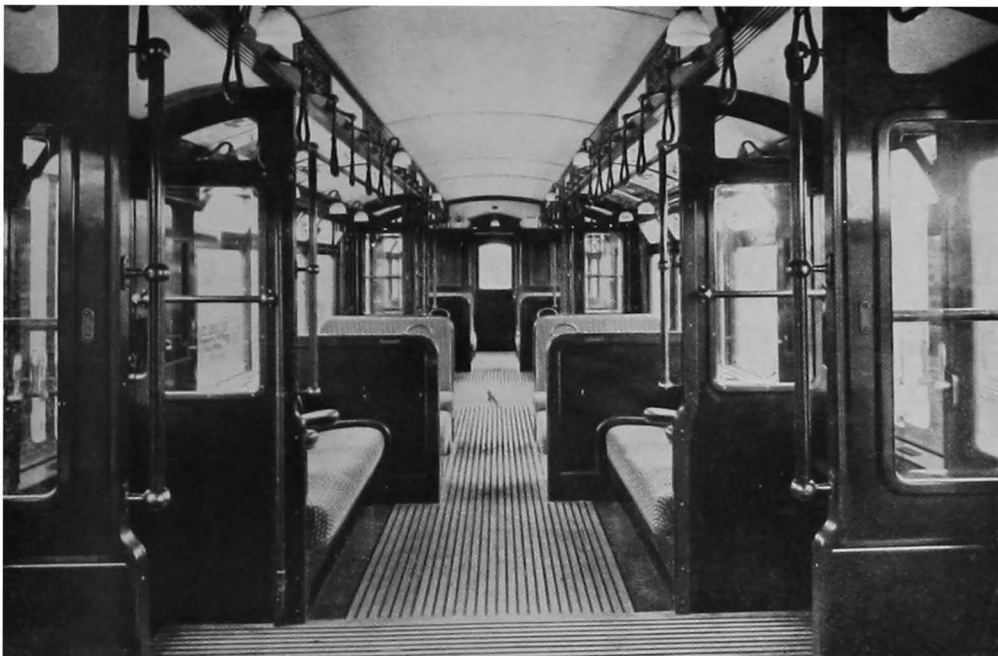


Fig. 84. Interior of District Railway car, introduced in 1923.

plate glass, and all metal fittings are finished in bronze or are nickel-plated. The whole of the interior is finished in steel, and the panelling and mouldings are painted to resemble teak. The floors are of steel, covered with linoleum, and the roofs with asbestos mill-board. To ensure absence of vibration and drumming, the steelwork is covered with canvas. Six large ventilators of an improved pattern are fitted in the roof, and there are windscreens on each side of the doors. The lighting comprises seven centre roof two-lamp fittings and six one-lamp fittings—two at each end of the car and two in the centre. Heaters, twenty in number, are placed under the seats on the front plate, which is perforated to allow the warmth to circulate around the passengers' feet.

After the 1920 stock had been in service a year or so it was thought that the all-steel construction produced a cold appearance, and steps were taken to brighten up the cars. The services of a prominent artist were obtained to plan colour-schemes for the interiors, and the upholstery was altered to match. In the latest design of cars a number of fittings have been introduced for the purpose of noise-reduction

and to give the cars a warmer appearance. The upright rods from floor to ceiling were dispensed with in favour of straps.

Further rolling stock was ordered in 1923 from the Gloucester Railway Carriage & Wagon Co. Limited, as shown in Figs. 83 and 84. The glass screens are dispensed with and an improved type of ventilation has been installed. The interior is in polished mahogany relieved by green, and all fittings are of copper oxidized finish. The upholstery merits attention. Planned on common-sense lines, the cushions of the seats and backs are not joined, but are separated by a metal channel connecting the frame-work, to which the cushions are secured; these channels can be cleaned in a few minutes and, in consequence, the cars are practically immune from an accumulation of rubbish and dirt. An important feature of all the newer rolling stock on the District Railway is the increased width of the doors, the two double pairs on each side of the car being provided with a safety catch and an indicator denoting whether the doors are 'locked' or 'unlocked'.

The rolling stock on the other sections of the London Underground Railways is dealt with in the next chapter.

Chapter XI

ROLLING STOCK (*continued*)

TO the City and South London Railway belongs the distinction of being not only the pioneer 'Tube' railway, but also the first electric railway in Great Britain, as it was on November 4th, 1890, that King Edward VII, then Prince of Wales, performed the opening ceremony and thus inaugurated a new epoch in urban transport. The original coaches, of which there were thirty, though constituting an entirely novel feature in those days, provide a queer



Fig. 85. Exterior view of one of the original City and South London Railway cars, in service in 1890.

appearance when contrasted with the luxurious rolling stock of the present time. Each train consisted of three 32-seater vehicles of the tramcar type (Figs. 85 and 86), hauled by electric locomotives, the total seating capacity thus being ninety-six. The bogie frames, it is interesting to note, extended beyond the ends of the body in the form of a semi-circle, and thus acted as buffers, intermediate platforms, equipped with lattice-work iron gates, being built on the bogie extensions.

It will be observed that the cars had no windows, the only openings at the sides being narrow ventilation slits just below the roof. 'Why windows', one can imagine the designers saying, 'when the trains are to run in tunnels?' Padded upholstery was a feature of the interior, and a glance at the photograph (Fig. 86) will enable one to understand why

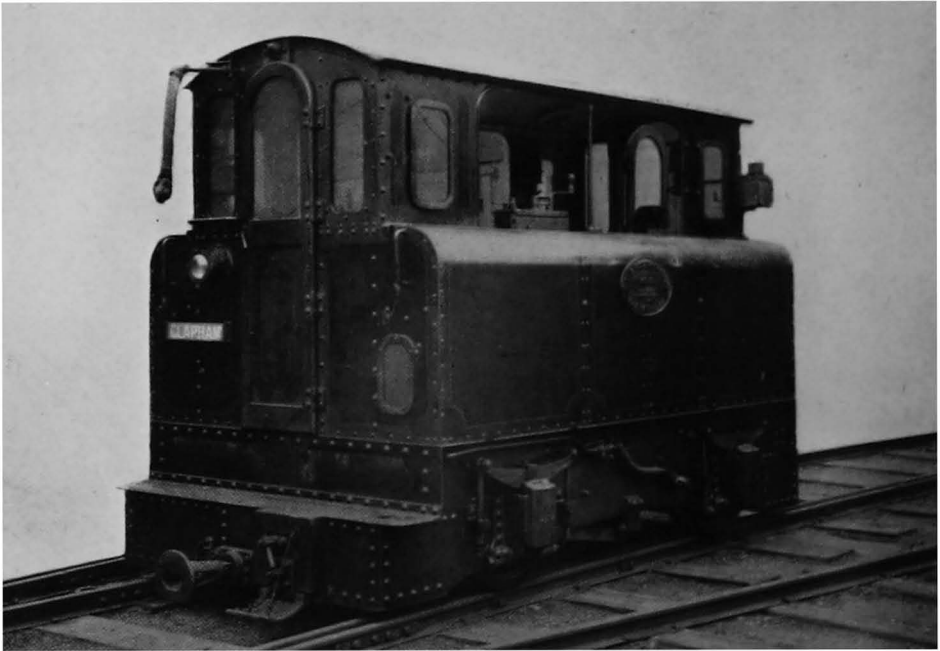


Fig. 88. One of the original electric locomotives on the City and South London Railway.

ELECTRIC LOCOMOTIVES

It was originally intended that the trains should be hauled by cables, one of which was to be installed between King William Street and Elephant, and the other between Elephant and Stockwell. However, on the proposition of Mather & Platt, Limited, of Manchester, it was decided to adopt electric traction, and the early locomotives, of which there were fourteen, as illustrated in Figs. 88 and 89, were equipped with two 50 h.p. motors, and embodied an innovation in the fact that the armatures were built directly on to the axles.

When it was opened, the whole of the line was in tunnel, but the repair depot and car sheds were on the surface at Stockwell, and provision had to be made for getting the stock out of the tunnels. At first this was done by means of an inclined plane of 1 in $3\frac{1}{2}$, up which empty cars and locomotives were hauled by a winding engine. But later this arrangement was superseded by the use of a 20-ton hydraulic hoist, working in a shaft over the tunnel siding. This device, which is illustrated in

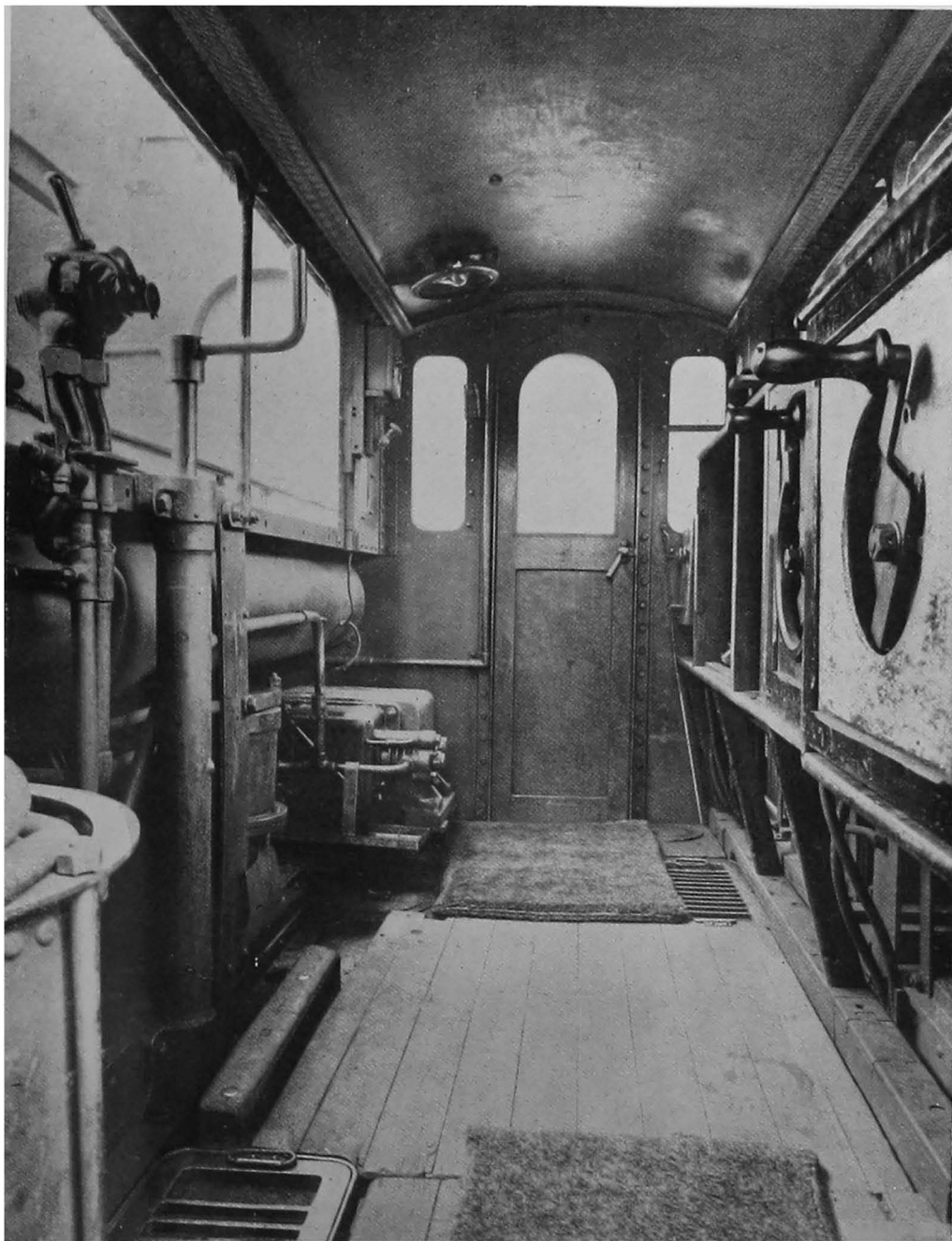


Fig. 89. Interior of original City and South London electric locomotive.



Fig. 90. The 20-ton hydraulic lift which was used at Stockwell to raise locomotives and coaches from the railway below preparatory to their undergoing repairs in the shops. The appliance proved invaluable during the subsequent reconstruction of the railway.

Fig. 90, proved valuable during the reconstruction of the railway in the years following the war.

ADDITIONAL LOCOMOTIVES

The various extensions of the railway naturally led to a big development of traffic with a need for additional rolling stock. For record purposes a list of the locomotives, with the names of their builders and the dates on which they were delivered, is appended:

Nos.	1-14	Mather & Platt, Limited	1889
„	15-16	Siemens Bros. & Co. Limited	1891
„	17	Built at Stockwell	1897
„	18	Crompton & Co. Limited	1898
„	19	Electric Construction Co. Limited	1898
„	20	Thames Ironworks, Limited	1898
„	21-22	Built at Stockwell	1900
„	23-32	Crompton & Co. Limited.	1899
„	33-42	„ „ „	1900
„	43-52	„ „ „	1901

From No. 18 onwards the locomotives were of a much improved and more powerful type, and when their use was eventually discontinued forty-five were in service. No. 1 now reposes in the South Kensington Museum. The engines were painted orange chrome in three panels, with black-and-yellow bordering. They were not fitted with the 'dead man's handle', and an assistant driver was carried. Between 1890 and 1907 165 cars were built and put into service. These vehicles weighed between 7 and 8 tons, and were 36 ft. in length and 6 ft. 10 in. in width. The average speed of a train was 14 miles an hour, including station stops.

The following details respecting the forty-four locomotives in service when the line was closed for reconstruction may be of interest:

<i>Builders</i>	<i>No. of Locomotives</i>
Crompton & Co. Limited	31
Mather & Platt, Limited	10
Electric Construction Co. Ltd. . . .	1
C. & S.L. Railway	2
	—
	44

Type: Four wheels; axle-box guides in side frames of cab; separate motors on each axle.

Wheels: Crompton—31 in. diameter; others 29 in.

Wheelbase: Crompton—5 ft. 6 in.; others 6 ft. 0 in.

Weight: Crompton—14 tons; others 11 tons.

Drive: Crompton—direct; Mather & Platt—geared.

Voltage: 600 D.C.

Horse Power: Thirty-three locomotives of 150 h.p., ten of 160 h.p. and one of 250 h.p.

THE LOADING GAUGE

Like many another pioneer work that has given impulse to progress, the City and South London Railway had certain features of design which militated against the adoption of the various improvements that were brought into operation on the Underground railways at a later date. The chief drawback was the size of the tunnels, which prevented the use of up-to-date rolling stock. On the original section of the line the tunnel was of 10 ft. 2 in. diameter between Monument and Elephant, and 10 ft. 6 in. between Elephant and Stockwell, due to the original intention of utilizing cable traction. There were to be two cables in each tunnel driven on the first section at 10 miles per hour, and on the other, where the line was straighter and more level, at 12 miles per hour, the

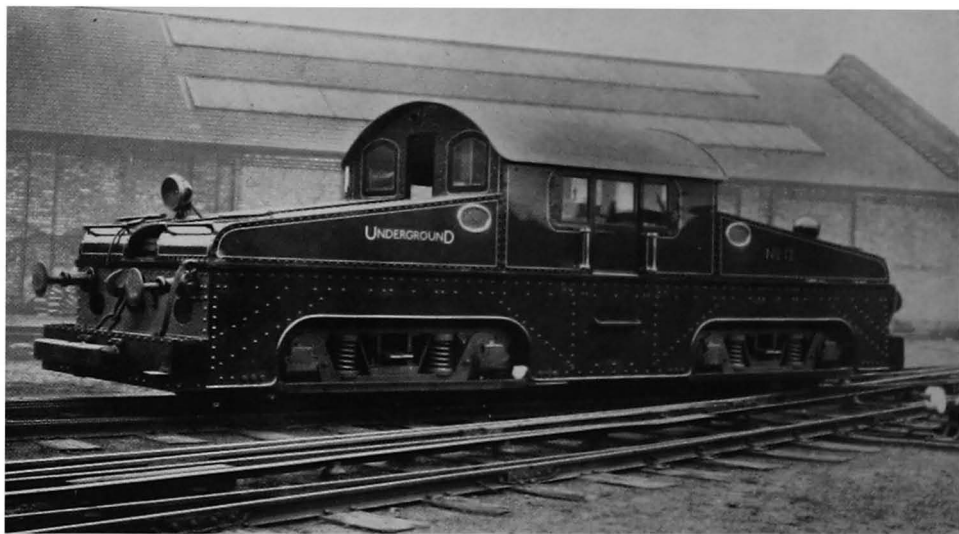


Fig. 91. Electric locomotives were at first used on the Central London Railway, which was opened in July, 1900; one of them is depicted above.

increase in diameter being intended to facilitate the operation of the cars at a higher speed.

The extension to Clapham Common was continued with 10 ft. 6 in. tunnels, but at the other end, as far as Moorgate, they were made 11 ft. 6 in. in diameter, i.e. almost standard with the 11 ft. 8½ in. of the Tube railways built later. Apparently for reasons of economy, there was a reversion to the 10 ft. 6 in. tunnel for the Angel and Euston extension. At certain stations—usually terminals—the running tunnels converged into a single tunnel of large diameter, and the trains drew up at an island platform. These station tunnels were 30 ft. in diameter, but in all cases the platforms on the old City line were only approximately 200 ft. long and therefore insufficient to accommodate a modern seven-car Tube train. Hence the need for the entire reconstruction of the railway, which was completed in December, 1924.

CENTRAL LONDON ROLLING STOCK

The Central London Railway was opened for traffic in July 1900, and for three years the trains were hauled by electric locomotives, as on the City and South London Railway, but, weighing 42 tons, they were of a much heavier type (Fig. 91). As considerable trouble was experienced as a result of the street vibration set up by these heavy engines, they were



Fig. 92. An early type of car on the Central London Railway.

withdrawn in 1903 and replaced by the multiple-unit system of traction, of which the Central London Railway Company were the pioneers in this country. The cars (Fig. 92) were supplied by the Ashburys Carriage & Wagon Company, the Brush Electrical Engineering Company, and the Birmingham Railway Carriage & Wagon Company, and were equipped electrically by the British Thomson Houston Company. Each motor was designed to give a drawbar pull of 2,500 lb., with a current of 200 amperes at 500 volts; the tractive effort was 650 lb. at the wheel tread, and the speed 27 miles an hour. The cars were provided with an electrically driven air compressor for the brake, which had a capacity of 35 cubic feet of free air per minute raised to a pressure of 90 lb. per sq. in. Hand and air brakes were fitted, the brake gear being of the quick-acting Westinghouse type, and each car was provided with a main reservoir of 8 cubic feet capacity. The electrical equipment was carried at the two ends of the train, the contactors and rheostats being placed in a steel compartment behind the driver's cab and separated from the passenger compartment by a steel bulkhead and a lining of asbestos.

In 1925 it was decided to remodel entirely the Central London rolling stock, in order to provide the same standards of comfort as were afforded on the more up-to-date Tube lines (Hampstead and City). The improvements, in brief, included more comfortable seats, pneumatically



Fig. 93. Interior of one of the remodelled cars, Central London Railway.

operated doors, better lighting and ventilation, and faster running (Fig. 93). The London Electric Railway, which is an amalgamation—authorized in 1910—of the Bakerloo, Piccadilly and Hampstead lines, operates a similar type of rolling stock.

ORIGINAL L.E.R. COACHES

The original London Electric cars were manufactured by several firms, notably the American Car Company, the Leeds Forge Company, and the Brush Electrical Engineering Company, whilst a number were of French and Hungarian construction. These vehicles (Fig. 94) were painted 'Derby Red', and were of all-steel construction with an internal panelling of non-inflammable mahogany, mounted on asbestos mill-board. The seating capacity of the motor cars was forty-two and of the trailers fifty-two. The principal dimensions were as under:

	<i>tons cwt.</i>
Motors, weight (incl. all equipment) .	27 10
Trailer cars, weight	16 11



Fig. 94. One of the original London Electric Railway cars.

	<i>feet inches</i>	
Length overall	50	1½
Width (maximum)	8	7⅞
Width (at floor level)	8	0
Height above top of rail	9	5
Wheelbase, motors	6	6
,, trailers	5	0
Wheel diameter, motors	3	0
,, trailers	2	6

The motor frame was of the box type with heads carrying the armature shaft bearings, arranged for nose suspension; it was provided with safety lugs to prevent the motor from falling in the event of the nose breaking. Each motor was provided with power circuit connection boxes into which the motor leads were connected with the car-wiring. The motor leads were protected by flexible metallic armouring, one end of which was sweated into a brass plug tapped into the motor frame, the other being secured to the connection box by standard pipe unions; mechanical protection was thus provided for the motor leads, uncoupling being easy when a motor had to be removed. The gear was split in half and designed to go directly on the axle.

The system of control was in two parts: first, a series parallel motor controller composed of a number of electrically operated switches



Fig. 95. A modern London Electric Railway car, with pneumatically operated doors.

(contactors) and an electrically operated reverse switch (reverser), the different electrical combinations of the motors being made by the contactors, which also regulated the starting resistance in circuit with them; and secondly, a master controller, by which the motor controlling contactors and reverser were operated, and the position of which indicated to the driver the exact resistance and motor combinations on all motor cars. Thus the motorman had the train under his immediate control and could utilize the full power of the motors in either direction in an emergency. For reversing the motors the master controller was provided with a separate reversing handle, which, by a mechanical interlocking device, was prevented from being thrown unless the main handle was in the 'off' position. The operating circuit was so arranged that unless the reverser was thrown for the direction of car movement, indicated by the master controller reverse handle, the contactors and motors on that particular car were inoperative.

AUTOMATIC DOORS

A far-reaching development in the operation of Tube trains was achieved on the Piccadilly line by the introduction of automatically operated doors. In addition to the usual end doorways of the cars, twin sliding centre-doors were added, a further 5 ft. opening (2½ ft. in the



Fig. 96. Interior view of modern London Electric Railway car.

motor cars) being so provided (Figs. 95 and 96). Thus, on a six-car train, composed of two motor and four trailer cars, the door service is increased by 25 ft. All the doors are electrically signalled and interlocked and are operated pneumatically from any part of the train. As mentioned in an earlier chapter, this innovation materially assisted in overcoming the dislike of the short-distance passenger to passing down the old type of car and thus causing obstruction near the doorways. The mechanism of these air-worked doors was so designed that any obstruction to the closing of the doors prevented the guard from giving the starting signal to the driver. The saving in train staff is obvious, for one guard with perfect safety can operate a seven-car train.

WATFORD EXTENSION STOCK

The rolling stock used on the Watford Extension of the Bakerloo Railway was built by the Metropolitan Carriage, Wagon & Finance Co. Limited, to the joint design of the London and North Western and London



Fig. 97. One of the cars that are used on the Watford Extension services of the Baker Street and Waterloo Railway.

Electric Railway Companies (Figs. 97 and 98). The floors are $4\frac{1}{2}$ in. higher than in the ordinary Tube stock, in order to adjust the difference in station platform heights of the two railway systems. The trains (six cars) are 314 ft. in length. Each motor car is fitted with two G.E. 212 motors, of 240 h.p., geared for a free running speed of 40–45 m.p.h. The leading dimensions of the cars are as follows:

	<i>feet inches</i>
Length overall	50 10
Width over body	8 9 $\frac{1}{2}$
Total height from rail	9 5 $\frac{1}{2}$
Centres of bogies	34 0
Diameter of motor wheels.	3 6
Wheelbase of motor bogie	7 0
Diameter of trailing wheels	2 8
Wheelbase of trailer bogie.	6 0
	<i>tons cwt.</i>
Total weight of six-car train (unloaded)	161 2

The brake equipment is of the Westinghouse type with quick-acting triple valves. The brake blocks are of unchilled cast iron, and the brake rigging on the trucks is of the clasp type, this being the first stock on the



Fig. 98. Interior of Watford Extension car, Baker Street and Waterloo Railway.

Underground fitted with double blocks. The air compressor is of the B.T.H. c.p. 30 a. type.

ELECTRICAL CONTROL

The British Thomson Houston system of control is of the relay automatic type, which is also now in use on the Ealing stock of the Central London Railway, and on the newer rolling stock of other lines. The normal method of operation in this system is to place the controller at once to the full parallel position when starting a train. The contactors are then picked up in their correct sequence by the current limit relay, which operates as soon as the motor current has dropped to a predetermined value. The relay consists of two shunt coils and one main coil. The latter carries current equal to that of one motor only. The actuating coils of the contactors are energized through one or other of the two shunt coils in such a manner that if one is energized through one shunt coil the next to close will be energized in series with the other shunt coil. The two relay shunt coils act on two plungers controlled by gravity. Each plunger, when in its lower position, closes a disc

switch in series with the other shunt coil. Thus, when one of the plungers is raised, the shunt coil acting on the other cannot be energized because of the break on the circuit produced by the above-mentioned switch, but although it is the control current that raises the plunger so as to produce this break, it is the current passing through the main coil that maintains the break, and the plunger is not released until this current has dropped to the predetermined value. Then the plunger falls and closes the switch, which completes the circuit for the next contactor coil to be energized.

The principle underlying the method of control adopted in connection with the current limit relay is that, after a contactor has been picked up, as described above, its coil is immediately transferred, by means of interlocks, to another wire. There are thus essentially two operating wires, the picking-up wire and the retaining wire (although other wires are introduced for forward and reverse, circuit breaker setting, etc.). As there is no main bus line down the train, a potential relay is fitted on each motor car, which drops all contactors on that car when the shoes lose current. This is necessary, because when no current passes through the main coil of the current limit relay it ceases to exercise its control over the rate of the picking up of the contactors. The controller has four forward points and two reverse (series only), of which Nos. 2 and 4 are running points where all resistance is cut out. A useful provision in the control is that if, in the course of the automatic notching up, the controller handle is brought back to the first or third notch, as the case may be, the automatic closing of contactors is stopped, but those already closed are kept up. A safety device, which is now part of all standard L.E.R. equipment, is the control circuit governor. By interrupting the control circuits it prevents the train being driven forward unless the train pipe of the Westinghouse brake is charged with air and unless the signal trip cock is cut in.

The locking and unlocking of the centre doors of the Watford stock is under the control of the gateman. Embodied in the pedestal, which holds the mechanism for operating the end car doors, is a switch which controls the circuits governing the electric lock of the middle door. When the gateman opens the end car door, he automatically unlocks the middle door, and this is indicated by the illumination of a red lamp. When the end door is again shut it closes the circuits which lock the middle door, and a green lamp in the pedestal is illuminated. Should the end door for any reason be shut and the centre door not properly fastened, the red lamp will continue burning until the matter has been rectified.



Fig. 99. New type of car, introduced in connection with the opening of the Morden Extension of the City and South London Railway.

HAMPSTEAD AND CITY STOCK

In view of the comparatively long runs which would result from the completion of the through line from Edgware to Morden, special attention had to be paid, in the design of the rolling stock, to the comfort of the passenger. Inquiries had elicited the fact that many passengers prefer to sit facing the direction in which the train is moving, and accordingly additional cross-seats were provided. The further rolling stock, which was ordered in connection with the Morden Extension, was built by Cammell Laird & Co. Limited, the Metropolitan Carriage, Wagon & Finance Co. Limited, and the Birmingham Railway Carriage & Wagon Co. Limited. Constructed to the specifications of the Underground Company, the new stock embodies the principal features of the six experimental cars built in 1922 by different manufacturers at the request of the Underground, with a view to arriving at the ideal car for electric railway service (Figs. 99 and 100).

The rolling stock for the conversion of the City line and the extension to Edgware cost £922,000, and comprised eighty-one motor cars, thirty-five control trailers, seventy-five ordinary trailers, and six experimental cars. The overall length of each car is 51 ft. 5½ in., width 8 ft. 10 in., and height from running rail 9 ft. 6 in. The unladen weight



Fig. 100. Interior of the new-type City and South London Railway car.

of the motor cars is $31\frac{1}{2}$ tons and of the trailers $17\frac{3}{4}$ tons. In place of the usual entrances and exits at the ends of the cars, there are two pairs of double doors on each side, situated more towards the centre, 4 ft. 6 in. in width, and working on roller bearings; the means of ingress and egress are thereby nearly doubled. The edges of the doors are fitted with soft rubber. Each door is operated by an electrically controlled air engine, and the speed of the door gradually retards as it approaches its neighbour. The controlling mechanism is so arranged that the doors can be operated from one or more positions on the train. An electrical device indicates to the guard when all the doors are closed, and by further electrical indication the guard is enabled to signal to the driver to proceed.

The roofs of the new cars are partly of the elliptic and partly of the clerestory type, in order to provide doorway headroom and ventilation respectively. Ventilation is effected principally by air scoops fitted into the clerestory and ornamental grilles fixed on the inside of the car. One of the most important features of the new stock is the reduction of

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noise usually associated with Tube railway operation. Extensive investigations were made and a series of 'sound' photographs taken to locate the principal causes of noise, which with careful experiment has been considerably reduced. In consonance with the safety precautions observed throughout the system, all rolling stock on the Underground railways is fireproof.

Chapter XII

BOOKING THE PASSENGER

THE practice of booking the passenger dates back to the old coaching days, when the names and addresses of the passengers and their destinations were entered in a book, the particulars being copied on to a waybill, which was handed to the guard; hence the phrase 'booking the passenger', and the terms 'booking-office' and 'booking-clerk'.

With the introduction of rail transport and the growth of traffic by that medium, a less laborious system of booking was soon found to be necessary, and it is to the ingenuity of one Thomas Edmondson that the present railway ticket system is due. Edmondson, who was the station-master at Milton, on the Newcastle and Carlisle Railway, in 1836 conceived the idea of making blocks with which to print cards or tickets. These he numbered serially, thus providing a check on daily issues and cash receipts. He also introduced tube-like racks to contain the tickets, so that by slipping them out from the bottom each one would appear in its numerical order, a practice which is still resorted to on the Underground and other railways. Finally, he invented a machine for dating the tickets, and his first model, which was made of wood, was very similar in principle to that of the 'bottle' press in use to-day.

In a rapid-transit undertaking, where fares are lower than on the main lines and train headways much shorter, it is obvious that a speedier booking system is essential to deal with an almost constant flow of passengers at a minimum of expense. The problem, however, is complicated by the different types of ticket which must be issued from the average booking-office, as indicated in the following table:

- Ordinary: local and through to other railways, including exchange with bus and tram.
- Workmen: local and through to other railways.
- Season: local and through to other railways, including exchange with bus and tram.
- Pleasure party and cheap excursion tickets.
- Merchandise tickets.
- Dog and folding mailcart tickets.
- Military and police tickets.
- Exhibition tickets (when required).

THE 'SCHEME' TICKET

A 'scheme' ticket is one to cover all journeys that can be made for the same fare from any station. It is only in use on the Underground group of railways in respect of all local travel on the lines owned by the company and to certain parts of the Metropolitan Railway and from a few stations to the section of the Great Western Railway between Ealing and Shepherd's Bush.

Prior to January 1st, 1911, it was the practice on the railways now forming the Underground Group to have, as on all other railways, one ticket for each station to each other station, except locally, where a ticket was issued to the farthest station covered by the particular fare. London traffic is not comparable with ordinary railway traffic, in that there is a greater density, and the element of speed is a governing factor. It was therefore necessary to institute methods to facilitate more rapid booking and to give a passenger the privilege of reaching his destination by an alternative routeing. With the co-operation of the Metropolitan Railway, the scheme was first tried on the Bakerloo section of the London Electric Railway on January 1st, 1911, and on the City and South London Railway from September 1st, 1914. In 1922, the 'scheme' system was applied to local and Common Fund bookings at stations on the Piccadilly, Hampstead and Central London Railways, the new tickets being introduced as renewals were required.

On November 1st, 1926, the scheme was extended to cover the Central London, Piccadilly, and Hampstead lines with the Metropolitan, and on January 1st, 1927, the system was introduced at District Railway stations, whilst on February 1st, 1927, the District scheme was made to cover the issue to East London stations. It was possible to withdraw no fewer than 7,000 sets of tickets from the booking-offices on the introduction of the recent 'scheme' bookings, thus facilitating the duties of booking-clerks and audit-office staff. The following are the advantages of the 'scheme' ticket system :

- Concentration of tickets in the booking-office, and use of ticket printing and issuing machinery, resulting in greater speed in booking.
- Avoidance of congestion at booking-windows.
- Affording passengers an opportunity of travelling with one ticket, by any available route, to any station to which the fares are the same.
- A better loading of trains.
- Saving in cost of tickets, as large quantities of one printing replace numerous sets of small quantities.
- Reduction in accounts work, both in the booking-office and the accounts department.

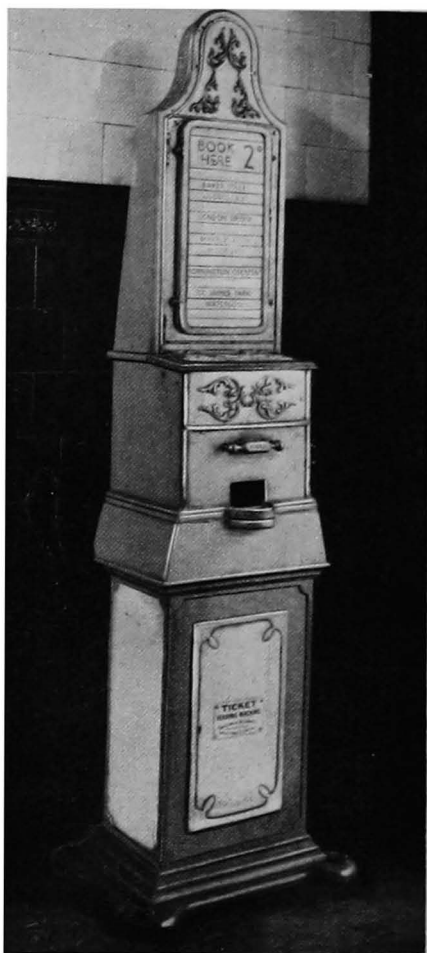


Fig. 101. Pull-bar automatic ticket machine.

central London Railway in 1904, and the standard electric machine (Fig. 102), originally installed on the District and London Electric Railways in 1908. The former is operated by hand in a similar manner to a chocolate machine, whilst the latter works electrically after the passenger has inserted the necessary coins in the slot. Both types of machine issue standard card tickets, and there are in use at the present time 121 electric and forty-four pull-bar machines, which issue an average of 60,000 tickets per day.

During the last three years a special scrutiny of tickets in booking-offices has been maintained, and tickets for which there has proved to be little or no use have been withdrawn, with the result that under the 'scheme' system the total ticket stock has been reduced from 50,000 to approximately 20,000.

MECHANICAL DEVICES

One of the most interesting and noteworthy achievements of the Underground has been the introduction of a large number of ingenious mechanical devices aiming at increased safety and speed in operation. In so far as traffic working is concerned, these have been referred to in previous chapters, and the following are some of the more important appliances used in the booking of passengers.

(a) *Automatic Machines*

Automatic ticket machines are a useful auxiliary to the booking-office service, because they relieve the congestion during rush hours. Two types of machine are in use—the pull-bar machines (Fig. 101), which first came into operation on the Central



Fig. 102. Standard type of automatic ticket-issuing machine.



Fig. 103. Automatic machine used in conjunction with passimeter equipment.

In recent years it has been found possible to adapt the electric machine to what is known as the automatic passimeter (Fig. 103). The machine is attached to the passimeter equipment, and performs the quadruple function of issuing, dating and cancelling a ticket, and of electrically releasing the turnstile, so that passengers, having obtained their tickets by placing the requisite coins in the machine, can proceed on their journey without further impediment by ticket examination at the barrier. The turnstile of the passimeter resets itself after passengers have passed through, and the entire process is automatic and, therefore, labour-saving.

(b) Passimeter Booking-Offices

As traffic increased on the Underground system the defects due to congestion at the booking-office windows became very noticeable during the busier periods of the day, and it was decided to apply the passimeter equipment generally to booking routine. The first passimeter booking-office was introduced at Kilburn Park in 1921. It proved quite satis-



Fig. 104. Passimeter booking-office at Westminster, District Railway.



Fig. 105. The 'Automatticket' machine.

factory, and others have consequently been installed at all new or reconstructed stations: that at Westminster is shown in Fig. 104. Its advantage is that it enables passengers to proceed on their journey without undue hindrance, each ticket issued by the booking-clerk being dated and cancelled simultaneously. At each entrance there is a turnstile, or 'flipper arm', which is controlled from within the booth and, when not in use, remains locked. During the busy hours separate entrances are generally used by season-ticket holders and those possessing return halves of tickets, thus relieving the gangways where passengers are booking. Only at the busier stations is it necessary to employ a ticket collector during rush hours.

At the time the passimeter scheme was first under consideration, experiments were made with two types of ticket-issuing machines for use inside the booking-offices. These were the 'Automaticket' and the 'Rolltic' (Figs. 105 and 106). The former works electrically and the latter is operated by hand. The tickets issued from these machines are printed on the 'zone' principle and produced on strips of paper containing from 1,000 to 2,000 tickets, as required, the difference in make-up in the two machines being that the tickets from the 'Rolltic' machine, as the name implies, are in rolls consisting of 1,000 tickets, whilst the 'Automatickets' are delivered in bundles of 2,000, the tickets being folded on the zig-zag principle of five tickets in each fold.

(c) *'Automaticket' Machine*

The 'Automaticket' machine (Fig. 105) is driven by a motor of approximately $\frac{1}{8}$ h.p., and the type of machine which has been in service since 1921 issues six denominations of tickets. The machine is fitted flush into the counter in front of the booking-office window, and the top has a brass plate containing the six issuing slots and serving also as the change plate. To each issuing slot there are two keys and four master-keys, by the operation of which a passenger can be booked with any number of tickets up to six at any one time. This is done by depressing the key corresponding to the number of tickets required. Prior to issue the bundles of tickets are placed in separate containers immediately below the machine and are taken up through the mechanism to the issuing surfaces by means of a finger wheel, the last function of the machine being to cut the strip according to the number of tickets required. There are now fifty 'Automaticket' machines in daily use.

(d) *'Rolltic' Machine*

The 'Rolltic' machine (Fig. 106) is of a different type, the machine itself being arranged in longitudinal tier formation, according to the units



Fig. 106. A 'Rolltic' ticket-issuing machine.

required. Those in use on the Underground—there are ninety-five at present in service—are six- or eight-unit machines, and three or four units, as the case may be, are placed on each side of the booking-office window. Each unit issues a different denomination of tickets, the rolls of tickets being suspended on spindles immediately in rear of the particular unit concerned. The tickets are then threaded through the respective rear mouthpieces until they engage the finger-piece inside the machine; then, by turning one of the side handles in the forward direction, the tickets required are passed through, dated, cut, and issued via the front mouthpiece. Both the 'Rolltic' and the 'Automaticket' machines have proved satisfactory and have been largely responsible for the speed-up in booking facilities.

(e) Ticket-Printing and Issuing Machine

Further mechanical means of issuing tickets from the booking-office have been devised, and a new type of machine, similar in principle to the 'Rolltic', but which, in addition, will actually print the tickets from



Fig. 107. Interior of a passimeter booth equipped with an automatic ticket-printing and issuing machine and (on left) a change-giving machine.

plain rolls, has been introduced on the Underground. It is known as the 'Rapid' machine, and is manufactured by the Allgemeine Electricitäts Gesellschaft, of Berlin (Figs. 107 and 108). Its use effects material saving in money, time and labour, and it has, in fact, revolutionized booking-office and ticket-printing methods. It is electrically operated by pressure upon one or more buttons according to the journey desired. It prints, cuts and ejects a ticket ready to the hand of the passenger; the ticket bears the date, station of origin, and destination, together with the legal conditions under which railway tickets are issued. Four such tickets can be issued in one second.

In the machines at present in use there are fifteen units, which produce ordinary single, cheap day, return, and workmen's tickets covering any journeys from the issuing station. The daily changing of the date can be done in fifteen seconds, a new roll of paper can be inserted in thirty seconds, and a defective unit, which, incidentally, does not



Fig. 108. Interior of an automatic ticket-printing and issuing machine.

adversely affect any of the other units, can easily be replaced in fifteen minutes (Fig. 108). No pre-printed ticket stock is necessary except for emergency purposes, and the clerical work in the booking-offices is materially reduced.

(f) Ticket-Printing and Change-Giving Machine

An automatic ticket-printing and change-giving machine for use in station booking-halls is now in service. This will issue tickets of fixed denominations from 1d. to 5d. inclusive, printed from a plain roll, and will give change for 6d. or 1s. 0d. The printing is done automatically on a roll of pasteboard long enough to provide 2,000 tickets, and there is no need, therefore, constantly to replenish the stock, as is the case with ordinary slot machines. The machine can issue a ticket either in exchange



Fig. 109. A combined ticket-printing and change-giving machine.

for the exact money or will give change when necessary. For example, a passenger requiring a fourpenny ticket and having nothing less than a shilling, inserts the coin in the slot and receives the ticket and eightpence change. This machine, which is illustrated in Fig. 109, is now in use at Mansion House and other stations, and is proving a popular innovation.

SPEED IN BOOKING

To ensure efficiency, returns are compiled periodically to show the speed of booking and change giving, and in this regard the following table is of interest:

Number of Passengers Booked in one hour (during busy evening service) and Number of Passengers Requiring Change.

<i>Oxford Circus</i>		<i>Leicester Square</i>	
Total Booked:	1,174	Total booked:	920
Required Change:		Required Change:	
	492 or 42%		528 or 57%
<i>Coins Tendered</i>		<i>Coins Tendered</i>	
6d.	221 or 54%	6d.	249 or 45%
1/-	158 „ 32%	1/-	157 „ 30%
2/-	61 „ 12%	2/-	69 „ 13%
2/6	48 „ 10%	2/6	44 „ 8%
10/-	3 „ —	10/-	5 „ —
£1	1 „ —	£1	3 „ —

The variety of fares in operation tends to retard the speed of booking as compared with the flat rate fare of twopence, which was originally in operation on the Central London Railway when it was possible for one booking-clerk to dispose of approximately 1,000 passengers in the hour. Passengers themselves influence the rate of booking very considerably—e.g. the celerity with which they pick up their change—and a new type of change plate has, therefore, been installed at the booking-office windows of the busier stations. This fitting, shown in Fig. 110, is made of brass and so constructed that the part nearest the passenger is curved and has an upward drive of about $1\frac{1}{2}$ in. This gives a slight scoop effect which enables passengers to take up their tickets and change quickly and easily. The plate is a great improvement on the old 'finger-groove' plate, and is of assistance to passengers, especially those wearing gloves.

Speed of operation is just as important in the booking-office as in train working, and the administration believes that the several new



Fig. 110. Another interior view of a passimeter booth, showing (on left) the booking-clerk's change-giving machine, the new type of brass change-plate, and (on right) a ticket-printing and issuing machine.

devices now used in the booking-offices will go far towards solving the passenger-booking problem. A recent test during an ordinary busy morning 'workmen' period, at one window only, revealed the under-noted figures:

<i>Time</i>	<i>Passengers Booked</i>
7.0 to 7.5 a.m.	105
7.5 ,, 7.10 ,,	109
7.10 ,, 7.15 ,,	103
7.15 ,, 7.20 ,,	106
7.20 ,, 7.25 ,,	120
7.25 ,, 7.30 ,,	120
Total	663 in half an hour,
	equalling 1,326 per hour or 23.6 per minute.

Besides their speed the machines have several other outstanding advantages. First, there is the reduction in the number of all pre-printed tickets, ticket storerooms and cupboards; in fact, the interest, deprecia-

tion and maintenance costs of the machines are met by the saving gained by the use of blank tickets. Secondly, the machines add considerably to the smart appearance and operation of the booking-offices, whilst the record of issue of each denomination of ticket is automatic. Their introduction has had the effect of disclosing new ways of grouping tickets and fares.

Experience with the machines has shown an improvement in design which will result in their initial cost being considerably lessened. By making the printing units interchangeable an eight-unit machine can perform the work of one with twice the number of units; thus, after the workmen's traffic is over in the morning, the units can be replaced by 'ordinary' ticket-booking units, thereby allowing an eight-unit to be used as a sixteen-unit machine.

To have few pre-printed tickets or none at all in the booking-office is the ideal sought by the Underground, and, in addition to the 'Rapid' printing machine, there is another machine, manufactured by the same company, and having 100 units. It is intended for dealing with those tickets whose issue is limited and, therefore, uneconomical in the operations connected with the 'Rapid' machine. The combination of the two machines should ensure a still more simple and efficient ticket system.

BOOKING-OFFICE COSTS

Although, as has been said, sets of tickets have been reduced by nearly one-half, the present system is still complex and costly. To handle the million passengers a day that travel on the Underground railways costs approximately £200,000 a year, and eighty per cent. of this sum is expended in labour. There are over 500 booking-clerks whose average earnings are £3 10s. a week—nearly £100,000 a year. There are, in addition, the wages of the ticket collectors, the traffic audit office staff, the season-ticket staff, and the ticket sorting and ordering staff, besides the stationery and printing costs. Booking-office costs represent approximately six per cent. of the total operating expenses of the Underground companies. Steps are, therefore, being taken to extend as far as possible the use of automatic ticket machines and to get the public to become accustomed to their use.

At the reconstructed station at Trafalgar Square, for instance, there is now only one passimeter booth, which is used mainly by passengers requiring change or by those needing foreign and special tickets. Others are encouraged to use one of a range of ticket machines, in connection with which the barriers admitting to the escalator are automatically



Fig. 111. The booking-hall at Trafalgar Square possesses only one **passimeter** booth and a range of automatic ticket-issuing machines.

operated when the ticket is issued after payment of the proper fare. The arrangements at Trafalgar Square are illustrated in Fig. 111. It will be realized that under this system a 100 per cent. booking service is available throughout the day. Thus, on the occasion of a storm, or other emergency, when booking-halls were apt to become unavoidably congested owing to few windows being open in the slack hours of the day, full use can now be made of the booking facilities provided by the automatic machines. At the busier stations change can be obtained either at the booking-office window or at a booth in which a clerk is on duty to operate a special machine for the purpose; this system is in operation at Bank Station (C.L.R.), as shown in Fig. 112.

LIFT PEDESTAL BOOKING

Before concluding the subject of passenger booking, reference may be made to the practice of providing miniature booking-offices in the lifts, as in Fig. 113, the ordinary offices being abolished. This system applies particularly to quiet stations, and twenty-five are so equipped. The liftmen in such cases receive training in the handling of tickets and cash, and are provided with a booking-pedestal, an automatic ticket-issuing machine, a dating press, and a rack for other tickets for which



Fig. 112. The automatic booking-hall at Bank Station; note the change-giving booth in the foreground.

there is a small demand. They are also given a telephone for attaching to bare wires, which run from the top to the bottom of the shaft, so that they may communicate with any point in the event of a breakdown. By means of a special lever they can operate the air gates on both sides of the lift, which starts automatically on the gates being closed. A fire extinguisher is also part of the equipment. Where the lift pedestal system is in operation a number of automatic slot ticket machines are installed in the booking-hall to supplement the booking facilities. The liftmen, who are able from their seats to operate the lifts and issue tickets, appreciate this comparatively recent innovation, because, whilst the monotony of their normal duties is to some extent relieved, they are also granted a special monetary allowance in respect of the additional responsibility.

A further development of the passimeter system at certain stations where lifts are installed is that the controlling switches and levers of the lifts are provided inside the passimeter offices, as at Angel and London Bridge Stations, the clerk operating the lifts with one hand and issuing



Fig. 113. A lift equipped with a pedestal booking-booth, an arrangement in operation at some of the less busy stations.

the printed tickets by the mere touch of buttons with the other. The operators have taken very well to this new system and have proved themselves efficient: it keeps them occupied and interested in traffic movement, and they receive increased pay for the additional duty.

SEASON TICKETS

Season tickets can be obtained between practically all Underground stations as well as through to certain points on the London General Omnibus and allied tramway systems, whilst 'through' season tickets to other railway companies' lines are also available. Quarterly and monthly tickets can be obtained at any station on demand. In addition to those season tickets issued for use on the railways, 'T.O.T.' season tickets can be obtained from the various exchange stations on the routes on which such tickets are available. It should be explained that the title 'T.O.T.' indicates that the season ticket is available for part of the journey by rail and for the remainder by tram or omnibus, and *vice versa*. These tickets, although a comparatively recent innovation, are very

popular. In addition to being issued at stations, they are also obtainable from agencies in the principal outlying districts adjacent to the bus and tram routes served, so that passengers can readily take advantage of the facilities offered.

A still more recent form of season ticket is the 'weekly season'. These tickets are issued after twelve noon on Saturday and up to and including Monday, and are available until the close of traffic on the following Saturday night. They were originally issued from only a few stations, but the demand has been so satisfactory that they are now obtainable at most Underground stations.

Chapter XIII

STATION DESIGN AND WORKING

THE trains of the Underground railways serve 194 stations in the Greater London area. From the busiest and most important stations to the less prominent ones on the quieter sections great care has been taken to introduce design and lay-out which shall be attractive to the public and productive of economy and efficiency in operation. Much progress has been made in recent years in the construction, equipment and general attractiveness of Underground stations. A generation has passed since the station was regarded as a dreary place where one had to queue up to buy a ticket and join a train, and to-day spaciousness, cheerfulness, and rapid movement are the prevailing characteristics. Incidentally, a pleasing and convenient feature of recent years has been the provision of well-lighted shops in the booking-halls at such Underground stations as Victoria, Oxford Circus, Piccadilly Circus, and Bank, whilst telephone services have also been amplified.

RECONSTRUCTED STATIONS

That the newer stations of the Underground should be convenient and handsome in design and equipment was to be anticipated in view of the far-seeing policy of the management, and the reconstruction of some of the oldest stations has brought about a remarkable transformation. Anyone, for instance, remembering the old Westminster Station, on the District Railway, which had done duty for sixty years, cannot fail to be impressed by the marked improvement in its appearance (*vide* Fig. 104, page 157). Appearance, however, is not everything, and the object has been to combine pleasant architectural effects with efficiency of service for the passenger, who, in these days, is always in a hurry. The old narrow, drab booking-offices and dark stairs are replaced by wide entrances and a commodious booking-hall equipped with the passimeter system, which avoids confusion and delay and has so stimulated the use of the station that 300,000 additional passengers used it during the year following its reconstruction, whilst 25 per cent. more passengers per hour can now be dealt with.

Another important reconstructed station is the Bank, on the Central London line, which contains a circulating area in the public subway, with openings to and from the booking-offices and escalators. A raised gallery surrounds the booking-hall, and at all times of the day people

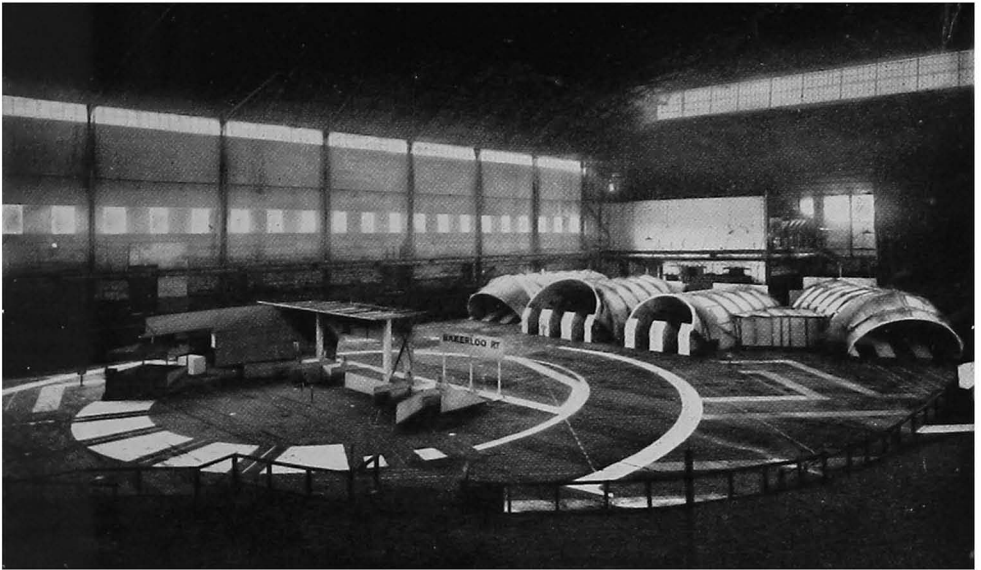


Fig. 114. A full-size model that was made preparatory to the reconstruction of Piccadilly Circus Station.

may be seen standing and watching with interest the streams of traffic which are handled rapidly and without congestion. At this station three escalator machines were introduced for the first time in one shaft, 25 ft. in diameter; two of the escalators work either upwards or downwards according to the heavy flow of traffic, while the third is used in the direction of light traffic, an arrangement which proved so successful that it has been repeated at Tottenham Court Road, Waterloo and Piccadilly Circus Stations. The modernization of the Bank Station cost £140,000, a sum which will serve as an indication of the amount expended in the rebuilding of Underground stations.

PRELIMINARY INVESTIGATION

The system adopted in the construction of new, and the reconstruction of old, stations requires not only the preparation of plans and specifications, but also the building of full-size models composed of battens and mill-board. These models afford opportunity for making the best use of the space available and for experimenting in the position and dimensions of the appointments, such as stairways, landings, passages, booking-offices, ticket machines, lighting effects, and all other details. Fig. 114 is an illustration of the model which was made as a preliminary

step to the reconstruction of Piccadilly Circus Station. The large white circle in the foreground represents the public subway directly beneath Piccadilly Circus, the white blocks on the left indicating the passimeter booths. At the right of the passimeter booths is the circulating area leading to the top of the five escalators numbered 1 to 5—there will be eleven at this station—shown in the centre of the photograph. The bottom of this first flight of escalators is shown in the form of tunnel construction, the commencement of the lower flight of escalators for the Piccadilly Railway being in the left background, and those descending to the Bakerloo on the extreme right.

DIFFICULTIES AT TOOTING BROADWAY

The difficulties which are encountered and overcome to-day in station construction may be instanced by reference to the case of Tooting Broadway. For the greater part of its course the Morden Extension passes through clay, but a very bad patch of ground was encountered at Tooting. Here the strata consists of an upper deposit of blue clay, below which are the Woolwich Beds and extensive pockets of water-logged sand. The Woolwich Beds, which are here at a higher level than is usual in the London area, are composed of a layer of shell and shaly clay hardened into a kind of natural concrete. Borings had indicated that the lowest stratum of sand (in which the inverts of certain sections of the tunnels now lie) was in places 20 ft. thick. The quantity of water here may be gauged from the fact that in Tooting's rural days quite a number of artesian wells had their sources of supply in the sand. The construction of a Tube station, with its large platform tunnels, its escalator shafts and passages, together with a siding and cross-over, on what was equivalent to an underground pond would seem at first sight an almost insuperable task.

To facilitate operations, which had to be carried out under compressed air, the section of the new line between Tooting Broadway and Trelvelyan Road was dealt with specially. Work was conducted from three service shafts sunk above the site of the 'down' running tunnel to the south of the station. These shafts were excavated as far down as practicable without resort to the use of compressed air. Vertical air-locks were then fixed in the top of the two shafts, and the sinking of the latter to the requisite depth of 50 ft. was completed. Meanwhile, the third shaft was sealed at the mouth with a steel diaphragm to prevent the compressed air escaping, as through a chimney. The first phase of construction, comprising the 'step-plate' junction that would link the

'down' running tunnel with the leading-in section of the siding and a portion of the similar junction on the 'up' running tunnel, was then carried out, under compressed air, through the vertical lock mentioned. The work on the 'up' tunnel was begun from headings driven across from the shafts containing the air-locks.

On the conclusion of the first phase of the work, the air-locks and the diaphragm were removed from the service shafts, and four horizontal air-locks were formed in the sections of tunnel completed. Operations were then resumed under compressed air (at about 15 lb. to the sq. in.), and the platform tunnels, running tunnels, siding, escalator shaft and various communication passages were constructed. The air-compressor plant maintained a continual supply equivalent to the compression of from 2,000 to 2,800 ft. of free air per minute. Any stranger descending to the lower levels at Tooting Broadway whilst work was in progress would have found himself among what appeared to be an irretrievable state of chaos, but even the worst job of Tube engineering comes to an end, and to-day a spick-and-span Underground station presents little evidence of the difficulties that had to be surmounted in constructing it, and none at all of the fact that it is situated partly in a subterranean pool.

NEW PICCADILLY CIRCUS STATION

The most extensive undertaking in connection with any one station was the construction of the new Piccadilly Circus Station, with escalators under the roadway of the Circus. Not only had provision to be made for the accommodation of an annual traffic of 50 million passengers, but regard had also to be paid to the future development of traffic for many years to come, as ultimately both the Piccadilly and Bakerloo lines are likely to be extended into new areas. Of the many thousands who crossed Piccadilly Circus every day, very few had any conception of the magnitude of the work carried on beneath their feet. An iron-lined pipe and cable subway has been constructed, 12 ft. in diameter, or $3\frac{3}{4}$ in. more than the ordinary Tube railway tunnel. This is quite a new departure, for while the Tube type of tunnel has been used for aqueducts and sewers in various parts of the country, it has not hitherto been adopted for this purpose in a British city.

Some idea of the arrangement of the upper part of the station may be gained by reference to the diagram (Fig. 115). Short stairways will lead down from seven points in the Circus to a circular public subway, whence direct access will be gained to an entirely new booking-hall, 15 ft. below the surface, covering an area of 15,000 sq. ft. From the booking-hall

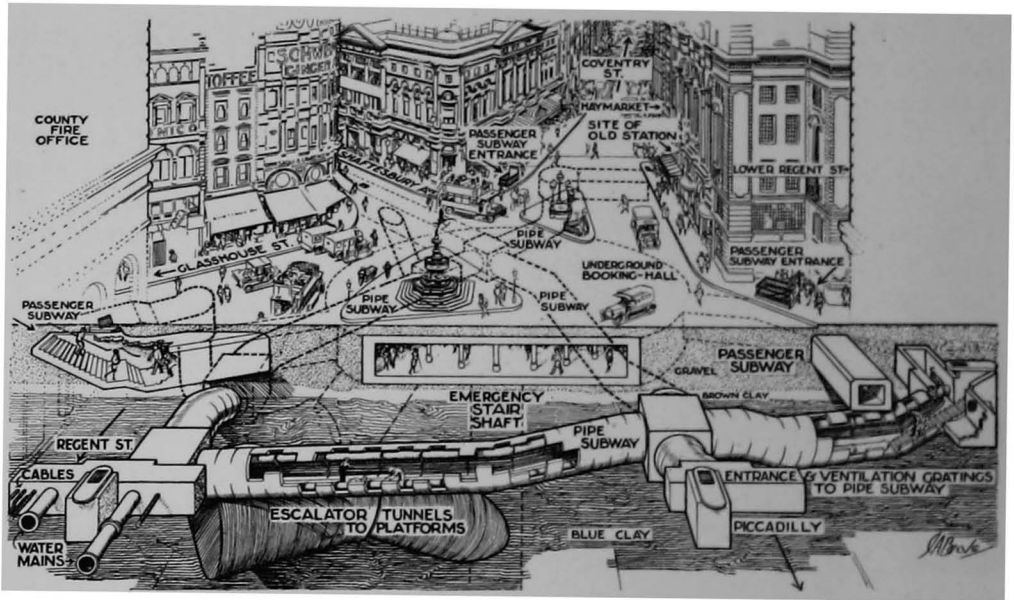


Fig. 115. Diagram showing arrangement of subways at the new Piccadilly Circus Station.

five escalators will descend in two tunnels to a common landing, 57 ft. below the surface. In the three-escalator tunnel, which is 22 ft. in diameter, one escalator will be reversible so that it can be operated upwards or downwards according to traffic flow. On each side of the landing, or circulating area, there are two 10-ft. passageways giving access to the Piccadilly and Bakerloo lines respectively, the platforms of which are situated 108 ft. and 88 ft. below ground level. The latter are reached by six further escalators carried in two tunnels, one of the three in each case again being reversible.

THE PIPE SUBWAY

The principal difficulty with which the engineers were confronted was the deflection of the L.C.C. pipe and cable subway running below Shaftesbury Avenue and ending in the middle of the Circus. As this site is occupied by a great circular booking-hall, the pipe subway had to be cut off and provision made elsewhere for the various pipes, cables and wires which it had previously contained. These were accordingly brought down to a lower subway, 570 ft. long, which practically surrounds the Circus at a depth varying from 12 to 30 ft. below the road level and constitutes a kind of outer circle to the pedestrian subway



Fig. 116. A new station on the Morden Extension of the City and South London Railway.

(see opposite page). The new pipe and cable subway, which is clearly shown in Fig. 115, has frequent undulations to enable it to pass under or over the several obstacles in its path, such as sewers and public lavatories. At every point where the street converges on the Circus, the subway rises to what is known as a pipe interceptor, which crosses the road below the street.

Water mains, 24 in. in diameter, with 18 in. branches striking off at the points of ascension to the pipe interceptors and going thence to the street, pass through the subway. Entrance to these interceptors is provided by manholes, situated at street refuges, and the inclined tunnels leading to the pipe subway have concrete steps. A drain extends along the invert of the main tunnel, and water collecting here passes off into a sump. Another handicap for the engineers lay in the fact that, owing to traffic difficulties, practically all the work had to be done from the main shaft, and 1,000 tons of clay were so raised every month. A complicated task was that of removing the various mains and placing them within the pipe subway, where they rest on brackets and are readily accessible: a much more convenient arrangement, as hitherto, in order to reach any strand of the tangled skein of pipes and cables, the roadway had to be pulled up, with consequent dislocation of traffic at one of London's busiest centres.



Photo:

(Topical Press

Fig. 117. Clapham South Station, City and South London Railway.

EXTERIOR DESIGN

To the passenger the station is merely the point of arrival or departure, whilst to the company it is, in addition, a medium for advertising and attracting traffic to the railway. The Underground station must, therefore, be so designed as to enable the transport of passengers between the street and the platforms with the least possible delay and be conspicuous by day and by night. At the new stations on the Morden line there are few stairs and subways, the passenger being virtually carried from the pavement to the trains by moving stairways.

The exterior design of the Morden stations originated from a visit paid a few years ago by officers of the Underground railways to the Paris Exhibition, when a number of buildings and styles of architecture were carefully inspected. As the line was to pass through thickly populated and developed districts, it was thought that the stations should be made conspicuous by the application of an æsthetic design which would render them distinct from other buildings, such as stores and cinemas. The design, however, was to be a flexible one, capable of adaptation to any site and of use in the reconstruction of existing Underground stations.



Fig. 118. Tooting Broadway Station, City and South London Railway, showing the striking effect of flood-lighting. The beam of a searchlight can be seen above the roof.

It was agreed to utilize flood-lighting for illuminating the exteriors of the Morden stations, and the requirements of this form of lighting largely determined the main features of the station designs. The reinforced concrete canopy with enamelled iron facia supplies the supports and cover for the lamps which project the light on to the walls both above and below. The large window to accommodate the Underground 'Bull's-eye' sign is the reason for the two stories. The projecting Underground silhouettes, with masts, are also flood-lighted and provide the necessary indication to those approaching the station from the sides. The wide entrances to the station and the large windows provide a maximum of light to the booking-halls. To obtain a satisfactory result from flood-lighting, a light surface is required, and Portland stone was used. This stone wears well and is easily cleaned. The illustrations in Figs. 116, 117 and 118, bear testimony to the attractive and clear-cut appearance of the new stations, which have met with unanimous public approval.



Fig. 119. Hendon Central Station on the Edgware Extension of the Hampstead Railway.

EDGWARE EXTENSION STATIONS

The design of the station buildings on the new extension from Golder's Green to Edgware, although probably not so striking as that prevailing on the Morden line, is nevertheless worthy of note. It differs materially from that followed in the construction of earlier Underground stations, as the extension is a surface railway and an endeavour has been made to provide buildings that shall harmonize with the amenities of the modern residential suburbs which the new stations will serve. Brent, Hendon and Colindale Stations are all built of red brick in the Georgian style, the front elevations having Doric colonnade porticos of Portland stone (Fig. 119). The floors of the booking-halls and offices are paved with black-and-white tiles, and the lower walls are faced with white glazed tiles relieved by green.

Edgware Station is designed in the Italian style and comprises a centre portion and two wings which form three sides of a quadrangle, 100 ft. in width and 69 ft. in depth (Fig. 120). The front elevation is of Portland stone, with a Doric colonnade along the centre and the west wing. The main entrance, which is in the centre, is flanked by small pavilions, which break the roof-line of this façade. The east wing contains a row of shops, divided by Doric columns to preserve the harmony of the general elevation. The roof is high pitched and covered with Italian tiles. The colonnades are paved with red and buff tiles, and the booking-hall with black-and-white tiles, whilst the interior walls are faced with

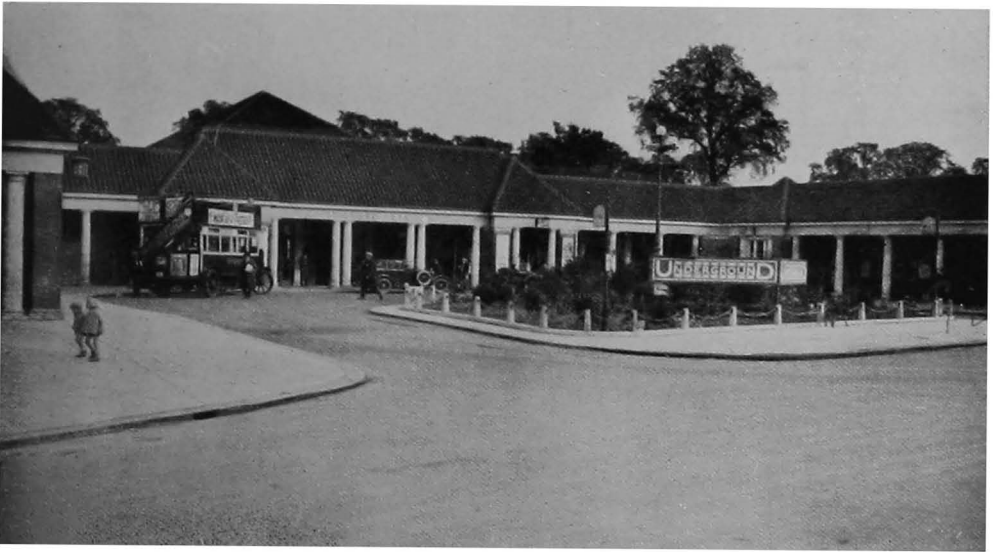


Fig. 120. The new Edgware Station.

white glazed tiles formed into panels by green borders. The joinery throughout is of polished oak, with bronze fittings. The motive underlying these designs is that the station shall have a dignified appearance calculated to gain the appreciation of the passenger.

PROGRESS IN DESIGN

So remarkable has been the progress in the design of Underground station buildings that already those of the London Electric Railway, constructed over twenty years ago, have become quite commonplace. For this railway fifty stations had to be erected in a comparatively short time. It was decided that they should be of a distinctive and uniform type so that they should be easily recognizable by the public. As the lift machinery had to be installed above ground level, two-story buildings had in each case to be adopted, the material used being terra-cotta because it presented an unusual colour, and, being cast in a mould, was economical in manufacture. An example of one of these stations is given in Fig. 121.

Advertisements were originally taboo except over the tracks. No posters were allowed on the platform walls, which were tiled in a different colour-scheme, station by station, on the supposition that this



Fig. 121. One of the original London Electric Railway stations.

would aid the passenger in identifying his destination. The expedient, however, was found to be an unnecessary one, and very soon posters, productive of useful additional revenue, were encouraged, and illuminated maps were installed at the station entrances. At the same time great care was exercised with regard to the type and disposition of the posters, and it is generally agreed that the display of artistic posters considerably improves the appearance of the Tube station platforms.

The advent of the escalator enabled the provision of single-story buildings. Kilburn Park was one of the first stations to be equipped with an escalator between street level and platforms, and a large skylight allows daylight to reach almost to the bottom of the shaft—a welcome improvement.

LIGHTING ARRANGEMENTS

A feature of the exterior of the new Morden line stations is the application of flood-lighting. The necessity for drawing the attention of the public to the existence and position of the stations was realized when the line was opened, and, in addition to the flood-lighting, searchlights were installed on the roofs of certain of the stations, as shown in Fig. 118. The lights were of 20,000 candle power and their beams seen two miles away.



Fig. 122. A subway at Finsbury Park Station, showing the effect of flood-lighting as applied to interiors.

Careful attention has also been given to interior station lighting, the aim being to obtain brilliance without glare. The introduction of gas-filled lamps has led to a 50 per cent. improvement in station lighting and to an effect closely akin to daylight. Flood-lighting has also been applied to passage-ways with pleasing results, a case in point being Finsbury Park Station (Fig. 122).

Electrical current for the lighting of station premises is obtained from the Lots Road power house of the Underground railways by means of special cables, which are distinct from those carrying power for the working of trains, lifts and escalators. Adequate emergency arrangements are also available, and should there be a failure at the railway power house, a supply of current for station lighting is immediately available from outside sources. Furthermore, in the event of an interruption in the supply of current for train operation, the electric lights in the tunnels and additional lights in the trains are automatically switched on; further lighting is available also from oil and candle lamps



Fig. 123. A guard giving the 'right-away' by placing the metal handle of his flag against two wires, suspended above the platform, which causes an electric bell to ring near the motorman's cab.

kept on the trains and at the stations. On the whole of the Underground system there are over 90,000 lights which use six million units of electricity annually.

TRAIN-STARTING DEVICE

At certain points on the District Railway the signal given by the blowing of the guard's whistle is no longer an indication that a train may proceed. In place of this old-fashioned process there has been substituted a device which consists of a number of rods, linked together with a cable and suspended from the roof at one end of each platform. Hanging from the cable are two wires which connect electrically with a bell at the other end of the platform. When it is desired to start the train the guard touches the two wires simultaneously with the metal handle of his flag (Fig. 123). The circuit thus formed rings the bell, which is conveniently placed near the motorman's cab. Experience shows that the

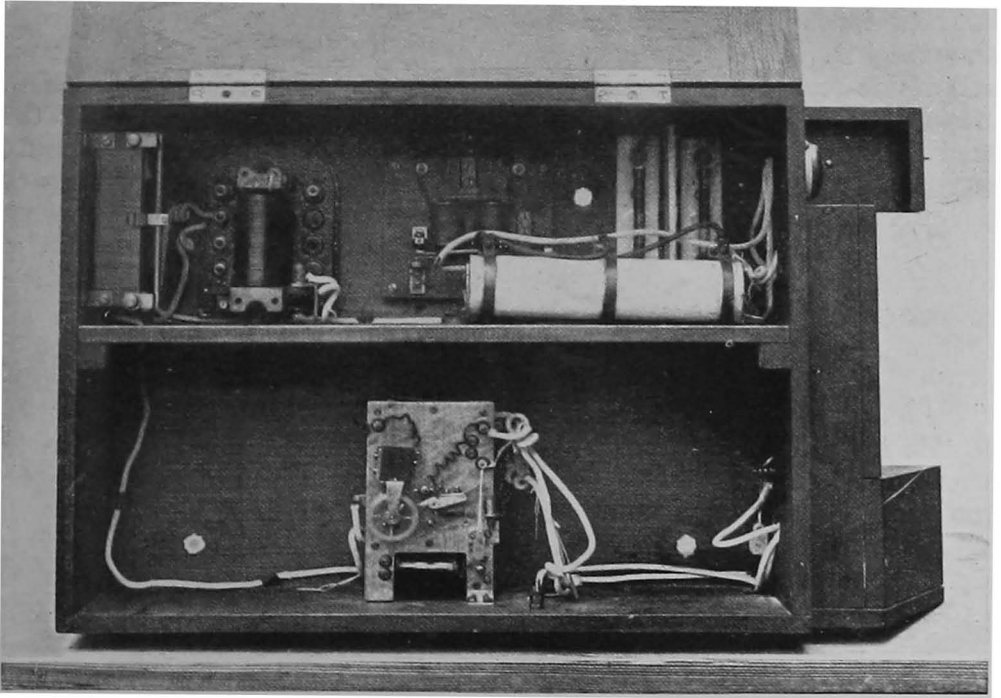


Fig. 124. The mechanism of the 'platform hustler'.

use of whistles, in addition to affecting the nerves of passengers and residents near the railway, causes delay to the service, particularly in the case of a long train when, with another train running on the opposite road, the guard has sometimes to blow his whistle several times before the driver or platform staff hear it. Tests have disclosed that the bell device saves many seconds in the starting of trains, and the bell also acts as a warning to passengers, because it can be heard from any part of the platform.

THE 'PLATFORM HUSTLER'

Another appliance which is used as a means of expediting train departures, particularly at the busiest stations, is that known as the 'platform hustler', which was referred to in Chapter VII. It is invaluable at a station like Victoria, an interchange point where punctual working is vital to efficient operation of the District Railway. It consists of a siren, which sounds at a predetermined time after a train has come to rest, and is a notification to the station and train

staff that the train must at once be dispatched. The mechanism is shown in Fig. 124. When a train enters the station the track circuit relay is de-energized; this starts the operation of a train of gears which, after a certain time, closes the contact for the siren, provided the starting signal is in the 'clear' position. If, however, the train should start before the time allowed, the mechanism is stopped by means of the current in the traction rails, which flows when the controller handle is moved; thus, immediately the controller handle is moved the siren is cut out of use for that particular train. The usual setting for the station stop is from 25 to 30 seconds.

TRAFFIC DIRECTION-SIGNS

Traffic direction signs are a feature of every station, and particularly interchange stations. At Charing Cross, for example, where some 100,000 passengers are handled daily, the signs must be as few in number as possible and carefully planned as regards form and position. Here will be found wall signs, illuminated finger-post signs and floor signs. One floor sign consists of glass letters countersunk in the concrete floor, beneath which are fixed lights that cause the legend 'To Edgware and Highgate Railway' to stand out conspicuously. Another sign, directing passengers to the District Railway, is composed of black rubber letters inlaid in aluminium troughs let into blocks of white rubber. The sign leading to the Bakerloo line is of metal letters in the concrete floor. The older Underground passenger will doubtless recognize the vast strides that have been made in the use of signs, both as regards style and clarity. In the early days it was the custom to crowd information into whatever space was available. This only led to confusion, and by the time the would-be passenger had digested a quarter of the voluminous information provided for his enlightenment, he had no doubt decided to avail himself of some other means of transport, or, having already taken his ticket, resolved not to travel that way again.

At the heavy interchange stations guides are on duty in the subways. These men are specially trained in knowledge of the railways of London; many of them can speak in two or three languages.

PLATFORM POSITIONS

Surprise is sometimes expressed at the want of uniformity on the Underground railways in the matter of platform position, and passengers



Fig. 126. The movable platform extension at Wood Lane.

MOVABLE PLATFORM EXTENSION AT WOOD LANE

A number of structural alterations were carried out at Wood Lane Station, Central London Railway, in order to cope with the increased traffic consequent on the opening of the White City Stadium for greyhound and cycle track racing. The booking-office was replaced by a number of passimeter booking-booths, equipped with electric ticket-issuing machines capable of providing 20,000 tickets an hour, whilst freedom of movement was ensured by the additional 800 sq. ft. of floor space thus made available. The most interesting alteration, however, concerned the lengthening of one of the platforms used by trains passing over the loop line from and to the City. This platform (No. 1) faces another (No. 2) on the other side of the single loop line, but its use was previously restricted as it was of insufficient length to accommodate six-car trains. Passengers had, therefore, to alight at No. 2 platform, in spite of the fact that, being on the outer edge of the curve, there is a considerable gap between the platform edge and the coaches, accentuated since the introduction of reconstructed rolling stock having centre- instead of end-doors. Apart from the risk to passengers, the care they had to exercise in passing from train to platform, and vice versa, resulted in delays at times of pressure.

By providing No. 1 platform with an extension to permit the longest



Fig. 127. A set of the latest type escalators.

trains to be dealt with, it was possible to cease using No. 2 platform. The existence of a turn-out leading from the main line to the local car depot prevented the provision of a fixed extension, and the ingenious method was adopted of providing a movable section, which is capable of being swivelled over a distance of approximately 4 ft. by mechanism operated from the adjoining signal-box. The platform was thus extended by 35 ft., and although the new section is normally in line with the platform and fowl of the turn-out, it can be swivelled into a position clear of the latter whenever it is necessary for trains to pass to or from the depot. The signal-box levers which operate the movable platform are of the dwarf type and similar in pattern to those used for working the points and signals. The movement is electro-pneumatic, and the levers are fully interlocked with the signalling system, so that no train can approach unless the hinged platform is in the appropriate position. A feature of the new device, which is illustrated in Fig. 126, is that in the event of a failure in the mechanism the platform can be moved by hand. It was designed and constructed by the staff of the London Underground Railways.

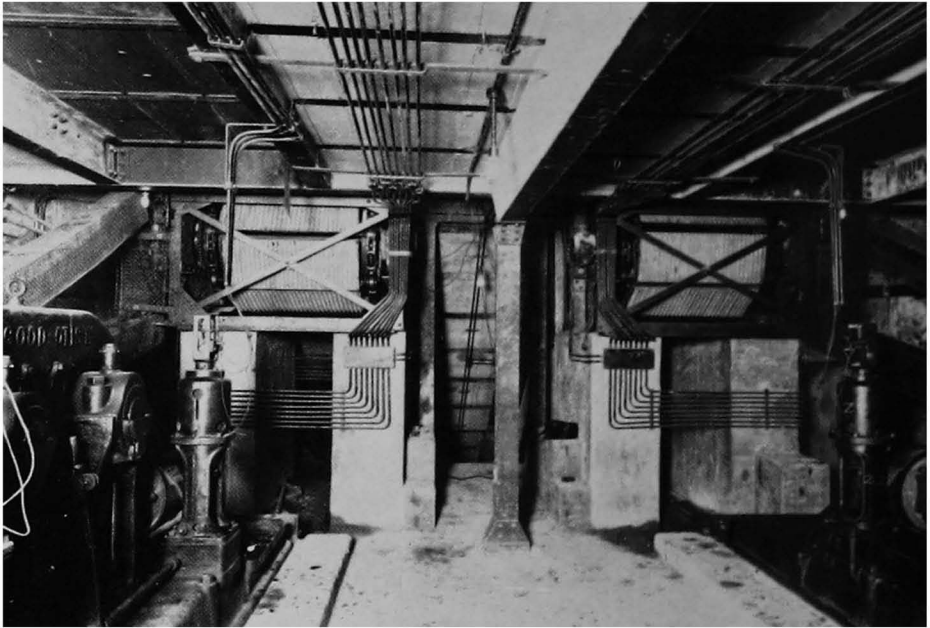


Fig. 128. Escalator mechanism.

ESCALATORS

Escalators as a means of conveying passengers from the street to the platform, and vice versa (Figs. 127 and 128), are gradually superseding lifts on the Underground. The first escalator was installed at Earl's Court in 1911; there were then 240 lifts throughout the system. With the general increase in traffic and the need for quicker transport of passengers to and from the street, escalators have been made a feature of practically all new and reconstructed stations. To-day, there are seventy-six machines in operation at thirty stations, and when the present escalator scheme is completed the number will have been increased to eighty-five machines operating at thirty-four stations; there will then be only 157 lifts in service. One 'up' and one 'down' escalator are regarded as being able to do the work of five lifts. If this means of transporting passengers had not been employed, a total of 372 lifts would have been required.

The advantages of the system over lifts are many. Principally, there is the freedom and rapidity of movement experienced by the passenger, particularly where escalators are operated in conjunction with the



Fig. 129. Comb-type escalators.

passimeter booking-offices. The irritating lift wait is avoided, and the roomy tunnels in which the escalators are installed provide well-ventilated and attractive surroundings. Where a third escalator is installed it can be operated in either direction, to correspond with the traffic flow, thereby saving the passenger still more time. That the travelling public prefer them to lifts is evidenced by the fact that wherever escalators have been installed an increase in traffic has resulted.

The original escalators were of the 'shunt' type, which necessitated a side-stepping movement in getting off, but these are being succeeded by machines that are known as the 'comb' type—the passenger being, as it were, 'combed off' the escalator in a forward movement (Fig 129). The advantages of the 'comb' type are that the landing is made simpler for the passengers and that the escalators can be reversed immediately. Thus, a 'down' escalator can at once be operated in the 'up' direction should the 'up' escalator happen to fail, the passengers being required to walk down the 'up' escalator when it is at a standstill. Although the speed

of an escalator is only a little more than one mile per hour, all the machines on the Underground system, in the course of a twenty-hour day, during which most of them are in operation, travel approximately 2,000 miles. Some stations, Tottenham Court Road for example, have five separate machines. The new station at Piccadilly Circus has no fewer than eleven escalators—a record for any one station in the world—and these will have to handle a traffic of fifty million passengers per annum.

The escalator is, in fact, contributing in no small degree to the solution of London's traffic problem. Whereas the lift collects passengers in a body and deposits them *en masse* on platforms or in streets, the continuous service provided by the escalator allows the traffic to flow more evenly on to the platforms, and the trains, in turn, are more evenly loaded. The cost of installing escalators is considerable. When the present scheme is completed over £6,000,000 will have been expended in this direction alone, inclusive of the shafts to contain the escalators and the rebuilding of the stations.

TRAFFIC AND STAFF

The volume of traffic to be dealt with at many Underground stations exceeds ten million passengers per annum, and the following figures in respect of one year may be of interest:

	1927
Charing Cross	33,043,800*
Oxford Circus	27,299,600*
Piccadilly Circus	24,868,250*
Hammersmith	23,764,700*
Bank	22,339,800*
Victoria	21,032,000
Tottenham Court Road	19,653,500*
Leicester Square	19,227,750*
Elephant and Castle	17,172,650*
Liverpool Street	16,808,350
Waterloo	14,904,500
Earl's Court	14,255,650*
Finsbury Park	14,082,550
Golder's Green	12,480,900
Mansion House	12,250,750

*Including interchange traffic

Nevertheless, large station staffs are not essential, as the mass-movement

of passengers is more or less automatic. The following table shows the personnel required for typical stations on the District Railway:

<i>Grade</i>	<i>Hammer-smith</i>	<i>Victoria</i>	<i>Charing Cross</i>	<i>Earl's Court</i>	<i>Mansion House</i>	<i>Black-friars</i>
Stationmasters	1	1	1	1	—	1*
Booking-Clerks	15	18	15	10	8	6
Station Inspectors	2	2	2	2	2	1
Foremen	1	1	1	1	1	1
Policemen	2	2	1	—	—	—
Ticket Collectors	9	9	9	7	5	6
Porters	18	14	17	18	6	5
Cloak Room and Lav. Attendants	3	4	2	3	—	—

*Controlled jointly with Mansion House Station

PUBLIC GARAGES

This interesting innovation at Morden Station consists of a public garage, owned and administered by the Underground, and provided primarily for the convenience of passengers who live farther afield and may desire to drive to the station, park their cars, and continue



Photo]

[S. F. Bowser & Co. Inc.

Fig. 130. Garage at Morden Station of the London Underground Railways.

their journey to London by Tube. The new garage (Fig. 130), which is the first of its kind in this country, has an area of 7,600 sq. ft., and provides accommodation for nearly 500 cars and cycles. Private lock-ups, with easily accessible entrances, are a feature. Besides the usual facilities for petrol filling and washing, there is a fully equipped workshop and a competent staff of mechanics. Specially cheap daily and weekly rates are charged to Tube season-ticket holders.

This experiment has already proved highly successful, and it is a contribution towards the solution of the problem of parking cars in crowded central areas. Instead of having to drive through the congested zone and then having to leave their cars in the London streets, business men are able to deposit them at the new garage until they require them for the return journey, and the arrangement is an equally convenient one for theatre-goers. It is likely that similar garages will be erected at other outlying terminal stations on the Underground railways.

Chapter XIV

RELATIONS WITH EMPLOYEES

AN alternative title to the above would be 'Staff Welfare', a term which in some quarters has been misinterpreted as implying the exercise of a form of charity. In the case of the London Underground Railways, however, it may be regarded as evidence of a desire on the part of the company to establish a cordial relationship with its employees, and so to promote understanding and co-operation, which are the elements of progress in large businesses.

Do welfare schemes pay? Do the staff appreciate them, and what is the net gain after all the trouble and expense? Such questions may savour of cynicism, but nevertheless they are debatable ones. In so far as the Underground is concerned, the belief is held that the staff appreciate the company's interest in their welfare and, in consequence, are encouraged to give more conscientious service than would result from an attitude of severe detachment. Ruskin once said that the wealth of a nation lies in the number of happy subjects it possesses, and the remark is equally appropriate to the large commercial and industrial undertakings of the present day. After all, the welfare of the workers depends upon the prosperity of the organism which they serve, and the call for the co-operation of all to secure efficiency and economy in management and working is an insistent and logical one.

SUGGESTIONS SCHEME

One of the methods employed by the Underground for fostering co-operation is known as the 'Suggestions Scheme'. Suggestions are invited from all grades of the staff in regard to such questions as methods of increasing traffic and securing economy in working, providing better facilities, improving train working, and enhancing the character and construction of rolling stock, works, depots, stations and their equipment.

A suggestion should, of course, contain some novel idea and show evidence of careful consideration. To call attention merely to an omission or error is insufficient, unless the matter is of exceptional importance. Awards are given at the discretion of the company, the minimum amount for suggestions accepted and carried into effect being 20s. A special merit award—minimum 10s.—may be given for suggestions which are partially adopted, or which lead to some action

being taken, or for other suitable reasons. A list of awards is published monthly, and full particulars of each case are entered on the staff record of the recipient. Some 6,500 suggestions are received during the year, and awards are made in about 10 per cent. of the cases.

In the period after the war the company had to face problems of great complexity, one being the severe congestion of the running lines. The management, in pursuance of its policy of consulting with its employees, thereupon appointed a Congestion Committee, consisting of various grades of the service, with the duty of investigating and reporting upon causes of traffic congestion. The staff were specially invited to make practical suggestions for the relief of the congestion and the improvement of the service, either verbally or in writing, to any members of the committee, and 63 awards were made.

STATIONS COMPETITION

Another of the company's schemes, which has proved markedly popular, is the 'Stations' competition, under which an award of £20 is made to the station on each line that achieves the best working results for the six months ending June and December in each year. Periodical inspection is made by the officials, and, finally, by the officers of the company, the award being made to the station credited with the highest number of points as under:

- Courtesy and general conduct of staff.
- Platform and telephone service.
- Traffic regulation.
- Lift and booking-office service.
- Tidy and cleanly appearance of station premises.
- Efficiency in dealing with signal, train and other failures.
- Economy in stores, etc.

The award, it may be added, is made to the winning station on each of the six lines comprising the Underground railways twice yearly and is divided amongst the staff according to grade. In addition to the money prizes, six shields are awarded—one for each of the winning stations—the shield in each case being exhibited in a conspicuous position on the station premises.

INSTITUTES

The institutes, clubs and associations of the Underground are managed by committees of the staff, whose efforts are supported by the managers and officers, although the latter take no executive part in the organization



Fig. 131. One of the messrooms for employees.

unless specially requested to do so by the committees concerned. Following are the institutes for the respective railways: District Railway, 'Albert Stanley' Institute, Hammersmith; London Electric Railway, Institutes at Golder's Green, Lambeth North and Hammersmith; Central London Railway, at Shepherd's Bush; and City and South London Railway, formerly at Clapham Common, now removed to Morden. Some of the institutes adjoin the messrooms, so that games, such as billiards and chess, may be indulged in after meals; a nominal charge is made for billiards, other games being free.

MESSROOMS

A comparatively recent feature of the staff organizations of large undertakings is the provision of proper accommodation where employees can have their meals. The Underground railways are well to the fore in this respect, and messrooms (Fig. 131) are provided at the more important terminal stations and also at several intermediate points, such as Hammersmith, Camden Town, Golder's Green, Morden, Queen's Park,

Elephant and Castle, Wood Lane, Kennington, and Sloane Square. The messrooms are installed and equipped at the companies' expense, the staff merely paying the cost of food, cooking and labour. Menus are changed daily, and there is always a variety of dishes to select from, in addition to the standard tariff. The messrooms are open all day and may be used by the staff at all times when off duty. Cooking facilities are also available for those of the staff who bring their own food, and a nominal charge is made when such cooking necessitates the use of materials. The messrooms referred to are used primarily by the outside staff.

For the indoor administrative staff the companies provided a large dining-room at South Kensington, with another room above for dancing and similar social activities. The premises were furnished and fully equipped and then handed over to a company, formed by the staff—registered under the Companies' Acts, limited by guarantee and not working for profit. The Underground companies pay the rates and the lighting and heating charges, and the dining club council has entire control over, and responsibility for, the club and its purchases. A subscription of 2s. 6d. per annum is paid by any member of the staff who cares to join, and certified accounts and balance sheet are issued annually.

T.O.T. BENEVOLENT FUND

One of the principal forms of staff welfare work is the T.O.T. Benevolent Fund. A voluntary contribution of 1d. per week, deducted through the pay-rolls, is made by each member of the staff, and the companies contribute an amount equal to the total staff contributions. The objects of the fund are to provide relief in cases of necessity or distress to members of the staff (or their dependents), to obtain medical, surgical, convalescent nursing, or other treatment, and, in cases of necessity, to assist in the maintenance, education, or training of members' dependents under the age of eighteen years, and to relieve immediate financial difficulties by monetary grants. The fund is managed by a council of fifty-four members, of whom twenty-one are nominated and six co-opted by the companies from amongst the directors and officers of the companies; twenty-one members are also elected by the twenty-one local committees as their representatives on the council, and six are co-opted by the elected representatives on the council, thus preserving the principle of equality, both of contributions and management, as between the subscribing members and the companies.

The same principle of fifty-fifty is followed in the constitution of the local committees and the subsidiary committees of the council.

Much of the administrative work of the fund is carried out by the local committees, whose efforts are purely voluntary, and there are also Finance, Relief, Convalescent Home Management, Housing, Hospital, General Purposes and Publicity Committees, titles which reveal the extent of the fund's activities.

The committees deal, on an average, with 2,500 applications for assistance during the year, and make monetary grants amounting approximately to £10,000. The fund is also utilized in affording advice to its members in the purchase of house property—a real difficulty in these days of inadequate accommodation. Free legal advice is given by the companies' solicitors, and their claims agent has in many cases, besides advising, been instrumental in obtaining settlements satisfactory to members concerned in outside accidents. The fund possesses a well-appointed convalescent home at Hythe, known as 'Philbeach', where members' wives and children are enabled to recuperate after illness or accident. Certified accounts and balance sheet are issued annually.

STAFF SUPERANNUATION FUND

The companies have established a superannuation fund for the permanent members of their administrative staff. To this fund the staff contribute a percentage of their salaries on a scale according to the age at which they become members. The amounts vary from $3\frac{1}{2}$ per cent. under the age of 21, to 6 per cent. at 42. A retiring pension is granted to members who have contributed to the fund continuously for at least ten years, on leaving the service at the age of 60 or upwards, when they are entitled to retire, or on reaching 65, when they are compelled to retire. The amount of retiring pension is equal to 2 per cent. of the total amount of the salary upon which contributions have been made to the fund. In the event of a contributing member dying before becoming entitled to a retiring pension his legal representatives receive a sum equal to twice the total amount of the contributions paid by him, and should a member resign or be dismissed from the service his contributions are returned and he has no further claim upon the fund. A material advantage to members is the fact that their contributions are allowed as a deduction from their income tax assessments.

EDUCATIONAL FACILITIES

Educational advantages are offered to members of the staff by the payment by the companies of the fees of approved applicants in connection with the London School of Economics, the Institute of Transport, the Chartered Institute of Secretaries, and other similar bodies.

The London School of Economics, which provides lectures and classes on railway and cognate subjects, attracts many members of the Underground staff as students, who are allowed to select their course, or courses, subject to approval. Each student is required to deposit, in advance, the sum of 10s. in respect of each course, this amount, however, being subsequently refunded if his attendances have reached 80 per cent. of the maximum. Similarly, for the Institute of Transport the fees of students and graduates who are members of the Underground staff are paid by the company, but only for a period of three years, unless the individual qualifies by examination for a higher grade. The value of these educational facilities cannot be over-estimated, and many notable successes have been gained by the companies' employees.

The female staff are not overlooked, and, with a view to encouraging the members of the shorthand typing staff to add to their efficiency, merit increases are granted, up to the age of 27, to those who obtain the Royal Society of Arts or Chamber of Commerce certificates for shorthand and typewriting. The merit increase is at the rate of 5s. per week over and above the scale rate, and this additional emolument has been the means of attracting as successful entrants practically all who are eligible, resulting in an all-round increase in efficiency.

STAFF MEETINGS

Educational staff meetings have been held during the past twelve years. The object of the meetings is the discussion of matters affecting all branches of transport work. The agenda commences with a paper, or series of papers, usually illustrated by slides or films. Typical subjects which have been discussed since the inception of the meetings are as follows:

- 'Safety First.'
- Time Tables and Duty Sheets.
- Staff Welfare Work.
- Notes on Traffic Control Problems.
- Problems of my Official Life (by members of various grades).
- The Source of Power for our Railways.
- Employment and Training of Railwaymen.
- Some facts about the construction of London Tube Railways.
- Where the money comes from and goes to.
- The Repair and Renewal of Electric Rolling Stock.
- The Signalling of a Rapid-Transit Railway.
- Design of Stations.

The papers are prepared and read by members of the staff, and the frankest expression of opinion, suggestion, or criticism is invited. When

they were inaugurated the meetings were promptly attended by from 500 to 700 of the staff. They are the means of extending the knowledge of the employees by giving them an insight into sections of the organization other than those in which they are immediately engaged, and, at the same time, they afford an opportunity for bringing forward original views and suggestions. One evening in each session is devoted to a purely social gathering; usually this is just before Christmas, when, for example, a carnival dance is held at Olympia and is attended by some 1,500 employees.

TOURS OF INSPECTION

The Underground appreciates the educational value of studying and observing methods employed by other transport and kindred undertakings, and periodically several of its officers are sent on a tour of the Colonies, the Continent of Europe, or the United States of America. On such occasions each officer individually represents a specific side of the organization. For example, one officer's interests may be concerned mainly with the design and maintenance of rolling stock, another's with electric power generation, and another's with signalling methods and equipment. Each prepares a report in the form of a paper, presenting his impressions, observations, and comments on what he has seen.

Arrangements are also occasionally made for selected members of the outdoor administrative staff to make tours of inspection of some of the provincial transport concerns of this country. The results of these visits are embodied in a joint report, which is circulated. Conversely, many transport officials visit the London Underground with the same objects, and in these progressive times the interchange of ideas regarding railway operation has proved extremely valuable.

LIBRARY

At headquarters there is a well-stocked staff library, which was inaugurated in 1921. It is managed by a committee consisting of officers and other representative members of the staff. Members of the administrative staff at head and branch offices and of the supervisory staff—the latter on the written request of their superior officer—are entitled to use the library. A printed general catalogue is issued, as also are supplementary lists of new books when frequent additions are made.

The library, which is in charge of a qualified librarian, contains some 3,000 volumes representing some 1,800 to 2,000 works. These are classified under the headings: Transport, Engineering, Technology,

Economics and Sociology, History, Geography and Statistics; Science and Art; General Literature; Topography and Archæology; Miscellaneous. It contains a reference department, consisting of works which may only be read on the premises, and a lending department, comprising the large variety of books that are available for home reading.

No charge is made for the use of the library, but any loss or damage to the books is the personal liability of the borrower. The librarian is always ready to assist members with advice on reading matter, and a special book is kept in which members are invited to make suggestions for the improvement of the library or additions to the stock of books. This institution is much appreciated by the staff, and it is well patronized both for study and reference purposes. It is particularly useful to students who are attending the London School of Economics, the Institute of Transport, and other institutions, in supplementing and amplifying the knowledge gained at the various lectures.

STAFF MAGAZINE

The T.O.T. Staff Magazine is issued monthly, and contains much interesting matter printed and illustrated on good paper, and the design of its cover is the result of a competition amongst the staff. The expense of production is subsidized by the company, and a nominal charge is made of one penny per copy. The success of the magazine has been due to its varied contents. The publication of personal and general social items, the presentation of popularly phrased articles on the scope and special problems of different departments, historical descriptions of the companies, the causes and effects of extensions and new works, and especially the recording of meritorious acts on the part of the staff, all these form interesting news items for the employees. In addition, brief notices of the activities of the numerous sports sections, together with a special page under the self-explanatory heading of the 'Market Place', wherein, for a small sum, members of the staff can advertise articles for sale or exchange, combine to make up an attractive summary of current Underground events. The editorial and production work is undertaken by members of the staff, and the number of copies at present issued monthly is over 26,000.

CIRCULATION OF TECHNICAL JOURNALS

The company circulates amongst its officers copies of all the technical journals containing information in which they are particularly interested. These are afterwards bound and placed in the staff library for reference



Fig. 132. Ealing Common—a prize-winner in the Station Gardens Competition.

purposes. Furthermore, Press-cuttings from all the newspapers, reviews and periodicals are circulated daily amongst officers and others concerned in order that they may be kept in close touch with events and developments in the realm of transport.

STATION GARDENS COMPETITION

A competition which is held annually and never fails to evoke lively interest is the 'Station Gardens' competition (Fig. 132). This should be included among the purely recreational activities, but its mention here is justified, inasmuch as the gardens add greatly to the cheerfulness of the railway. The competition is promoted annually as an incentive to members of the staff to cultivate flowers, plants and shrubs for decorative purposes. Prizes amounting to £35 are awarded for the best kept gardens. The company provides the necessary ground for the cultivation of the selected plot and gives five shillings in each case towards the purchase of seed, the produce of which is the property of the

employee undertaking the cultivation. At the end of July in each year a committee of directors and officers of the company makes a tour of inspection of the various gardens and decides upon the awards. The prizes are not necessarily given to the stations having the best gardens, but are awarded to the competitors who make the best use of the conditions existing at their stations. Great interest is taken in the competition, and fine displays of flowers and shrubs are to be seen at many points on the line—on station platforms, banks and sidings—in fact, in any corner where cultivation is at all possible.

HORTICULTURAL SOCIETY

A side-light of recreational activity is the Underground Railways Employees' Horticultural Society. Managed by an enterprising committee, large quantities of seeds, roots, manures and gardening tools are purchased by the Society and retailed on a co-operative basis at anything between 50 and 75 per cent. less than retail cost. The company rents to the staff, at a small nominal sum, plots of land to be cultivated as allotments and also makes a substantial contribution towards the prize-money at the society's annual show. Otherwise, the society is entirely self-supporting on the receipts from members' subscriptions at rs. per annum, and on the proceeds of the shows and sales of commodities. The administrative work is purely honorary, and lectures are given from time to time by experts in the various branches of garden cultivation.

T.O.T. RADIO ASSOCIATION

The interest of the staff in the science of wireless telegraphy is shown in the formation of the T.O.T. Radio Association, whose objects are mutual help and guidance in all matters relating to the science of radio telegraphy and telephony, the promotion of lectures and lantern lectures, the reading of papers, and practical demonstrations in connection therewith. Visits are paid to Government wireless stations and the headquarters of the British Broadcasting Corporation. Elementary, advanced, and experimental 'talks' are held frequently, and the exchange of experience is very helpful to the novice in studying the rudiments of the science. Such an association affords very suitable means for keeping in touch with any developments in the science which would be of practical utility to a transport organization such as the Underground railways.



Fig. 133. One of the company's sports grounds.

SPORTS

There are two flourishing athletic organizations, excellently managed by the staff—the District Railway Athletic Association and the London Electric Railway Athletic Association—whilst the Central London and City and South London Railways have similar organizations, but on a smaller scale (Fig. 133). The membership in each section is very considerable, and for the small subscription of 2d. per week, which is deducted through the pay-rolls, the members participate in cricket, football, tennis, swimming, hockey, boxing, quoits, bowls, angling, and rifle shooting. Two modern sports grounds are provided, one at Acton for the District Railway, and the other at Burnt Oak for the London Electric Railway, which are fitting venues for the many matches and contests which take place. These grounds, which are each of about ten acres in extent, together with the excellent pavilions attached, have been provided by the companies, and many valuable cups and other trophies are put up for open competition.

T.O.T. PHILHARMONIC SOCIETY

The T.O.T. Philharmonic Society was established in 1920 with the object of co-ordinating the musical efforts of the staff, extending the

scope of the existing choir and bands, and encouraging generally the development of the musical and dramatic activities of the Underground staff. The Society comprises three sections: (a) Operatic and Dramatic, (b) Orchestra, and (c) Military Band. It is managed by an executive committee and a business sub-committee, the members of which represent the various departments, and are drawn from all grades of the staff.

The operatic and dramatic section is in the front rank of amateur organizations in London, and, unlike many of the latter which have to rely on professional coaching, utilizes the services of a producer and a musical director who are members of the staff. Several performances are given during the year at the Scala Theatre, which on these occasions is invariably crowded by members of the staff as well as the general public. Practically the whole of the Gilbert and Sullivan operas have already been performed, as also a number of other well-known light operas.

The orchestra, consisting of from fifty to sixty members, is under the conductorship of the operatic section's musical director. In addition to playing at the operatic performances, it gives public concerts in various parts of London, such as the Central Hall, Westminster. It has an extensive repertoire of the standard symphonies, overtures, ballet-music, and symphonic poems, and has the merit, musically, of being properly balanced in all sections.

The military band, in which both the conductor and musicians are members of the staff, has, each year, passed the examination of the adjudicator to the London County Council Parks Music Committee. It performs during the summer in one or other of the London Parks and also participates in numerous concerts, including a week's programme every year at Boulogne at the invitation of the mayor of that town.

LIST OF STAFF ORGANIZATIONS

Whilst the foregoing is a general though brief description of the more prominent of the staff welfare activities of the Underground railways, there are others, and an insight into their varying scope and objects may be gained from the following complete list of organizations which cater for the material, moral and social interests of the staff:

T.O.T. Philharmonic Society.
T.O.T. Benevolent Fund.
T.O.T. Radio Association.
Omnibus, Railway and Equipment Companies' Staff Superannuation Fund.

Underground Railways Death and Distress Fund.
Underground Railways Employees' Horticultural Society.
Underground Electric Railways Dining Club, Limited.
Underground Railways Minstrel and Pierrot Troupe.
Underground Superintendent of the Line's Office Cricket Club.
Metropolitan District Railway Mutual Provident Society.
Metropolitan District Railway Mutual Provident Society (Approved
Section).
District Railway Athletic Association.
'Albert Stanley' District Railway Men's Institute.
District Railway General Offices Staff Levy Fund Association..
District Railway General Offices Staff (Wives) Levy Fund.
London Electric Railway Employees' Benefit Approved Society.
London Electric Railway Employees' Benefit Society (Additional
Section).
London Electric Railway Institutes and Athletic Association.
London Electric Railway Trainmen's Sick Club.
City and South London Railway Club and Institute.
Central London Railway Employees' Sick Benefit Society.
Central London Railway Institute.
Underground Accounts Office Social and Athletic Club.

Chapter XV

ELECTRIC RAILWAYS AND OTHER MEANS OF TRANSPORT

GREATER LONDON to-day has a population of over 7½ millions within its vast area of 699 square miles. Over 3 million passengers, bent on work or pleasure, travel to and fro daily, and most of them have to be carried out and home again within a very short period, morning and night. It is, therefore, of interest to examine the characteristics of this daily movement and to consider the relative advantages of the available means of transport—electric railways, omnibuses and tramways.

London differs materially from other great cities in one important respect. Paris and Berlin, for instance, were developed in accordance with well-defined schemes of town-planning for which appropriate transport facilities were originally provided. London, however, has had its requirements met in haphazard fashion according to the individual whim of a number of promoting companies. The main line termini were built on the fringe of the central area, and are now linked up by means of electric railway and omnibus services which have been gradually improved by private enterprise.

Likewise, as new suburbs were developed, little or no regard was paid to the most suitable means of transport for the workers. Tramways were laid here, there and everywhere, and omnibus services were instituted, with the inevitable result of street congestion, and in many cases the requirements would more adequately have been met by the provision of Tube railways. A certain amount of control over such chaotic conditions is now exercised by the London and Home Counties Traffic Advisory Committee, and at the time of writing there are signs that the long-desired co-ordination of London's traffic facilities will at last be secured, in the interests of the public and the undertakings concerned, by a carefully conceived system of pooling.

MOVEMENT OF POPULATION

A highly significant factor in London's transport problem is not only the increase in population, but the movement of the inhabitants, and the following table is of interest as showing the movement of population in London from 1851 to the last census:

MOVEMENT OF POPULATION IN LONDON

Year	Central area (<i>approx.</i>)		Total : County of London		Extra-London <i>i.e.</i> area between County and Greater London boundaries		Total : Greater London	
	No.	% Inc. or Dec.	No.	% Inc. or Dec.	No.	% Inc. or Dec.	No.	% Inc. or Dec.
1851	1,560,000	12·8	2,363,341	21·2	317,594	11·0	2,680,935	19·9
1861	1,662,000	16·3	2,808,494	18·8	414,226	30·4	3,222,720	20·2
1871	1,667,000	·3	3,261,396	16·1	624,245	50·7	3,885,641	20·6
1881	1,648,594	1·1*	3,830,297	17·4	936,364	50·0	4,766,661	22·7
1891	1,579,261	4·2*	4,227,954	10·4	1,405,852	50·1	5,633,806	18·2
1901	1,529,136	3·2*	4,536,267	7·3	2,045,135	45·5	6,581,402	16·8
1911	1,393,013	8·9*	4,521,685	·3*	2,729,673	33·5	7,251,358	10·2
1921	1,266,843	9·1*	4,484,523	·8*	2,995,678	9·7	7,480,201	3·2

* Decrease.

It will be observed that the population in the central area increased between 1851 and 1871, but subsequent to that a gradual decrease occurred, this, however, being offset by a considerable increase in the County of London area. This movement continued until 1901, since when further increases have taken place, mainly in the Extra-London area, the latter undoubtedly being consequent upon the rapid development of travelling facilities without which London would not have reached its present dimensions.

RAIL, BUS AND TRAM

The relative scope of railway, omnibus and tramway transport in Greater London can be gauged by the number of passengers carried annually

MILLIONS OF PASSENGERS CARRIED ANNUALLY

Year	Local Railways (<i>excluding suburban traffic of Main Line Railways</i>)	Omnibus	Tram	Total
1901	237	270	341	848
1911	474	400	822	1,696
1921	615	932	1,009	2,559
1926*	542	1,716	970	3,228
1927	601	1,822	1,010	3,433

* Figures affected by the general strike (May, 1926)

over a considerable period. The table on preceding page shows the development under each of these heads since the introduction of the more modern modes of transit.

Until a few years ago (1922) the trams carried the largest number of passengers in Greater London, but with the gradual increase in the number of omnibuses the tramway passengers were soon exceeded, and to-day the buses carry nearly twice the number conveyed by trams. The numbers of vehicles engaged in each form of transport in the under-mentioned years were as follows:

	1923	1924	1925	1926
Omnibuses	4,482	5,033	5,204	5,013
Tramcars	2,969	2,814	2,803	2,757
Railway Cars	1,955	2,180	2,205	2,390

WHERE THE MOTOR-BUS SCORES

The motor-omnibus possesses the great advantage of flexibility of operation, besides which its overhead charges are low in comparison with its operating costs. No track has to be laid, as in the case of the railway or tramway, and its service routes can be changed whenever desirable. Unlike the tram, it is not confined to a track, and it can pass other vehicles and obstacles in the streets—a particularly useful factor in operation, especially in crowded and narrow thoroughfares. Buses, too, cause less obstruction to other vehicles, as they can take their place in the most convenient traffic stream and need not follow a definite line like the trams. When a tram breaks down the whole system is held up for an indefinite period, whilst a bus breakdown involves one vehicle only and the service is not affected unduly. The bus has another advantage in being able to stop beside the pavement to take up or set down passengers. Moreover, it does not entail the erection of overhead equipment, which is a necessary complement of the tramcar and is apt to cause disfigurement of new suburban thoroughfares.

The legal limitation of the speed of omnibuses to 12 miles per hour, and tramcars to 20 miles per hour, which is subject to further reduction in busy streets, allied with the need for frequent stopping, prevents both the bus and the tramcar from fair competition with local railways so far as journey times are concerned. That omnibuses and trams both

deal particularly with the passenger who travels distances up to about three miles is confirmed by the average distance travelled per passenger, which in the case of the L.C.C. Tramways is one and three-quarter miles and in that of the omnibuses approximately two miles.

JOURNEYS PER HEAD OF POPULATION

How the number of journeys per head of the population has varied in post-war years is revealed in the following table:

<i>Year</i>	<i>Local Railway (excluding suburban traffic of Main Line Railways)</i>	<i>Omnibus</i>	<i>Tram</i>	<i>Total</i>
1919	95	117	143	355
1920	97	125	143	365
1921	82	125	135	342
1922	79	131	137	347
1923	76	162	136	374
1924	74	193	127	394
1925	76	215	126	417
1926	70	219	125	414
1927	75	231	128	434

The increasing number of private motor-cars and their effect upon public means of transport must not be overlooked. There were, in August, 1927, approximately 1,203,000 motor-cars in Great Britain, and 671,620 motor-cycles. The motor-car is being used more and more each day to carry business people to and from their offices. It is mainly the lack of adequate parking accommodation, and partly the delays due to street congestion, that prevent every car-owner from journeying in this manner. Additional parking places, however, are being provided, and very soon the increase in vehicular traffic will no doubt result in an intensification of the congestion of the streets such as will still further retard the speed of public passenger vehicles.

UNDERGROUND RAILWAY SPEEDS

The speeding-up of the train service which has taken place on the Underground railways since the lines were first opened is considerable. Sixty years ago, when the District—the oldest railway of the Underground

Group—was opened, steam trains ran at a speed of only from 10 to 11 miles an hour. The City and South London Railway—the next oldest line and the first electric railway in the United Kingdom—operated between Euston and Clapham Common at a speed of 14 miles per hour. The Central London Railway was opened in 1900, and three years later the multiple unit system of electric traction replaced heavy electric locomotives on that railway. This system was adopted as standard for subsequent Tube lines, since when a steady increase in speed has been maintained. For example, the Central London Railway has reduced its journey time from Shepherd's Bush to the Bank from 25 to 21½ minutes, and on the Piccadilly line the journey time from Hammersmith to Finsbury Park has been lowered from 35 to 28 minutes. The Bakerloo also shared in the speeding-up process, the journey between Elephant and Castle and Baker Street being accomplished in 11½ minutes as against the former 15½ minutes.

Following the completion of the electrification of the District Railway in 1905 there was an automatic increase in speed on that line, and further improvements in running times were made when non-stopping was introduced in 1907, the journey between Mansion House and Ealing being reduced from 34 to 31 minutes. The greatest improvement of all has been on the old City and South London Railway, where, since the rehabilitation of the line and the replacement of the old electric locomotives by modern rolling stock, the running time between Euston and Clapham Common—to quote but one example—has been reduced from 31½ to 23½ minutes, an increase in speed of 25 per cent.

NON-STOP TRAINS

The advantage to the suburban passenger of carefully scheduled non-stop trains is obvious, and his requirements have been very carefully studied. For example, a train has been timed to make the journey from Edgware to Charing Cross, a distance of 11 miles, in 30 minutes, running non-stop to Golder's Green and passing the preceding train by means of a special loop road at Brent. It is correct to say that no surface vehicle, public or private, could safely accomplish the journey at the same time of the day so expeditiously.

The average scheduled speed of the Underground railways, including stops, is approximately 18 miles per hour, but where non-stops are run the average speed rises to 22 miles per hour, and, in certain instances, 25 miles per hour. The following table gives details of speeds

on each of the railways at the present moment compared with the average speeds obtaining when the lines were first opened or electrified:

	<i>District Railway</i> <i>m. p. h.</i>	<i>Bakerloo Railway</i> <i>m. p. h.</i>	<i>Piccadilly Railway</i> <i>m. p. h.</i>	<i>Hampstead & City</i> <i>m. p. h.</i>	<i>Central London</i> <i>m. p. h.</i>
Max. scheduled speed for special fast trips .	21·02	20·67	18·39	21·31	18
Average scheduled speed .	18·08	17·0	17·76	18·37	16·22
Original average speed .	14·3*	14·8	14·4	14·5 (C.S.L.) 14·9 (H. & H.)	13·6

* 1905

The relation of average speed to the number of intermediate station stops is clearly shown in the under-noted table:

	<i>Distance</i> <i>Miles</i>	<i>Interme- diate station stops</i> <i>No.</i>	<i>Time</i> <i>Minutes</i>	<i>Average distance between station stops</i> <i>Miles</i>	<i>Average speed</i> <i>m. p. h.</i>
Mansion House to Ealing (non-stop)	10·9	11	31½	·99	20·76
Edgware to Charing Cross (non-stop)	10·8	11	30	·98	21·6
Elephant and Castle to Watford	20·8	22	61	·87	20·46
Mansion House to Ealing .	10·9	19	35	·54	18·69
Hammersmith to Finsbury Park (non-stop)	8·9	15	29	·59	18·41
Charing Cross to Edgware .	10·8	16	33	·64	19·64
Liverpool St. to Wood Lane .	6·8	13	25	·49	16·32
Charing Cross to Highgate .	4·4	10	16½	·40	16·0
Morden to Euston	12·5	19	40	·63	18·75

CAPACITY

The maximum capacity of any particular mode of transport rests upon the accommodation of the vehicles used and the frequency of service in which they can operate. On the Underground railways it is possible, with electrically controlled automatic signalling, to operate forty trains

per hour in one direction over a single track, and the highest number worked in one hour has been forty-three. The maximum number of passengers which can be carried past any point on the railway in an hour, based on the seating capacity of the trains, is about 13,500, and with 100 per cent. of standing passengers, 27,000. A tramway track is found by observation to permit of the movement of sixty-five tramcars in one direction in the hour. The number of passengers, therefore, which can be carried in the hour past a given point is, on the basis of seating capacity, about 5,000, or, with a complement of standing passengers, approximately 10,000.

It is not suggested that sixty-five is the maximum possible movement for tramways. American results would suggest a higher figure by about 25 per cent., but to secure this in London a considerable simplification of routes and tracks would be necessary. However, the maximum possible passenger movement on the tramways may be taken as 12,500 in the hour. An arterial road used by motor-buses is found by observation to permit of the working of 150 buses in each direction in the hour, which, on the basis of fifty passengers per vehicle, means a total possible passenger movement of 7,500 per hour.

The latter figure will be considerably increased with the more general use of six-wheeled buses, many of which are already capable of carrying sixty-six passengers. It should be noted, also, that the possible passenger movement per hour by tram, given above, includes trams with trailers attached; without the latter the figure would be about 5,800 with standing complement. In comparing tram and omnibus it is assumed, of course, that the roadway is sufficiently wide to allow at least two lines of traffic in each direction.

On the foregoing figures the railway is clearly best adapted to the movement of heavy volumes of traffic, the tram being second, and the motor-bus third, although the difference between tram and bus will speedily diminish. The conclusion already indicated is thus confirmed: that the railways are essential to free and extensive passenger movement in a metropolitan area, and that as an auxiliary to railways in congested areas the motor-bus has certain advantages over the tram.

RELATIVE SPEEDS

The traveller by bus or tram, of course, is saved the time occupied by the rail passenger in getting his ticket and reaching the train, but this is only of moment on short journeys and under certain conditions, as will now be indicated. The diagram (Fig. 134) demonstrates the speed

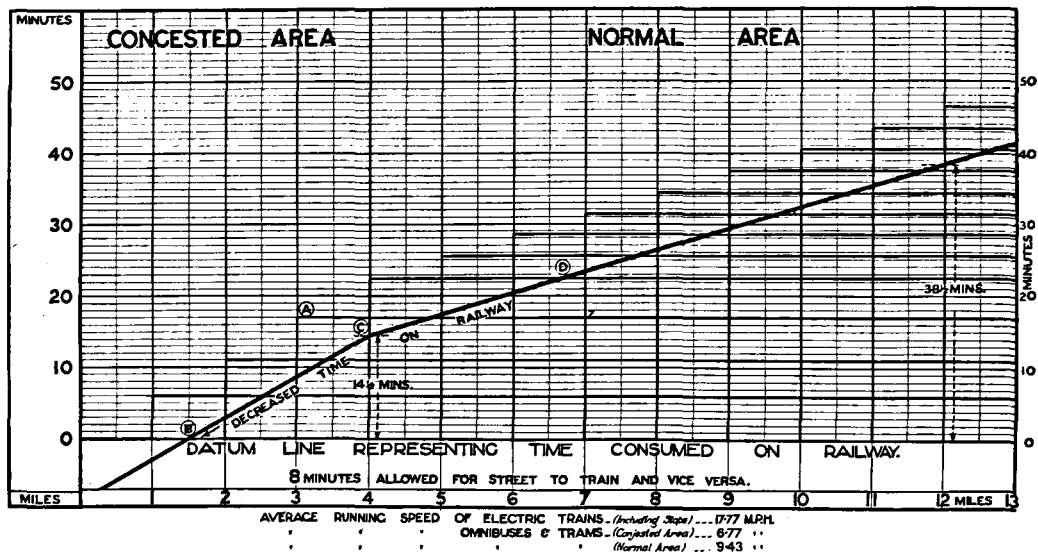


Fig. 134. Chart indicating the relative time occupied in journeying by various means of transport.

advantage of electric railways compared with omnibuses and trams under actual conditions of operation in the County of London. The average speed of electric trains throughout the systems, viz. 18 miles per hour, has been taken as a basis and is represented by the datum line 0-0. A liberal allowance of eight minutes is made for reaching the station and for station delays. This operates against the actual time taken for a journey by rail, and has therefore been added to the travelling time before assessing the differences between surface and sub-surface speeds. The station delay of eight minutes, where it occurs, is a handicap in the bid for short-distance traffic. A section of the road, approximately four miles in length, in the 'congested area', shows an average speed by surface transit of 6.77 miles per hour—at the Bank, Piccadilly Circus and Elephant, for short distances, the speed is a little over four miles per hour. After allowing the eight minutes mentioned, the diagram shows that up to a distance of one and a half miles in the congested area the time occupied by rail, bus or tram is equal, the lines intersecting at 'B'. After one and a half miles the curve rises rapidly in favour of the rail, until over the section of four miles (letter 'C') there is a rail saving of 14 minutes.

As these congested surface conditions only operate for comparatively short distances, a further section of road—a 'normal area'—permits an average speed of 9.43 miles per hour, and the advantage to the railway does not operate until a distance of two and three-quarter miles is covered (Letter 'D'). For a distance of four miles in the normal area the saving in favour of the rail is four minutes, as against fourteen minutes for a similar distance in the congested area. For distances up to one and a half miles in the congested area, or two and three-quarter miles in the normal area, it is immaterial, from the time element, whether the passenger uses the surface or sub-surface means of transit. Taking a run of twelve miles, four in the congested and eight in the normal areas, as shown on the diagram, the time by bus or tram is 86 minutes and by rail 47 minutes, or an advantage in speed of 82 per cent. by rail.

Where the journey is taken partly inside and partly outside the congested area, the datum lines are given for each mile to enable the difference in time to be read easily; e.g. assume a journey to be taken which is three miles in the 'normal area' and one mile in the 'congested area'. The datum line at the three-mile point is taken up to the right-angle 'A', the difference in time being read by measuring the height from horizontal line 'A' at the seven-mile point, i.e. three miles in the 'normal area', to the inclined line, which is six and a half minutes.

ELECTRIC RAILWAYS' ADVANTAGE

The foregoing indicates the advantages of electric railways over surface means of transit in all but the shorter journeys. The figures apply, of course, to normal conditions, but there are instances when even the shortest journey can be accomplished more quickly by rail than by a street vehicle, as on the occasion of processions or the carrying out of street repairs, and so forth, when highway traffic has to be diverted, sometimes over the most circuitous routes. It may be remembered that when, in the late summer of 1927, Piccadilly was entirely closed for neary ten weeks for re-surfacing, all traffic had to go by way of Pall Mall, the Mall and Constitution Hill, and then at a greatly reduced speed that was still further affected by the congestion at intersecting points.

In the inner zone of the City and West End of London (where there are no trams) there are many instances where the electric railway is quicker than the bus, and even the taxi-cab and private car, as the following examples show:

KNIGHTSBRIDGE TO CANNON STREET:

By Bus	. 29 mins.	. Fare 4d.
„ Taxi	. 22 „	. „ 3/-
„ Rail	. 19 „	. „ 4d.

QUEEN'S ROAD AND TOTTENHAM COURT ROAD:

By Bus	. 18 mins.	. Fare 3d.
„ Taxi	. 16 „	. „ 2/3
„ Rail	. 11 „	. „ 3d.

Such figures merit the close attention of those who are prone to regard the comparatively expensive taxi-cab as the speediest means of urban communication. They should be equally illuminating to those who are under the mistaken impression that they can save time and money by using their own cars in the Metropolis.

Chapter XVI

GROWTH AND ACHIEVEMENTS OF THE UNDERGROUND

HOW many people had ever heard of Golder's Green before the Underground railway reached there? The construction of the Charing Cross, Euston and Hampstead Railway in 1907 evinced a realization on the part of the promoters that Tube railways could no longer be confined to the built-up portions of London, but that if they were to be remunerative they must, like the surface railways, be extended to the outer suburban areas to satisfy the need of the City worker for a dwelling far removed from the centre of the Metropolis. In this connection it is of interest to note that the capital expenditure on lines in the open is usually about a quarter of that for sub-surface systems, whilst maintenance costs are also reduced; projection beyond the tunnel stages is therefore desirable from many points of view.

The incursion of the Tube railway into the undeveloped territory of Golder's Green was an experiment of which the results were very quickly manifest. Housing development began almost simultaneously with the commencement of railway construction, and land values appreciated by no less than 600 per cent. With the exception of the later period of the war, the growth, as may be seen by reference to the chart in Fig. 135, has continued at an extraordinary pace year by year. In 1906 the aspect of Golder's Green was entirely rural, and the change that has been wrought by the piercing of the Hampstead Heights is strikingly shown by the two photographs reproduced in Figs. 136 and 137. These views were taken from the same point, the one in 1904—a year after the commencement of the tunnel boring—and the other in 1927.

This transformation of green fields and hedgerows into a populous town with substantial buildings, well-paved streets, gas, water, electricity, and other public services, could only have taken place by the institution of progressive means of transport and facilities for the handling of dense masses of people. At the present time about 13,000,000 passengers a year are handled at Golder's Green Station, a number nearly equivalent to twice the population of Greater London.

The chart in Fig. 138 shows the expansion of traffic at Golder's Green Station year by year since its opening. The war temporarily set back the

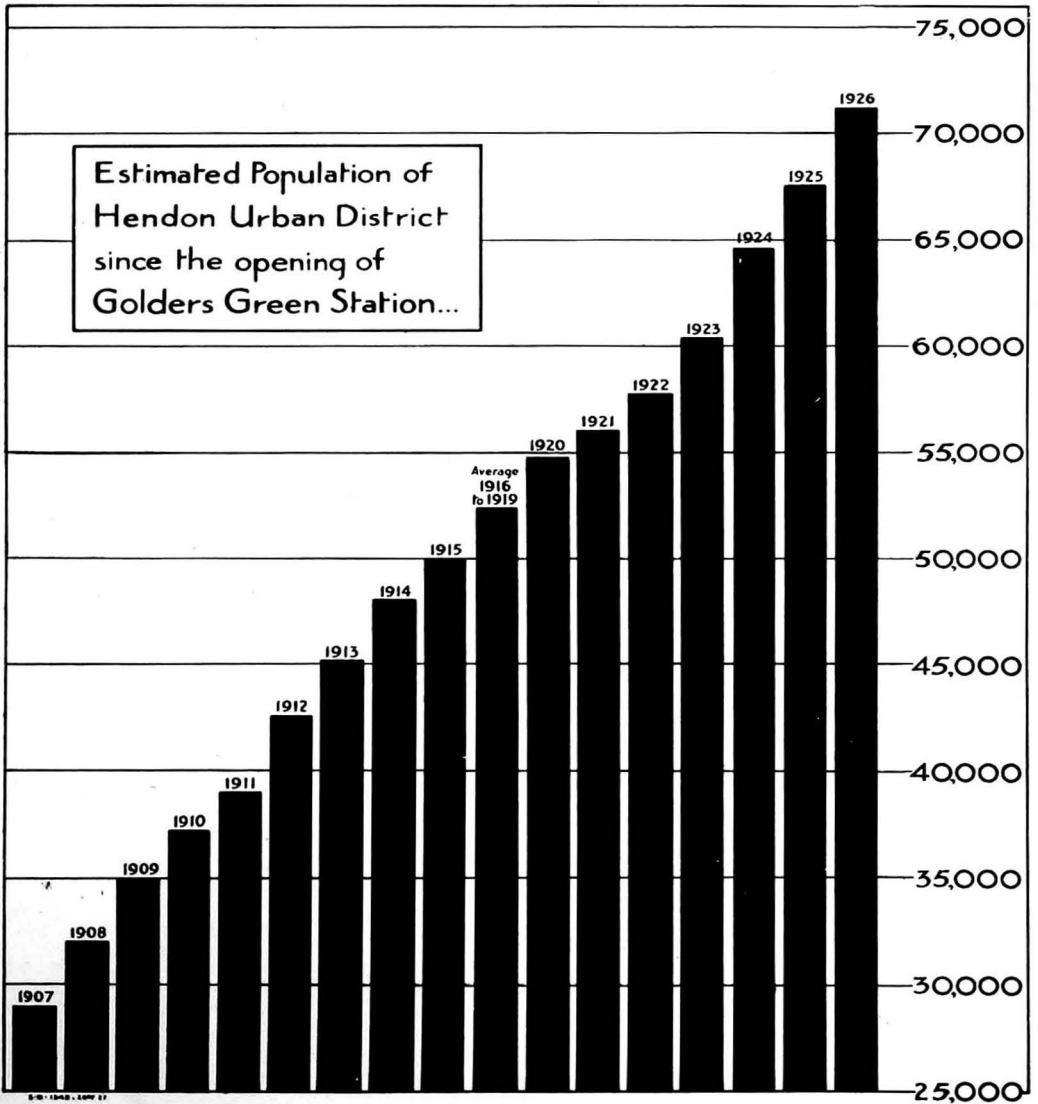


Fig. 135

rate of increase, as also, to a slight extent, did the extension of the railway to Hendon and Edgware, owing to the transference of a certain number of passengers to the new stations nearer their homes. These losses, it will be seen, have since been retrieved, and the continued increase in population, together with visitors drawn hither on business

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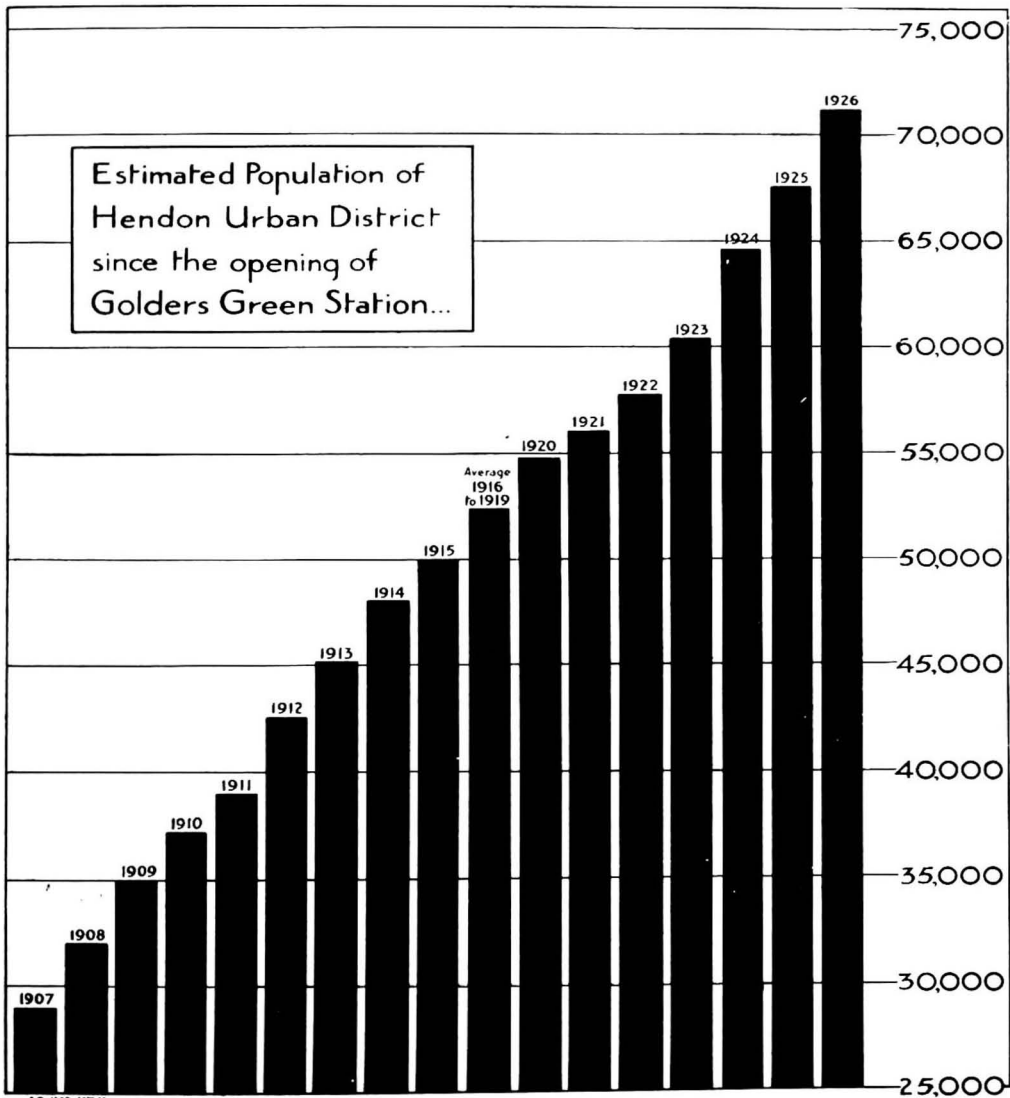


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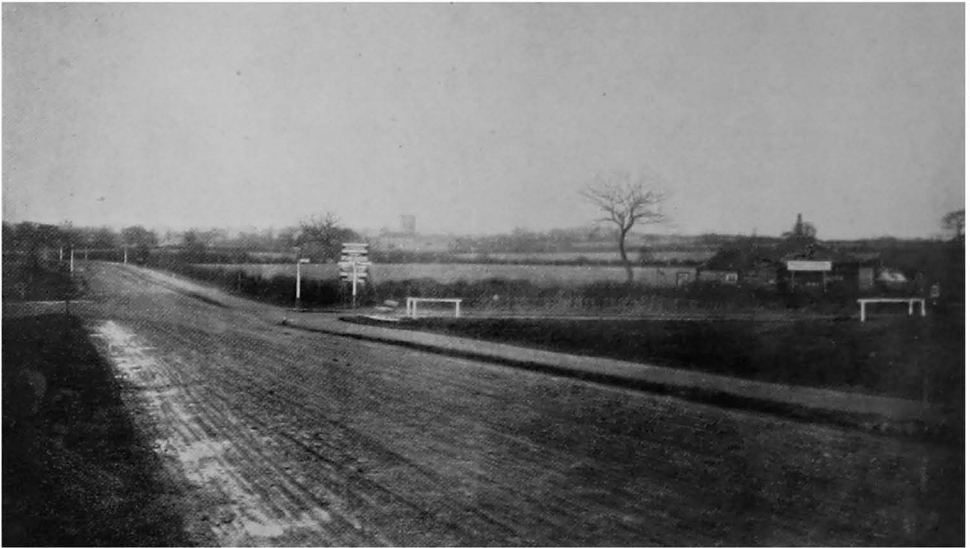


Fig. 136. Golder's Green in 1904, before the advent of the railway.



Fig. 137. Golder's Green in 1927. The view was taken from approximately the same point as that in Fig. 136.

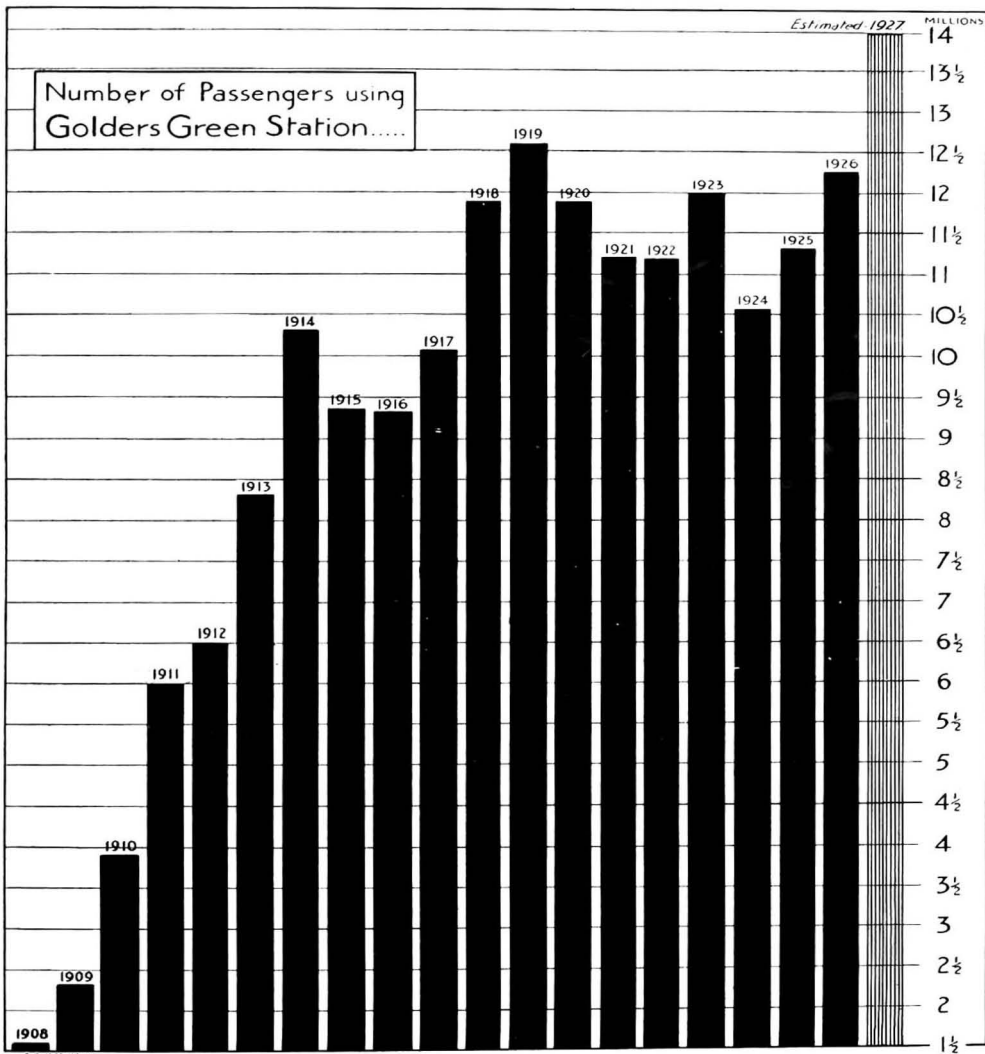


Fig. 138

or pleasure, has again created an upward tendency in the curve. Latterly, the new through service of trains to the City and South London Railway, via the new Tube junction at Camden Town, has brought additional residents to the neighbourhood.



Fig. 139. Brent Station on the Hendon Extension of the Hampstead Railway; new residential property in the neighbourhood is clearly visible.

EXTENSION TO HENDON

The extension of the Hampstead Railway as a surface line across undeveloped country to the villages of Hendon and Edgware was considered to be justified two or three years after the termination of the war. The provision of direct rail access to the heart of the City and the West End, and beyond, from these rural areas had given promise that in the course of time a population would spring up of sufficient volume to justify the cost of the railway extension. The first sod of the extension was cut on June 12th, 1922, and seventeen months later (November 19th, 1923) the Hendon section was opened for traffic, an intermediate station being provided at Brent (Fig. 139), close to the diminutive river bearing that name.

Hendon Central Station, which is illustrated in Fig. 119, page 178, faces a circus, 240 ft. in diameter. Architecturally, the station buildings are of a most interesting design, which has received the commendation of experts in this and other countries. Four approach roads intersect at the circus, providing access to all parts of Hendon and the surrounding district. Happily, no older buildings exist to mar the symmetry of the lay-out, which may be regarded as an outstanding example of the co-ordination of road planning with passenger station requirements. (See also the chart, Fig. 140.)

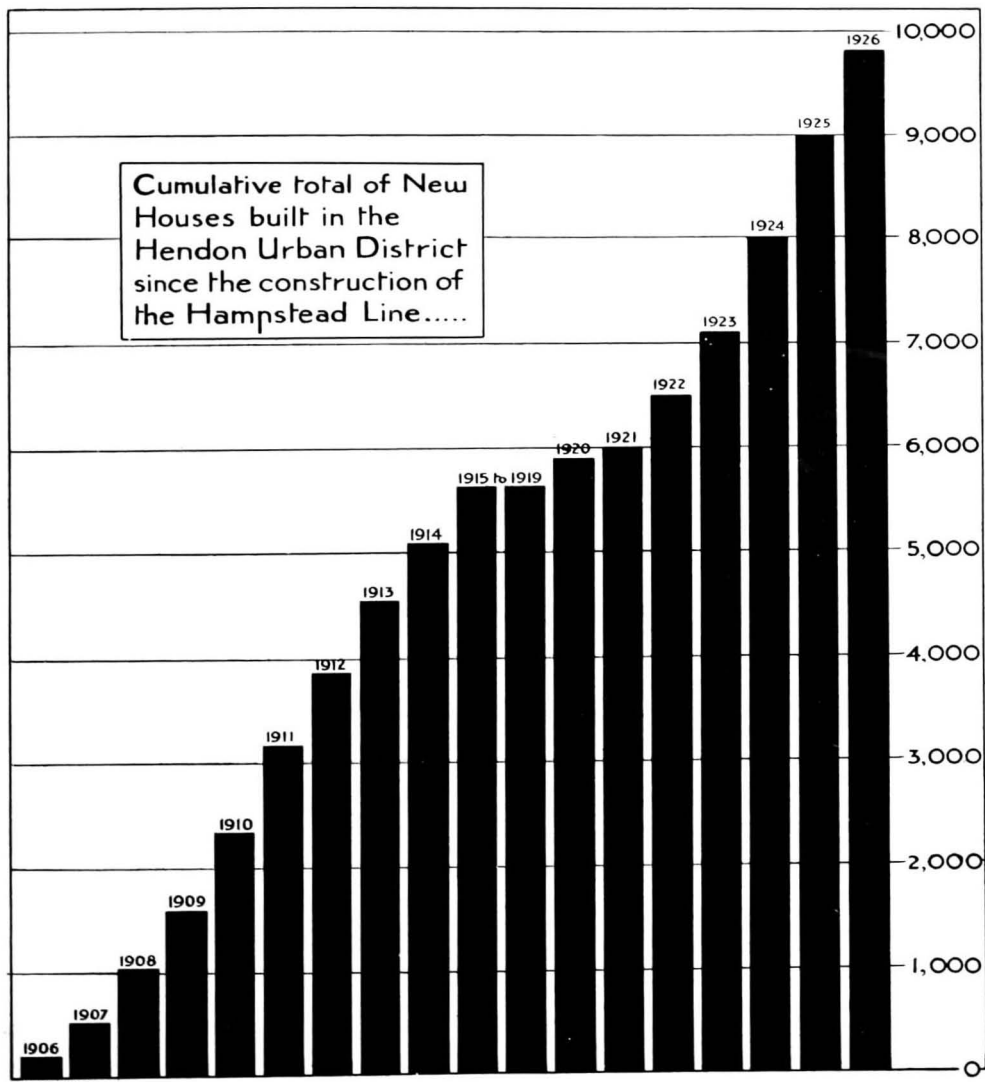


Fig. 140

ON TO EDGWARE

On August 18th, 1924, the further extension to the village of Edgware was opened, intermediate stations having been built at Colindale and Burnt Oak. Around Edgware Station, building developments are proceeding apace. Many homes for London's workers have already



Fig. 141. Burnt Oak Station on the Edgware Extension of the Hampstead Railway, showing houses in course of erection.

been provided within thirty minutes' travelling time of the West End and City, and within reach by Underground connection of 200 stations throughout Greater London. The same story of development may be told of the intermediate stations on the Hendon and Edgware Extension. Planted in the midst of fields and rapidly becoming centres of ever-widening clusters of new houses, it seems safe to predict that in a few years small townships will exist around each of these new stations. An example may be seen in the development of the area from Burnt Oak Station (Fig. 141), across to Mill Hill, where 3,000 houses have been erected since the opening of the electric railway.

THE MORDEN EXTENSION

The most recent instance of a Tube railway converting a rural into a residential locality is that of the City and South London Railway, which was extended in September, 1926, from its long-established terminus at Clapham Common, through the crowded districts of Balham and Tooting, to Morden, an unimportant and little-known village just beyond the built-up area of South London (Fig. 142). The surrounding country is probably the most undulating and pleasant of any on the outskirts of London, and it is likely that the growth which has taken place at



Fig. 142. Aeroplane view of the new station and car sheds at Morden, City and South London Railway.

Golder's Green, Hendon, and Edgware will be repeated here. As at Golder's Green, rural conditions remained long after other districts equidistant from the Metropolis had become populous suburbs. The railway, which enables the dweller in this district to reach the City or West End within half an hour, will convert the countryside into a modern suburb and will provide one more incentive to the Londoner to forsake the congested areas for the healthier localities on the outer fringe.

At Golder's Green the vast development we have seen was brought about by a comparatively short projection of the line from the built-up area of Hampstead, the terminal station forming a nucleus around which gathered the beginnings of a magnificently planned township. In the case of Morden also, the terminal station is situated but a mile or so beyond the densely populated areas of Tooting, Wimbledon, and Merton in a comparatively unpopulated area, many square miles in extent, and a similar development to that at Golder's Green may be anticipated.

AUXILIARY BUS SERVICES

Before the completion of the country terminals of the Underground, arrangements are invariably made for the provision of subsidiary services of omnibuses. Wherever roads permit, these traverse the undeveloped territory farther afield, gathering traffic from the sparsely inhabited districts and conveying it to the railway. At Golder's Green, in 1909-10, while development was yet in its early stages, these essential auxiliary services were strengthened by the construction of tramways connecting the railway with the districts of Child's Hill and Cricklewood in one direction, and Finchley, Whetstone and Barnet in the other. In the direction of Hendon and Mill Hill, omnibuses alone performed this service.

Morden, in the first instance, depended upon small-capacity, pneumatic-tired omnibuses, which were found sufficient for the light traffic to be conveyed during the period immediately following the opening of the railway. As passengers increased in number these were gradually replaced by double-deck vehicles, which connect the terminal with the outlying sources of traffic at Worcester Park, Cheam, Sutton, Carshalton and Wallington—all within a three-mile radius—and, farther still, with Ewell, Epsom, Banstead and Burgh Heath. The passengers brought to the railway by omnibus or tramcar are encouraged by the issue of combined ordinary and season tickets, available on train, omnibus or tram, as the case may be, at a reduced rate for quarterly, monthly or weekly periods. These tickets minimize the inconvenience and delay which would otherwise be occasioned at the booking-office.

BAKERLOO AND CENTRAL LONDON

The Baker Street and Waterloo Railway, as its name implies, was opened for purely urban services in 1906 and extended, in stages, to the Marylebone terminus of the London and North Eastern Railway, to the Paddington terminus of the Great Western Railway, and to Queen's Park, where a junction with the London, Midland and Scottish Railway enabled through trains to be run to Willesden on that system. In 1917 through running was extended to Watford—at that time a town of over 40,000 inhabitants, the distance from the Elephant to Watford being 20 miles. The principal districts which it has aided in developing are, in addition to Watford—which now embraces over 50,000 population—Wembley, Wealdstone, Hatch End and Bushey. The direct connection with Oxford Circus, Piccadilly and Charing Cross yields at the present time 5,000,000 passengers annually between these points.

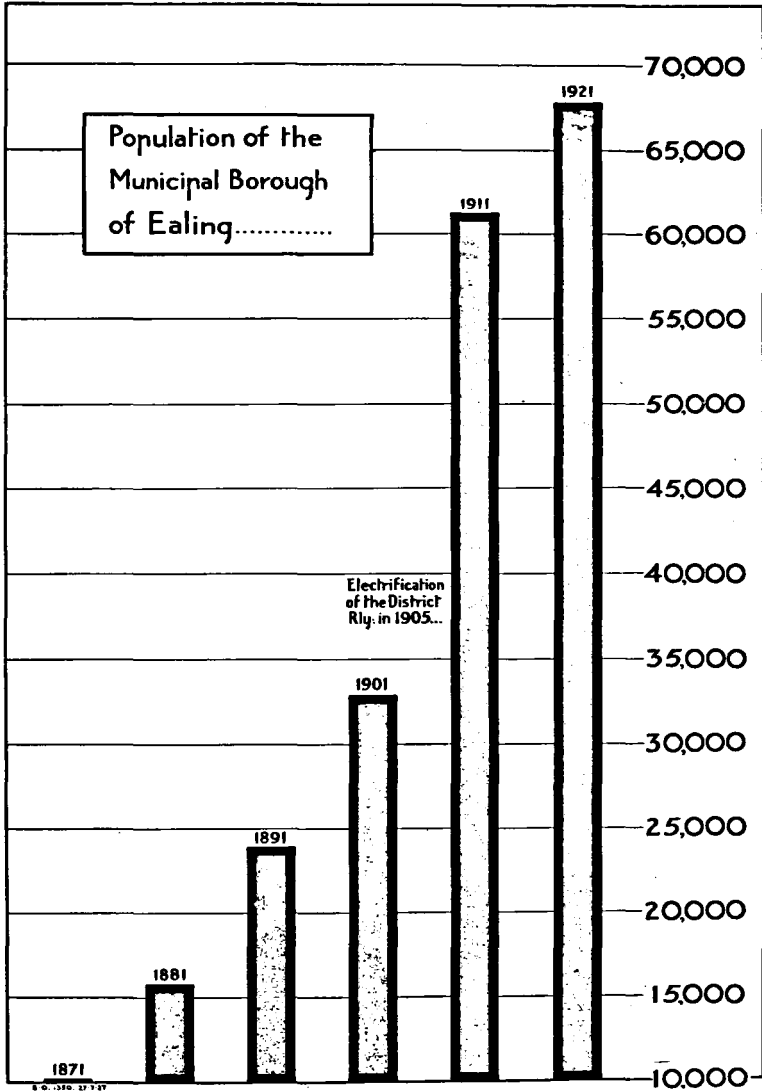


Fig. 143

The Central London Railway—the original ‘Twopenny Tube’—which runs through London from the City to Shepherd’s Bush, extended its train service in 1920 to Ealing, over lines owned by the Great Western Railway. This has proved of immense value in providing rapid access to the centre of London. Four and a half million passengers use the extension annually at the present time, and the number is growing rapidly, the train service having been increased by 100 per cent. since its inception.

DISTRICT RAILWAY DEVELOPMENTS

In considering these later instances of development following Tube railway extension to the outer areas, it should not be overlooked that in the latter part of the nineteenth century similar progress resulted from the building of the original Metropolitan District Railway. The early sections were constructed in 1868 as a shallow underground railway, serving only the central areas of London. It was gradually extended into the open to various points, mainly in the west and south-west, and thereby contributed to the founding of new suburbs in what, at that time, were very sparsely populated localities. The first important extension took place in 1874, when the line was projected from the Earl’s Court terminus to Hammersmith Broadway. Its effect may be gauged by the growth in the population of Hammersmith from 42,691 in 1871 to 71,939 in 1881, an increase of 69 per cent. in ten years.

From Hammersmith the construction of a short connecting-link with the Southern Railway at Ravenscourt Park was effected in 1877, thus serving an extensive area comprising Chiswick, Turnham Green, Gunnersbury, Kew and Richmond. These places rapidly became large residential districts, and the first ‘Garden Suburb’ scheme in this country was laid out at Bedford Park. The journey from Richmond to the Mansion House by the District took 54 minutes, not an excessive time in those slow days, but electrification reduced it to 41 minutes, and certain trains now perform the journey in 35 minutes.

EALING

Ealing, which in 1871 was a town of only 9,959 inhabitants, came within the range of the District Railway in 1879, when an extension from Turnham Green was completed. There followed a big increase in population. In 1881 it had risen to 15,764, and by 1891 to 23,979, a growth in twenty years of 141 per cent. The further progress of this suburb is shown on the chart in Fig. 143. From this it will be seen that

the population rose from 33,031 in 1901 to 61,222 in 1911, a circumstance largely due to the electrification of the railway in 1905. The reduction in the running time and the increased frequency of service account for the growing popularity of Ealing as a residential area. In 1900, under steam operation, the journey to the Mansion House occupied 48 minutes and only about thirty-eight trains were run daily; now the journey takes but 31 minutes and the number of trains in the service is 154.

It is an interesting fact that as early as 1883 District Railway trains ran as far as Windsor, providing a through service between the Royal Borough and the City of London by means of a junction with the Great Western at Ealing Broadway, but this arrangement so complicated traffic operation that it was discontinued in 1885.

PUTNEY

Putney was the objective of a further extension of the District Railway in 1880, when a line was constructed from West Brompton, through Walham Green and Parson's Green, to the Fulham side of the Thames at Putney Bridge. The effect of this extension was amazing. The district of Fulham, which in 1871 had a population of 23,350, had risen by 1881 to 42,900, and by 1891 to 91,639, an increase in twenty years of 292 per cent.

In 1889 the London and South Western Company constructed a connecting-line between the Putney Bridge terminus of the District and its own lines at Wimbledon. This link facilitated the through District service of trains from Wimbledon, via Putney and Earl's Court, to Central and East London. The improvement occasioned by the conversion to electric traction is shown by the reduction of the running time from 48 to 32 minutes, and the increase in the daily number of trains from 34 to 120.

HESTON AND ISLEWORTH

On the western outskirts of London the extensive area of Heston and Isleworth was opened for development in 1883 by the construction of a line from the District at Acton to Hounslow Town, fifteen miles from the City. This railway was built and operated in the first instance by a separate company, but was taken over by the District a year after its opening. The development of the area was initially disappointing. The distance from Town and the slow speed of the steam service were probably factors which retarded its growth. A change, however, took

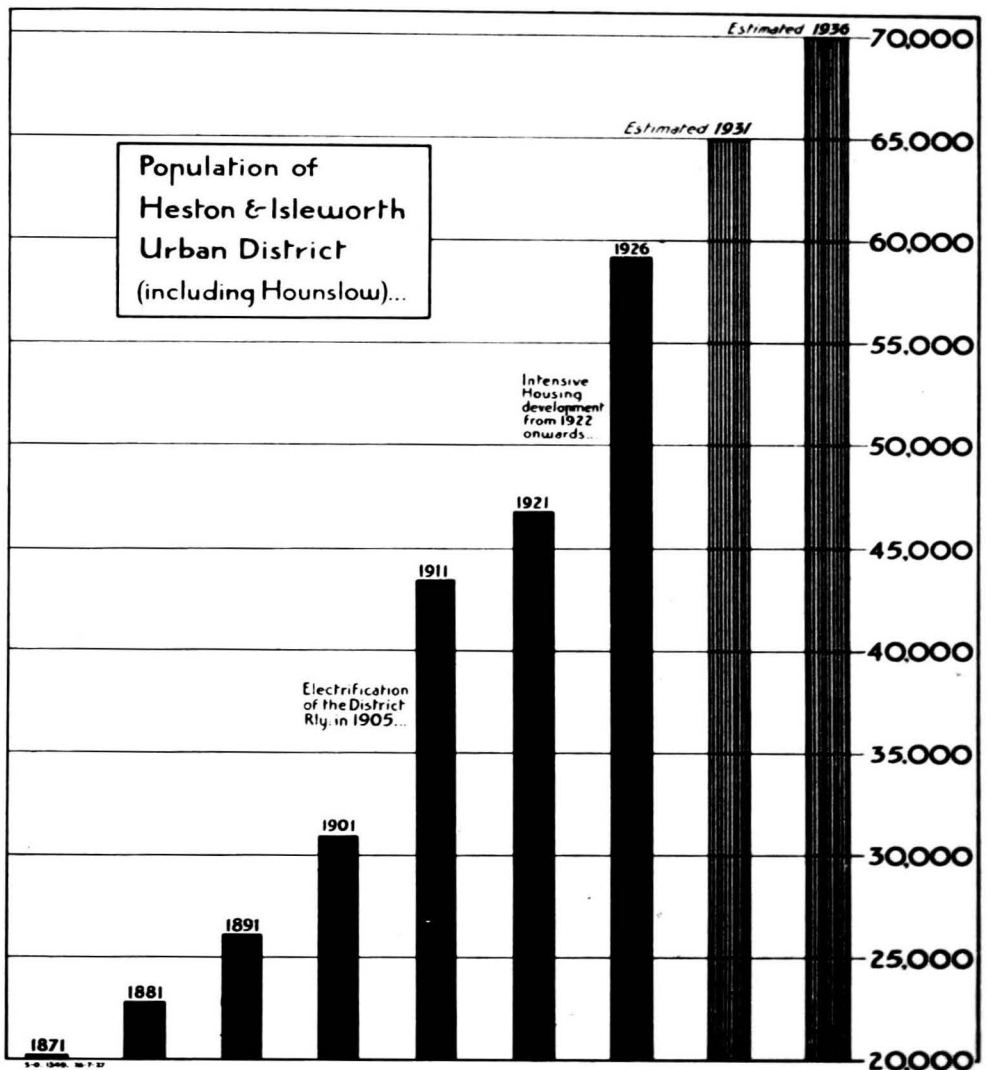


Fig. 144

place on the electrification of the District Railway in 1905. The service was not only quickened but the number of trains greatly increased. In the steam days Hounslow had to be content with twenty-two trains a day; these now number 170 per day, and the rate of housing development has not been exceeded anywhere except at Golder's Green. The chart (Fig. 144) shows the impetus given to the expansion of Heston and

Isleworth between the years 1901 and 1911, due chiefly to the electrification of the line in 1905. Large numbers of residents have been drawn to this district in recent years, the population increasing from 46,664 in 1921 to 59,110 in 1926, and it is estimated that in 1936 the population will be 70,000.

EXTENSION TO SOUTH HARROW

In 1903 a further extension of the District Railway was opened to the public from Ealing Common to South Harrow, skirting the districts of Ealing and Wembley. This line was electrically operated from the commencement, so that no comparison with steam days is possible. The area through which it runs was at the time of its construction mainly meadow land. The district of Wembley, comprising 4,564 acres, had in 1901 a population of only 4,519, or less than one person per acre. In 1911 the population had risen to 10,697 and in 1921 to 16,187. This rate of progression has been accelerated during the past few years, and it is safe to estimate that the next census returns will show a population in 1931 approaching 40,000. In 1910 a short connecting-line was constructed between the Metropolitan Railway at Rayner's Lane and the South Harrow terminus of the District Railway. Through services were then given by the District trains as far as Uxbridge, $21\frac{3}{4}$ miles from the City.

OTHER DEVELOPMENTS

In 1884 a service between Hammersmith Broadway and New Cross was inaugurated over the lines of the East London Railway. This continued until the electrification of the District in 1905. It was not until 1913 that the East London Railway was converted from steam to electric traction.

The Whitechapel terminus of the District was linked up with the then London, Tilbury and Southend (now L.M.S.) Railway by the construction, in 1902, of the Whitechapel and Bow Railway. This facilitated the District services being projected over these lines to Barking and the village of Upminster, sixteen miles from the City. On the electrification of the District three years later these services were withdrawn, and East Ham became the eastern terminus until the process of conversion from steam to electricity had reached Barking Town Station, when the District resumed its services to the latter point.

In the district of Barking and the southern parts of Ilford, within reach of Barking Station, large vacant areas have been developed and



Fig. 145. An Ealing—Southend train being hauled over the District Railway by an electric locomotive.

new suburbs formed. The population of Barking has increased from 21,000 in 1901 to 40,000 at the present time. The most distant through-working of the District Railway began in 1910, when a service was inaugurated between the Ealing terminus and Southend-on-Sea, over the lines of the London, Tilbury and Southend Railway. As the electrified lines terminate at Barking Town, these trains are drawn by electric locomotives (Fig. 145) from Ealing to Barking and there replaced by steam locomotives.

Space does not permit of further description of developments following Tube railway construction, but the foregoing instances will perhaps show in what manner the London Underground Railways have been of service to the community. They have provided Londoners with a speedy, reliable and comfortable means of communication between all parts of the Metropolis, and, by stretching farther afield, have been the means of creating new and attractive suburban resorts within easy reach of the business centres. That there yet remains great scope for the extension of the activities of the Underground Group there can be no question, and circumstances in the future will no doubt justify a still more comprehensive policy of Tube railway construction in Greater London, coupled with the widening of many of the lines in the more congested areas.

APPENDIX
*
PERTINENT FACTS
CONCERNING LONDON'S
UNDERGROUND

POWER

745 tons of coal consumed daily, leaving
54 tons of ash.
76 boilers, delivering
1,250,000 lbs. of steam each hour to
11 turbo alternators of
102,000 k.w. capacity, and an output of over
1,032,900 k.w. hours daily, at a pressure of
11,000 volts.
431 miles of high-tension cable deliver this
current to
43 sub-stations, ranging from
1,800 to 10,000 k.w. capacity and supplying
91 miles of railway and
49 miles of tramway carrying
2,000,000 passengers daily.

TRACK

79 route-miles owned or leased.
128 " " including mileage of other
companies' lines run over
by Underground trains.
62 " " in tunnel.
66 " " in open.

SIGNALS

1,839 installed, of which
868 are automatic.
269,000 signal-movements are made daily.

ROLLING STOCK

1,950 cars owned, or operated.
261 trains are worked daily, totalling
1,615 cars in service, which provide
72,671 seats, or
11,375,000 seat-miles daily.

STATIONS

125 stations are owned.
194 stations are served by the company's trains.
56 of those owned are equipped with lifts, and
33 are equipped with escalators.
6 of a mile is the average distance between
stations owned.
171 lifts are in service, varying from
30 ft. to 181 ft. in depth of shaft and travelling
800 miles daily and making
63,000 stops each day.
85 escalators will shortly be in service from
17 ft. to 60 ft. in depth, and travelling at the
rate of
90 to 100 ft. per minute, or
603,146 miles per annum, and capable of trans-
porting
765,000 passengers per hour.

LIGHTING AND VENTILATION

90,000 lamps are used in the trains, or
102,000 lamps in all, varying from
18 to 200 candle-power each.
230,000,000 cubic feet of purified air are pumped into
the tunnels daily.

SERVICE

80,000,000 car-miles are run per annum, or
255,000 car-miles each week-day.
101,405 station stops are made daily, and
1,020,000 passengers a day are carried.
273,366,341 tickets are issued annually, of which
160,000,000 are issued mechanically from
220 booking-office machines and
350 slot machines.
86,000 season tickets are in use.
40 trains an hour, or one every 90 seconds, are
scheduled on each of the tracks between
Mansion House and South Kensington
Stations, capable of transporting
20,000 seated and standing passengers per hour
in each direction, an increase of 120 per
cent. since the old steam days.
18 miles per hour is the average speed of the
trains,
22 " " " the average speed of non-
stopping trains, and
31 " " " is the maximum scheduled
speed between any two
stations.
108 trains per hour are handled at Kennington
Station and
100 " " " " " " Camden
Town Station
1,721 " " week-day pass through Oxford
Circus Station.
2,815 " " " " " Charing Cross
Station.

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