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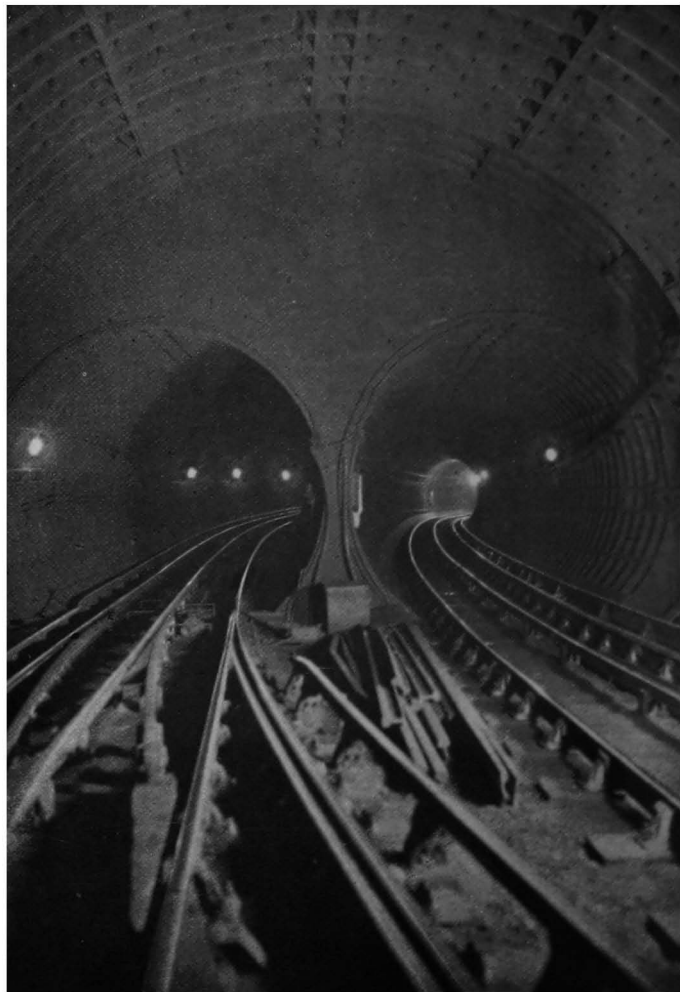


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UNDERGROUND RAILWAYS

*S. G. Patil*  
*Hampden. 11th Dec 1988*

No. 8



**What the driver sees.**

# UNDERGROUND RAILWAYS

THEIR CONSTRUCTION & WORKING

*by*

VERNON SOMMERFIELD

Author of

"London's Buses" "London Transport"

"The Railway Grouping Scheme," etc.

*Illustrated from photographs  
and drawings*

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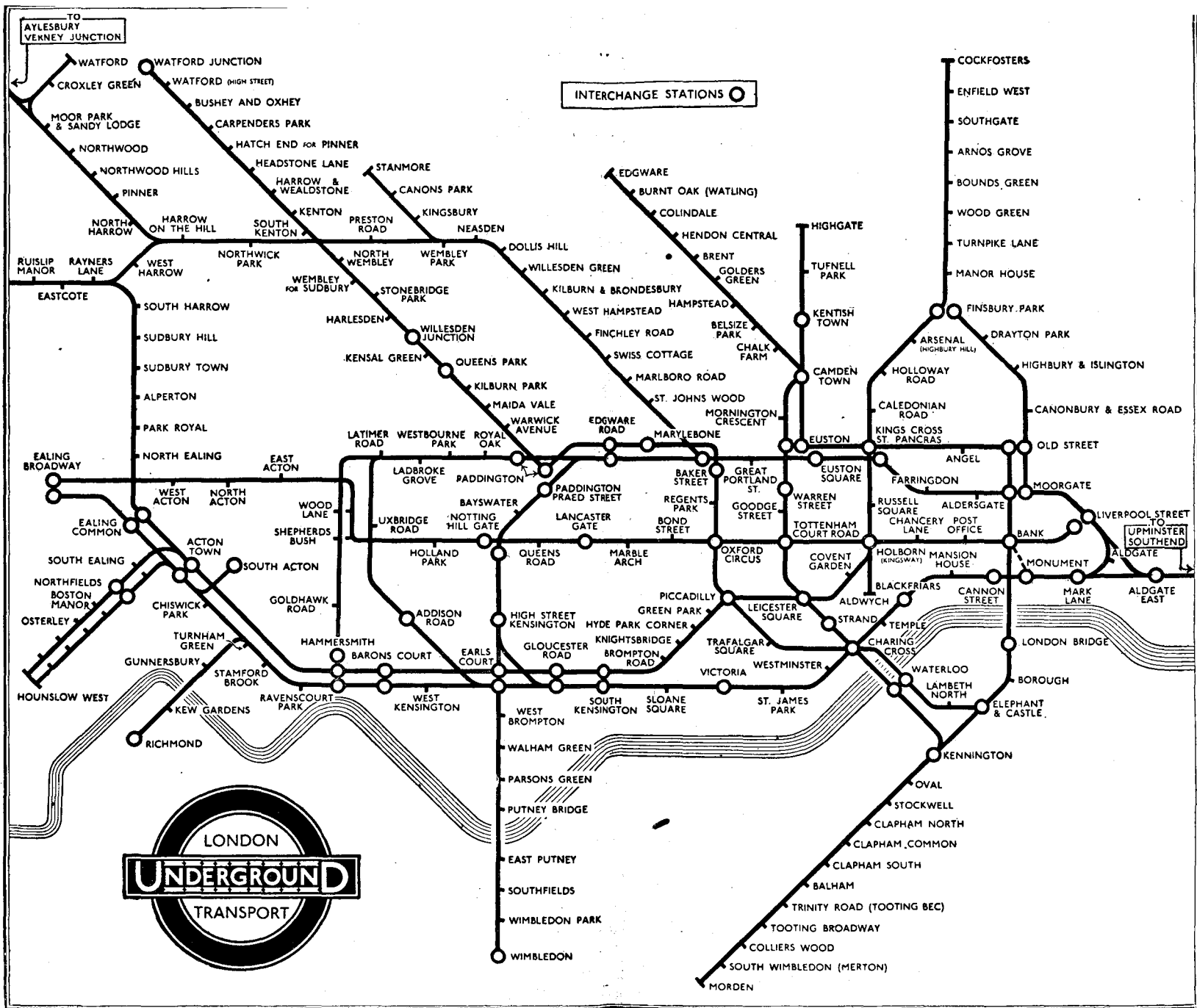
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FOR  
PETER MICHAEL

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VERNON SOMMERFIELD.

# UNDERGROUND RAILWAYS

## CHAPTER I

### FROM COLLIERY LINE TO TUBE

The first railways—Why railways go underground—Tubes and other tunnels—The first Tube—The London Underground—A cable subway.

No one knows exactly where and when the first railway was built, but we do know that a line of parallel wooden tracks was laid down near Newcastle about 1602, to allow colliery wagons to be hauled more easily to the waterside. In those days carriage by road was so slow and expensive, that coal for London and other parts of the south of England was sent from the Tyneside by water, for which reason people talked for over two hundred years of "seaborne coal," or simply "sea coal."

The railway system of the whole world grew out of those little colliery lines in the north of England. Wood was found not to be strong enough for the tracks, and, after a time, the upper sides of the rails were faced with strips of iron. Then iron rails were invented. These were used in 1776 on a line built near Sheffield. The sleepers, or baulks, on which the rails are supported, which are now made of timber, and sometimes of steel,

were stone blocks. Next time you go to Waterloo station take a look at the old Bodmin and Wadebridge carriage on exhibition there, and you will see a track as it was in the early days, with lozenge-shaped stone sleepers and "fish-bellied" iron rails.

At first the rails were built with flanges. That is to say, they were L-shaped, the part at right angles to the rail proper keeping the wagon wheels on the track. Then some one hit on the idea of taking the flanges off the rails and putting them on the wheels, which simplified matters many years later, when it came to building complicated junctions and crossings. The gauge, or distance between the inner sides of the rails, was 4 ft. 8½ in., this dimension being chosen in order to fit the little colliery wagons then in use. To this day, our railways and those of the United States and Canada use the same gauge—the "standard gauge"—while that on the Continent is the same to within a fraction, except that Spain and Russia use a wider gauge—as Ireland does.

The early railways, like the early tramways, used horses, but before the end of the eighteenth century steam-engines had been so successfully employed for draining the Cornish tin mines, and driving machinery in the Birmingham engineering works, that engineers began to think of putting wheels under the engine and building a "steam carriage" that would move by itself. Richard Trevithick, the Cornish engineer, went still further; he not only built a locomotive, but put it, in 1804, on a Welsh colliery railway, where it successfully hauled a load of twenty tons of iron. He was the grandfather of the locomotive, while George Stephenson was

its father. Actually a Frenchman, Nicholas Joseph Cugnot, had built a steam carriage in 1769, and another in 1771. His second machine, which was locked up after it had knocked down a wall in Paris, was a very crude affair; it could not travel more than three miles an hour, and Cugnot never tried to run it on rails. So I think we can quite fairly say the locomotive was an English invention, in the sense that it was Englishmen who first put it to practical use.

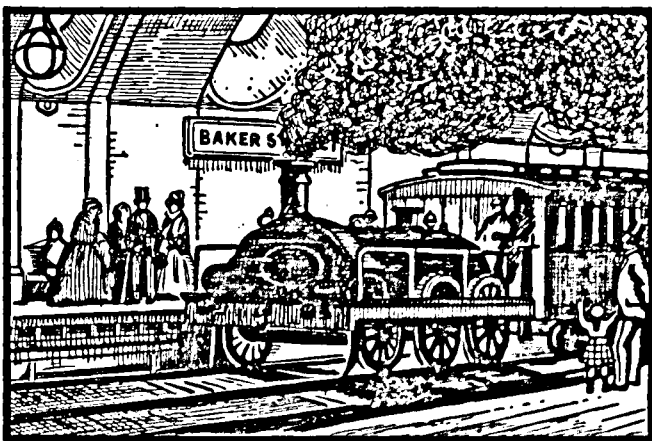
Ten years after Trevithick had shown the people of South Wales what the steam-engine could do in the way of hauling loads, George Stephenson, a self-taught engineer, built a locomotive for the Killingworth Colliery, Northumberland, where he was employed. Stephenson had studied the engines of other makers that used to come to him for repair, and he built something rather better than any one else had done until then. He became known for his locomotives, and when the Stockton and Darlington Railway was opened in 1825, he supplied the first engines.

The Stockton and Darlington was neither the first railway nor the first to use locomotives, which had been put to work on a Scottish line some years earlier. But it was the first public railway. That is to say, it was the first to be built with the idea that any one could, on payment, travel on it or have his merchandise carried, while the colliery lines were private affairs, used only by the mines to which they belonged. For that reason we date the real beginning of railways from 1825.

We may say that the London Underground Railways grew out of this short line between Stockton and Darlington. But it was not until a few years after 1825 that

## UNDERGROUND RAILWAYS

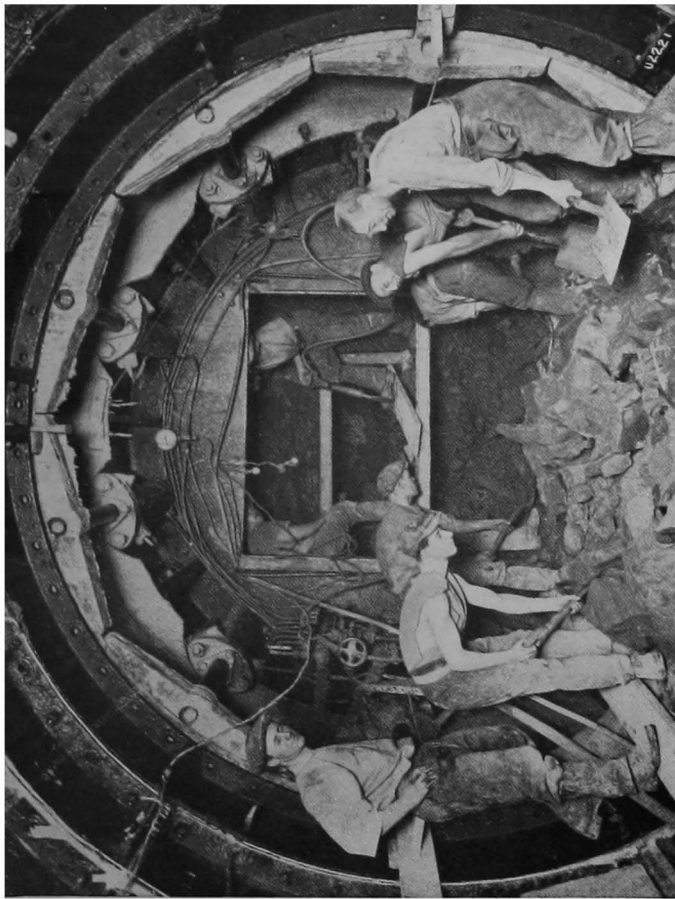
people definitely made up their minds that heavy loads could be hauled safely and quickly by steam. Many engineers in those days believed, wrongly, that a smooth-wheeled locomotive, running on a smooth metal track, would not have sufficient adhesion—that is, would not grip the rails firmly enough—and quite unnecessary



The beginning of the Underground: the earliest type of Metropolitan Railway steam train.

complications, such as rack wheels and rack rails, and engines having legs like those of a mechanical horse, were suggested in order to overcome what was really a non-existent difficulty. Even in 1829, shortly before the Liverpool and Manchester Railway (now part of the L.M.S.) was to be opened, it had not finally been decided whether to use locomotives or stationary steam-

(8,900)



Constructing a tube. Note the built-up segments.

winding engines, to which the trains were to be attached by cables. The railway company decided to hold a competition—the celebrated Rainhill Trials—for which four machines were entered. One of these, called the "Cyclopede," was disqualified because it was worked by a horse mounted on a moving platform. Of the other three, Stephenson's "Rocket" was so easily the best that it won the prize of five hundred pounds; the railway company made up its mind to use locomotives; and nobody bothered much more about adhesion.

Then, seven years later, the steam-worked railway came to London, when the London and Greenwich, now part of the Southern, was opened as far as Deptford. And in 1863 London had its first underground railway, which was also the first in the world. This was the Metropolitan, of which the original section was built on the broad, or 7-ft. gauge, the same as was then used by the Great Western, which worked the new line for the first few months. But before the end of the year standard gauge locomotives and carriages were used, and the last of the broad-gauge tracks were taken up in 1869.

Once I was asked why railways go underground, since building a tunnel is so costly, and most people would prefer to travel on the surface. The answer is simple. In the open country it may actually be cheaper to build a tunnel under a hill or a mountain, than to run a much longer line up to the top and down again on the other side. Such a tunnel railway is also cheaper to work, both because an engine can haul a bigger load on the level, and because a longer distance between two points means

a bigger coal bill. Also, in some instances, as in the case of the Simplon and Mont Cenis tunnels through the Alps, it would either be impossible to take a railway right up to the top, or it would cost far too much to wind a corkscrew line up the mountainside. In cities it is different; there the railway often has to go underground because streets and buildings were already there, while even if it were possible to build a railway along Regent Street, for instance, without interfering with the other traffic, the cost of buying the land would be quite out of the question.

Now London, which has more people than any other city in the world, already had a population of over a million long before the railway was built from Stockton to Darlington. It was a much smaller place than it is now, but it was also much more huddled together, most of the streets being narrow. When the railway first came to London, the terminal stations were built at some distance from the centre—Paddington, for instance, was still a village when the Great Western opened its station the year after Queen Victoria came to the throne—and there was thus no reason why the railways should not be built above ground. But when it came to building them in the middle of London, there was no room for them on the surface, and so they had to go below.

To most people a tunnel is just a long and more or less disagreeable hole in the ground. But if you come to look at it, you will see that it is very much more. Whether it is dug out by hand or by machinery, it must follow the engineer's plans so exactly that even if it is miles in length it must end within a fraction of an inch of the spot where



it has been designed to finish. It has to be kept drained and ventilated, and be lined with bricks or other material if it is driven through moist soil or in the neighbourhood of springs, otherwise there is always the danger of water bursting through. In some instances, as in the case of the Severn Tunnel on the Great Western Railway, pumping machinery is at work day and night.

The ordinary railway tunnel is shaped like a horse-shoe, or an "O" flattened out at the bottom, and even if it has been built to carry only one line of rails, it is fairly roomy. A Tube, on the other hand, is truly circular, and so narrow, except at stations and junctions, that the trains fit in it nearly as tightly as a piston in a cylinder. The tunnel itself is carved out either by an appliance known as the Greathead shield, or by a rotary excavator. The first pushes its way through the soil, a steel cutting edge being worked by hydraulic rams, while the second acts with a whirling motion. The rotary excavator can dig its way rather more than twice as fast as the Greathead shield, but it is suitable only for tunnelling through clay, while the Greathead can be used in the hardest soils.

As these machines move forward and scoop out the soil, a ring of iron segments, bolted together, is built up immediately behind, and liquid cement, or "grout," is forced by compressed air into the narrow gap between the earth walls and the metal rings. In this way a continuous pipe or tube is constructed, and it will be realized that the process is very different from that of building an ordinary tunnel.

Even the many people who pass it every day could

not tell you the situation of the first Tube. If you take a walk to Tower Hill you will see a little round structure, rather like the "pill-boxes" used in the war as miniature forts, with no windows, but having a door. The door is the entrance to the very first Tube tunnel ever made—the subway between the Tower and the Monument, which was opened in 1870, and carried passengers for a time in a car hauled by cable traction, but which is now used only for hydraulic power mains. The contractor was James Henry Greathead, the inventor of the shield of which you have just heard.

But just as the early colliery lines in the north of England were not the first railways in the sense in which we use the word nowadays, so this little Tower Subway is not usually regarded as being the first Tube. That did not come until 1890, when the first section of the City and South London Railway was opened to traffic. The early carriages on this line were of a distinctly peculiar appearance; since it was thought that passengers would not want to look out of the window to admire the scenery in the tunnels, there were no windows. The seats were hard, wooden benches, with a central gangway between them, and the vehicles looked rather like dingy, windowless tramcars. In the beginning, and for many years after, the trains were hauled by electric locomotives, as you will hear later, and at the Stockwell end of the railway, which ran at first only between that station and King William Street, in the City, there was a hydraulic lift that was used for bringing locomotives and cars to the surface when they went into the "shops" for repair or overhaul.

It was at first intended to work the City and South London by cable traction, but the plan was never carried out. It was due to this idea that the diameter of the tunnels was only 10 ft. 2 in. on some sections, and 10 ft. 6 in. on others, as compared with 11 ft. 8½ in., which is the standard on the newer Tubes. A few years ago the whole line was reconstructed, the railway extended southwards to Morden, the old tunnels enlarged to the standard size, and junctions made to allow of through running with the Hampstead Tube.

If you will now go back a minute, you will see that only sixty-five years elapsed between the opening of the first public railway in the world and that of the first Tube, and only thirty-eight years between the first railway and the first underground line. So that there are still many people living who can remember the time when the underground railway was still the latest novelty, just as quite young people of to-day can recall the beginning of wireless broadcasting.

This is a good place to explain exactly what the London Underground Railway system is—the largest in the world. First, there are the Metropolitan and the District Railways, which were worked by steam in their early days and for many years after. These are now entirely electrified, except for part of the Metropolitan's country lines. Then there are the six Tubes—the City and South London, Central London, Great Northern and City, Bakerloo, Hampstead, and Piccadilly. The last three form the London Electric Railway. All these eight lines now belong to the London Passenger Transport Board—which also owns all the London buses and tram-

ways—and whenever the words “Underground” (with a capital “U”) or “London’s Underground” are used in this book, they refer to these eight railways.

There are also three other underground railways in London—the Post Office Tube, the Waterloo and City, and the East London. The first does not carry passenger traffic, being used only for the carriage of mail-bags for the General Post Office. Not many Londoners seem to know anything about it, or even that it exists, but it is an interesting engineering job, and does very useful work. You will understand that just as it is necessary in such a city as London to build underground railways for carrying passengers because the streets are crowded, and the railway is quicker than the bus or the tramcar, so can mail-bags be carried more speedily below ground than above. The Post Office Tube was not finished until after the war, but a much smaller pneumatic tube ran to Euston station as early as 1862.

The Waterloo and City, which belongs to the Southern Railway, is another interesting line. It is the only underground passenger-carrying railway to have no more than two stations, although the Holborn-Strand branch of the Piccadilly Tube also has only two. Another unusual point about the Waterloo and City is that it has no booking offices, tickets being issued on the trains by the guard. Its City terminus is at the Bank, which is the only underground triple “interchange station,” being served also by the Central London and City and South London Tubes, although at Moorgate subway connection is provided between three underground railways.

Of the Underground lines, the Metropolitan is the only

one to carry goods as well as passenger traffic, though the East London also carries both. This line, which was one of the earliest underground railways in the world, is only four miles in length, but it is of considerable importance, because it connects the main railways north and south of the Thames, for which reason it is very useful for handling through goods traffic, and was most handy during the war for carrying munitions from the north of England to the Channel ports. In spite of its shortness, it belonged at one time to no fewer than six different railway companies, including the Metropolitan and District. To-day it is, like the Waterloo and City, owned by the Southern, but the passenger traffic is worked by the Metropolitan, which runs through trains over it, and the goods traffic by the London and North-Eastern. The nearest approach in England to such a short line of which the working concerns so many other railways is the West London Extension, between Addison Road and West Brompton, which is only five and a quarter miles in length, but is owned jointly by the Great Western, the Southern, and the London, Midland, and Scottish.

When one thinks of the number of large towns and cities in Great Britain, it is rather curious that there is such a very small underground railway mileage outside the London area. In fact, there is only one other underground line in England—the Mersey Railway; one in Scotland, and none in Ireland. The Mersey, which runs under the river of that name and connects Liverpool with Birkenhead, was opened in 1886, and was at first worked by steam, but is now electrically operated. The Glasgow Subway, nicknamed the “Caley,” is circular,

and the trains are worked by a continuously moving cable, to which the cars are attached.

It is also curious that there are so few underground railways abroad, for which there are, however, a number of reasons. Most of the principal streets in London are much too narrow for the traffic they are called on to handle, so that passengers have for many years been more and more driven to travel beneath the surface, while many Continental and American cities, such as Paris, Berlin, New York, and Buenos Aires have wider main thoroughfares. Then foreign cities, as is also the case with provincial towns in England and Scotland, make more use of tramways, which scarcely penetrate the Central London area, and in some foreign cities, such as Berlin and New York, there are overhead railways. As a matter of fact, a good deal of the western section of the Metropolitan, and part of that of the District, are built on embankments and bridges, but these surface lines are not in the central area. This applies also to the above-ground portions of the Tubes.

The principal foreign cities with underground railways are Paris, Berlin, New York, Madrid, and Buenos Aires, while a Tube is also being built in Moscow. Except for the last, most of these lines are not Tubes, although there are short under-river Tube sections in Paris and New York.

The Paris Metropolitan, or "Metro," as it is generally called, is built on an unusual plan, being composed of a number of shortish circular lines linking up with each other. This may sound a convenient arrangement, but it is actually not so handy, since it is necessary to change

from one section to another when making a journey of any length. The Berlin system, which used to be known as the "Hoch und Underground Bahn," or "Elevated and Underground Railway," is, like our own Metropolitan, partly beneath the surface and partly carried on bridges, and there is one place where the line runs right through a house, part of which was cut away when the railway was built, while the remainder was left standing. Both the Paris and the Berlin underground lines have always been worked by electricity.

The New York system—whose full name is the Interborough Rapid Transit Company, but which is always spoken of as the "Subway"—is partly above ground and partly below. The above-ground lines, which are about half as long as those in tunnel, are elevated. On some of the busiest sections the lines are four-track. Only one fare is charged, so that it costs you twopence-halfpenny whether you are travelling only from one station to the next, or from end to end of the line. A uniform fare was at one time also charged on the Central London Railway, which came, in consequence, to be known as the "Twopenny Tube"; but it was found that the method did not pay, and it was given up many years ago. The twopence-halfpenny fare also does not pay in New York; if you want to know why it has not been given up there, I can only tell you that politics have to do with the matter.

The New York Subway has one great advantage over the London Underground; on the busiest sections of the line there are four tracks, two of which are used for express, and two for stopping trains. Passengers wishing

to change from the fast to the slow trains, or vice versa, do so at those stations where the expresses stop. It would be much easier to handle traffic in London if nearly all the working were not over only two tracks, which is a very great inconvenience to the Metropolitan, for instance, where all the trains on the Extension Line have to get in and out of Baker Street station over a two-track bottle-neck. Yet the Underground handles its traffic so skilfully that it actually works more trains an hour over two running lines than the New York Subway does on four.



## CHAPTER II

### MORE ABOUT LONDON'S UNDERGROUND

The West London Railway—An underground tramway—Power-houses—Car sheds.

IN the first chapter I explained what is meant by the London Underground Railways. (Nowadays more than half the system is above ground.) There are a number of other lines which, while not actually forming part of the Underground, are either worked over by its trains, or are in tunnel. For instance, the old North London Railway, which is now part of the London, Midland, and Scottish, is electrified, and runs partly in tunnel, as is also the case with the London, Midland, and Scottish electric lines running into Euston, which dive over and under the main tracks near Camden Town.

Then there are those two interesting railways, the West London and the West London Extension, which not only link up main lines north and south of the Thames, and thus allow of through expresses being run between Birmingham and the south coast, for instance, but also form a connection between the Metropolitan and District lines. This connection has been discontinued, however, since the electrification of the District line caused traffic to be too congested at Earl's Court, the junction station.

For many years previously, the London and North-Western used to work a steam service over what was known as the "Outer Circle." This began at Broad Street station on the North London Railway, crossed the North-Western main tracks at Willesden Junction, ran over the West London, got on to the District line at Earl's Court, and ran thence to the Mansion House station, thus traversing an almost complete circle, and ending up within a mile of the starting-point. Since the London, Midland, and Scottish suburban lines were electrified, its trains have been run over the West London so far as Earl's Court, but they no longer go any farther.

There are still some very interesting steam services on the City section of the Metropolitan, where there are four tracks between King's Cross and Moorgate stations. Only two of these are used by the Metropolitan itself, the others being worked over by the London and North-Eastern, and London, Midland, and Scottish. At one time the South-Eastern and Chatham (now part of the Southern Railway) also used to run trains to Moorgate, but this service was withdrawn some years ago, partly on account of the electrification of the Underground, and partly because through services were given up during the war and were never restored.

If you ever happen to be in the City, take a look at this section of the Metropolitan between Moorgate and King's Cross. At the latter station, the Metropolitan tracks are on the south side of those used by the steam railways, but at Moorgate they are on the north. By means of a "burrowing junction," the steam-worked tracks dive under the Metropolitan, and come alongside

## MORE ABOUT LONDON'S UNDERGROUND 17

again on the other side, a remarkable feat of engineering, especially when one remembers that it was carried out so many years ago. This burrowing junction makes it unnecessary for the steam trains to interfere with the Metropolitan working by crossing its lines on "the flat." At Edgware Road station, where the Inner Circle leaves the Metropolitan's Hammersmith and City line, there is actually a tunnel junction, and trains on one section sometimes hold each other up, as is also the case with the tunnel junctions at South Kensington and Baker Street.

London also has an underground tramway line. This starts in Theobald's Road, near Holborn, runs beneath Kingsway, where there are stations complete with platforms and seats, and comes to the surface again at Waterloo Bridge, where it connects with the tramways running along the Thames Embankment. Just as the East London links up the railways north and south of the river, so does this tunnel form a link between the tramways on either side. When it was first opened, it was too shallow to take anything but single-deck cars, but since it has been rebuilt it is used by double-deckers.

London's Underground gets all its electric current from two power-houses—Lot's Road, Chelsea, and Neasden. The first is much the larger, since it supplies all the Tubes (except the Great Northern and City), the District, and some of the tramways. Neasden is used only by the Metropolitan. If ever you have the chance to visit it, you will find Lot's Road one of the most interesting places in London. It is a large building, standing by the river, with four immense chimney stacks

that can be seen miles away. Everything at Lot's Road is done by machinery. As the coal barges (filled with "pea coal," the size of small marbles) come into the dock, the fuel is taken by machinery to the top of the building, being automatically weighed before it goes up, and is then discharged on to a "conveyor." This is an endless, continually-moving band, running over rollers, which deposits the coal in the bins. From there they drop down to the boilers. Stoking of the boilers is entirely automatic: a "chain grate stoker" (a metal platform, also endless) slowly moves the coal through the firebox at exactly the speed at which it will burn properly. At the other end of the firebox the clinker is automatically pushed out, and is taken from the power-house on little wagons. From the moment the barges anchor until the coal is burnt to ash, it is not touched by hand.

Lot's Road is the bigger power-house, but Neasden is, in some ways, more interesting, because it not only generates electrical current; the Metropolitan's car sheds and sidings, locomotive sheds, and repair "shops" are also situated there, so that it is really a little railway town—a Crewe or Swindon on a small scale. When you pass it you will notice some curious-looking wooden structures outside the main buildings. These are the condensers. The boilers of a power-house use a great deal of water, and water is expensive when it has to be bought in millions of gallons. So, after it has passed through the boilers in the form of steam, the steam flows into the condensers, where it is turned back into water and thus repeatedly used in the boilers. In this

## MORE ABOUT LONDON'S UNDERGROUND 19

way it also becomes softer and purer, and this prevents the boilers from becoming clogged up with "scale," which is much the same thing as the "fur" in an ordinary kettle.

Besides Neasden, there are car sheds at Wood Lane, Golder's Green, and Morden for the Tubes. Morden is the newest of all; it was built when the extension of the City and South London from Clapham Common made it necessary to have large new sheds and sidings at the southern end of the line. It has twenty sheds and sixteen siding "roads," or tracks, with a total length of over 21,000 ft., or a little less than 4 miles, and can stable 386 cars, or about one-eighth of the whole of the Underground rolling stock. The car sheds are situated in the middle of the depot, and the sidings to the right and left and at the end. Since so much of the car cleaning work has to be done at night, the sidings are flood-lit, and there is a loud-speaker installation to enable the signalman at Morden station to communicate with the depot.

The principal depot for overhauling the cars is at Acton, where about five thousand vehicles are dealt with in the year, which is at the rate of about fourteen a day, counting Sundays. This figure is even larger than it sounds; since the total number of cars in use on the Underground is only about three thousand, you will see that each car comes in for a thorough overhaul about twice a year.

While the Metropolitan and District were worked by steam for many years before they were electrified, the Tubes were built for electric traction from the beginning. London and Liverpool are the only cities in the world

to begin with steam underground railways ; everywhere else the underground lines were built for electrical working from the start. This is more important than you may think. In London we have had to experiment and invent, because the men who built the Metropolitan and the District were building the first underground railways in the world, and were doing something so new that they had nothing to guide them. And, after building, it was necessary to rebuild ; to change from steam to electricity, to widen tunnels, as was done on the City and South London, to change over on the Tubes from electric locomotives to motor cars, to scrap the signalling system, and to take out into the country and on to the surface railways that had been planned as short lines running entirely underground. All this was not necessary in Paris, New York, and Berlin. London's Underground would have been different in many ways to-day if it had been begun as recently as these foreign systems and had therefore never used steam.

## CHAPTER III

### IN THE TUNNELS

Switchbacks and telephones—Emergency lighting—Seaside air below ground—Junctions and "interchange" stations—A costly job.

I WANT you to imagine that you are coming with me on a journey over London's Underground Railways. There is so much to see that it is a little difficult to know where to start, so we had better begin with the tunnels themselves.

You already know that most of the Underground is, in fact, above ground ; there are 72 miles in tunnel, and 101 miles on the surface. The reason, as I shall explain more fully later, is that as London, and especially what is known as "Greater London," grew both in size and population, the railways also reached outwards, and as they spread into the less crowded districts, it was possible to bring them above ground. As they went out still farther, they were built in more or less open country, and here, of course, there were no streets under which it was necessary to tunnel. So that most of the Metropolitan and District Railways now run on the surface, while the Tubes also have a large mileage above ground.

The Tube tunnels vary slightly in detail, but if we

look at those of the Central London, we shall have a very good idea of what they are like in general. This line, although it was opened only ten years after the City and South London, was from the beginning far more up-to-date in every way. The Central London tunnels are built as switchbacks, that is, the running tracks slope downwards immediately on leaving the stations, and rise again on entering them. These inclines help trains to get up speed when going downhill, and act as brakes when they are going up.

There is a very simple reason for the switchback, which is also used on a small section of the City and South London's Morden line. Except on the new sections where the lines are above ground, the Tube stations are so close together—on the underground section of the Central London they are less than half a mile apart—that a good deal of the actual travelling time is spent in getting up speed and slowing down again, and this makes the average speed from end to end of the line much less than the top speed between any two stations. Trains enter and leave the stations about every two minutes, and such a frequent service could not be run unless seconds were saved wherever possible; but that is not so easy when the trains have to make so many stops that they are hardly ever given a fair chance to show how fast they really can travel.

Now, an electrically-driven train is actually not faster than one hauled by a steam locomotive, although many people imagine that it is. (As a matter of fact, the world's fastest expresses are run on steam railways, and no electric railway has yet beaten the record of the



Great Western's "Cheltenham Flyer," the fastest train in the world.) But electricity has one great advantage, especially where trains have constantly to start and stop because the stations are so close together; it takes a shorter time than with steam both to get up speed and to slow down from top speed to a standstill. That is what engineers call greater "acceleration" and "deceleration," without which it would be impossible to run about five electric trains on the District Railway for every two that could be worked in the steam days. By improving "acceleration" and "deceleration," the switch-back helps to get the most out of electricity.

You will notice electric lamps spaced out at regular intervals throughout the tunnels. These are fifty feet apart. At one time the tunnel lights were always kept burning, but as their use is only in emergency, they are now lit only in case of accident or breakdown. You will also notice two parallel wires a few inches apart. These are for telephoning, for switching off the track current whenever necessary, and for the lighting. A portable telephone outfit is carried in every driver's cabin. In any emergency, the driver has only to clip his telephone on to the wires and ring up the nearest sub-station—where the current is transformed from the high voltage, or pressure, at which it is delivered from the power-house, to the lower voltage at which it is sent through the "live" rails. On the driver's message being received at the sub-station, the current is cut off from that section of track, and if the breakdown seems likely to last a long time, or it is necessary to haul the train away to a siding, passengers can then walk through the tunnel to the

next station in safety, without any danger from the "live" rails. As the action of cutting off the track current automatically switches on an emergency current which turns on the tunnel lights, they walk through a lighted tunnel.

But it is not necessary even to telephone the sub-station in order to have the current cut off and the lights turned on. Partly as an additional safety precaution, and partly because of the need for "saving seconds," it was decided some years ago that any member of the train crew should be able to signal the sub-station without leaving his post. All that is necessary is to pinch the wires together, and the current "cut-out" automatically comes into operation and the lights go up.

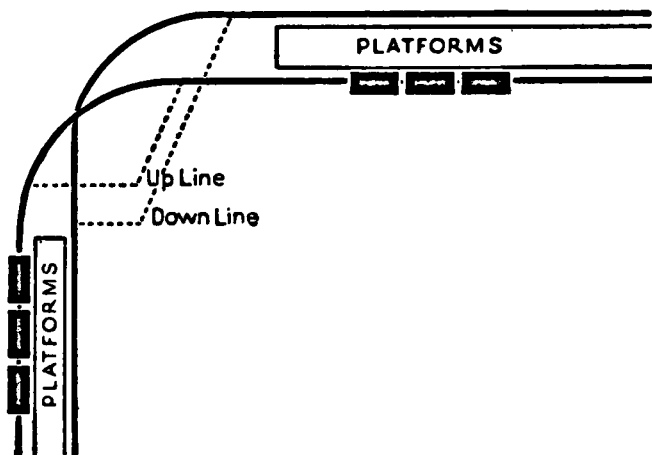
In winter, the Underground tell you that "it is warmer down below," and in summer that "it is cooler," which means that the temperature below ground is independent of that above. This is done by heating or cooling the air, as the case may be, until it has been brought up or down to the right degree. If you will think it over, you will see that the ventilation of a Tube is a much more difficult matter than that of an ordinary tunnel railway, because the Tubes go so far below ground, that it is only in exceptional instances possible to run an air-shaft to the surface, while there are also no cuttings open to the sky, as on the Metropolitan and District. So the Tubes have to make their own weather, so to speak, by means of a complicated system of ventilating pipes and machinery. On the Central London they have gone even further, by having machinery for making ozone, which is pumped through the tunnels and makes the stations smell like the seaside.

A certain amount of fresh air also reaches the stations through the lift and escalator shafts, and on a few sections through shafts that were used during the building of the line, and have been left open. To some extent the trains themselves help in the ventilation ; they fit so tightly in the tunnels that they push a moving column of air in front of them as they come into the stations, while they suck out air from behind, like the action of a piston in a cylinder.

A special reason why it is necessary to take such care to ventilate a Tube is that a good deal of heat is given out by the train motors, and some of this remains behind. Indeed, when tests were made in New York some years before the war, it was discovered that this heat was so difficult to get rid of that every year the tunnels became a little warmer.

On the New York Subway, as I have said, traffic is carried over four running tracks, two for express and two for stopping trains, passengers changing, where necessary, from the fast to the slow or the slow to the fast trains at interchange stations. Most of the London Underground Railways have only two tracks, the only four-track section below ground being between South Kensington and Earl's Court, where District trains use the southern lines, the northern tracks being reserved for the Inner Circle service. On both the Metropolitan and District Railways, except for this four-track circle section, the "up" and "down" tracks pass through the same tunnel, as is generally the case on steam lines. On the Tubes a separate tunnel is built for each track, except where there are cross-over roads to allow trains to be

switched from one line to the other, either so as to reverse them at the end of their journey, or to allow trains to be switched off from a track that is blocked through a break-down. At some stations the platforms are on the same level, but they are kept distinct, and serve only one track,



This diagram shows why passengers may have to enter a train on one side and leave from the other.

although they are built with openings to allow passengers to pass from one to the other. At other stations, such as Baker Street, the "up" and "down" platforms are on different levels.

This often puzzles people, as also the fact that you may enter a train from the left side but have to get out at a right-hand platform. The drawing on this page

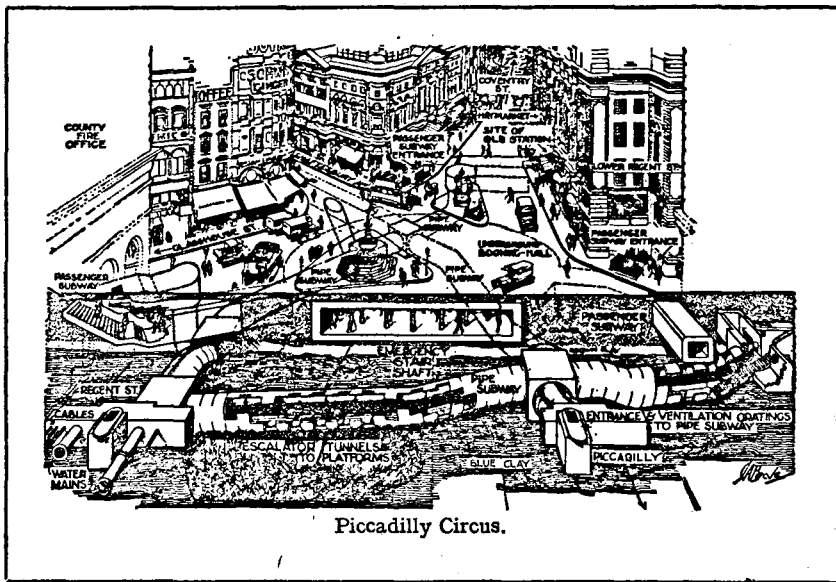
explains why. The station entrances must be situated at convenient positions on main roads, and it sometimes happens that one station is on the north side of the street and the next one on the south. In other instances it has been necessary to build an adjoining pair of stations in streets at right angles to each other, so that the tracks between them have to be laid on a curve. If you look at the drawing you will see that by changing over the positions of the platforms the curve can be made wider ; if that were not done, it would be necessary to reduce speed while passing over a sharp curve, just as you have to slow up when going round a corner on a bicycle or in a car. There are various reasons for building the platforms at the same station on different levels ; for instance, it may be necessary to avoid underground drains.

There are many more junctions on the Metropolitan and District than on the Tubes. This is partly because it is very expensive and difficult to link up two lines of railway carried at a great depth below ground, and partly because the early Underground Railways began very soon both to extend their own systems—so that the Metropolitan now ends right in the country—and to connect with other lines over which their trains run. On the other hand, when Tubes were first built, it was thought that they would never be anything but very short railways, running only in the most crowded parts of London, and not linking up with any other lines. Even when they began to extend, junctions were for a long time not built between one Tube and another, but only between a Tube and a surface line, as, for instance, between the Bakerloo and the London, Midland, and Scottish Railway,

which allows the Bakerloo trains to travel all the way to Watford. That explains why, although there are so many "interchange stations," such as Oxford Circus, Piccadilly, the Bank, and Holborn, where you can change from one Tube to another, you have not only to change cars, but also to finish your journey on another railway built at a different level.

Had the extension of the Tubes been foreseen, it is possible that the tunnels would have been made wider, so as to take through trains from the main lines, whose coaches are of greater height and width. If that had been done, an express might start to-day from Birmingham or Glasgow, and end its run at Piccadilly or the Bank, which would be a very convenient arrangement, since most of the main line terminal stations are situated some distance from the centre of London. There is actually not a single terminus in the West End, although in the very early days of railways it was planned to give the Great Western and the London and North-Western a joint station in the neighbourhood of Oxford Street. As a matter of fact, the Great Northern and City tunnels *are* wide enough for main line rolling stock, but they have never been used for this purpose, although the line was originally intended to be used for working trains over the Great Northern Railway, by means of a junction at Finsbury Park that is still waiting to be built. Therefore, while the Bakerloo trains can run over the tracks of the London, Midland, and Scottish Railway, the trains belonging to the L.M.S. are too wide to be used in the Bakerloo tunnels.

However, junctions between the Tubes had to come



Piccadilly Circus.

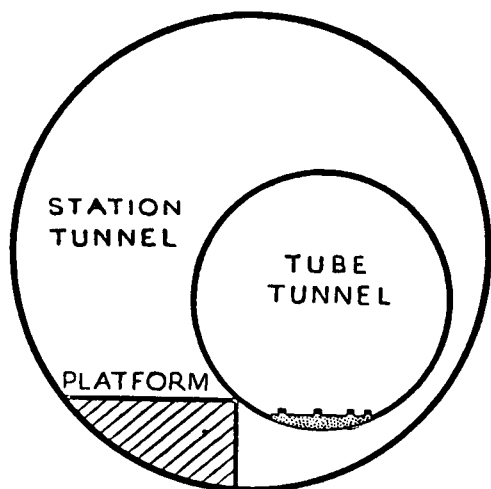
sooner or later. Where the Tubes go above ground it is, of course, a simple matter to build connecting lines between a Tube and another railway, but it is a very difficult engineering work to build a junction between two deep-level Tubes, or two sections of the same Tube. Both have been done at Camden Town, where the Hampstead Tube splits in two and also links up with the City and South London. The two lines also connect at Kennington. These two stations are the only junctions between different Tube railways in London.

You will learn more about Camden Town and Kennington later in this book. Another very interesting station is Holborn. From the opening of the line until 1933, the Central London had a station called British Museum, on the north side of Holborn. The Piccadilly Tube's Holborn station is on the south side of the street. The British Museum station has now been closed, and Holborn, which has been rebuilt and enlarged, serves both Tubes, although there are no junctions between the two lines, whose platform tracks are, of course, at different levels. This is the only instance of one station being made to serve two Tubes, each of which used to have its own.

If you travel much on the Tubes you may have noticed that the longest trains on the Central London have no more than seven cars (six is the more usual number), although eight are used on the other Tubes during the busiest periods. The reason is that some of the Central London platforms are not long enough to take more than seven cars alongside, and if eight were used the last car would still be in the tunnel when the remainder of the



train was in the station. Now, the more cars there are on a train the more passengers can be carried in a given time, and I once asked an Underground engineer why the Central London's shorter platforms could not be lengthened, which seemed to me a simple and inexpensive job.



Tunnel construction at a tube station.

As an engineering work it would not be specially difficult, but it would, I was told, be enormously expensive, since at the least it would cost well over half a million pounds. That seemed to me such an extraordinarily large sum of money for lengthening a few platforms that I asked some more questions. And this is what I was told.

The Tubes are at work for about twenty hours out of the twenty-four, so that any repairs or new work in the tunnels can be done only between about one and five in the morning, when the "juice," or track current, is cut off. Lengthening a platform below ground is a much more difficult and lengthy affair than doing the same work on the surface. If you look at the drawing on page 31 you will see that while the stations are also built in tube (although their cylindrical shape is partly hidden by the platforms), their diameter is much greater than that of the running tunnels. Therefore, the tunnel entrances would have to be widened before there was any room for the platforms to be extended. But in carrying out such a job as widening a tunnel mouth, a certain amount of time is taken up, after the last train has left, in "making ready" the excavating gear and other tackle required, and enough time must also be allowed for dismantling the gear before the current is turned on again. It would thus not be possible to work for more than about two hours at a time, but the workmen would have to be paid a full day's rate, and the wages bill would therefore be so heavy as to make the lengthening of the platforms cost far more money than it was worth.

I mention this because here, as in the changing over of the platform positions, there are many difficulties which most people do not realize. That is, of course, true of all railway working, but there are special difficulties underground, because the cost of building is so much heavier and the engineering difficulties are so much greater.

## CHAPTER IV

### ENGINES AND CARS

Steam and electric locomotives—The " Multiple-Unit " System—  
The " Dead Man's Handle "—Brakes—Pullman cars—Auto-  
matic doors—" Saving seconds "—" Converted " trains.

STEAM locomotives are still used on some sections of London's Underground—as we shall see later—and in the early days there was nothing but steam.

The early Metropolitan and District Railway carriages, as well as those used until well on in the present century, were compartment coaches, and had three classes. (To-day there are only two—first and third—while the Tubes have always had only one.) Both on account of the passengers and because of the ventilating shafts and open cuttings, it was necessary to do away with smoke and fumes as much as possible, and the locomotives were of the " condenser " pattern, in which the steam is not exhausted through the chimney but passes into a condensing tank. Unfortunately, it was impossible to prevent smoky fumes altogether, and the old Underground had an almost stifling atmosphere in parts.

The first Tubes were built before the Metropolitan and the District were electrified. The Tubes had, of

course, to be worked electrically, since it would have been impossible to have ventilated a deep-level narrow tunnel using steam-engines. You will not see an electric locomotive on the City and South London or Central London to-day, but they were used when these lines were first opened. Those on the City and South London were little four-wheeled affairs, while the Central London engines, which came ten years later, were much larger and had eight wheels. If you want to see what the electric locomotives were like, you will find the City and South London's "No. 1" at the South Kensington Museum, alongside some very early steam-engines. It is much brighter than its neighbours, being painted in orange chrome, with a "lining," or border, of black and yellow.

The electric locomotives did their work well, but they had two faults; they were noisy and caused vibration above ground, which annoyed people living near the Tubes, and they were expensive to run because traffic on the underground railways varies very greatly at different times of the day. During the morning and evening "rush hours" many passengers cannot get a seat, no matter how often the trains are run or how long they are. But in the slack periods, short trains at longer intervals provide more seats than there are passengers.

Now, a locomotive, whether steam or electric, must be powerful enough to haul the longest and heaviest trains it is called on to pull. On a steam main line, where there are express and slow trains, long trains and short, goods as well as passenger traffic, and where much shunting and hauling of empty trains has to be done, a

number of different types of engine is used, each designed for its particular job. But on a railway carrying only passengers, and where all the trains run at much the same speed, a single type of engine has to do all the work. If you build a locomotive powerful enough to haul a train of eight or six cars, it is wasteful to use it during the slack hours on a train of half that length, while if you have one set of engines for the heavy and another for the light tracks, you are using more engines than you really need, which is also wasteful.

But there is a way of fitting the power to the load without having more than one type of engine, and that is by doing away altogether with locomotives, and fitting electric motors to the cars instead. It is not necessary to have a motor on each car; one to every two or three is enough. This system, known as the "multiple-unit," is now used on all the London Underground lines, and also on underground railways in other countries. Instead of having one or more locomotives at the head of the train, every second or third car is equipped with motors, those not so fitted being called "trailers." In this way not only is the power increased or decreased according to the length of the train, but trains can be split in two during the slack periods—which prevents the haulage of unnecessary cars—and reassembled in the rush hours.

The multiple-unit system has another advantage; there is no need for shunting or backing an engine round at the end of a journey, since the driver simply changes from the front to the rear driving cabin (which, of course, then becomes the front end of the train), and the train

is at once ready to start out again in the opposite direction. It is as simple as when a tramcar driver walks round the car to change driving platforms at the end of a journey. The system also makes it possible to drive a train from any car fitted with the necessary control gear.

The first railway in England to use the multiple-unit system was the Central London, which scrapped its locomotives in 1903. The City and South London did not follow until twenty years later, when the line was closed for rebuilding. The other Tubes used the system from the beginning, and it was also employed when the Metropolitan and District changed over from steam to electric traction. The Metropolitan, however, also uses electric locomotives, since the whole of its Extension Line is not yet electrified, and long-distance trains are hauled by electric engines between London and Rickmansworth, where a steam-engine is attached for the rest of the journey. These electric locomotives, of which there are twenty, all have names, a privilege usually reserved for steam-engines. Electric locomotives are also used on the District for the through trains to Southend, part of this journey being over a section of the London, Midland, and Scottish Railway that has not yet been electrified.

As I have said, the Metropolitan is the only Underground line to carry goods as well as passenger traffic, and its goods trains are drawn by steam-engines, which are also used by Great Western passenger and goods trains running over the Hammersmith and City section of the Metropolitan. You will see, therefore, that on the Underground there are to-day three forms of traction—



**Locomotive and coaches used on District Railway before electrification.**



**Electric Locomotive used on Central London Railway before adoption of the Multiple-Unit system.**

multiple-unit electric, electric locomotives, and steam-engines.

If you have ever noticed that only one man is carried in the driver's cabin of an Underground train, while most steam locomotives have two men on the footplate, you may also have wondered what would happen if the motorman should suddenly be taken ill. This is one of the many possible risks that have been guarded against, the protection here being an extremely simple device called by the rather gruesome name of "Dead Man's Handle." (As a matter of fact, I have never heard of its having any other or official name.) It is nothing more complicated than a flat knob, placed on the controller or driving handle, and having a spring that is automatically pressed down so long as the motorman has a proper grip of the controller. But should he by any chance let go the handle, or even loosen his grip, the automatic brake is at once applied.

The brake itself is a very complicated appliance, or rather series of appliances—pumps, tanks, cylinders, valves, tubes, couplings, and air compressors—and it is difficult to explain it properly without an elaborate diagram showing all the working parts. Put as simply as possible, each car is fitted with cylinders in which air is stored, and kept at high pressure by a pump worked by electricity. Inside the cylinder is a piston, and the piston rod is attached to levers working the brake blocks. When air at ordinary pressure is allowed to enter the cylinder, which takes place when the motorman wants to stop or slow down, the pistons are set in motion and



force the brake blocks against the car wheels. These brakes are automatic in action; they apply themselves if the train runs past a "danger" signal, and also if a train should break in half, which disconnects the brake pipes that are coupled up throughout the train, and admits low-pressure air to the cylinders.

The cars used on the Metropolitan and District are much roomier than those on the Tubes, and the Metropolitan has an unusually large variety of rolling stock. It uses trains that were built for electric traction, steam trains converted for electrical working, and trains for use on the long-distance services that have been designed for haulage both by steam and electric locomotives. It also has Pullman cars—the only Pullmans on the Underground.

The newest type of cars now running on the Underground are, in their way, as much of an improvement on the windowless Tube coaches of 1890 as electricity has been an improvement on steam. There has been much in this change that the ordinary passenger does not notice. He will, of course, notice such things as more comfortable seats, better lighting and ventilation, and smoother and less noisy running. But he has no idea of the elaborate experiments that were made in order to obtain less noise and vibration and easier riding. The rolling stock, all of which is fireproofed, has been made better in a number of other ways. For instance, the first Central London cars had only two doors, one at each end, which meant only one door for the use of passengers on the early multiple-unit motor coaches, since the other gave access to the driver's cabin. To-day, the standard type of car,

both on the Tubes and on the Metropolitan and District Railways, has three doors, the one in the middle giving a wider entrance and exit space than those at the sides. This design means a certain lessening of the seating accommodation, but it has the great advantage of allowing passengers to get on and off more quickly.

On the Tubes and the District, but not on the Metropolitan, the doors are not opened and closed by hand, but worked and controlled by the guard by means of a compressed-air mechanism. These pneumatically operated doors not only help to reduce the station stops by speeding up the movement of passengers (stop-watch tests have shown that the time can be halved), but the work can be done by fewer men. With the old type of door, a six-car Tube train carried a crew of six—driver, guard, and four gatemen. Now, trains of six and even seven cars can be handled by only a driver and guard. The train telephone system, of which you will hear more in another chapter, has also helped to make possible the employment of only two men.

Since all the doors are worked by the guard, it has been necessary to use safety devices to prevent a train from starting until every door has been properly closed. When this has taken place, the guard operates a bell signal, which cannot be brought into use before then, and gives the driver the "all clear." The guard himself knows that it is safe to start when a signal light on his platform gives him the sign. Another safety device prevents a passenger from being injured if he should try to get on or off while the doors are being closed. During the last five inches of the travel of the doors the air pressure for

working them is slowed down, while they also have soft rubber-covered edges as a further precaution against injury.

But we have not yet finished with the doors. There is always a possibility, especially with a long train, of the driver slightly "over-running" the station—that is, instead of the whole train being alongside the platform, the front car or part of it is brought to a standstill within the tunnel. In that event, the driver operates a special switch that will prevent the front doors from being opened, thus making it impossible for passengers to get out except by walking through the car until they reach a door properly alongside the platform.

There is yet another ingenious device. At a crowded station, especially if the platforms are on a curve, the guard cannot get such a good view of the front part of the train as any one standing in the middle of the platform, and he might thus delay the start by waiting an unnecessarily long time to give the "all clear" signal. To overcome this difficulty, the newest type of car is fitted with a "plunger," a small box having a projecting rod beneath it. If a porter in the middle of the platform sees that all the passengers have got on, but that the "right away" has not been given, he pushes the plunger in, and thus signals to the driver.

I have already mentioned that the Metropolitan uses on its long-distance services a certain number of trains that have been converted from steam traction. In the days of steam all the coaches on both the Metropolitan and District were of the compartment type, and as each compartment had to have a separate door on either side,



Latest type of steam train, Metropolitan Railway. Note the Pullman car.



Standard tube railway car with automatically-operated doors.

the short coaches then in use had ten or twelve doors. These were, of course, worked by hand, which so slowed down the movements of passengers that the station stops had to be much longer than they are to-day. From the beginning the Tube cars have been of the "open" type, with no compartment divisions, and a gangway down the middle, and this pattern was also introduced on the Metropolitan and District when they were electrified. (Some of both the Metropolitan and District cars are divided into two compartments, either to separate the smoking from the non-smoking portions, or because they carry both first and third class passengers, but they also have the central gangway throughout, and passengers can cross from one part of the car to the other through a door in the middle.) But when the Metropolitan began to electrify the more distant sections of its Extension Line, it had some new compartment coach steam trains that were too good to scrap. Some of these are used on the services that are worked partly by electricity and partly by steam, and others (the converted trains) have been fitted with electric motors and driving gear, though the compartment design has been left unaltered in both.

The number of cars on the Underground trains varies from two to eight, while on the Holborn-Aldwych section of the Piccadilly Tube, single-car trains are used during the slack hours of the day. Seven is the largest number on the Tubes and the Metropolitan electric trains, and it is only on the District that you will see eight. On this line it is the rule to have one motor car to every trailer, so that the four-car trains have two motor coaches, and the eight-car trains four. The same proportion is used on the

Tubes, except that the three-car trains, which are really half trains, must, of course, have two motor cars. On the Metropolitan the rule is that where a train has an even number of cars, half are motors ; but the seven-car trains have as many as five motor coaches, the five-car trains three, and the three-car trains two, the same as on the Tubes. You will see from these figures how the haulage power can be added to or lessened in accordance with the length and weight of the trains, which would be impossible with steam, unless several different kinds of locomotives were in use and were changed about during the day. There you have a very good idea of the advantages of the multiple-unit system.

## CHAPTER V

### SIGNALS AND SIGNALLING

A lazy man's invention—Interlocking—How trains signal themselves—The "train stop"—The "upper quadrant"—Colour-light signals—Track indicators—The Camden Town junctions.

Most people believe that railway signals are used only for the sake of safety. That was true at one time, but it is no longer the case to-day. Besides making travel safe, signals are also necessary for controlling traffic, and without modern signalling methods it would be impossible to run forty trains in an hour on a single line of rails, as is done every day on certain sections of London's Underground during the "rush" or busiest morning and evening hours.

The history of signalling goes back to the earliest days of passenger carrying railways. The first signals were not shaped like the familiar "semaphore" arm, moving up and down on its post, to which you are accustomed, but were either square or circular, rather like those you can still see on railways on the Continent, and were moved round on a pivot to indicate whether the line was clear or not. In those days trains were run on what is known as the "time interval" system. That is to say, on the line being clear, one train was allowed to start, and after

a fixed time, a quarter of an hour, for instance, it was thought safe to let the next one leave the station. The drawback was that if the first train had broken down, which was not an infrequent occurrence, there would be a collision unless the second driver could pull up in time, and, unless he could see quite a long stretch of track ahead, the odds were against him, since he had nothing but a hand-brake on which to rely. So the "time interval" gave place to the "space interval," on which all signalling is really based; if you can make it impossible for two trains, or a train and a "light engine" (one running without a train) to occupy the same section of line at the same time, you cannot have a collision between trains, although you can, of course, still have derailments. But as most bad accidents are due to collisions, you have gone a long way towards stopping accidents if you can prevent collisions.

In the very early days the signals were on the station platforms, and a porter or some other official on duty had to move them by hand on the arrival and departure of each train. That meant a good deal of walking up and down, especially at a busy station, and, before long, some one hit on the idea of connecting wires with the signals, so that any number could be worked from one place without the operator having to move about. No one quite knows who first thought of this labour-saving idea, but railwaymen will tell you that the inventor is believed to have been a lazy porter who solved the problem of looking after his signals with the least effort by fastening to them pieces of cord on which he could haul at his convenience.



By being able to work a number of signals from one spot, the signal-box was made possible. And the "space interval" gives us the block system. The two together made it possible to have signalling methods under which express trains can follow each other every few minutes with perfect safety.

Now, there is one very interesting and very important feature that you can trace right through the history of railways; inventors have continuously been trying to replace the man by the machine. The man can make a mistake, and a mistake on a railway may mean a bad accident, so the greater the use that can be made of automatic or semi-automatic devices the greater the degree of safety. The early signals had the great defect that there was nothing to prevent "line clear," being given for a track that was occupied, or for a signal being given for the wrong track. So the next step was to connect the points with the signals in such a way as to make it impossible to set a signal for one track and the points for another, and also to link up the points and signals worked from one box so as to prevent, for instance, trains being allowed at the same time to come on a main line from a right and left hand siding or junction. Without this method of linking up, which is known as "interlocking," it would be quite impossible to work several hundred trains a day in and out of a busy station, or to have safe control of traffic at junctions.

On most steam railways the points and signals are manually operated, that is to say, the signalman works them by handling heavy levers that move the wires and rodding. This system, which involves a good deal of very

hard work, is gradually giving way to power signalling—all-electric or electro-pneumatic—in which the signalman handles a number of miniature levers, not much larger than those in the signal cabin of a good-sized model railway. These levers are, in fact, only switches, which turn on the electric current that does the real work, and thus operate either the electrical mechanism or the combination of electrical and compressed air machinery used with the electro-pneumatic system. Power signalling is used at the London Underground junctions.

But the Underground has gone still further. Except at junctions, or where sidings connect with the running lines, the trains signal themselves. This is how it is done. The signals, instead of normally being at "danger," as on most steam lines, are kept at "safety" so long as the sections that they control are unoccupied. The track is divided into sections that are electrically insulated from each other, and an electric current passes along the rails on one side of the section through an appliance known as the "track relay," and flows back through the rails on the other side, thus creating an electrical circuit. But electricity, like water, always follows the easiest path, so that when a train enters a section, the current, instead of continuing to flow through the track relay, takes the shorter and easier way through the wheels and axles. This opens the track relay contacts and breaks the signal circuit, and the signal is automatically thrown to "danger," in which position it remains until the train has cleared the section, when it automatically goes back again to "safety." In other words, the signals are set, not by a signalman, but by the trains themselves.

You may perhaps be puzzled to know why the "normal clear" system is used, instead of keeping the signals at "danger" until they are lowered to allow a train to proceed. Actually, the explanation is so simple that you should really be able to work it out for yourself. Even on the busiest railway a section of track is unoccupied for more time during the day than it is occupied, and the line will therefore normally be clear. Consequently, it is much more sensible, also, to have the signals normally clear, and to have them set at "danger" only when a train is in a section, while the system also makes it easier for the trains to signal themselves.

Now, if you stop to think a moment, you will at once see that, however automatic and foolproof this system may be—and it practically never goes wrong—it does not go far enough for absolute safety. Supposing that, for some reason or other, the motorman should run past a signal that is at "danger" because the section is already occupied, the train would stop by the working of a very simple piece of machinery. A pivoted metal bar—the "train stop"—is coupled to the signal, and so long as that shows "line clear," the bar, which is placed between the rails, lies flat. When the signal goes to "danger" it projects, and should a train pass over it, it hits a "tripcock"—or valve handle on the train—and the brakes are automatically applied.

Just as the early disc signals gave place on steam railways to the semaphore arm, so is the semaphore now gradually disappearing from the Underground, although you will still see it in open sections on the Metropolitan, the District, and the Tubes. But it is different from the

old semaphore in one important point ; instead of the arm going down for " safety," it goes up. This is known as the " upper quadrant " method, which, as is the case with a number of other modern ideas in signalling, came to us from the United States. There is a simple reason for using the " upper quadrant." If a signal goes to " danger " when it should be showing " line clear," nothing more serious is likely to happen than a slight traffic delay. On the other hand, if it is at " safety " when it should be at " danger," there is the strong possibility of an accident. Should the ordinary type of semaphore get out of order, as, for instance, in the case of breakage of the signal wire, gravity will force it to drop and thus to show " line clear." But the " upper quadrant " will fall to " danger," which is an error on the safe side. There is a photograph at page 52.

Instead of the semaphore, most sections of the Underground now use what is known as the two-position colour-light signal, in which " safety " and " danger " are shown only by the colour of the light shining through a glass disc. These discs are illuminated both by day and night, and the mechanism is so designed that only one can be lit up at a time.

Because so much of the London Underground is actually in the open air, fog can interfere with traffic working just as much as it can on the main lines. The signalling system must therefore be designed so as to be capable of dealing with it.

The modern fog signal is also very different from the old-fashioned kind. This was a large sized percussion cap, shaped rather like the top of a bicycle bell, which was,

when required, placed by hand on the rails, to which it was fastened by two flexible metal clips. If a train passed over, the driver was warned by a distinctly audible explosion, which you can still hear on foggy days on the main lines, but not on the Underground. "Fog repeater" signals are used instead. These are of the colour-light type, and are placed so low beside the track as to be at the level of the driver's eyes, and are situated about three hundred feet ahead of the main signal. This distance is enough to allow the driver to pull up in time if the repeater shows the signal proper to be at "danger." The repeater is, of course, also automatic in action.

It is not impossible that mechanism will one day be invented to enable trains to set their own points, just as they already signal themselves. In the meantime, signalmen remain necessary at junctions. The Underground signal-cabins use power signalling, except that the ordinary type of box, with manually worked levers, is still to be seen at the Metropolitan country stations. Part of this section is, however, worked only by steam, and the traffic is not heavy enough to need automatic or power signalling.

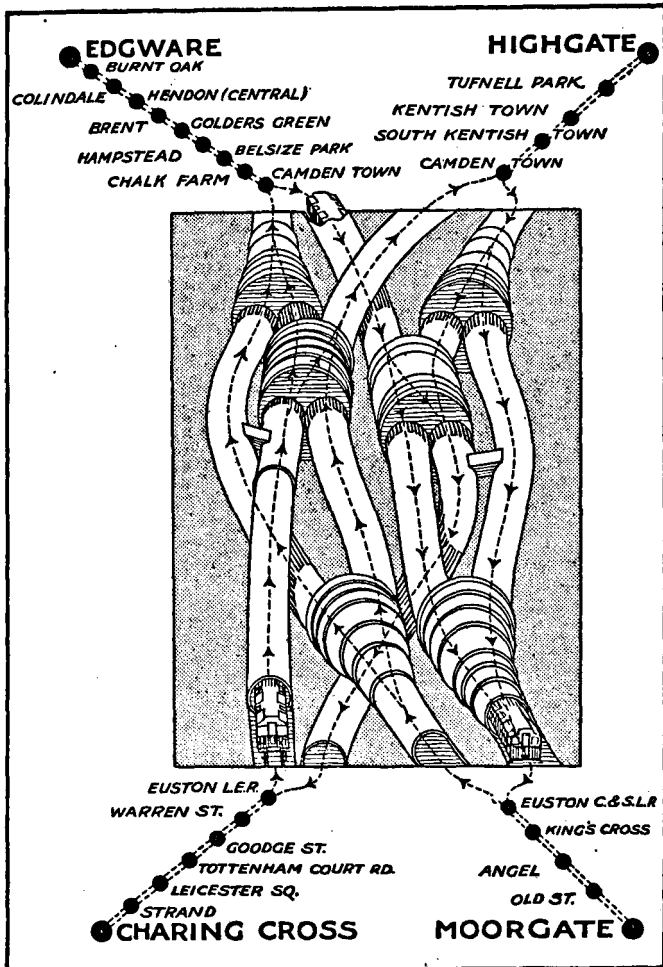
There is one very interesting point about the signals worked from the power cabins; they are semi-automatic, and go to "danger" immediately on the passing of a train independently of the position of the lever, while with the ordinary manual system they can alter their position only if the necessary lever or levers are handled by the signalman.

You will realize that while the signalman on a surface railway usually has a clear view of the tracks for some

distance on either side of his cabin, on an underground line he can see them only when they are actually in the station, and even then he may have a view of only one platform. So the cabins are equipped with a "track indicator." This is a glass diagram, electrically lit from behind, which shows both the tracks and the position of every point and signal worked from that particular box. Lighting is by a number of small lamps, and as a train enters a section one of the lamps is automatically switched off, and that part of the diagram becomes dark. In this way the trains signal their movements to the signalman, who can see at a glance not only the exact position of every train in his section, but also whether it is moving or at a standstill.

One of the busiest signal-boxes on the Underground is at Camden Town, where there is the most complicated series of tunnel junctions in the world. Here Tubes cross and re-cross each other in a manner that can be made clear only in a diagram, which you see opposite. Actually, the diagram does not show how extraordinarily complicated is this network of junctions, which makes Camden Town like nothing else on the London Tubes, where most of the interchange stations are not junctions. For instance, at Piccadilly Circus you have to change stations to get from the Bakerloo to the Piccadilly Tube. But at Camden Town, not only does the Hampstead Tube split in two, but it also links up with the City and South London Tube, which makes it possible to run through trains from Edgware in the north to Morden in the south.

As I have already said, it would be impossible to handle the enormous Underground traffic without the



The Camden Town junctions.

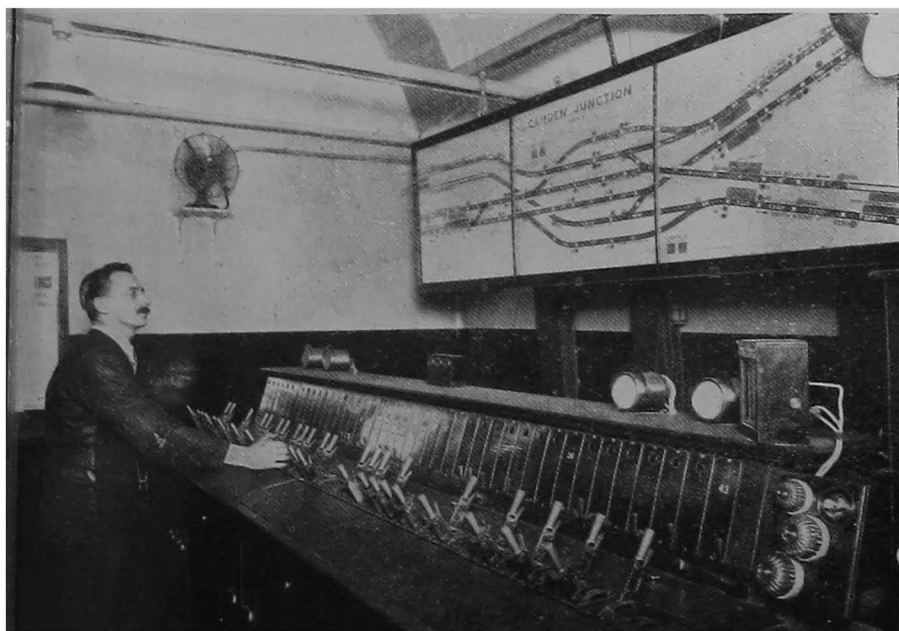
most modern signalling methods. If a railway has long block sections, each of which can be occupied by only one train at a time, it is impossible to run so many trains in an hour as it is on a line split up into shorter sections. On the Underground it is necessary to run the largest number of trains within the shortest time, and the stations are generally close together, so the signalling sections must be short. But to run thirty or forty trains an hour it is also necessary that the signals should change very quickly from "safety" to "danger" and back again. Automatic operation is faster than manual working, while if each automatic signal works independently, the signalling as a whole is quicker than it would be if a considerable number were worked from the same cabin, and it also becomes simpler to split up the line into very short sections. By increasing the number of signals, the number of trains can also be increased, and on the Underground it has actually been found possible to allow a "headway," or interval between trains, of as little as fifty-four seconds. That would be out of the question on a main line with block sections of two or two and a half miles in length.

You will now see what I meant by saying that on a modern railway signals are necessary not only for safety, but also for handling the traffic. On certain very crowded sections of steam-worked main line, it has been found possible to increase the number of trains by changing from manual to mechanical signalling. But on a surface railway, except perhaps in the neighbourhood of the very busiest stations in large towns, there are other ways of increasing the number of trains on lines that are





Side by side. Bakerloo and London, Midland, and Scottish trains near Queen's Park Station. Note the differences in size and the Upper Quadrant signal.



Camden Town signal-box and illuminated track diagram.

already carrying as much traffic as they can handle. One method is to build additional running tracks. New platforms and platform lines can also be built at stations, and new passing places laid out in open country. But these methods are usually too costly on tunnel railways—on the underground sections of the Tubes they would be quite out of the question—so that the traffic department has to make the most of existing stations and tracks, except on sections of line, such as the new above-ground extension from Ealing to Hounslow, where there is more elbow room.

The traffic department could not do what it does had the signal engineer not come to its help. On the main lines train times are worked out in minutes, but on the Underground the time-table is built up on seconds. Immediately the District was electrified, the number of trains an hour was more than doubled—to-day it is nearly trebled during the rush hours. Electrification has certainly been an immense help in speeding up the service owing to its greater acceleration and deceleration, but the fullest advantage could not have been taken if the old signalling methods were still used. That explains why the most modern power signalling methods are also used on the electrified lines of the Southern Railway.

Here are a few figures to show what modern signalling can do. At Camden Town signal-cabin about fifteen hundred trains are dealt with every week-day, which means about 9,400 lever operations. Only twenty-six working levers are needed to deal with this immense movement. Kennington is even busier. The signalmen there have to control the working of over sixteen hundred

trains a day, necessitating more than 13,100 lever movements, and all this traffic is handled by no more than thirty-two levers. If you can imagine the hard physical work alone that has been abolished by giving the signalmen little switches to operate instead of the old-fashioned heavy point and signal levers, you will get a good idea of how the use of machinery in the signalling department has made it possible to run nearly three trains for every one in the days of steam working.

## CHAPTER VI

### TRAINS AND TRACKS

Reversing trains—Loops and crossings—Terminal and through stations—The Kennington junctions—"Fouling" tracks.

You may perhaps think that railway stations are pretty much alike, except that some are larger than others, while some are certainly handsomer than others. Actually, stations have to be designed to suit the traffic they are built to handle, and just as there is a considerable difference between the Great Western's passenger and goods termini at Paddington, so is there between the various stations on the Underground.

The simplest form of railway working imaginable would be on a short line, without junctions, on which all the trains ran from end to end and back, and stopped at every station. That was the way in which the first Tubes were worked. At the terminal stations it was, of course, necessary to "reverse" the trains, that is, to allow them to cross over from one running line to another so as to be able to start off again in the opposite direction, while at one end of the line the running tracks were linked up with the car sheds and sidings. Working the traffic was a much simpler job in those days than it is now.

A train can be reversed in two ways. The simpler method, which is not much used on the London Underground, because it requires a good deal of space and is very expensive to lay out beneath the surface, is the loop, of which there are several in Paris, Boston (U.S.A.), and Philadelphia, among other foreign cities. This is a very simple arrangement. As soon as all the passengers have got out at the arrival platform, the train runs round the loop and comes alongside the departure platform. (A single "island" platform can serve for both up and down traffic if required.) This track lay-out not only makes points and crossings unnecessary, but no signal-boxes are needed if automatic signals are used, and the driver has not to walk from one end of the train to the other. A disadvantage is that running a train round the loop may take more time than using a cross-over between the up and down tracks, while during the busy hours it may for this reason be necessary to keep an extra train standing on the loop so as to keep the traffic moving.

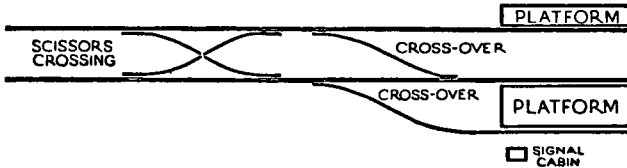
Where the loop is not used, trains pass at the end of their journey from one track to another by cross-overs, which may be either single or double. The latter are known as "scissors crossings." You will notice in the drawing showing the lay-out at Liverpool Street station, on the Central London Railway, that there is a scissors crossing at each end. That on the left connects the running lines, while the right-hand cross-over lies in the sidings beyond the station, which are long enough for stabling spare trains.

You may ask why it is necessary to have two cross-

overs. Actually it is not, but it is a very convenient arrangement in case of accident or any other emergency. Should the sidings be blocked, trains can be reversed at the other end of the station, while if either platform line is blocked, the other one can be used for traffic in both directions. You will understand, of course, that it is especially necessary at terminal stations that traffic



Track diagram of Liverpool Street station (underground) showing cross-over roads at each end.



Typical three-platform station above ground.

should be able to be diverted to one running line if the other is blocked for the time being by a breakdown.

There are only two running tracks at Liverpool Street, but a number of terminal stations have more. You will see by this diagram of Hounslow West station (as it was before it was rebuilt to serve the Piccadilly Tube as well as the District Railway) how a double-track running line can be widened so as to serve three platform tracks. You will also notice that only two platforms are needed for the three tracks, the two lower "roads" using a single "island" platform.

Liverpool Street and Hounslow West are true terminal stations, that is to say, they are at the end of their sections of line. There are also stations, as on the main lines, at which some trains finish their journey, while others go farther on, and since the Tubes were extended considerably beyond the stations where they were at first planned to end, the number of these stations has been increased. This diagram of Golder's Green, on the Hampstead Tube, shows how a station can be designed both for terminal and through working. Trains going no farther than Golder's Green can start off again in the

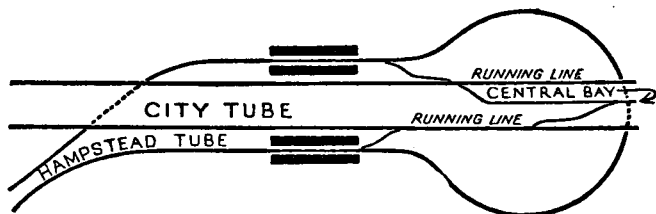


Arrangement of tracks, platforms, and cross-overs at above ground station used both for stopping and through trains.

right-hand direction from the same platform, and then pass on to the proper running track by means of one of the cross-overs, or be sent into the car sheds or on the sidings. (All the tracks and sidings are not shown on the diagram.) Or a train can be reversed through the crossings on the left side of the station. With this type of lay-out all the platform lines can be used for either through or stopping trains, while the middle track is also reversible—that is, it is designed for starting trains in either direction.

Golder's Green serves only one Tube. Where the same station serves two, as at Kennington, the lay-out becomes more complicated, because the lines burrow

over and under each other, instead of crossing "on the flat." The Kennington junctions are particularly interesting, because the station is a terminus for the Hampstead Tube, but not for the City and South London, while the Hampstead line, which passes underneath the City Railway, has a terminal loop. The line at the right side of the loop between the City Railway tracks—a "central bay road"—also allows trains to be reversed without using the loop, and it can further be used as a



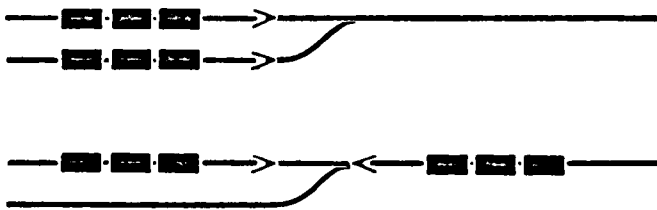
The Kennington junctions, showing reversing loop, and central bay for reversing.

siding for a train that has broken down, and for running through trains between the two Tubes. If you have carefully studied these station diagrams, you will see how the loop and the bay road between them make it possible to do without a number of points and crossings that would otherwise be necessary.

Points and crossings not only add to the complication and expense, but, where one line crosses another, the tracks are "fouled." The top drawing in the diagram (page 60) shows trains on both an up and down track that ends in a single line. When the train on the lower track has

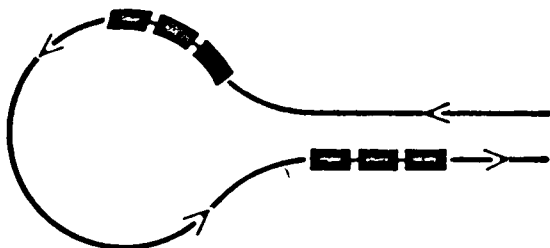


crossed over, as seen on the second drawing, one train holds up the other, no matter in what direction it travels.



How running tracks are "fouled" by train movements at a cross-over.

On a loop, as you will see from the drawing at the bottom, reversing a train causes no fouling, and trains can proceed continuously round the loop so long as there is the necessary space interval between them. But the loop lay-out has several drawbacks. A breakdown on a single track holds up the whole service, while it



How trains are reversed through a loop.

may take longer to run round the loop than to reverse through a cross-over. Also, where cross-overs are used,

a sufficient margin of time is given to allow of a small amount of late running being made up, but on a loop, without siding accommodation, trains have to be kept moving all the time, and there is no margin for unpunctuality. That is where the bay road at Kennington is so useful, while, if you will turn back to the Golder's Green diagram on page 58, you will see how the central platform track allows trains to be reversed without fouling either of the running roads.

The reason why I have described the lay-out of so many different stations is that you cannot properly understand how trains are worked, or a time-table is drawn up, unless you first know something of station and track planning. With automatic signalling it becomes easy enough to run a train every two minutes, or even at shorter intervals, past a given point. But when most trains stop at every station, and the stations are generally also close together, they must be specially designed for such quick working. And since the longest time that a train is supposed to stop at a station is less than the shortest time in which it can be reversed, at the end of its run, a time-table of thirty or forty trains an hour over each running track cannot be worked unless the reversing arrangements, whether loops or cross-overs, are designed so as to "save seconds."

## CHAPTER VII

### MAKING THE TIME-TABLE

Jig-saw puzzles—What late running means—Non-stop trains—  
The importance of "saving seconds"—Spacing the signals—  
Traffic conditions and peculiarities.

THIS business of making a time-table really deserves a book to itself. It is a highly complicated affair—a mass of jig-saw puzzles that have to be fitted into each other—so intricate that most railwaymen, even, could not tell you very clearly how it is done. But one can explain the problem in a sentence ; it is that of giving the public the best possible service while running no more trains and cars than are needed.

Let me give you a very simple example. A fast train leaves London for Dover, stopping at only a few stations on the way. One of those stopping-places is a junction serving a country branch line. When a new time-table is being drawn up, it is decided to stop the train at an extra station on the London side of the junction. This will make it reach the junction five minutes later, as can also happen when the summer train time-table is being changed over for the winter service. With the present time-table a connecting train for the branch leaves the junction three minutes after the arrival of the main line

train. So the departure time of the branch line train must also be made a trifle later, otherwise passengers would lose the connection, which might be a serious matter, especially if it was the last train of the day. But the branch line train connects with another train at a junction farther down the line, and it is therefore also necessary to alter the timings of this third train. So you will see that a slight alteration in the time of one train may cause the alteration of quite a number of other services, and that if this is not done, or not done so as to allow a sufficient margin of time at stations where passengers have to change, the late running of one train may upset the working of others on sections of line fifty or a hundred miles away.

On the other hand, if the London-Dover train were speeded up so as to arrive at the junction ten minutes earlier, passengers changing there would have a longer wait, and might grumble. For this reason, and also because it may ease the traffic working, speeding up on one section may lead to the earlier departure and arrival of trains on other parts of the line.

Now, multiply this one example by several thousand. Remember that the main lines alter their time-tables twice a year, once for the summer and once for the winter service; that the week-day service is not the same as that on Sunday; that the Saturday time-table is different from that on the other week-days; that express trains, slow, stopping trains, and semi-fast trains use the same tracks, which are also used by goods trains, both slow and fast; that a special time-table has to be drawn up for every Bank Holiday period; that steam and electric

trains may run over the same tracks ; that it must at all times be possible to sandwich in a "special" or other extra train ; and, lastly, that whenever an accident or breakdown throws the time-table out of gear, the railwaymen must be prepared both to work on an emergency time-table and to get back to the proper timings as soon as possible ; and you will begin to have an idea of the difficulty of making a time-table.

In many ways the difficulties are not so great on the Underground. The lines are shorter ; there are fewer junctions ; trains have not to be fitted in so as to connect with others several hundred miles away ; on most of the lines only electric trains are run, and most trains stop at all stations ; most of the trains on the same section of line can be run at much the same speed ; and, except for the Metropolitan Railway, no goods traffic is carried. But in other ways the Underground has the bigger job. More trains are run every hour over each track ; junctions are closer together ; the service is worked for more hours every day ; and there is for most of the working day so little "headway" or time interval between the trains, that a very little unpunctuality can have a serious effect.

Moreover, unpunctuality has a cumulative effect, that is to say, with every increase in the number of trains not running to time, the greater the unpunctuality in the long run. For example, the time-table on a certain section of line is drawn up so as to allow a stop of twenty seconds at stations. A number of trains run dead on time, and then one is delayed because traffic is heavy and passengers are slow in getting on and off. In con-

sequence, this train stops forty seconds at the station. So do the next eleven, which means that the twelfth train is one hundred and sixty-eight seconds—two minutes and forty-eight seconds—late. That is enough to throw the whole time-table out of order for quite a long time afterwards.

Another difficulty on the Underground is caused by the running of non-stop trains—those which miss certain stations, either to speed up traffic during the rush hours, or because some stations, such as Lancaster Gate and Covent Garden, do not handle a very heavy traffic, and do not, therefore, require so many trains to serve them. On the main lines, the running of both stopping and non-stopping trains is made easier by having four or more tracks on certain sections, and also by having extra tracks at stations, so that the fast trains can run over the middle tracks, while stopping trains use the platform tracks. Most of the Underground traffic is worked over only two running tracks, and most of the stations have no extra platform tracks. Fitting in these non-stop trains is, therefore, not easy, but it is worth doing, because it can save, perhaps, two minutes on an end-to-end journey of half an hour, and thus help to speed-up the service as a whole.

Here we come across something that puts the whole time-table business in a nutshell. If two minutes are saved on a thirty-minute journey, passengers will not notice the difference, especially as most of them travel such short distances that they will not save more than a minute. But those two minutes allow an extra train to be worked in both directions in an hour, and two more

trains in sixty minutes mean a great deal during the busy hours when there cannot be too many trains.

But that is not all. Except on Sundays, the Tubes are open for about twenty hours out of the twenty-four. Imagine all the trains on a particular line running backwards and forwards all that time and taking exactly thirty minutes for each end-to-end journey. During the working day they would each make twenty journeys in each direction, or forty in all. (Actually, railway working is not quite so simple as all that, which does not, however, alter what I am driving at.) Now, if we knock three minutes off each run, we can get four more journeys a day from each train, and that means either that we can increase the service without needing any more cars to do the work, or that we can give the same service while using fewer cars. In other words, the faster you run a train over the track, the more work you will get out of it. Now you will understand why I so often talk of the importance of "saving seconds." You should also understand what I meant in the last chapter by saying that to grasp just how a time-table is planned you must first know something about station design and track lay-out. The lay-out of stations and cross-overs must be specially designed for the purpose if trains are to arrive and leave every two or three minutes, but it would be of no use to draw up such a time-table unless the signals were both quick-acting and spaced close together.

Perhaps it is not clear to you what the situation of the signals has to do with the time-table. One explanation is that the closer the signals are together, the more the "headway" can be cut down, so that the number

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of trains that can be run over a given section of line in a given time depends, among other things, on the number of signals in that section. In one instance an increase in the number allowed the "headway" to be cut down from sixty-seven to fifty-four minutes, which is much more than it sounds.

The other explanation is that traffic working is made easier if the signals are so far as possible spaced so as to allow of an even time-interval between trains. You might also be interested to know that the signals on the Underground are arranged so as to prevent trains being stopped in the tunnels, because passengers do not like it.

To understand properly how traffic is worked on the Underground, you must also remember that the system is made up, not of one railway but of a number, each of which has its own difficulties, peculiarities, geography, and distinct traffic conditions. The Metropolitan itself is really two railways, for the extension line to Aylesbury, Watford, and Uxbridge is, in a sense, a separate affair from the line between Hammersmith and the City. Through trains are actually run between the City and stations on the Extension line, mostly during the rush hours, but for many years, following an accident in the tunnels at Baker Street, the two sections were cut off from each other so far as train running was concerned. The Metropolitan also runs over the District tracks, since the Inner Circle is partly in District and partly in Metropolitan "territory." The District, in turn, works over the Metropolitan section of the Circle, reaches South-end by running over the London, Midland, and Scottish tracks, has a southern terminus at Wimbledon, and four



western terminal stations—South Acton, Ealing Broadway, Hounslow West, and Richmond. To reach Wimbledon and Richmond it has to run over lines belonging to the Southern Railway. This lay-out of tracks means that although the railway is quite short—its own lines amount to only twenty-five miles of route—its trains work over nearly fifty-nine miles, and serve a relatively large number of terminal points. In drawing up the time-table, allowance has to be made not only for the junctions where the branches for such stations as Richmond and South Acton leave the main tracks, but through trains have also to be fitted so as not to interfere with the running on "foreign" lines—*i.e.* those belonging to other companies.

Extensions in both directions from the original terminal points have also made the working of the Tubes much more complicated than when the lines were first opened. The Hampstead Tube has two northern terminal stations—Edgware and Highgate—so that at Camden Town the line splits in two, and this means that the time-table must be arranged to give the largest possible number of trains on the sections north of Camden Town. Then, at the southern end, it connects at Kennington Junction with the City and South London Tube, so that through trains can be run all the way between Edgware and Morden. The Kennington and Camden Town junctions have also made it possible for through trains to be run between the City and South London and Hampstead Tubes. If you will work out these connections on the map, and remember that traffic working is not made easier, as on the main lines, by having four or

six running tracks on the busier sections, you will see that I was right in saying that, in some ways, it is a more difficult job to arrange the Underground time-table than that of the Great Western, for instance.

The least difficult section to work is the Central London, which is the shortest of the Tubes, and has no connection with any of the others. It has, therefore, the simplest time-table to study. Now that you know something of how a time-table is made, we will spend a day on the Central London and see how it is worked.

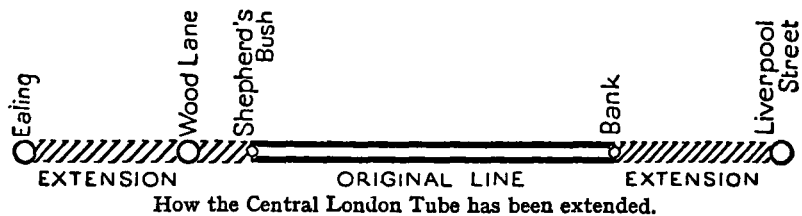
## CHAPTER VIII

### WORKING THE TIME-TABLE

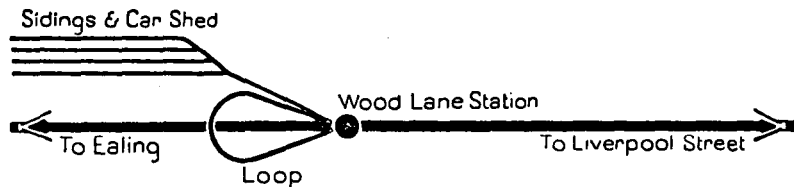
Starting the day's work—Six and three cars—The rush hours—  
Length and load—"Balancing"—The last train.

You know by now that both tracks and stations must be designed to suit the traffic, and that although the Tubes were at first very short lines, they now run out to quite a considerable distance from the centre of London. That extension has had a great deal to do with the planning of the present time-tables, partly for the reason that, while at one time all the car sheds were conveniently placed near one end of the line, on the Central London and the Hampstead Tubes, they are now between the end stations.

Perhaps you may think that the change does not matter much, but you will be mistaken. The Central London's car sheds are at Wood Lane, which was at the western end of the line when it was first opened. But to-day, as you will see from the drawings on page 71, the western terminus is at Ealing, which is more than half as far from Wood Lane on the one side as Liverpool Street station is on the other. The Ealing-Wood Lane section, by the way, is above ground. This has entirely altered the train working at the beginning and end of



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Traffic working at the Central London's Wood Lane (above ground) terminus, showing reversing loop and car sidings.

the day. So long as the line ended at Wood Lane, all the first morning trains ran eastward to the City terminus, and there was no running in the opposite direction until the first train had finished its outward run and been reversed. Late at night, as the trains came into Wood Lane from the east, they went straight to the car sheds after discharging their passengers, and no trains were worked into the sheds or sidings from the west. But to-day trains have to leave the sheds for both west and east in order to start up the service in the morning, and at night they come back from each end. In other words, instead of planning the time-table (which also includes the working of empty trains) so that all the trains start their day's work in only one direction and finish it in the reverse way, they now have to start and finish in both directions.

Now let us see how this works out. The electric current is switched on to the running tracks at about five in the morning. At 5.25 the first train leaves Wood Lane, bound for Liverpool Street. It is made up of three cars, and is a "staff train"—that is, it carries the men who will have to be on duty at the stations directly they are open for traffic. The 5.25 is timed to reach Liverpool Street at 5.50, and it is then reversed through one of the cross-overs, and becomes the 6.0 a.m. "down," or west-bound train, which carries ordinary passengers all the way to Ealing.

In the meantime another three-car train has left Wood Lane at 5.44 for Ealing, where it arrives at 5.54, and then starts off again in the opposite direction as the 5.59 "up" to Liverpool Street, but on the reverse journey it has six

cars. In this way, and by the use of only two trains in the first instance, the staff has not only been brought to the stations for duty, but traffic has also begun over the whole railway in both directions.

It is still quite early, but so many people are starting off for their day's work that by 7.20 trains are already running every two or three minutes. This rush hour service, worked by six and seven-car trains, is continued until about a quarter to eleven. The number of cars to a train is a very important matter, and it is part of the job of making the time-table to see that neither too few nor too many are run.

This is where the multiple-unit system is so useful. The Central London "working time-table," which is for the use of the staff only, shows that the 5.25 staff train is made up of "3 (6)" cars. That means that on its east-bound journey it has only three cars, and that it is still the same length when it starts off again as the 6 a.m., west-bound from Liverpool Street. But when it gets to Wood Lane, three more cars are attached. Other trains are shown as "6 (3)," which means that they start off with six cars, and afterwards drop three. This coupling and uncoupling is done at Ealing as well as Wood Lane, where two minutes are allowed for the work. On days when traffic is specially heavy, such as at Christmas, or in bad weather, or if a breakdown on one line should send extra passengers on to another, you will see that it is easy to arrange, if required, that a train which should be split in two will continue to run with six or seven cars.

If more cars are run than required, electric current is being wasted, and expenses go up in other ways. If, on

the other hand, the trains are too short, not only is there overcrowding, but passengers take a longer time to get on and off, and the station delays upset the time-table. On the Central London the trains are more crowded when running east during the early morning rush hours, but in the afternoon and evening there are more passengers travelling westward. This means that many of the morning trains that are full up on their way to Liverpool Street are half-empty on the return journey; while in the evening, trains that have only a few passengers on the way between Ealing and Liverpool Street come back fully laden.

Now just think what that means. Long trains must be used to carry a heavy load in one direction (even seven cars are not always enough on the Central London, but, as you have already heard, that is the largest number that can be run), and however long they are, many of the passengers may have to stand during the busiest hours, but on the return journey these trains are much longer than is required by the traffic. If the railway were above ground, it might be possible to have such extensive sidings at each end of the line, and elsewhere, that trains could be split up as soon as they reached their terminus. Most of the uncoupling and coupling has, however, to be done on the western section, so it becomes necessary to run a certain number of half-filled trains, and a considerable number of empty ones, after the morning rush is over, while in the evening trains start on the eastbound journey with a light load, and return full up.

This running of empty and half-empty trains is known as "balancing," which has to be done on all railways,

for the simple reason that it is impossible to arrange the traffic so as to have an even flow in both directions at the same time. That is why you will often see on the main lines a long train leave with only a few passengers. It is being worked down the line to a station from which it will come back with a full load, and it is better to run it out with even a small number of passengers than to send it off empty, since it costs just about the same to run a full and an empty passenger train. "Balancing" also explains why you will sometimes see a powerful express engine hauling a short stopping train, or two engines when one would be enough.

But we have got away from our time-table. During the busy hours some trains must be made up of six or seven cars. But, unless the traffic is not too heavy, it is also possible to sandwich three-car trains in between them. And that is what is done on the Central London.

Except on Saturdays, when the second rush-hour period begins several hours earlier, traffic is generally light between half-past ten in the morning and five or half-past in the afternoon. By the way, because fewer people travel in the slack period, which means that the time of the station stops can be cut down, rather more trains are actually run on the Central London in the less busy hours, when the journey time between Wood Lane and Liverpool Street is reduced by a minute. On Sundays, when fewer trains are run, it is shortened by as much as two and a half minutes, which means a good deal on a journey normally timed to take twenty-five minutes.

"Balancing" begins again a good time before the start of the evening rush hours, because long trains have



to be sent out to take back a full load. As early as 3.20 p.m. traffic is worked with six and seven-car trains, until about half-past seven. After that, three cars are run again until the end of the working day.

You have seen how the trains come on to the line in the morning, and how, later in the day, they are first split up and then reassembled. Let us now watch them going back to the car sheds at night. The last east-bound train to run the whole length of the line leaves Ealing at 11.59 p.m., and reaches Liverpool Street at 12.33 a.m. It then becomes the last "down" train, leaving Liverpool Street at 12.42 a.m., and arriving at 1.6 at Wood Lane, where it goes off to the sheds. Like the first train in the morning, this is also a staff train, which carries the last porters, ticket collectors, liftmen, etc., to remain on duty, although I believe that passengers are also allowed to travel on it if they have missed the last regular trains, which leave Liverpool Street at 12.18 for Ealing, and 12.28 for Wood Lane. The Ealing train, which arrives there at 12.57, runs empty to Wood Lane, which is reached at 1.7 in the morning, and then goes off to the car sheds. Between 11.59 and 12.57 five other trains, all empties, also leave Ealing for Wood Lane.

Although you have seen the working on the Central London for a whole day, we have not yet finished with its time-table. Really, there are three separate time-tables. The first, which is the one we have been studying, is for Monday to Friday; the second is for Saturday only; and the third for Sunday. It is necessary to have a different time-table on Saturday because that day is a half-holiday, so that the second rush-hour period



**The latest style in station architecture : Chiswick Park,  
District Railway.**



**The latest type of Escalator.**

begins much earlier—at about half-past twelve. This leaves such a short interval between the morning and afternoon rush hours that for balancing purposes it is necessary to run full-length trains for most of the time between the start of the day's work and about three in the afternoon. After that, with a few exceptions, only three-car trains are run, although it may be necessary to put on additional six or seven-car trains for a football match or other special event.

Additional or altered train workings have to be arranged for every week. These are shown in the "Traffic Notices" issued to the staff. Among the alterations, which are usually only for the time being, are special speed restrictions, due to permanent way relaying or other work on the track or at the stations. It may also be necessary to notify the staff that a train or a number of cars has been reserved for a party who will be journeying between certain stations, and travel outward and home at a fixed time. But that is more a matter for a line such as the District than for the Central London.

On all the Underground lines, whatever the special arrangements, and however often the time-table may be altered, or how many temporary alterations it is necessary to make, the timings of the first and last trains are left unchanged, if possible. That is done not only for the convenience of passengers travelling on any particular railway, but also so as not to upset early and late connections with other railways. On the Central London, the times of the first and last trains are the same on Saturdays as on the other five week-days.

The Central London's Sunday service, which is worked

with three-car trains only, begins with the 7.48 a.m. staff train from Wood Lane to Liverpool Street, and finishes with the 11.44 p.m. in the opposite direction (which is also a staff train), and an empty train leaving Ealing for Wood Lane at 12.6 a.m. Actually, as you will notice, the working day is not so much shorter than during the rest of the week, but running only three-car trains, and having a longer interval between them, makes a very great difference to the number of cars required for handling the traffic. On week-days, the largest amount of rolling stock needed for the service—and less is usually required—amount to thirty-seven complete trains and two hundred and twenty-five cars; but on Sundays eighteen trains and fifty-four cars are considered to be ample.

For traffic-working purposes there are actually four terminal stations on the Central London. Trains not only start and stop at Ealing, Wood Lane, and Liverpool Street, but also at Marble Arch, where a certain number are reversed during the slack hours. If you ever hear "All change!" at this station, don't imagine there is a breakdown; your train is not supposed to run any farther. South Kensington and Mansion House, on the District Railway, and High Street, Kensington, on the Inner Circle, are also intermediate stations at which a number of trains start and finish their journey, but the first two of these stations have four running tracks, and the third has three, while at Marble Arch there are only two.

From end to end, the Central London is just under eleven miles in length, and the journey time, except during the slack hours and on Sundays, when, as I have already said, it is speeded-up, is thirty-seven minutes.

This gives an over-all average speed of eighteen miles an hour, which is much faster than you may imagine, since most of the trains that travel all the way have to stop at seventeen stations, not counting the terminus. The distance between stations affects the speed. The average distance between the eighteen stations is three-fifths of a mile, but between Ealing and Wood Lane it is a little over a mile, while between Wood Lane and Liverpool Street it is only two-fifths of a mile. Trains on the Wood Lane-Ealing section have thus more chance to get up speed, and a longer time in which to travel at top speed, which explains why the average journey between Wood Lane and Liverpool Street is made at the rate of only sixteen and a fifth miles an hour, as compared with eighteen for the end-to-end journey, and as much as twenty-one miles an hour between Ealing and Wood Lane.

It is because the service can be speeded-up by increasing the distance between stopping-points that the stations on the Piccadilly Tube extension from Finsbury Park to Cockfosters, which was opened in sections between 1932 and 1933, are farther apart than those on the earlier portions of the same line. It was possible to plan the extension in this way because, when it was built, the new line ran largely through what was still more or less open country, but as it becomes built over it may perhaps be necessary to build several additional stations between those now existing. As the Cockfosters line lies largely on the surface, it would, in that event, be easier to lay down additional running tracks or platform lines—thus allowing the continuance of high speed—than it is under-

ground, where the cost makes the doubling of the tracks out of the question.

Traffic handling on the Tubes would, of course, be made much easier if the busiest sections had four tracks. Many years ago it was suggested that this should be done on part of the District Railway, either by building new tracks alongside the present ones, or by constructing a second deep-level tunnel. Owing to the immense cost of the work, it has not been possible to do anything of the kind on the District itself, but the pressure has been relieved by the Piccadilly Tube, which runs between South Kensington and Hounslow West, either beneath or alongside the District tracks. Additional running lines are still badly wanted on the very crowded section between South Kensington and the Mansion House.

It is because most of the traffic on the Underground has to be carried over two tracks only that so much attention has been paid to "saving seconds" in every way, from automatic signalling to pneumatically worked car doors.

## CHAPTER IX

### TRAFFIC CONTROL

The traffic controller—Emergency instructions—Single line working.

IN talking about the time-table we have rather been taking it for granted that once it had been drawn up it would be kept to, barring breakdown or accidents, and with allowance for such alterations in working as are, from time to time, shown in the weekly traffic notices. But running a railway is not quite so simple as that, especially in the case of lines that may at any moment be called on unexpectedly to carry a large amount of additional traffic, either on account of sudden bad weather, or because a breakdown on one section throws more work on to another. A bad breakdown on the Central London, for example, especially if it happens during the rush hours, may send a large number of additional passengers on to the Metropolitan or District. Now there must be some means of dealing with cases of this kind, so as to restore the service on the interrupted section in the least time, and also to cause the smallest amount of inconvenience to passengers in the meanwhile. And the best way to do that is to have a system for dealing with train movements on the Underground as a

whole, instead of leaving each section to handle emergencies as they occur. Quite apart from breakdowns, there must also be some means of dealing immediately with any change in the volume or direction of the traffic.

In the steam days this was a simple enough matter. If there was any trouble on the District Railway, a message was sent to the telegraph office at Earl's Court station, which notified one of the booking-offices, where instructions were given for sending out such men as were required for the necessary repairs, or other work. But when the line was electrified, this method was no longer capable of dealing with all emergencies, partly because electrification brought about an immediate and very large increase in the number of trains, and partly because the failure of electric current on a section of line can be a much more serious matter than the breakdown of a single steam locomotive. So the principal terminal stations and the car sheds were linked up with the offices and the principal intermediate stations, such as Charing Cross, Hammer-smith, and Mansion House, by a private telephone service. That, also, was not enough, and a "control office" for the District Railway was set up at Earl's Court, and another for the Bakerloo, Hampstead, and Piccadilly Tubes at Leicester Square.

The traffic controller's job is, first, to see to it that the time-table is observed, or that "working is to schedule," as railwaymen say. By means of a private telephone switchboard he can communicate with every signal-box, and with the car sheds, the power-houses, and the more important stations. The telephone switchboard is designed on what is known as the "visual system"; no



bells are rung, but a red disc appears when the control office is being called up, and a small lamp is lit if the line should be engaged. Besides the telephone equipment, the control offices contain maps and diagrams showing the electric wiring arrangements of all the lifts and escalators.

Linking-up the control offices with the signal-boxes makes it possible for the control officer at any time to give emergency or special instructions. These are of all kinds. If trains are not running to time, which, as you have already heard, makes the unpunctuality worse the longer the late running goes on, the controller can either order certain trains to be stopped short of their destination and reversed, or he can cancel them altogether. In case of breakdown, he can take steps to restore the normal service more quickly than would be possible if it were left entirely to the men on the spot. If the breakdown is serious, the controller will order single-line working, and trains will be reversed at the nearest cross-over until the section on which the breakdown has taken place is open to traffic again. The controller will also advise other Underground lines that may be called on to carry extra passengers.

Single-line working during a breakdown, of course, slows down the service, but by reversing through the nearest cross-over it may be possible to run trains at intervals of about four minutes, or even less. Over sixty of the Underground stations are provided with either cross-overs or loops, so that however bad the breakdown, it should generally be possible to start a single-line service fairly soon, unless, of course, the inter-

ruption is due to a failure of current affecting the whole line. At about forty stations sidings are also provided which can be used for stabling disabled trains.

Traffic on the Underground is to-day so heavy that the telephone service, which at Leicester Square deals with a call about every two minutes during the working day, is not enough by itself. So the control offices, as well as the Underground head offices, the power-stations, and the car sheds, are also equipped with "tape machines," such as are used by newspapers. The news of every happening of any importance, and every train delay of over three minutes, are immediately wired to the office concerned, and if the cause is known that also is mentioned in the message.

The control officer's work keeps him busy. Besides dealing with such matters as breakdown and the failure of the electrical current that works the lifts and escalators, he makes arrangements for dealing with a sudden traffic rush due to bad weather. There is also a thermometer, to tell him when he should give instructions for the electric car-heaters to be turned on or off, as the case may be. Should the controller wish to communicate with any station or other point that is not served by the private telephone system, he can use the Post Office telephone service.

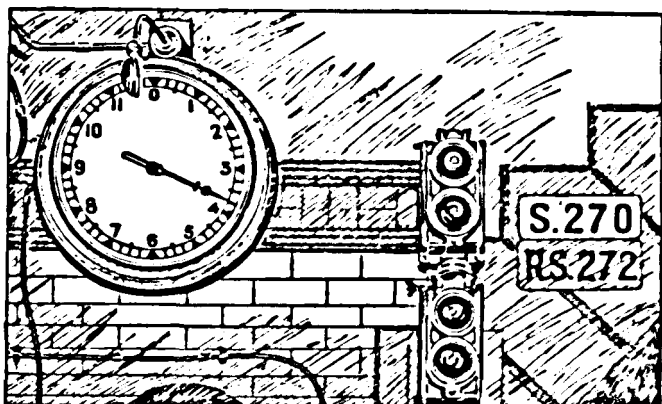
## CHAPTER X

### SOME GADGETS

"Headway clocks"—Train telephones—The "platform hustler"  
—The train-running indicator—Platform train indicators—  
Lifts and escalators.

It is possible that one day we may be able to run railways almost entirely by machinery; that trains will drive themselves, and be stopped and started from outside—perhaps, even automatically; and that where drivers are still used they will set the points and signals at junctions and cross-overs, and not rely on signalmen to do it for them. In the meantime, the Underground is continually getting nearer to the all-machine age by making use of new mechanical devices for speeding up the service and making it safer. You have already heard about the signalling system, the tunnel telephones, and the mechanically worked doors on the trains, but these are only a few of the many gadgets in daily service.

At the tunnel mouths at many stations you will notice a clock with only one hand. This is the "headway clock," which is used, not to tell the time, but to let the driver know how many minutes the preceding train is ahead of him. It works automatically, and registers



Headway clock. Note colour-light signals at the right.

up to twelve minutes. As a train leaves the station its passage sets the hand of the clock to "0," and it then starts showing the minutes until it is again set back to zero by the passing of the next train. Since the driver knows what the time interval between his train and the one in front should be, the headway clock tells him whether he can safely try and make up time, if the space interval is longer than is necessary—or whether he is too close on the heels of the train in front.

Attached to each headway clock is a paper chart, divided into hourly spaces, which revolves during the whole of the working day. As a train leaves the station, a little hammer, worked by electricity, falls on an inked ribbon, and in this way the train records on the chart its exact time of departure. At some stations—St. James's Park is one—you can see the mechanism of

these headway charts at work, and recording the passing of trams as well as of trains.

The headway clock only tells the driver the time that has actually gone by since the train in front left that particular station, and therefore does not necessarily show whether his own train is running punctually or not. At Earl's Court Station he is also told by a "train-running indicator" how many minutes he may be running late. This indicator is a square, glass-fronted box, bearing eight numbers, which shows late running of from half a minute to four minutes. It is illuminated from behind, and the figure that happens to be lit up at any particular time shows the amount of lateness, while the driver is further warned by the illumination of the word "Late" at the bottom of the indicator. If the train is running ahead of time, the word "Wait" is lit up at the top of the indicator.

Besides telephoning from his train to a station or signal-box, the driver can ring up the guard at the rear end of the train, for which purpose the telephone sets in the driving cabins and guard's platforms on the newest trains are fitted with loud speakers. These telephones are among the many devices used for "saving seconds"; if the guard, for instance, receives a special instruction regarding non-stop working or a breakdown, he can at once let the driver know without walking the whole length of the train.

A particularly ingenious, but very simple, contrivance, which is also used for "saving seconds," is the "platform hustler," which you can hear at work at Victoria station. This is a siren, or hooter, which sounds so soon as a train

has stood at the platform a fixed number of seconds. The mechanism is electrical, and the siren is not sounded unless the signal is at "clear." Should the train get away in less than the fixed time, the mechanism is stopped, and the siren will not be sounded until after the arrival of the next train.

The District Railway also uses another train-starting device. This consists of a number of metal rods connected by a cable and hung from the station roof. Attached to the cable are two wires that are electrically connected with a bell at the other end of the platform. When the guard is ready to start the train, he touches both wires with the metal handle of his flag, and the bell rings, warning both driver and passengers. It has been found that a train can be started more quickly in this manner than by giving the "right away" by means of the old-fashioned guard's whistle.

Because of junctions and non-stop trains, and also owing to the fact that on the Tubes all the trains do not run the whole length of the line, passengers often have difficulty in knowing whether a train will take them to the station for which they are bound. At many stations they can find out by looking at the "platform train indicator," a glass-sided box, which shows the route or terminal station of the next three trains. These indicators are worked by signalmen, and at each station at which they are used there is also a complicated mechanism that receives the description of each train, and stores it up until required. As a train leaves the station its description automatically disappears from the indicator, and its place is taken by that of the next train.

There are staircases at many of the Tube stations, but since most of them are much farther below ground than on the Metropolitan and District, the stairs are intended only for use in emergency. When the Tubes were first built, access to and from the platforms was by lifts, but these have gradually given place to escalators, which are now in use at over ninety stations.

Lifts and escalators may seem ordinary, everyday things, but they are both worth more than a glance. The lifts have a number of ingenious safety and other mechanical devices. Among these is the safety catch, which prevents starting before the gates have been properly closed ; the governor, which regulates the speed of the lift ; and the landing control gear, which enables it to be stopped and started from the top or bottom, so that no attendant is needed to travel up and down with it. In this way one man can work a number of lifts. The landing control also opens and closes the gates, and regulates the speed at which they work.

Have you ever thought what would happen if you were in a lift that stuck in the shaft ? You would get out in a very short time, for this is another of the many emergencies that have been thought of and provided against on the Underground. So far as possible, the lifts are so arranged that two travel in the same shaft. A door, which is usually hidden by the advertisement panels, is built into the right side of one lift and the left side of its neighbour. Should one of the lifts jam, the other is brought exactly alongside, the doors of both are opened, and passengers walk through from the out-of-action lift to the one that is working.

The arrangement and number of the escalators vary at different stations, according to the heaviness of the traffic, the depth of the platforms beneath the surface, and whether the station serves more than one railway. In the latter case there are two sets of escalators, as at Piccadilly and Holborn, both of which are interchange stations, where the two railways are built at different levels. The first flight of the escalators takes passengers only as far as the upper platforms, whence the second group travels down to the lower station.

The escalators are so arranged that they can be stopped if required, thus converting them for the time being into fixed staircases. This may happen as the result of a breakdown of the mechanism, or be done on purpose so as to slow down the movement of passengers when the platforms are so unusually crowded that the trains either cannot carry all the waiting passengers, or can carry them only at the expense of punctuality. Where a station has only two escalators, one is used only for upward, and the other for downward traffic ; but if there are three, the one in the middle is arranged for reversible working. In this way two of the three can travel up or down at the same time, which speeds up the movement of passengers during the rush hours. At less busy times the third is generally put out of working, which saves electrical current, while many people prefer to use a fixed rather than a moving stairway.

If you were ever to ask any one to guess how fast an escalator travels, you would almost certainly get a wrong answer, since they move much more slowly than most people would imagine. Actually, the speed is less than



two miles an hour, which is, of course, much less than the rate at which a lift travels. Even so, two escalators can do the same work as five lifts, since they are continuously on the move, and there is thus no waiting, while an escalator which is occupied from top to bottom carries more people than the largest lift. Although two miles an hour sounds little enough, the Underground escalators, between them, travel over two thousand miles a day, which is more than equal to going round the world once every fortnight.

It may sometimes be necessary to stop an escalator in a hurry, and there is a simple emergency device that allows this to be done either by passengers or the station staff. It consists of a circular metal box or drum, rather like a street fire alarm, with a paper cover beneath which are two bare wires. If the paper is broken and the wires are pinched together, the current is cut off, just as the track current can be turned off by pinching the wires running through the tunnels.

## CHAPTER XI

### "TICKETS, PLEASE!"

The "scheme ticket"—Automatic machines—Printing while you wait—The booking clerk's job.

EVERY day the best part of a million and a quarter people are carried by London's Underground. It may help you to understand better what this figure really means if you realize that it is more than equal to carrying the whole population of Australia every week, or of Scotland and Ireland together, or in a year to carrying every man, woman, and child in England, Scotland, Ireland, and Wales ten times over. Each of these passengers has to have a ticket, and, as is the case with everything else in London transport, providing them is a much bigger affair than most people imagine.

Twenty-five years ago, a railway company ordered tickets from the printer, who delivered them in batches, usually numbered consecutively up to 9999. A separate ticket had to be printed for the journey between each pair of stations, which meant, for instance, that although a threepenny fare from any particular station might allow you to travel to a number of stations from your starting-point, you would want a different *ticket* for each station. The tickets were placed in racks

in the booking office, each kind having its own rack, and stacked so that the lowest number was placed at the top. By checking the top number in each rack when he came and went off duty, the booking clerk, with a very little use of arithmetic, could see whether the money in his till was correct. It was a very simple system, and is still generally used on the main lines; but it was expensive on account of the large number of different tickets that had to be kept in stock, while the booking clerk could not always issue tickets fast enough during busy hours.

Rather less than twenty-five years ago, some one on the Underground came to the conclusion that it would be both cheaper and save time and space in the booking office if the number of different tickets, which then amounted to about fifty thousand, could be lessened. So the " scheme ticket " was invented. This will carry you to any station from your starting-point for which that particular fare is charged. For example, you may get a 3d. ticket that allows you to travel to as many as a dozen termini, as well as to any intermediate station. In this way the number of sets of tickets was in a few years cut down by more than half.

It needed more, however, to quicken up the actual issue of the tickets, and that has been done by the use of a number of very ingenious machines. One is the slot machine, which allows you to take your own ticket when the booking office is crowded. Actually, there are several kinds of these machines. Some of them, which also give change, are worked by electricity, the current being set in motion when you drop in the money. Others, which are used by the booking-office clerks are electrically worked

by pressure on one or more buttons, and not only issue the tickets, but also print them on long rolls of thin cardboard. There are also smaller printing and issuing machines worked on the slot system.

Then there is an ingenious affair known as the "Passimeter," which you can see working at Westminster and Kilburn Park among other stations. At the entrance to the booking office there is a turnstile arm, or "flipper," which is controlled by the booking clerk and kept locked when not in use. As a passenger passes the barrier, he receives a ticket that is both dated and cancelled at the time it is issued. The idea of these turnstiles is that they make it easier to regulate a queue of passengers. Another kind of turnstile is used at some stations in conjunction with the slot machines.

At some stations one man attends to both the issue of tickets and the working of the lifts, but the machinery for doing this is different at large and small stations. For instance, at Baker Street (Bakerloo Tube), where tickets are sold for both the Tubes and the Metropolitan Railway, a booking office is necessary, the booking clerk opens and closes the lift doors by means of levers, and the lifts themselves travel up and down unattended, although there is a man at the bottom to collect tickets and send the lifts up to the top. But at other stations the traffic is so small that it has been found possible to do away with the booking offices altogether and issue tickets on the lifts. One of these is Aldwych, on the Holborn-Strand section of the Piccadilly Tube mentioned at the beginning of this book. This is a single-line branch, worked by two-car trains in the rush hours, and by single-

car trains during the rest of the day. The liftman here is provided both with racks for storing the ordinary cardboard tickets and with a number of drums for issuing the tickets printed on rolls, which are made of a thinner card.

Since all the Underground system came under the ownership of the London Passenger Transport Board—on July 1, 1933—it has been found possible to simplify the ticket system still further. One of the first actions of the Board was to standardize the colours. All first class tickets are now white, and third class green. Perhaps I should explain about these two classes. In the steam days, the Metropolitan and District had three classes of carriage, as did nearly all the main lines in those days, although the old Midland (now part of the London, Midland, and Scottish) did away with the second class as far back as the beginning of 1875. When the Metropolitan and District were electrified, they dropped the second class, leaving only first and third, as is also the case on practically the whole of the main line system to-day. The Tubes had only one class from the beginning, but since you can buy a through ticket taking you from a station on the Tubes to another on the Metropolitan or District, or a " foreign " line, first class tickets are also issued on the Tubes.

I could go on for a long time talking about tickets—a much more interesting subject than most people imagine—and I could give you some remarkable figures. Here is just one example showing how the use of machinery in the booking offices has enabled the selling of the tickets to be speeded up. Some time ago a test was made at

Oxford Circus station during a busy evening hour. Exactly 1,174 people bought tickets in sixty minutes, or nearly one every three seconds. That is quick work in itself, but is even faster than it sounds, since so much of the time of the booking clerk was taken up by giving change, which was wanted by rather more than two passengers out of every five. It is this business of having to give change, as well as issue tickets to so many different stations, that slows down the work of the booking office, and you will therefore understand why the newest or busiest stations are provided with machines for giving change. If you try to imagine what it means to sell twenty tickets every minute, give change eight times a minute, see that every one gets the right ticket and the right change, *and* answer passengers' questions (I have no figures about the questions, but they mount up), you will see that the booking clerk's job amounts to a good deal more than just handing out pieces of cardboard and taking the money. As a matter of fact, he has to pass a pretty stiff examination before he is allowed to take on the work. The examination paper consists of no fewer than forty-three questions, most of which I should not care to have to answer myself.

This seems a good place to explain that every one on the Underground has to pass an examination before he can begin his duties. If you want a job on the operating staff—which includes everybody connected with the actual working of traffic—you must begin as a platform porter, and go to the Training School at Lambeth. This is a rather interesting school, with a double-track model railway 50 ft. long, complete with automatic signals,

points, and crossings, with brake gear and a full-sized section of a driver's cabin with control gear. There are twenty-six questions in the porter's examination paper, but he is obliged to know a good deal more than his title would suggest, including the geography of London and of the Underground Railways, how to use the private telephone service, what to do in the case of signal failures and breakdown of trains, and how to put out a fire at a station.

The guards, drivers, signalmen, and stationmasters are chosen from the porters, and have to pass a further examination before they can be promoted. The driver's examination is the hardest of all ; there are eighty-three questions on his paper, dealing with such matters as brakes, electric control circuits, power circuits, emergency battery lighting, train defects, and special working conditions on the District Railway. In comparison, the liftman has an easy time ; he need answer only twenty-one questions, such as, " If a lift goes on to Slow Speed whilst in the middle of a deep shaft, what would you do ? " and " If the Police Relay comes into action, what must be done ? "

As an Underground official once told me, " Every one of our men must be a specialist in his particular job."

## CHAPTER XII

### OTHER CITIES

Beneath the river Mersey—A cable railway—"Cut and cover"—  
The Moscow Tube.

Now that you have learnt about the construction and working of London's Underground railway system, you may also want to know a little about underground railways in other cities. We will take three—one in England, one in Scotland, and one in South America.

The English line, as you already know, is the Mersey Railway, a short but very useful system, of which a relatively large part is carried beneath the river Mersey. Liverpool, by the way, also has an electric overhead railway, which runs along the docks, and is thus one of the very few cities in the British Empire to have short-distance electric passenger lines both above and below ground. Starting below the main-line Central Station in Liverpool, the Mersey railway travels under the river, and when it gets to Birkenhead, on the other bank, it splits up into two sections. At each terminus on this side traffic is interchanged with the London, Midland, and Scottish, and other railways.

As underground railways go, the Mersey is fairly old, having been opened in 1886, or four years before the first



Tube, but its history goes back to a much earlier date. As far back as 1825, some months before the opening of the Stockton and Darlington Railway, and when a line between Liverpool and Birmingham (which afterwards became part of the London and North-Western, and is now a section of the London, Midland, and Scottish) was being planned, the Liverpool and Birmingham Railway Company thought it would be a good idea to build a tunnel under the Mersey to link up with their line. (The Mersey estuary is so long and wide, that to travel between Liverpool and Birkenhead by land means a lengthy and roundabout journey, and a tunnel therefore saves a good many miles.) So far as I have been able to find out, it was not intended that a railway should be built in this tunnel, but only that it should be used by passengers and carriages, in the same way as the Thames Tunnel, constructed some years later by Brunel, the famous engineer who built the Great Western Railway.

Nothing was, however, done in the matter until 1866, when Parliament sanctioned the building of a tunnel railway. It was at first planned to work by compressed air, but before the line was finished it was decided to use steam instead. Since 1903 the whole railway has been electrically worked, and it was thus among the first steam lines in England to make the change from steam to electric traction.

The Mersey Railway is four and three-quarter miles in length, and has seven stations, of which three are below ground, one is partly in tunnel and partly on the surface, and the other three are above ground. The tunnel section is three and a half miles long. There are

actually three tunnels beneath the Mersey, of which the principal one carries the running tracks, while the others are for draining and ventilation. Some of the underground stations have no shafts or other openings, and although immense fans were used, and over £5,000 a year was spent for ventilation, the atmosphere of these totally enclosed stations was never satisfactory. The ventilation difficulty was one of the reasons for the electrification of the railway.

The main tunnel which, unlike those on the London Tubes, carries both the "up" and "down" tracks, is 26 ft. wide and 19 ft. high. It is lined throughout with brickwork set with cement, and it will give you an idea of the nature of the work when you know that about thirty-eight million bricks were used on this section alone. The ventilation and drainage tunnels are not separate throughout, but meet at about the middle of the river, where they are united for a short distance. Automatic and power signals are used, together with the automatic train stop as in London, and trains are run every three minutes.

At the Liverpool end, the Mersey Railway has no direct connection with the main lines, but at the Birkenhead terminal stations it links up directly with the London and North-Eastern, and London, Midland, and Scottish Railways.

The Glasgow Subway, worked on the cable system, which was opened at the end of 1896, is a circular line, six and a half miles long, with fifteen stations at a depth of from 15 to 45 feet beneath the surface. The line travels under the river Clyde at two points, and is in

several respects an unusual railway. It is the only underground passenger-carrying line in the world that both forms a complete circle and has no junctions; unlike the London Inner Circle, which joins up with other sections at a number of points, and the Paris Metropolitan, which is made up of a number of circular lines connecting with each other. It is also the only underground passenger line in Great Britain of less than standard gauge, the width between the rails being only 4 ft. (The Paris Metropolitan, it is interesting to note, was at one time intended to be built on a still narrower gauge—that of a metre, or 3 ft. 3½ in.—but the standard width was actually chosen.)

The Subway is carried in two tunnels, the “up” and “down” tracks being kept separate except at the stations, where both lines come alongside a single “island” platform. The standard tunnel width is 11 ft., as against the London Underground standard of 11 ft. 8¼ in.—on some sections the width is actually 12 ft., and on others as much as 16 ft.—but in parts they are rather narrower. There are neither sidings on the running lines nor track cross-overs, a very inconvenient arrangement, since it means that the same number of cars has to be kept working continuously throughout the day, whether the traffic is light or heavy, while, when the cars come off duty at the end of the day’s work, they have to be kept bunched together in the tunnels. These inconveniences cannot be helped with the cable system, but the line is now being electrified, and it is hoped that electrical operation may begin shortly after this book is published.

The present arrangements for taking a car off the  
(3,900)

track for overhaul or repair are also most inconvenient. The workshops are on the surface, immediately above the tunnels, in which there is an open shaft, or car pit, having a travelling crane at the top. To remove a car from the running lines, it is necessary to stop it at the bottom of the pit, sling it on to the crane, lift it to the surface, move the crane, and then lower the car on to the workshop sidings. To bring it back to the track again this process has, of course, to be reversed, and while a car is being either raised or lowered, all traffic has to be stopped on both the "up" and "down" lines.

Electrification will improve the line in every way. Platforms are being lengthened, and it is proposed to have some form of escalator at the deeper stations, and to build new entrances at others. Modern signalling will, of course, be used, and in place of its present very old-fashioned "underground," Glasgow will have a very up-to-date electric railway, with trains running at double their present speed.

The two tunnels, known as the "Inner Circle" and "Outer Circle" are partly carried in iron tubes. In other sections, where the line was built in soft soil, the tunnels are also circular, but are lined with brick and concrete, while on certain parts of the line, where hard strata were met with, they are of the more usual horse-shoe shape. The two tubes lie side by side, at distances from 2 ft. 6 in. to 6 ft. apart, and at the stations they unite in one large arch, with a span of 28 ft.

Trains of only two cars, about 40 ft. long, and seating forty-two passengers each, are used. The line is open from six in the morning until midnight, except on

Sundays, when the trains do not start running until the afternoon. Trains run at four-minute intervals.

The Glasgow Subway is the only underground line in Great Britain to use the cable system of haulage, which works in this way. There are two cables, one for each tunnel, an inch and a half thick, and weighing fifty-seven tons, which are driven by steam from the main-power stations. The cables, which are placed between the tracks, and are kept in motion during the whole time the line is open, run at a speed of twelve and a half miles an hour. Underneath the cars is a gripper, worked by screws or levers. When this is applied to the cable the car moves forward, and when the gripper is released the train comes to a standstill. The gripper consists of two steel jaws, of which the bottom one is fixed, while the top jaw can be raised or lowered through an arrangement of links and levers operated by the driver. It looks rather complicated, but is really simple enough.

At one time the cable system was quite common in England, and was used on some of the early tramways both in London and other cities. On tramways, it is always necessary to place the cable in a conduit or grooved slot, as it might easily be damaged, and also be dangerous and inconvenient to other traffic if it were not carried below street level. On the Glasgow Subway it is raised, so that the lowest part of the gripper is several inches above rail level. The gripper gear is usually worked by a hand lever, but if the driver should by any chance fail to use this at the cross-over (where the cable enters and leaves the power station), a small roller makes contact with a bar between the rails, and

the gear automatically comes into operation. To stop a train at a station, the upper jaw is raised so as to bring it slightly out of contact with the cable.

The Buenos Aires "underground" is a short section of line belonging to the Anglo-Argentine Tramways Company, which works about 425 miles on the surface. The subway portion, which is at present only about four and a half miles in length, runs beneath the southern part of the centre of the city, and ends close to the docks. There is also in Buenos Aires an electrically worked goods line, two miles long, which connects the Buenos Aires Western Railway's station with the docks, where there are extensive electrified sidings.

It is planned to make the Subway ten miles long, when it will run from the north to the south of the city. The line is not a tube, but runs only a few feet below street level, and was built on what is known as the "cut and cover" system. This principle, which has also been used in New York, is employed where an underground line is planned to run at such a little depth beneath the surface that there would not be enough "head room" to build a tunnel in the ordinary way. The streets beneath which the line is to run are dug up, the railway tracks are laid in the cutting, and the surface of the roadway is then covered in again. In this way there is only a very small space between the roadway and the crown, or top, of the tunnel, while the London Tubes burrow down to about 200 ft. below ground.

There are two running tracks, both of which are carried in the same tunnel; as on the Metropolitan and District, automatic signalling is used.

The latest city to have an underground railway is Moscow, where a tube—the first in Russia—is now being built. Constructing this line has been a long job, because in winter the soil becomes frozen so hard that work is impossible for several months. It is interesting to know that the Russian engineers took London as their model: construction, station design, and escalators have been copied from those of our Tubes, and I am told that at least one of the stations will be designed on the same lines as Piccadilly. This will not only be Russia's first tube, but the first underground railway of any kind to be built in that country. It is being built in sections, and the first of these it is hoped to open in 1937.

We have started in London and finished in Moscow, and I have tried to show you something of the way in which underground railways are built and worked. Our story covers just over seventy years. In that time, less than the life of many men, steam has given place to electricity, and instead of the dirty, smoky tunnels of the Eighteen Sixties, we have railways on which the trains do almost everything except run without drivers. Perhaps that, also, may come before many years have passed; you can never say to the engineer, "Thus far, and no farther."

THE END

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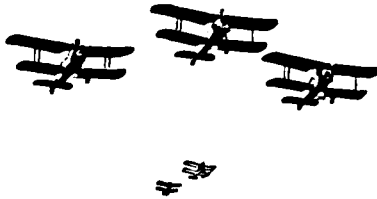
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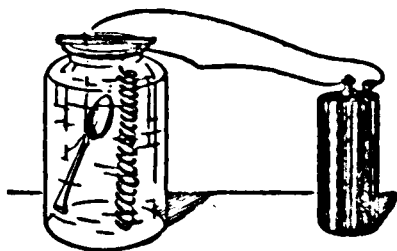
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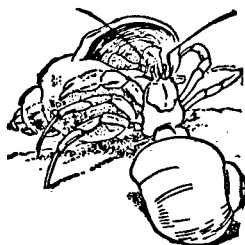
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