MELBOURNE'S ELECTRIC RAILWAY SYSTEM

SITTING comfortably in your morning train to the city, chatting with your neighbour or scanning your news-sheet, do you ever give a thought to the mighty force that propels you effortlessly and safely to your destination? Riding easily and swiftly by seascape or towards distant blue hills to the rhythmic clack-clack of well-sprung wheels on their twin steel ribbons, and with fresh air and bush scents blowing through open windows, does the wonder of man's achievement in harnessing Nature to your service ever occur to you?

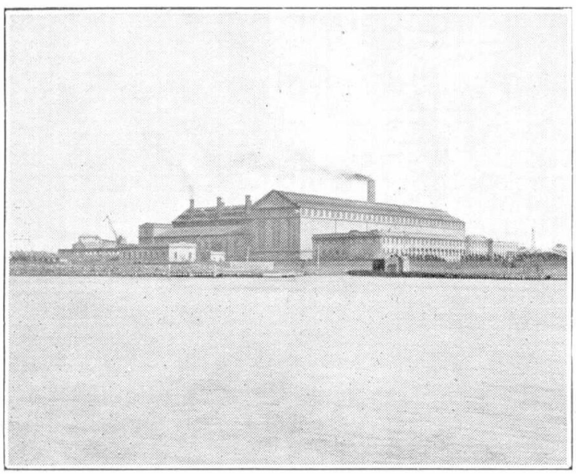
Yet what would you say and do, and how would you regard the rude interruption to your placid routine, if some giant hand whisked away Melbourne's 163 route miles of suburban railway system, which cost £6,500,000 to electrify, and which is now the largest and most up-to-date of its kind in the world?

This pamphlet has been written to give you some idea of the organisation of men and metal that runs so smoothly, day in, day out, of the wonderful, intricate machinery behind the scenes, of the colossal feats of transportation it accomplishes, of—in a word—your electric railway system.

Melbourne's Electric Railway System

Situated close to the mouth of the Yarra and occupying a site of approximately 36 acres, Newport Power House is an object of early interest to overseas visitors. Planned originally for railway traction purposes, Newport "A" with a capacity of 78,000 kilowatts (104,000 horse power), carried a considerable portion of Melbourne's industrial load for some years. Its capacity was later increased to 108,000 kilowatts (144,000 horse power) by the addition of Newport "B" Power House, which was built to supply industrial power. Newport "B" is owned by the State Electricity Commission, but is operated by the Victorian Railways.

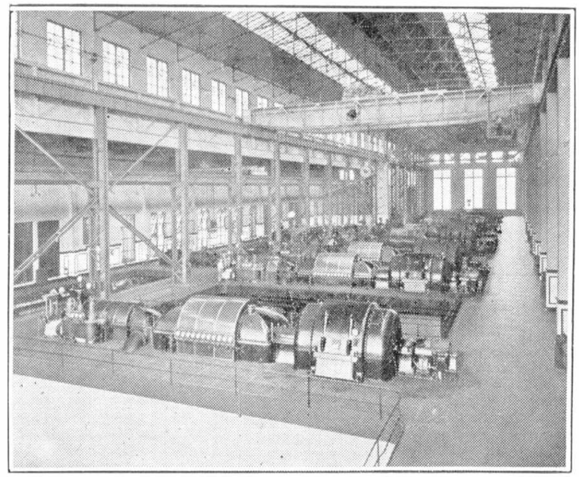
Our power used for the electric trains, together with a considerable amount for industrial work, is supplied from Newport "A," this being generated by six turbine driven generators. Steam at 210 lb. pressure is supplied to the turbine by 24 water tube boilers. For the year ending 30/6/27 196,000,000 units of electricity were generated, over 180,000 tons of coal burned under the boilers, while approximately 36,500 million gallons of salt water were pumped through the condensers.



Newport Power House.

Newport Power House consumes about twice as much water per day as the whole population of Melbourne uses for domestic supplies. Incidentally, the output from the condensers provides a warm sea bath throughout the year for local residents.

Prior to the completion of the State Electricity Commission's Power House at Yallourn, Newport gave considerable assistance in coping with Melbourne's industrial load, its best performance being in 1923-24 when 271,000,000 units were generated.



Turbine Room, Newport Power House.

Again in 1924-25 the total generated exceeded 260,000,000 units, and in this respect it is interesting to note that in the same period only two stations in Great Britain generated more than 200,000,000 units. Newport's industrial load within the Department is still of some magnitude. A considerable amount of energy is used in lighting the various workshops, main buildings, goods yards, &c., while over 650 electric motors are almost continuously in use.

The dimensions of the turbine room—440 ft. by 78 ft. 6 in. by 68 ft. high—quite dwarf the turbo-generators, whose ceaseless activity is denoted only by a rhythmic hum and wisp of steam escaping from the steam sealed glands.

In the boiler room one encounters six boilers in a row on either side of a wide, clean and well lighted firing aisle, six men at work quietly attending to their various duties. No hand firing or manual handling of coal are to be seen as machinery and automatic devices are used everywhere.

From rail trucks coal is elevated to overhead bunkers by mechanical bucket elevators, then by gravity to the boiler hoppers and carried by travelling chain grate stokers through the furnaces. Then when all the combustible is burned the ash is finally delivered back to the trucks by a pneumatic ash extractor.

In the reserve stores 40,000 tons of coal are normally kept in stock for emergency and provision has been made for most of this to be handled mechanically.

The boilers evaporate approximately 2,744,000,000 pounds of water each year, the supply to each boiler being regulated by an automatic feed regulator.

The number of automatic instruments and regulators in use is a feature of the Power House, and is of special interest to the visitor. Curve drawing instruments installed on each boiler give a permanent record of the amount of air used in combustion, the pounds of steam delivered by the boiler and the temperature of the flue gas, thus enabling an accurate check to be kept on the efficiency of the plant.

Automatic relays protect the generating machines and cables against damage from electrical faults. Automatic regulators maintain the voltage at a steady value under all load conditions, while a number of curve drawing instruments give a continuous and permanent record of the voltage, frequency, total power generated and the temperature of the generating machines. In the boiler room, turbine room and control room, various installations of electrical thermometers enable temperatures to be taken from equipment which it is difficult or even dangerous to approach.

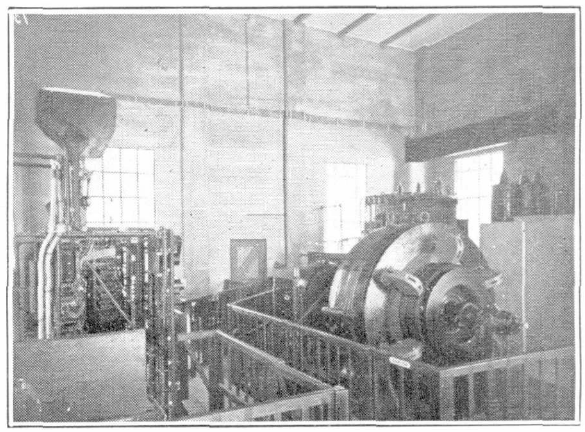
Power Supplies

Power generated at Newport is transmitted to the various sub-stations in the metropolitan area through the high tension distribution network, which comprises 144 miles of steel armoured underground cable and 120 miles of overhead feeder. The power supply to the outgoing cables is controlled by oil switches erected in a separate switch house parallel to the turbine room, all switching operations being carried out electrically from a small control room located at the end of the switch house.

Sub-Stations

At the sub-stations electrical power arriving as 3 phase 25 cycle alternating current at 20,000 volts pressure is converted into direct current at 1,500 volts, in which form it is most suitable for traction purposes. Conversion is carried out in 18 of the sub-stations by rotating machines known as rotary converters; in the remaining two stations stationary mercury arc rectifiers are used.

Most of the sub-stations are manually operated, but 7 in the outlying districts, including the two equipped with mercury arc rectifiers, were designed for automatic control, and are run unattended. Some of the older stations are now being converted from manual operation and equipped to operate on the supervisory and automatic control system, which is considered to be a distinct improvement on the earlier types.



Interior, Rotary Converter Automatic Sub-Station.

The equipment of any sub-station may be grouped under one of four sections—

(1) Switchgear for controlling the high tension current from the Power House;

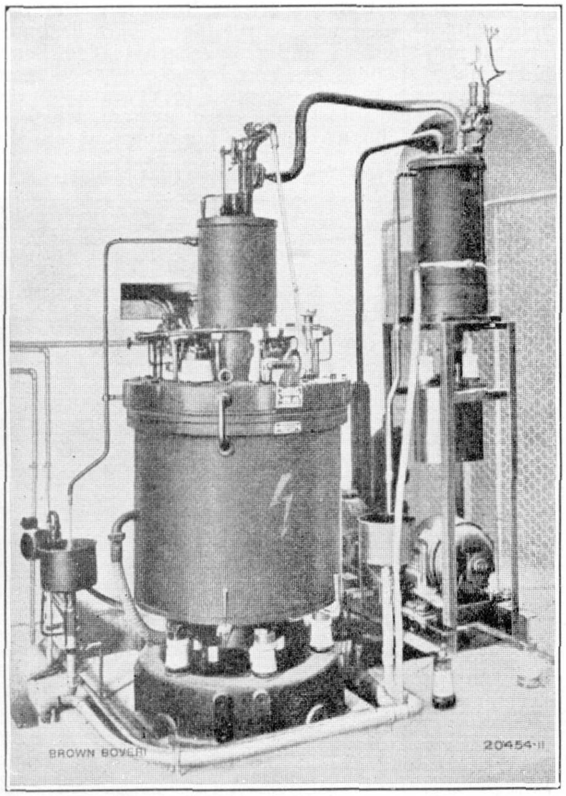
(2) Apparatus for converting high tension alternating current to 1,500 volt direct current;

(3) Switch gear for controlling direct current supplied to trains or trams;

(4) Protective relays for guarding equipment against electrical and mechanical faults.

In a manual sub-station all service operations are performed by attendants who are also relied upon to guard the machines against damage from mechanical faults, automatic protection being provided against electrical faults only.

An automatic sub-station runs unattended, all switching, starting and stopping operations being performed by automatic relays, protection against all mechanical and electrical faults being provided by the same means. As usually installed, automatic sub-stations start up on load demand.



Mercury Arc Rectifier, Automatic Sub-Station.

When a train enters a section normally supplied by an "automatic," the demand for power causes the line voltage to fall below its normal value. This actuates a "master relay" which in turn starts a sequence of operations culminating in the sub-station supplying power to the section and restoring the voltage to normal. The station is shut down by another relay some seconds after the train passes out of the section and the demand for power no longer exists.

In some cases automatic sub-stations are fitted up for remote control, i.e., by the aid of pilot wires, the machines may be started or stopped from a distant point. No provision is made, however, for sub-dividing the various switching movements and the operator has no means of ascertaining the effect of his operation.

Supervisory System

With supervisory and automatic control the advantages inherent to automatic operation are retained and the previously mentioned disabilities removed. In other words, automatic operation and remote control are both employed while all operations are under supervision.

Elwood sub-station equipped with three rotary converters and supplying power for the St. Kilda-Brighton tramway is at present manually operated. After conversion the operators will be replaced by the supervisory and automatic control equipment, most of which will be installed at Elwood. A certain amount, comprising the supervisory section, will, however, be located at Jolimont sub-station, connection between the two sub-stations being maintained by three small pilot wires.

This installation enables the supervisor at Jolimont to perform any of the following operations at Elwood:—

(1) Close or open the high tension switches;
(2) Start or stop any or all of the three converters;
(3) Close or open the direct current switches and so regulate the current to the overhead contact wires supplying the trams;
(4) Change the high tension supply from one cable to the other.

Any of the above operations require a number of separate movements which must be performed not only in the correct sequence but within a definite time. The closing (by hand) of one small switch at the supervisory station (Jolimont) is all that is necessary, and the sequence of movements then proceeds automatically. The completion of the operation is signalled by the lighting of a small signal lamp back to the supervisor, who is then able to proceed with the next operation.

The machines and cables are protected by relays just as in a plain automatic sub-station, but with this addiiton, that the stoppage of a machine and consequent failure of supply is signalled to the

High-speed Circuit Breaker Panels, Automatic Sub-Station.

supervisor by the ringing of an alarm bell and by the signal lamp changing from red to green.

Provision is made to enable the three machines to be started up at any time by the supervisor, or, alternatively, the first machine may be so started while the others start only on the load becoming too great for the first machine. In the case of this one failing to start at all, the second machine automatically takes its place. To further provide against failure of supply, the machines may be started or stopped from the Tramways Running Shed, situated close by, while any of the converters may be manually operated within the sub-station itself.

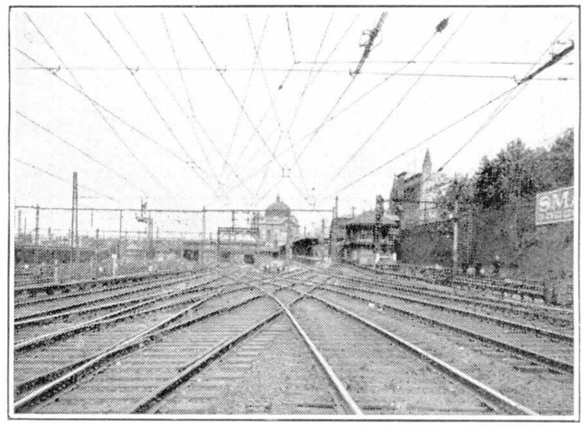
Adequate protection is provided against conflicting operations from different points, and in the event of a serious failure of any machine it is permanently locked out of service and cannot be started again until an Inspector visits the sub-station.

The ingenuity of the supervisory system can best be appreciated when it is realised that all of the operations detailed above are carried out through the three small wires connecting the two sub-stations.

The provision of automatically operated sub-stations, especially in the outlying districts, considerably reduces working expenses and enables lines to be electrified while serving sparsely populated districts.

Overhead Network

To meet the requirements of the suburban railway system with its increased voltage and high capacity, catenary construction is employed. Fabricated steel structures placed approximately 300 feet apart afford direct support to a heavy, stranded copper cable known as the catenary or messenger cable, from which the contact wire is suspended. The catenary is erected in sections of approximately 3,000 feet and rigidly attached or anchored at each end to extra heavy tensioning structures spaced 180 ft. apart, thus allowing the catenaries to overlap by that amount.



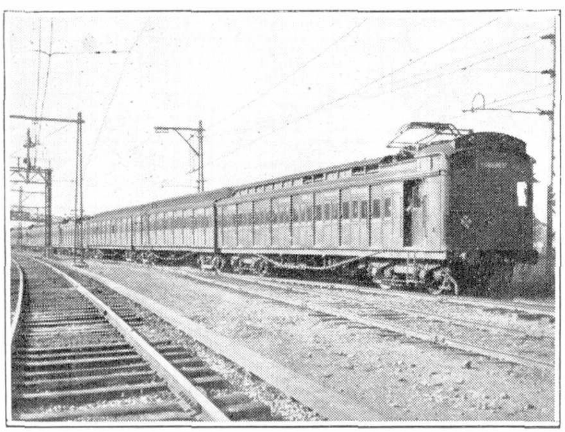
Overhead Network at Princes Bridge.

For fast railway service the contact wire must be kept at a constant height above the tracks and not allowed to sag between supports. It is therefore suspended from the catenary at intervals of 15 ft. by copper dropper wires and in addition is automatically tensioned by heavy weights or springs attached to each end of the 3,000 ft. sections. The previously mentioned tensioning structures support the weights and the necessary pulley equipment, the overlap between the two allowing the train pantograph to pass smoothly from one section to the other. The contact wire is of solid round copper but with a V notch on each side to facilitate attachment to the dropper wires. To prevent side sway the contact wire is attached to each structure by a steel pull-off arm carried on an insulated support. Catenary cables, contact wires and droppers are all electrically connected, but the entire network is insulated from the supporting structures by heavy porcelain insulators.

The steel supporting structures vary somewhat in general design to suit special conditions. At North Melbourne Junction several structures of the "pin arch" type carry the overhead for 13 tracks. These are the largest on the system, having spans of 120 ft. and weighing 14 tons. Many six and four-track structures have been erected, but two-track construction is the most common. Wherever possible, the structures are also used to carry the automatic signal gear in addition to the overhead.

On the more recently electrified lines steel structures have been dispensed with except within large station yards and wood poles used instead, thereby reducing installation costs. Copper catenary has been retained on some of the lines but between Ringwood-Upper Ferntree Gully and Ringwood-Lilydale a steel catenary has been adopted, the contact wire being copper. Copper feeder cable is then carried on the poles at the side of the track and attached to the contact wire at suitable points. Steel catenaries are also used to a limited extent on sidings.

The overhead network, although acting as a common supply line for all of the electric trains, is nevertheless divided into a number of separate sections. Up and down tracks are sectionalised and as a general rule sections on either side of a sub-station are separated. Hand operated switches are provided to enable different sections to be coupled or tracks to be paralleled when necessary. Sidings are usually maintained as separate sections, being also fed through hand operated switches as required.

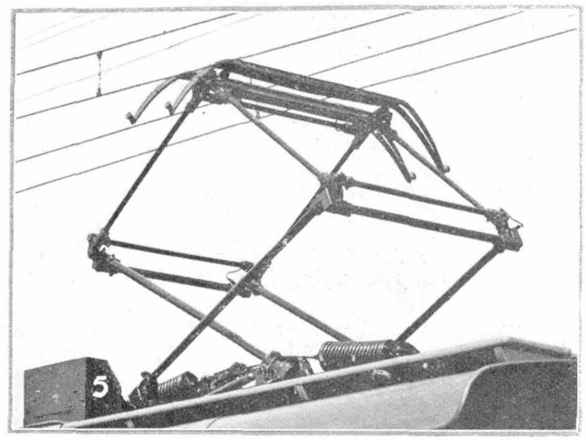


Main Line and Siding Overhead Equipment.

Tramway Crossings

Several interesting features are incorporated in the overhead network. At several points in the metropolitan area electric tramways cross the railway line and apparently trains and trams use the same overhead current indiscriminately. Actually this is not the case.

A section of the overhead spanning the roadway is specially constructed to suit both train and tram current collectors and entirely insulated from the remainder, air breaks being used on the railway section and moulded insulators on the tram wire. The insulated section is fed through automatic circuit breakers with Railway current at 1,500 volts or tramway supply at 600 volts, as required. The circuit breakers are so interlocked with the railway gates that it is impossible to supply either train or tram with the wrong current. Neither is it possible to have both circuit breakers closed at the same time and obtain a mixture of supplies.



Pantograph on Converging Contact Wires.

On the inter-urban system there are now 404 miles of single track electrified. Over 8,000 tons of steel were used for the structures, while the copper in the network weighs over 1,800 tons. A large proportion of both steel and copper was produced in Australia.

Breakdowns and their Repair

To keep this extensive system in order a highly efficient break-down staff with headquarters at Batman Avenue is maintained. A fault on the overhead, whether due to a lightning stroke or to a magpie building her nest too close to a live wire, requires prompt attention to prevent disorganisation of the service. The break-down staff is therefore equipped with high speed motor trucks carrying all necessary repair material.

On days of abnormal traffic, mobile emergency units are also stationed at strategic points, thus enabling faults to be repaired without delay.

Electric Train Equipment

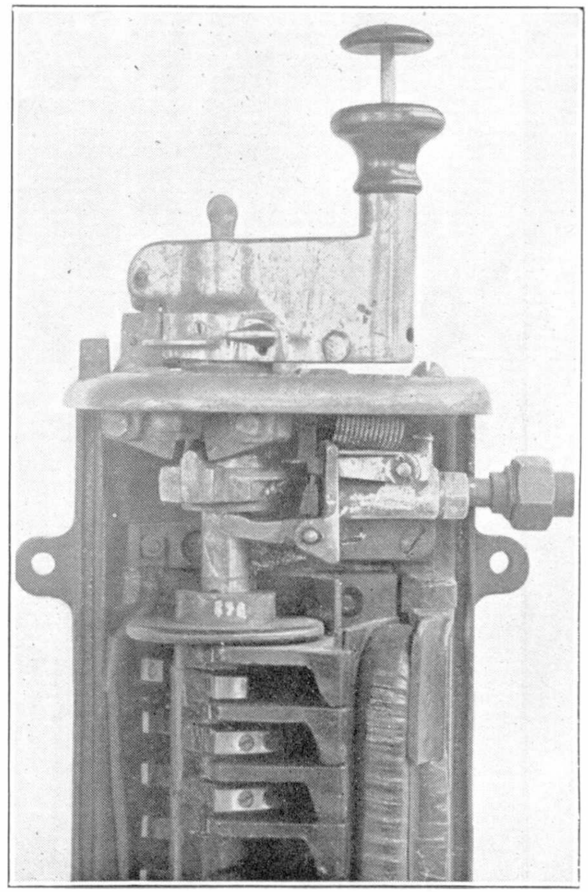
The particular type of equipment in use on the Victorian Railways is "all electric," and is known as the Sprague General Electric System of Automatic Control. The system under which the train is controlled and operated is known as "the Multiple Unit Control System." The significance of the term "multiple unit" will be readily understood by comparing a steam train with an electric train. The steam train has only one source of tractive force—the locomotive—whereas a multiple unit electric train is composed of two or more units, each unit consisting of a motor coach and one or more trailer coaches and each motor coach being a separate source of tractive force.

Each motor coach is equipped with four motors rated at 140 h.p. each and the necessary apparatus for the controlling and operation of the train. Provision has been made on a number of trailer coaches for controlling and operating a train, these coaches being known as Driving Trailers.

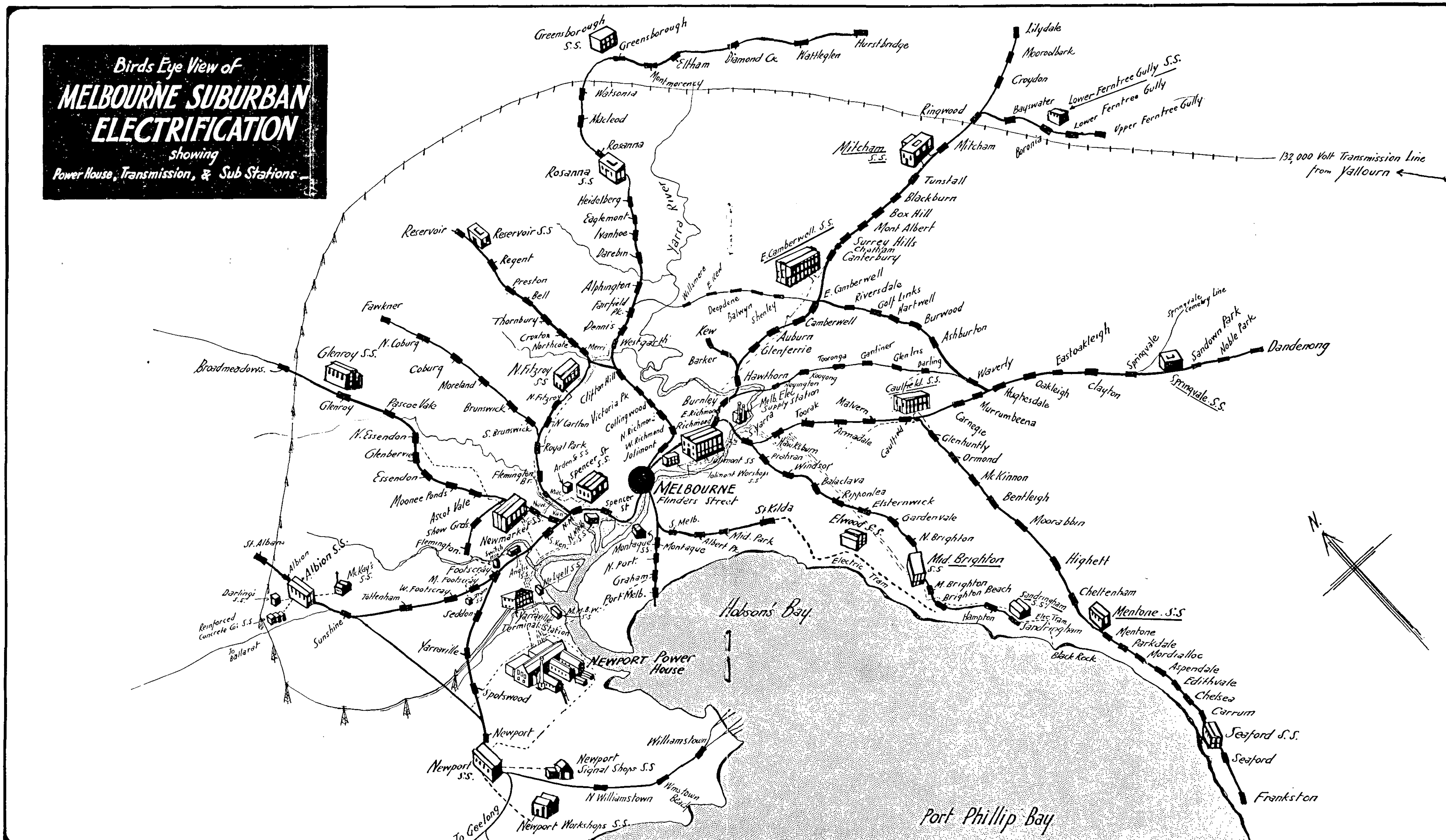
The system comprises two distinct sets of control apparatus, namely, "Master Control" and "Motor Control." The Master Control is operated by the electric train driver, the motor control depends for its operation on the master control. The motor control apparatus, with which every motor coach is equipped, serves to carry current from the pantograph collector at 1,500 volts at the roof of the car through the motors to the track rails, forming a different combination of motors and cutting down resistance in starting that particular motor coach. Every motor circuit is local, being confined to its respective car. Every motor coach is equipped with the master control apparatus which operates on 750 volts. Its function is to operate the motor control. An important feature of the master control is the train cable comprising nine insulated conductors running the entire length of the train with suitable couplers known as "Nine Core Jumpers" between cars. On every motor coach a connection is made from the train cable to the master control apparatus of that car and to the master controller which is operated by the motor man for regulating the supply of current to the train cable for the operation of the motor circuit. Consequently, the entire train can be energised and all the motor control apparatus connected thereto can be operated through any master controller on any coach in the train.

Safety Appliances

In the design of the multiple unit system extraordinary precautions have been taken to ensure the safety of the travelling public. Lightning arresters are fitted to each motor coach and electrical fires are impossible, all live cables being highly insulated and enclosed in fire-proof metal pipes or boxes. In the event of damage to the safety apparatus the train cannot be operated unless an extra man remains in the cab to assist the motor man. Both men are able to start the train independently. One of these safety devices is known as the pilot or dead man's valve. The master controller is so arranged that a special key has to be inserted before the handle can be moved. It is opened against the action of a spring and in the event of a motor man becoming incapacitated and releasing the handle it automatically moves to the "off" position, cutting off the power. In addition the train is brought to a standstill by the action of the dead man's valve, which is so designed in the handle of the master controller that the release of the button on the top

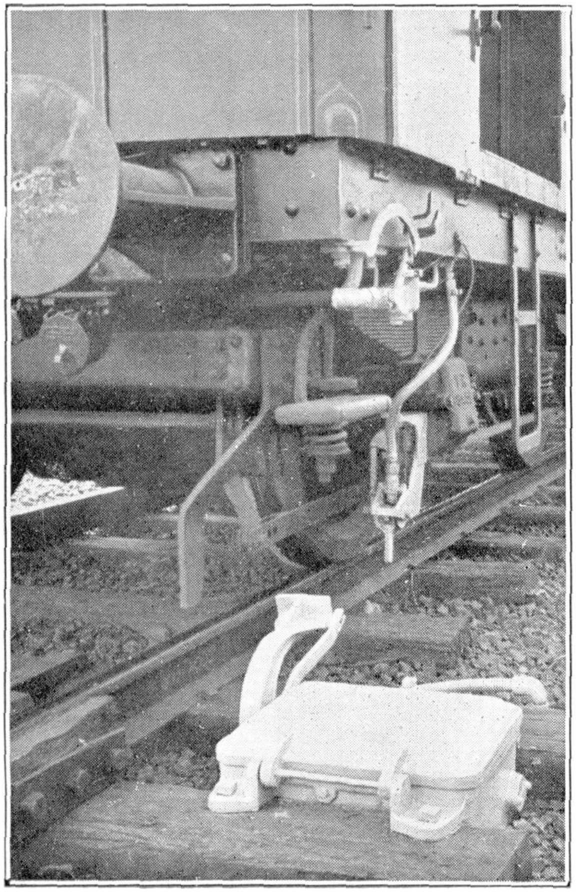


The Master Controller.

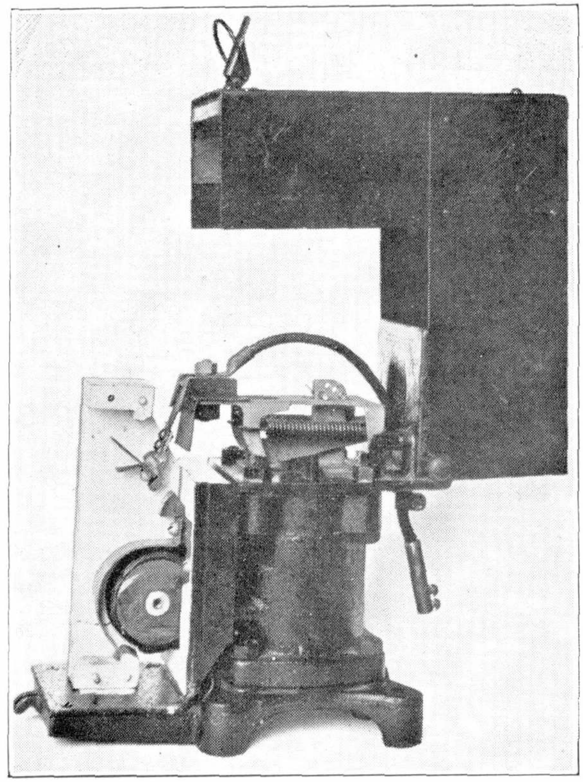

Birds Eye View of
MELBOURNE SUBURBAN ELECTRIFICATION
showing
Power House, Transmission, & Sub Stations
132,000 Volt Transmission Line from Yallourn
MELBOURNE
Flinders Street
NEWPORT Power House
Hobsons' Bay
Port Phillip Bay
Yarra River
N.
Greensborough S.S.
Greensborough
Montmorency
Eltham
Diamond Ck.
Wattleglen
Hurstbridge
Watsonia
Macleod
Rosanna
Rosanna S.S.
Heidelberg
Eaglemont
Ivanhoe
Darebin
Alphington
Fairfield Pk.
Dennis
Westgarth
Merri
Clifton Hill
Victoria Pk.
Collingwood
N. Richmond
W. Richmond
Jolimont
Lilydale
Mooroolbark
Croydon
Bayswater
Lower Ferntree Gully S.S.
Lower Ferntree Gully
Upper Ferntree Gully
Boronia
Ringwood
Mitcham
Mitcham S.S.
Tunstall
Blackburn
Box Hill
Mont Albert
Surrey Hills
Chatham
Canterbury
E. Camberwell S.S.
E. Camberwell
Camberwell
Riversdale
Golf Links
Hartwell
Burwood
Ashburton
Willsmere
E. Kew
Deepdene
Balwyn
Shenley
Kew
Barker
Auburn
Glenferrie
Hawthorn
Burnley
E. Richmond
Richmond
Jolimont S.S.
Jolimont Workshops S.S.
Melb. Elec. Supply Station
Heyington
Kooyong
Tooronga
Gardiner
Glen Iris
Darling
Waverly
Eastoakleigh
Oakleigh
Hughesdale
Murrumbeena
Clayton
Springvale
Springvale Cemetery Line
Springvale S.S.
Sandown Park
Noble Park
Dandenong
Caulfield S.S.
Caulfield
Malvern
Armadale
Toorak
Hawksburn
Prahran
Windsor
Balaclava
Ripponlea
Elsternwick
Gardenvale
N. Brighton
Mid. Brighton
Mid. Brighton S.S.
M. Brighton
Brighton Beach
Hampton
Sandringham S.S.
Sandringham
Elec. Tram
Electric Tram
Black Rock
Carnegie
Glenhuntly
Ormond
McKinnon
Bentleigh
Moorabbin
Highett
Cheltenham
Mentone S.S.
Mentone
Parkdale
Mordialloc
Aspendale
Edithvale
Chelsea
Carrum
Seaford S.S.
Seaford
Frankston
Elwood S.S.
St Kilda
Mid. Park
Albert Pk.
S. Melb.
Montague S.S.
Montague
N. Port.
Graham
Port Melb.
Reservoir
Reservoir S.S.
Regent
Preston
Bell
Thornbury
Croxton
Northcote
N. Fitzroy S.S.
N. Fitzroy
N. Carlton
Royal Park
Fawkner
N. Coburg
Coburg
Moreland
Brunswick
S. Brunswick
Broadmeadows
Glenroy S.S.
Glenroy
Pascoe Vale
N. Essendon
Glenbervie
Essendon
Moonee Ponds
Ascot Vale
Show Grds.
Flemington
Flemington Br.
Newmarket S.S.
Arden St. S.S.
Spencer St. S.S.
Spencer St.
N. Melb.
S. Ken.
Switch S.S.
Footscray
M. Footscray
W. Footscray
Tottenham
Seddon
Yarraville
Yarraville Terminal Station
McLyell S.S.
M.M.B.W. S.S.
Spotswood
Newport
Newport S.S.
Newport Signal Shops S.S.
Newport Workshops S.S.
N. Williamstown
Wmstown Beach
Williamstown
To Geelong
St. Albans
Albion
Albion S.S.
McKay's S.S.
Darlington S.S.
Reinforced Concrete Co. S.S.
Sunshine
To Ballarat

of the controller handle causes an escape of air from the brake system and a consequent emergency application of the brakes throughout the train. We include a photograph of this apparatus and the master controller handle with the plunger button in the raised position can be clearly seen as well as the pilot valve under the handle frame.

Another safety device is known as the trip valve. On the left hand leading axle box of every coach fitted with a driving compartment, set in such a position as to be operated by a train stop arm on the track interlocked with the signal, is fitted a trip valve which would operate in the event of a train passing an automatic signal at danger. This



Trip Valve and Train Stop.

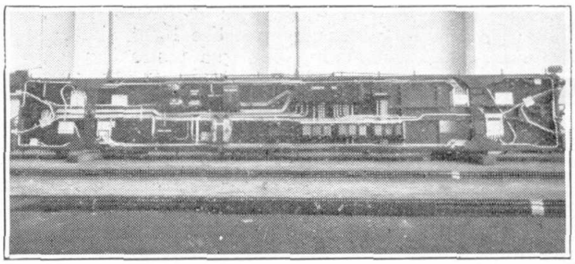


The Control Governor.

action causes an emergency application of the brakes as well as cutting off the supply of power and will bring a seven-car train loaded with 600 passengers and travelling at 36 miles per hour to rest in 10$\frac{3}{4}$ seconds, and within a distance of 375 ft. We include a photograph of the trip valve, from which the manner of its operation can be clearly followed.

A further safety device is the control governor. This apparatus, which is situated near the roof of the motorman's compartment, consists of a pneumatically operated switch in the circuit of the master control. Its action is such that it is impossible to start an electric train unless the air pressure of the Westinghouse air brake system has reached a pre-determined safe value for its efficient operation. Should a fault occur on the air brake system, causing a reduction in the train line pressure, the power supply would be simultaneously cut off with the automatic application of the brakes throughout the train. The accompanying photograph shows the governor with the cover raised, disclosing the contact tips when they are open.

Regarding safety as applied to switches, employees are protected from coming in contact with any live parts of the switches in the cab, as the switch handles are interlocked in such a manner that it is impossible to remove a fuse while the switches are in a closed position. All the wiring for both motor control and the master control circuit is run in steel conduit, each wire being in an individual conduit, thus ensuring protection and reliability in the operation of the apparatus. The accompanying photograph of the underside of a motor coach underframe shows clearly the steel conduit in which the power and control cables are run. The total length of the steel conduit on one motor coach as shown in this photograph is 1,078 feet.

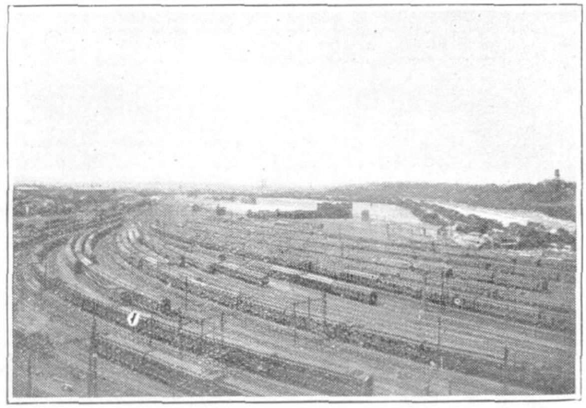


Steel Conduit for Cables on Motor Coach.

General Particulars of the Suburban System

To cope with the work involved in the inspection, overhauling, painting and general maintenance of the electric rolling stock a modern plant known as the Jolimont Workshops has been built in the Railway Yards off Batman Avenue. The Workshops comprise three main sections, namely, the lifting and repair bay, the inspection bay and the painting bay. The train equipment is thoroughly inspected in the inspection bay on completion of every 3,000 miles of running, and the reliability of the equipment may be gauged from the fact that the delays in service due to electrical equipment failures for the 12 months ending June 30th, 1927, were one failure for every 162,000 car miles. The total car mileage for the above year was 38,500,000 miles.

During the year ending June, 1919, immediately prior to electrification 103,500,000 suburban passenger journeys were made, whereas during the same period ending June, 1927, the suburban passenger journeys were over 160,000,000. The total mileage travelled by these passengers was over 904,000,000 miles.



Jolimont Yard with Workshops in background.

During the evening peak loading an average of 88 electric trains arrive and 114 trains depart from Flinders Street and Princes Bridge stations between the hours of 5 p.m. and 6 p.m. In fact, if all the cars required for service conditions were coupled together they would extend from Flinders Street to Oakleigh, a distance of over 9 miles.

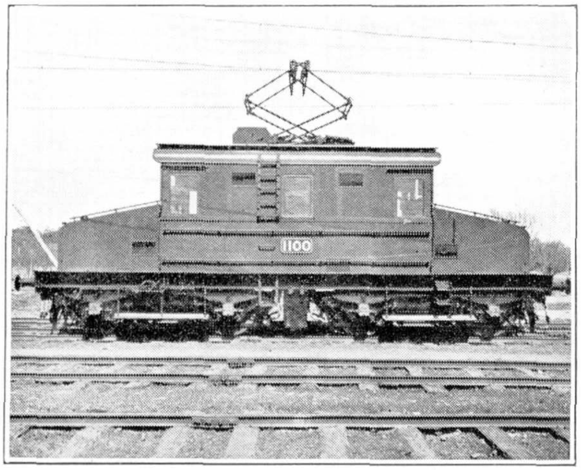
The total number of electric light globes required to equip the electric coaches is 15,500, and these globes would cost £775. The current consumed by all these lamps burning for only one hour would be sufficient to supply the electric light requirements of an ordinary 5-roomed suburban house for over four years.

The total cost of an electric motor coach completely equipped for service is £7,480, while that of a trailer car is £3,800.

The total weight of the electrical equipment on a motor coach is 14 tons 18 cwt., and of this weight there are 1¾ tons of copper or, in other words, almost 12% of the electrical equipment of an electric motor coach is composed of copper.

The total length of the insulated wire used in the manufacture of the electro magnet coils for the operation of the control apparatus on one coach is over 30½ miles, while the total length of the electric cables for the power and control circuit used in equipping all motor coaches on the electric system was over 360 miles and cost £38,000.

The energy required to take a 7-car peak loaded train from Flinders Street to Sandringham is 222 units of electricity and the total energy required per annum for electric traction purposes is over 144,000,000 units.



Electric Locomotive for Suburban Goods Service.

Car Lighting Equipment on Steam Trains

It is a tradition that the honor of first lighting railway cars belongs to one Thomas Dixon, the driver of "The Experiment," as the coach was called, on the Stockton and Darlington Railway, England, in 1825. It is said that on the dark winter nights out of pure goodness of heart he used to bring in a penny candle and set it on the rough board that served as a table in the centre of the coach. In those days the railway companies made no effort to light their cars except to offer candles for sale to passengers. Gradually times changed, and a few smoking candles were placed in each car, not so much in consideration of the passengers' comfort as to enable them to find their way in and out of the car. Later, oil lamps were substituted and these, as railway transportation developed, have been superseded by other lighting until to-day we have an excellent system of electric lighting for the cars of steam trains.

As far back as 1895, there is on record an electric light system in which the dynamo was driven off the car axle. This system has been improved on, and to-day we find many of our country cars with the Stone lighting system. The cost of equipping a carriage with electric light approximates £500, so that the amount of capital funds in electric lighting equipment of country cars is considerable.

In the Stone lighting system a constant speed dynamo of one kilowatt capacity, and generating 24 to 32 volts at 950 to 1,020 revs. per minute, suspended under the car is belt driven off a pulley on the car axle. By means of adjusting screws on the suspension the tension of the belt is adjusted to regulate the output of the dynamo, the belt slipping at speeds higher than 20 to 25 miles per hour of the train. To prevent the generator being switched into circuit before the correct speed and incidentally voltage is attained, a special switch is arranged to automatically cut in or cut out the dynamo as the speed of the train increases or decreases to 15 miles per hour.

A double set of accumulators, each consisting of 12 storage batteries of 120 ampere hour capacity and giving a voltage of 24 to 32 are so arranged through convenient automatic switches that with the dynamo in operation and the light switched on one set is always being charged while the other is on discharge. Each set of batteries is automatically changed over from charging to discharging each time the dynamo is switched into circuit, thereby eliminating the possibility of overcharging one set of batteries on long express runs of the trains with lights burning. In a sleeping car of the Adelaide or Sydney express type there are 30 15-watt lamps, 24 25-watt lamps and two electric fans of 72 watts each.

Electric Headlights on Steam Locomotives

While entirely suitable for passenger car illumination, the fitting of an axle-driven generator and storage batteries on a locomotive would be quite impracticable. The current is therefore provided by a small turbine-driven generator mounted on some convenient part of the locomotive, steam for the turbine being drawn from the boiler and finally exhausted to atmosphere.

This equipment consists of a turbo-generator and apparatus for the illumination of the headlight, cab, tender and marker classification lamps. The steam driven turbo-generator designed for a speed of 3,200 revs. per minute and generating 32 volts is of 500-watt capacity. The head lamp used is a 250-watt lamp and is capable of brilliantly lighting up the track for a distance of over 500 yards ahead.

This powerful electric headlight is of great assistance to both the engine driver and the road user, affording the driver at night time a clear view of the track and providing an additional warning to the road user of the train's approach.

The "Wig Wag" Signal

There are in Victoria approximately 3,600 level crossings, where roads cross railway lines on the same level, and of these about 3,350 are open level crossings where gates are not provided. It is realised that there is a risk of collision at each level crossing, but it is impracticable to equip every level crossing with gates or to eliminate them entirely by the provision of bridges.

Every open level crossing is provided with one or more signs in the form of a diagonal white cross bearing the words "Railway Crossing," which indicates clearly the presence of the level crossing.

Although the mere presence of a level crossing should incite caution even in the most reckless, it has been found advisable to give some further protection at certain crossings where the view is limited or where other special conditions exist. This additional protection is provided in the form of an automatic warning signal which displays this warning indication when a train is approaching. The essential requirements of such a signal are—it must be reliable in operation, it must give an arrestive and distinctive warning signal which can be instantly recognised and it must give an audible as well as a visual signal.

Careful investigation of the devices in use resulted in the adoption of the Wig Wag signal. This signal has been thoroughly tried out in other countries where thousands are in use, giving good service.

The "Wig-wag" Signal.

The Wig Wag signal consists of a suspended red disc which carries a red light in the centre and an audible signal is provided by means of a bell. When the disc is stationary no light is showing. This indicates the absence of trains and that it is safe to pass over the crossing.

When the disc is swinging the red light shows in the centre of the disc and the bell rings. This indicates that a train is approaching and that it is dangerous to cross.

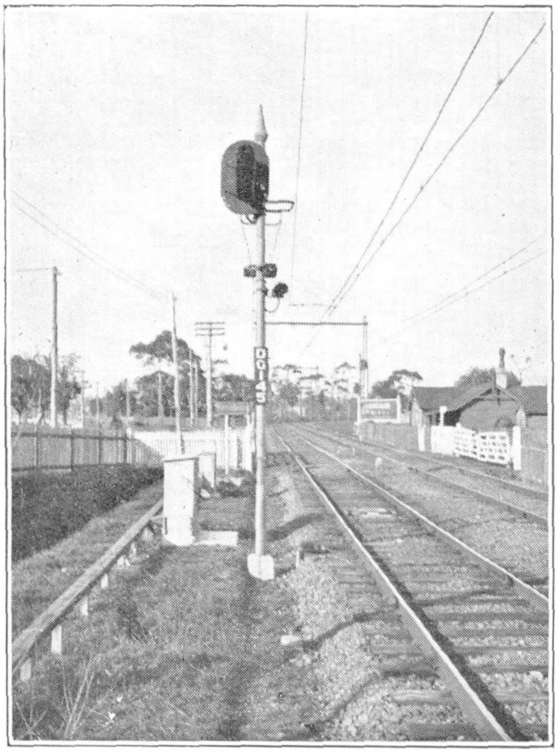
If the device is out of order a banner falls to a position immediately below the disc and exhibits the notice—Out of Order. The swinging disc or light of the danger indication of the Wig Wag signal is arrestive and it is much more likely to attract attention than any stationary warning signal. It is also more easily recognised than any lettered sign. Lights flashing intermittently would provide an arrestive signal, but such lights are largely used for road beacons and for advertising signs and a swinging light or disc gives a more distinctive signal, one which is less likely to be mistaken for anything else.

Electric Signalling and Interlocking

Prior to the electrification of the Melbourne suburban lines, all signals and points were worked through the medium of wires and rods by levers operated by signalmen. This was sufficient for steam trains and the traffic then offering, but the increased frequency of train service under electrification could not be handled economically by mechanical means and power signalling was therefore introduced on some of the busier lines concurrently with electrification. This system of signalling is being extended gradually as increased traffic justifies it.

In power operated sections the points or switches at a junction or station yard and the signals which govern movements of trains over the points are controlled by levers in an interlocking machine, which is housed in a signal cabin; the intermediate signals between signal cabins are automatically controlled, the indication displayed by any signals depending on whether the sections of track immediately beyond the signal are occupied or not. The automatic signals can be spaced much closer than is practicable with manually operated signals and a much greater frequency of train service can then be obtained. Some of the suburban lines are signalled for trains at intervals of $1\frac{1}{2}$ minutes.

There are now some 650 main line power signals in use, of which 500 are operated by electric motors and have semaphore arms; the remainder are light signals. The light signals have the advantage that they can be used in positions where owing to obstructions it would be impracticable to use semaphores. Light signals exhibit the same indication by day as by night and they are more readily distinguished at dusk and during fogs.



Automatic Light Signal.

Mechanically operated signals have two indications only, viz., STOP and PROCEED, which need no explanation. Power signals have a third indication—WARNING, which means Proceed—next signal at STOP. On seeing this signal the driver immediately brings his train under control and prepares to stop at the next signal. Power signals are divided into two classes—home and automatic. Home signals are controlled from a signal cabin and are distinguished by a red marker light vertically below the signals or by a square ended semaphore arm. Home signals are placed at junctions and other places where conflicting train movements may be made and a train may not pass such a signal exhibiting the STOP indication unless by special instruction by the Signalman. Automatic signals have the red marker light diagonally below the signal and the semaphore signal is distinguished by a pointed arm. If an automatic signal is showing STOP the train must be brought to rest and the driver may then proceed cautiously prepared to stop short of any obstruction until he arrives at another signal. This arrangement is safe and automatic signals are never placed where an opposing movement could occur, and it has the advantage that trains may proceed as far as possible consistent with safety in the event of a block in traffic or the failure of signals.

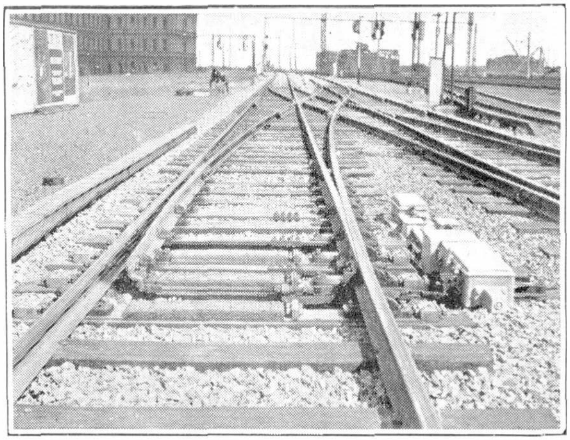
Train Stops

Each main line power signal has a train stop which works in conjunction with it. The signal is controlled by the track for a distance beyond the next signal ahead which allows ample margin for stopping a train which may inadvertently pass a signal at STOP. The train stop is similarly controlled and every electric train is fitted with trip gear which shuts off power and applies the brake if the train passes a signal when the line is not clear for the required distance ahead. The train cannot be started after having been tripped until the trip gear has been reset and this requires the motorman to get out of the train, as the trip gear cannot be reset from the driving compartment, and the necessity for extra vigilance when passing a signal at stop is thus impressed upon him.

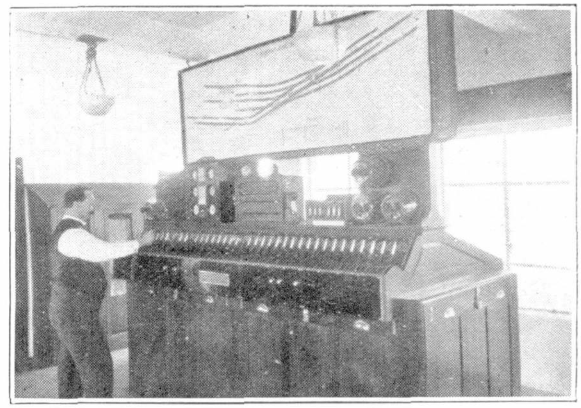
The Interlocking Machine

Where points and signals are worked from a signal cabin they are controlled by levers grouped in an interlocking machine. The levers are so interlocked mechanically and electrically that before a signal governing any movement can be altered from its normal position, i.e., STOP, the route over which the train is to pass must be set up with the points locked in the correct position. When the signal lever is pulled all signals which would permit conflicting moves are locked and the points remain locked until the entire train has cleared them.

An illuminated diagram of the area controlled from the signal cabin is provided and the presence of a train on any section is indicated by the lights in that section being extinguished, the passage of a train may thus be followed on the diagram. This



Electrical Point Operating Mechanism.



Electric Interlocking Machine with illuminated diagram.

is of great assistance to the Signalman, especially where a portion of the Yard is out of view, at night and during fogs. The points are operated by means of electric motors which are controlled by the levers in the interlocking machine.

Precautions are taken to ensure that the points follow the movements of the lever and the stroke of the lever cannot be completed until the points have been locked in the corresponding position.

When the precautions to prevent accidents are considered and the possible number of combination of lever movements is taken into account, it is not surprising to learn that in the installation of a comparatively small interlocking over 100 miles of insulated wire may be used.

The whole of the signalling arrangements are based on the principle that any failure of apparatus should result in the exhibition of STOP signals.

PUNCTUALITY, reliability, service and safety are the corner-stones on which the edifice of successful electric train operation stands four-square to the public. And the greatest of these is safety.

Without safety there can be no confidence and, it follows, no patronage. The fact, therefore, that no fewer than 160,000,000 passenger journeys were made on Melbourne's Electric Railways last year, is ample testimony of their safety, just as the regular daily patronage of hundreds of thousands of people is of their punctuality, reliability and service.

September, 1927.

Issued by the Victorian Railways Commissioners.

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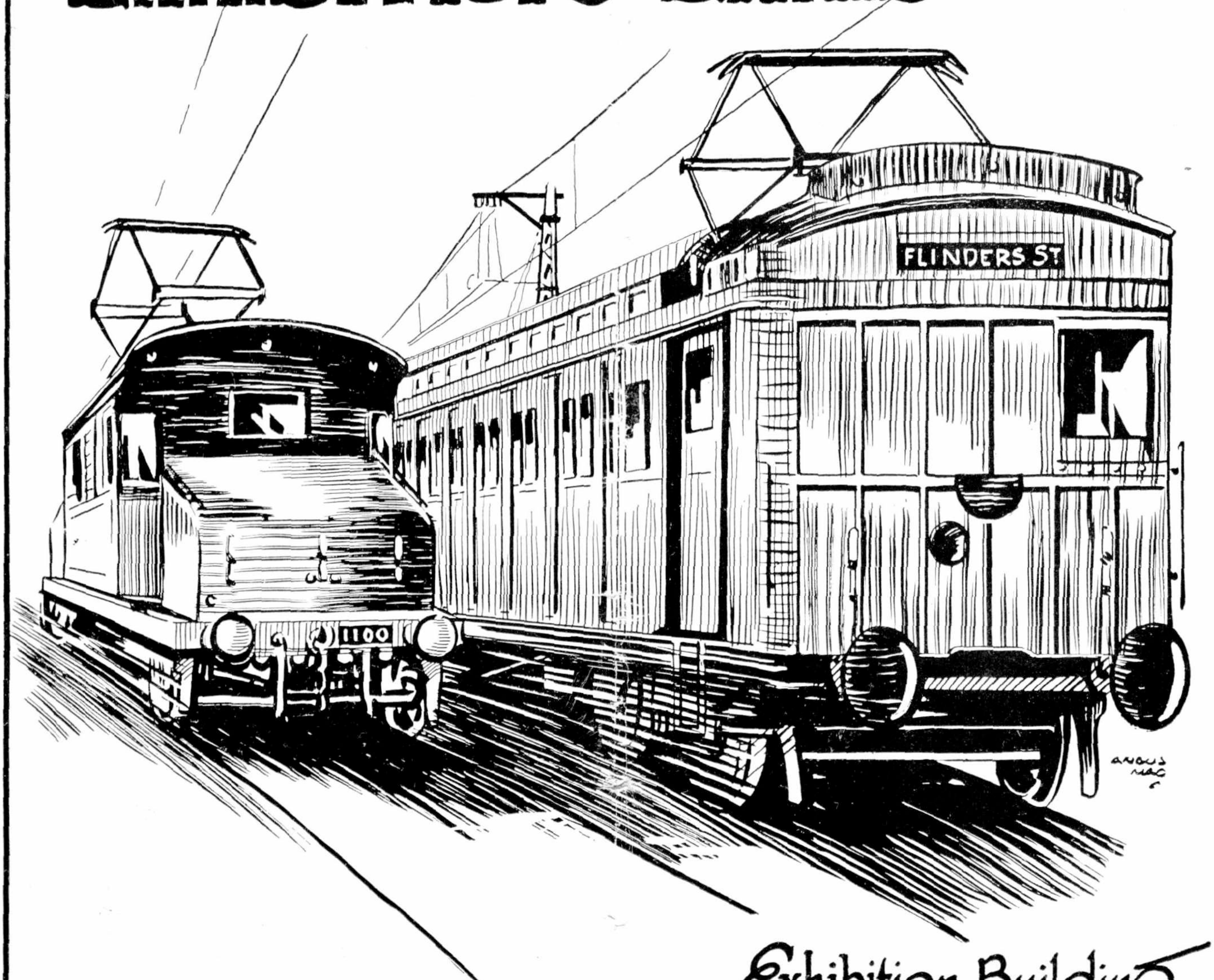

Exhibition Building
Melbourne
Sept 10th — Oct 1st

Facts concerning the Melbourne Suburban Electric Railway System.