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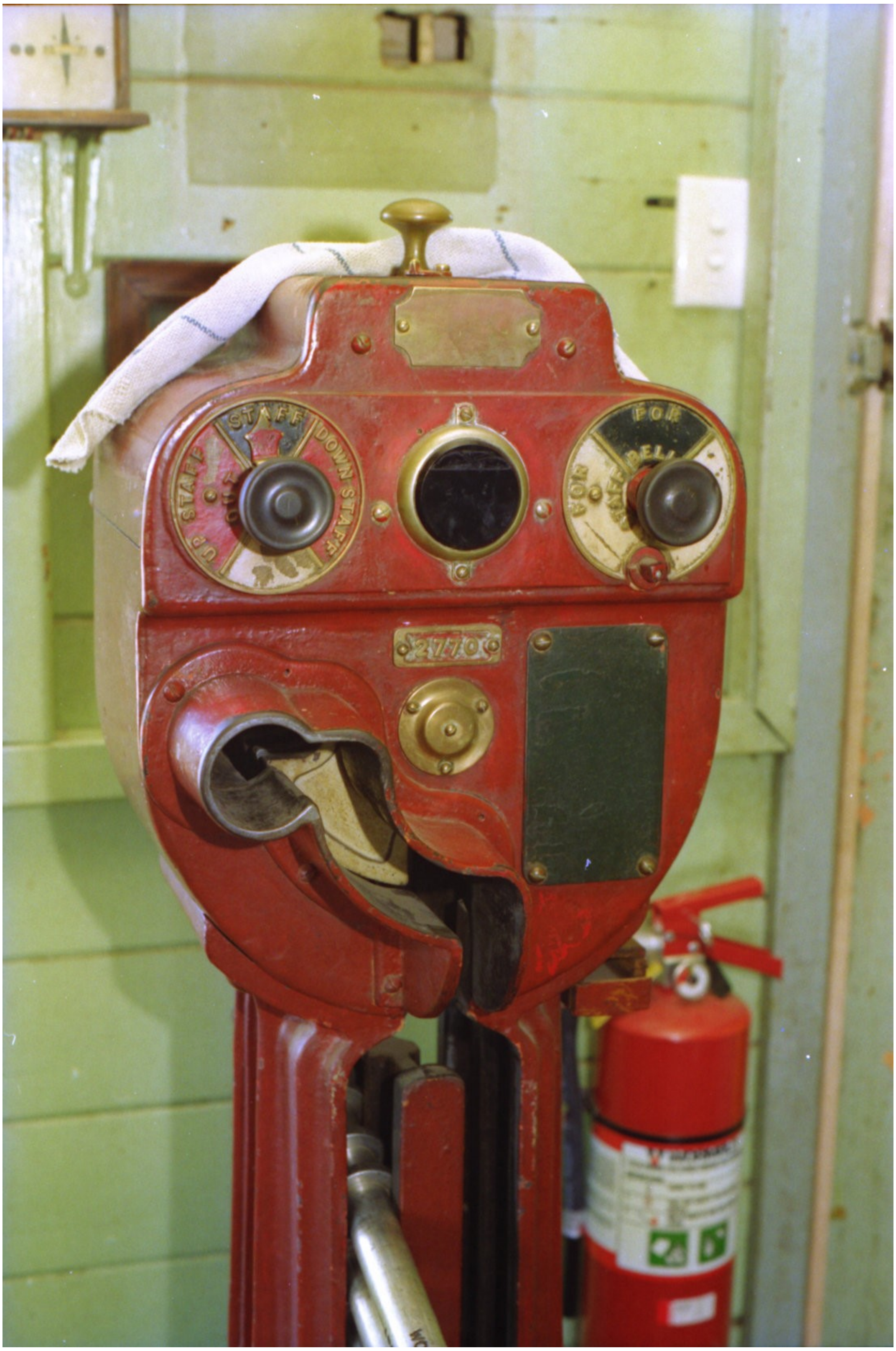

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MINUTES OF MEETING HELD FRIDAY 8 NOVEMBER 2019, AT THE SURREY HILLS NEIGHBOURHOOD CENTRE, 1 BEDFORD AVENUE, SURREY HILLS, VICTORIA

Present: – Glenn Cumming, Graeme Dunn, Chris Gordon, Judy Gordon, Bill Johnston, Keith Lambert, David Langley, Andrew McLean, Roo Richards, Laurie Savage, James Sinclair, Rod Smith, David Stosser and Stuart Turnbull.

Apologies: – Michael Formaini, Neil Lewis, Peter Silva and Andrew Wheatland.

Visitors: – Paul Horder and James Sinclair.

The President, Mr. David Langley, took the chair & opened the meeting at 20:05 hours.

Minutes of the September 2019 Meeting: – Accepted as read. Rod Smith / Andrew McLean. Carried.

Business Arising: – Nil.

Correspondence: – Letter to Wayne Bastin at Metro Trains Melbourne thanking him for granting permission for the signal box tour.

Letter to Keith Lambert thanking him for his assistance on the day of the signal box tour.

Letter to Surrey Hills Neighbourhood Centre with dates for meetings in 2020.

Letter to J B Were authorising the closing of the SRSV bank account.

Letter to Frank Hinde of Wendouree welcoming him to membership of the SRSV.

Laurie Savage / James Sinclair. Carried.

Reports: – Tours. A report on the successful signal box tour in September 2019 was provided. Suggestions are invited for future tours.

General Business: – Glenn Cumming advised the meeting that due to ongoing problems with our existing banking arrangements, SRSV had decided to transfer all our banking to Community Sector Banking, a division of Bendigo Bank.

Glenn Cumming reported that he had been advised that the West Line between Brooklyn – Newport had been out of service for approximately three (3) months because of an Absolute Occupation for the construction of the West Gate road tunnel.

Glenn Cumming reported that all the level crossing equipment at the Calder Highway level crossing at Mittyack on the Kulwin Line had been removed.

Laurie Savage reported that the overpass at Warncoort had been in use for approximately six (6) months but the level crossing and boom barriers have not been removed.

Keith Lambert advised that level crossing removal at Reservoir would be completed as part of a two (2) week occupation commencing Tuesday 3 December 2019. Crossovers will be provided at each end of the new railway station.

(Front cover). The large Electric Staff instrument at Wodonga Coal Sidings controlled broad and standard gauge movements over the Bandiana branch. Broad gauge movements accessed the branch from a junction at the Down end Wodonga yard, and the drivers of the movements received the staff from the Signalman at Wodonga A. Standard gauge movements accessed the branch from Wodonga Coal Sidings box and received a staff from this instrument. This instrument was an intermediate in the Wodonga A – Bandiana section, hence the lack of a bell key and galvometer. Photo Andrew Waugh

Keith Lambert noted that a track machine siding will be provided at Keon Park to replace the siding at Bell.

Chris Gordon advised that the pedestrian crossing at the Up end of Hampton will be closed.

Rod Smith asked about headways on the Dandenong Line. It was noted that headways between Caulfield – Dandenong are now 150 seconds.

James Sinclair asked about testing of High Capacity Metro Trains (HCMT) on the Pakenham Line. Keith Lambert replied that some testing of HCMTs will be done between Berwick – East Pakenham at night under absolute occupation conditions.

Chris Gordon noted that HCMTs will only run anti-clockwise through the Melbourne underground loop because of the requirement to move signals at underground loop stations and this work will only be done at one end of each station.

Chris Gordon reported on plans for signal and interlocking alterations at Caulfield in June 2020.

The track layout at West Footscray for the provision of an additional platform was discussed.

It was reported that the design of the new Metro tunnel will only allow one (1) HCMT in every 'ventilation' section in the tunnel.

Bill Johnston described recent changes on the Victoria Line on London Underground that allow 36 trains per hour for three (3) hours in the AM peak and three (3) hours in the PM peak.

Syllabus Item: – The planned Syllabus Item was to have been the Thirtieth Annual Screening of slides from the collection of the late Stephen McLean, presented by Rod Smith.

However, due to a failure of the projector on the night it was not possible to screen the slides.

The Syllabus Item will be rescheduled for an SRSV meeting in 2020.

Meeting closed at 22:00 hours.

The next meeting will be on Saturday 22 February, 2020 at the Box Hill Miniature Steam Railway Society.

SIGNALLING ALTERATIONS

The following alterations were published in WN 46/19 to WN 52/19, and ETRB A circulars. The alterations have been edited to conserve space. Dates in parenthesis are the dates of publication, which may not be the date of the alterations.

25.11.2019 Armadale – Caulfield (SW 571/19, WN 46)

Between Friday, 22.11., and Monday, 25.11., the following signals were converted to Siemens Style 'L' Mark 2 LED three aspect signal heads:

- Down Caulfield Local: D237, D249, D259, D271, & D285
- Up Caulfield Local: D262, D276, D288, D296, D308, & CFD627
- Down Caulfield Through: F237, F249, F259, F271, & F285
- Up Caulfield Through: F262, F276, F288, F296, F308, & CFD667

(26.11.2019) Book of Rules, Section 36 (SW 203/19, WN 48)

Book of Rules Section 36 (Version 19.04) was reissued. The alterations concern Rule 1 (alterations to Rule 1K, the North Geelong C resignalling (SW 176/19), and the duplication Caroline Springs to Melton (SW 191/19), and Rule 6 (alterations to Rule 6H – remote axle counter resets; North Geelong C (SW 176/19); and the Caroline Springs – Melton duplication (SW 191/19)).

SW 61/19 is cancelled.

(26.11.2019) Batesford – Ballarat East (SW 198/19, WN 48)

Commencing forthwith, permission is granted to issue Train Orders for the Batesford – Ballarat East Train Order Territory to the drivers of Velocity Transfers at Lara.

26.11.2019 Caroline Springs – Parwan Loop (SW 191/19, 202/19, & 204/19, WN 46 & 48)

On Tuesday, 26.11., the duplication between Caroline Springs and Melton was brought into service and Cobblebank station was provided (but not opened until 2.12.). The ATC sections Caroline Springs – Rockbank – Melton were replaced by Up and Down lines worked under the Rules of Automatic Block Signalling Caroline Springs – Melton.

Validation and test trains operated on Tuesday, 26.11.

The following alterations took place.

Caroline Springs

- The existing single line became the Down line and the new Up line was connected to the Down side of Points DPW27.
- New Up Home DPW726 (22.900 km) was provided for moves from the Up line to No 1 Road.

- New Up Dwarf DPW728 (21.712 km) was provided for moves from the Down line to Nos 1 or 2 Roads.
- Down Home DPW730 (from No 2 Road) was provided with a low speed aspect.
- Down Home DPW732 (from No 1 Road) will only apply to moves to the Down line. DPW732 will only display Stop, Clear Medium Speed, or Low Speed Caution. When Down Home DPW239 is at stop, DPW732 will display Low Speed Caution. When a 'Clear Medium Speed' indication is displayed on DPW732, the speed restriction only applies until the train has cleared the points. A notice board is provided at DPW732 to this effect.
- Automatic A245 was redressed as a Home signal and renumbered DPW239.
- The passive speed signs for Up and Down trains at 22.085 km were abolished.
- An active '130' km/h speed sign (Up trains) and a passive '160' km/h speed sign (Down trains) were provided at 22.100 km.

Caroline Springs – Rockbank

- This section was duplicated with the existing single line becoming the Down line and a new Up line being provided.
- Homes DPW246 & RBK270 were provided. Automatic A269 was redressed as a Home signal and renumbered RBK269.
- Hopkins Rd (24.441 km) and Troups Rd (27.819 km) were altered to operation by axle counter equipment. At both crossings, automatic pedestrian gates and electromagnetic emergency gates were provided on the Down side of the crossing.

Rockbank

- No 1 Road became the Down line and No 2 Road the Up Line.
- Homes RBK710, RBK710P, RBK712, RBK712P, RBK726, RBK730 & RBK732 were abolished. The Down notice board for trains from No 2 Road was abolished.
- Home RBK706 was renumbered RBK289. Home RBK296 was provided.
- Leakes Rd (29.571 km) was altered to operation by axle counter equipment. Automatic pedestrian gates and electromagnetic emergency gates were provided on the Down side of the crossing.
- Trains through the Up platform will be restricted to 130 km/h. This speed restriction will commence at 30.720 km, where an active '130' km/h sign will be provided, and end at 24.900 km, where a passive 160 km/h will be provided. The active '130' km/h sign will not be alarmed to the signalling VDU.

Rockbank - Cobblebank

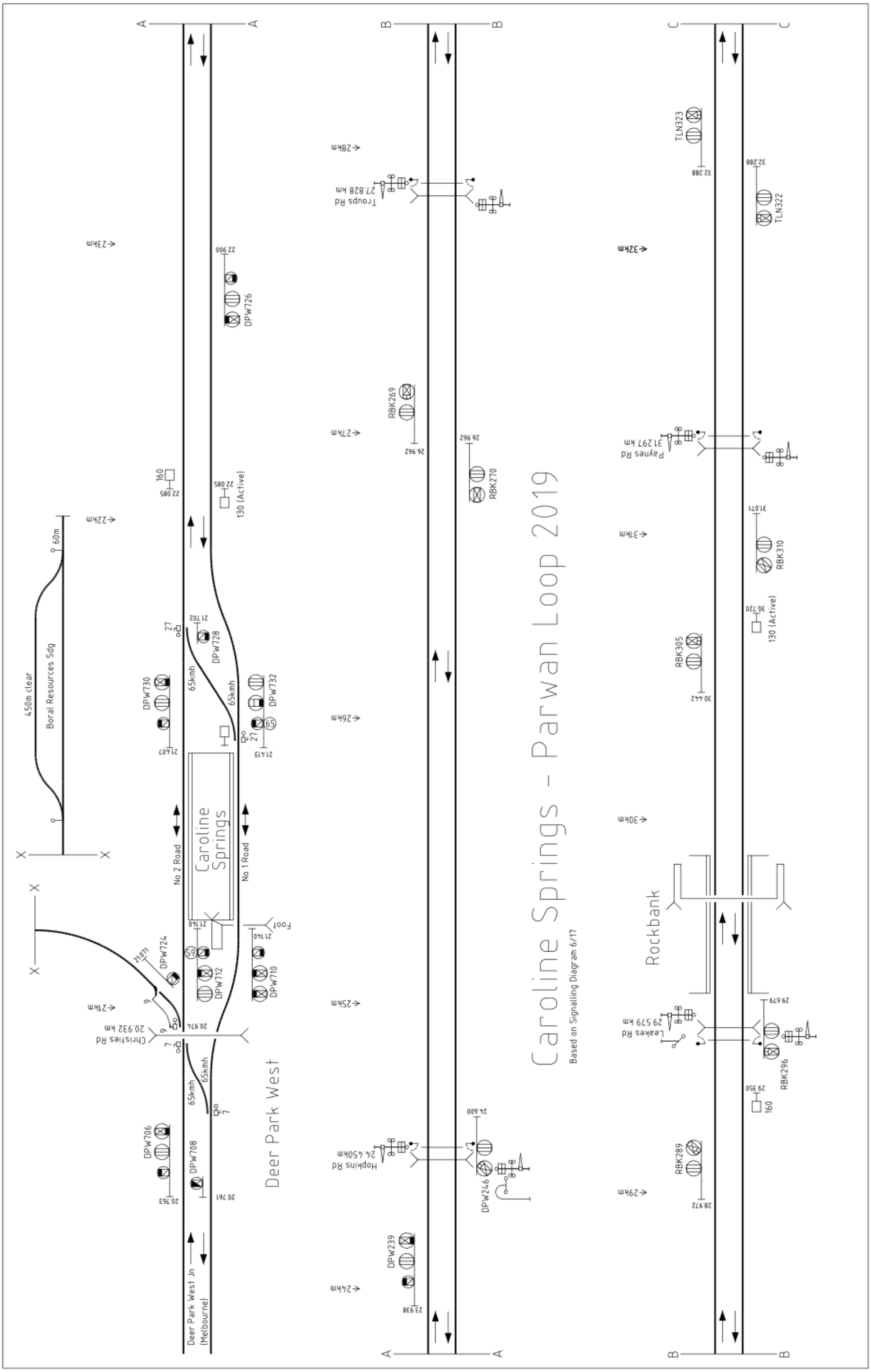
- This section was duplicated with the existing single line becoming the Down line and a new Up line being provided.
- Homes RBK305, RBK310, TLN322, TLN323, TLN335 & TLN336 were provided.
- Paynes Rd (31.288 km), Mt Cottrell Rd (32.933 km), & Ferris Rd (34.603 km) were altered to operation by axle counter equipment. At each crossing, the level crossing predictor signs were abolished and automatic pedestrian gates and electromagnetic emergency gates were provided on the Down side (Paynes Rd & Mt Cottrell Rd) or Up side (Ferris Rd) of the crossing.

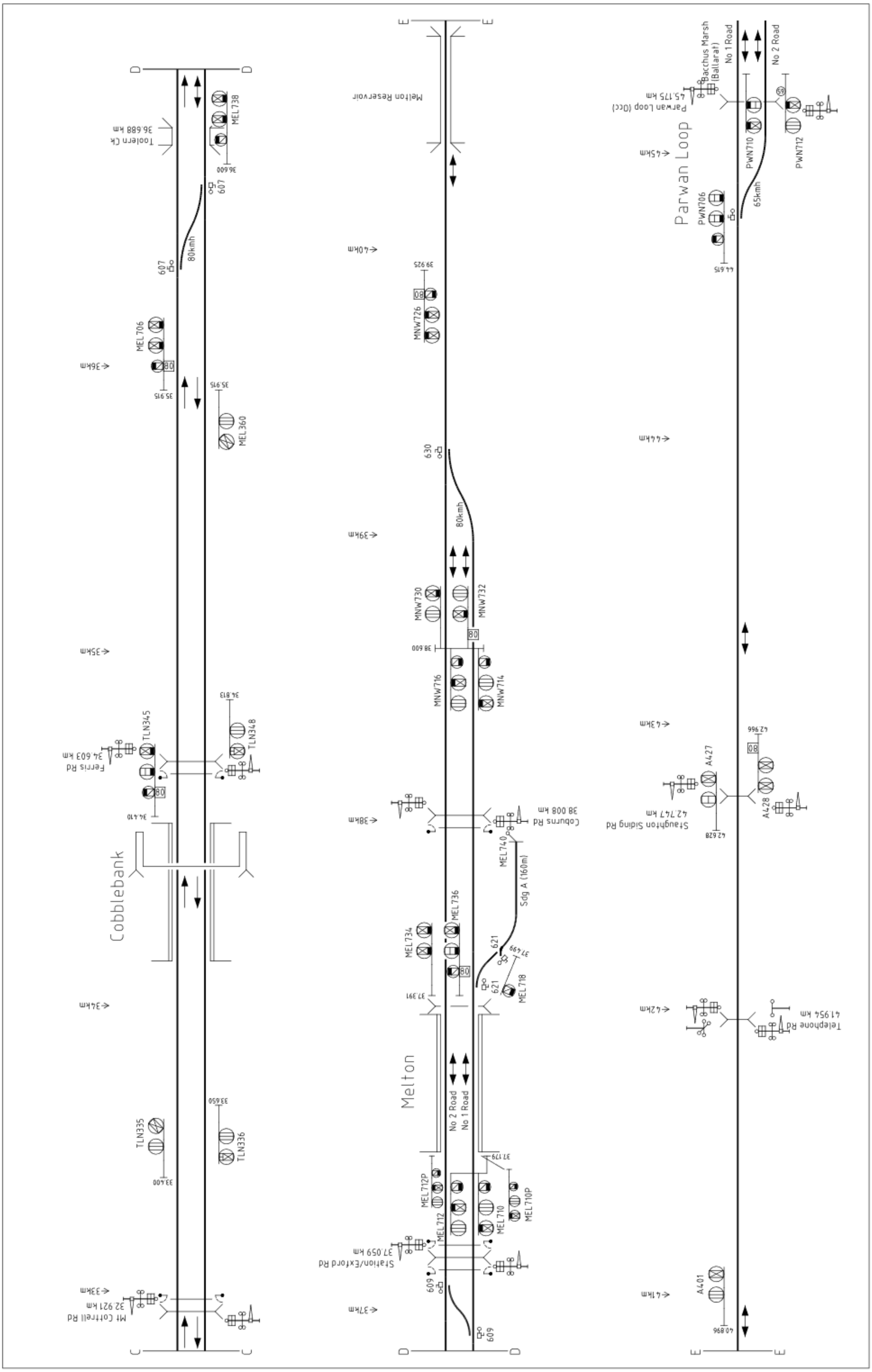
Cobblebank

- Cobblebank (34.275 km) station was brought into use with two 250 metre platforms connected by a footbridge.
- Homes TLN345 & TLN348 were provided.

Melton

- The existing single line from Rockbank became the Down line and the new line became the Up line connected to the former crossing loop.
- Nos 1 and 2 Roads swapped identities; No 1 Road is the former loop and No 2 Road the former main line.
- Home MEL710 was altered to display Normal and Low Speed aspects. Home MEL712 was altered to display Medium and Low Speed aspects. Co-acting signals MEL710P & MEL712P were provided.
- Homes MEL360, MEL706, MEL738, MEL734, MEL736, MNW714, MNW716, MNW730, MNW732, & MNW726 were provided.
- Facing Crossover MEL607 were provided on the Up side of Toolern Creek bridge (39.300 km) on the Down side of Melton. These points are 80 km/h points.
- Trailing Crossover MEL609 was provided on the Up side of Exford Rd to allow movements from No 2 Road to the Up line.


Caroline Springs - Parwan Loop 2019
Based on Signalling Diagram 6/17
Deer Park West Jn (Melbourne)
Deer Park West
Caroline Springs
No 2 Road
No 1 Road
Boral Resources Sdg
450m clear
Christies Rd 20.932 km
Hopkins Rd 24.450km
Troups Rd 27.828 km
Rockbank
Leakes Rd 29.579 km
Paynes Rd 31.297 km
DPW706
DPW708
DPW710
DPW712
DPW724
DPW726
DPW728
DPW730
DPW732
DPW239
DPW246
RBK269
RBK270
RBK289
RBK296
RBK305
RBK310
TLN322
TLN323
130 (Active)
160
65kmh


Cobblebank
Melton
Parwan Loop
Melton Reservoir
Toolern Ck 36.688 km
Ferris Rd 34.603 km
Mt Cottrell Rd 32.921 km
Station/Exford Rd 37.059 km
Coburns Rd 38.008 km
Sdg A (160m)
Telephone Rd 41.954 km
Staughton Siding Rd 42.747 km
Parwan Loop (Occ) 45.175 km
Bacchus Marsh (Ballarat)
No 1 Road
No 2 Road

- A 160 metre siding was provided leading from No 1 Road at the Down end of the platform. Points MEL621 were provided leading to the siding, and Catch MEL621 was provided to provide roll-out protection. A friction Buffer Stop and fixed red signal MEL740 were provided at the end of the siding. Points MEL621 auto-normalise.
- Points MEL630 were provided on the Up side of Melton Weir at the end of the single line. These are 80 km/h points.
- Exford Road (37.059 km) was altered to be operated with axle counter equipment. Automatic pedestrian gates and electromagnetic emergency gates were provided on the Up side of the crossing. The existing mechanical locks for the remaining three gates were retained.
- Coburns Road (38.008 km) was altered to be operated with axle counter equipment. Automatic pedestrian gates and electromagnetic emergency gates were provided on the Up (No 1 Rd) side of the crossing. The existing mechanical locks were retained for the Down (No 2 Rd) side.

Melton – Parwan

- Automatic A400 was abolished.
- Automatics A401, A427, & A428 were redressed as Home signals. They will retain their numbers, and the aspects shown by A401 & A427 were unaltered. Home A428 was altered to display Normal and Medium Speed indications with an illuminated '80' indicator.

Parwan Loop

- Up Home PWN710 was altered to display Reduce to Medium Speed.

The intermediate Home signals between Caroline Springs and Melton can be replaced and blocked from the Corridor Signalling VDU. Where the intermediate Home signals are in the approach to an active level crossing, the Home signal is interlocked with the active level crossing.

The intermediate Home signals between Melton and Parwan Loop are not manually controlled.

TPWS was provided on all Home signals between Caroline Springs and Parwan Loop.

All train detection between Caroline Springs and 40.289 km (on the Up side of Melton Weir) is by axle counters.

Diagrams 70/19 (Ardeer – Rockbank), 68/19 (Melton – Parwan Loop), 104/19 (Bacchus Marsh – Rowsley) & 114/19 (Bungaree) replaced 36/19, 38/19, 40/19 & 12/19 respectively.

Operating Procedure 67 (Deer Park West – Wendouree Defective Signals) was reissued. SW 51/19 was cancelled.

27.11.2019 Cardinia Road (SW 609/19, WN 49)

On Wednesday, 27.11., the pedestrian crossing on the Up side of Cardinia Road was closed to public access. The pedestrian gates and audible warning device will remain active and the Up side crossing will be used by project staff.

02.12.2019 Cobblebank (Regional Rail Revival)

On Monday, 2.12., the station was opened for passenger traffic. This was preceded by the usual 'community day'.

02.12.2019 Bacchus Marsh – Ballarat (SW 196/19, WN 47)

Between Saturday, 9.11., and Monday, 2.12., the following alterations took place:

Bacchus Marsh

- Platform coping stones were installed on the new platform on No 2 Road.
- Nos 1 & 2 Roads were slued so that the track spacing was compliant with requirements
- The boom barriers at Parwan Rd (51.214 km) and Osborne St (52.312 km) were relocated to make space for a second track.
- The single line between Parwan Rd and Osborne St was realigned.

Bacchus Marsh – Ballan

- New signal gantries were provided at 51.409 km, 52.093 km, 52.501 km, 52.737 km, & 53.276 km.

Ballan

- A new signal mast was provided at 78.532 km

Millbrook

- New signal gantries were provided at 96.120 km, 96.990 km, 97.330 km, & 98.494 km.
- New signal masts were provided at 94.470 km, 99.680 km, 100.264 km, 101.362 km.

Amend Diagrams 40/19 (Bacchus Marsh – Rowsley), 48/19 (Ballan – Gordon), & 12/19 (Bungaree).

02.12.2019 Croxton – Thornbury (SW 583/19, WN 48)

Between Friday, 29.11., and Monday, 2.12., the boom barrier mechanisms at Woolton Ave and Normanby Ave were replaced by Western Cullen Hayes 3593-E type mechanisms.

03.12.2019 North Shore (SW 214/19, WN 50)

On Tuesday, 3.12., Points COR35 (East Line) were booked back into use. SW 180/19 is cancelled.

03.12.2019 North Geelong C (SW 214/19, WN 50)

On Tuesday, 3.12., an unspecified alteration to Gates CGL45 occurred. Indications and controls for the gates are provided on the signalling VDU, but the gates remain secured open. SW 180/19 is cancelled.

07.12.2019 Cheltenham (SW 585/19, WN 48)

On Saturday, 7.12., the back platform road was abolished. Crossover 7 and Points 11 were secured normal. Up Home 10 and the buffer light in the back platform road were removed. Track feed 10ATF was decommissioned.

08.12.2019 Southern Cross (SW 212/19, WN 49)

On Sunday, 8.12., a Drivers Indicator SST593DI was provided on Platform 7B, 5 metres in advance of Home SST593. This indicator takes the form of stencil showing a lower quadrant semaphore home arm at 'clear' which is illuminated when SST593 is at proceed. The Drivers Indicator is not a fixed signal. It will be extinguished as soon as the leading wheel passes the block joint at Home SST593.

Diagram 74/19 (Southern Cross V/Line Passenger Lines) replaced 116/14.

(10.12.2019) Brooklyn (SW 216/19, WN 50)

The flashing light mast at Somerville Rd (15.497 km) on the lead to the Apex Siding has been restored to use. SW 81/19 is cancelled.

11.12.2019 Warncoort (SW 220/19, WN 51)

On Wednesday, 11.12., the Princes Highway level crossing (139.906 km) was replaced by a road overpass at 139.724 km (outbound) and 139.799 km (inbound). The boom barriers, signage, track circuits, and Active Advance Warning Signs have been removed.

Diagram 32/19 (Birregurra – Colac) replaced 54/17.

13.12.2019 Dimboola – Rainbow (SW 221/19, WN 52)

On Friday, 13.12., the Dimboola – Rainbow corridor was booked out of service due to sleeper condition. Baulks were provided at the 'Commence'/'End' Train Order Working Boards at Dimboola. The Absolute Occupation between Dimboola and Rainbow (SW 356/19) was cancelled.

13.12.2019 Epping (SW 607/19, WN 49)

On Friday, 13.12., a system changeover switch was provided at Epping to allow the new EBILock control interface to drive the existing signalling assets within the Epping – South Morang interlocking. This is to allow testing of the CBTC signalling. No change was made to the existing Epping Smartlock or TCMS, and the changeover switch will only be used when authorised as part of the CBTC trial.

Down Home EPP126 was equipped with working A and B arms, and Up Home EPP127 was equipped with a working B arm. All of these new arms are only used under CBTC testing.

14.12.2019 Wendouree (SW 217/19, WN 50)

Between Saturday, 7.12., and Saturday, 14.7., a new dead end platform track was provided on the Down side of the line opposite the platform.

Points 609W were provided in the single line on the Down side of Gillies St (123.113 km). The points face in Down direction and are equipped with a dual control point machine. The points are secured normal.

The buffer stop on the new track is at 123.517 km.

Home 105 was relocated 51 metres further out and is now 71 metres on the Down side of the platform.

The pedestrian crossing on the Down side of Gillies St, and the boom barriers, were modified to accommodate the additional track.

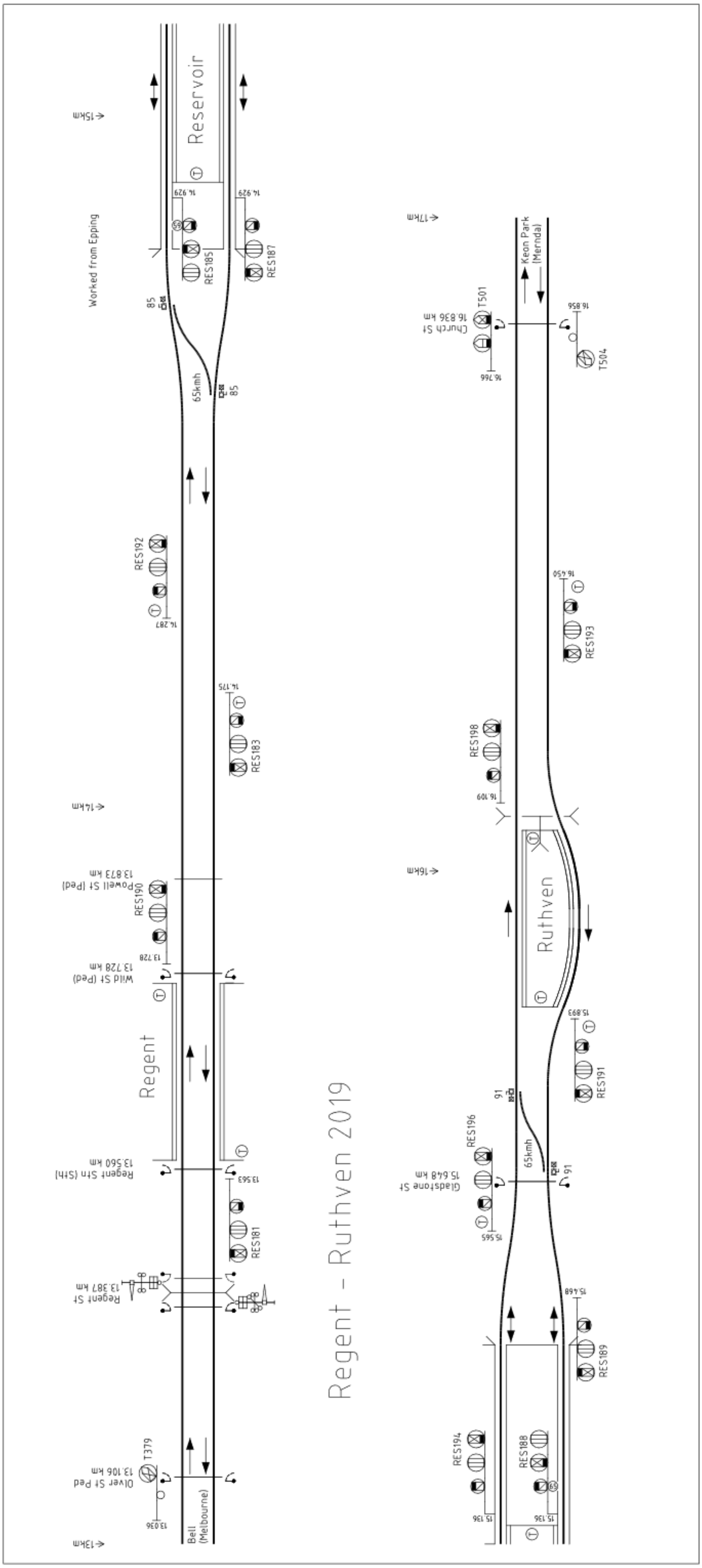
Amend Diagram 66/17 (Wendouree – Beaufort).

16.12.2019 Regent – Reservoir – Ruthven (SW 600/19, SWP15/19, WN 49)

On Monday, 16.12., the new viaduct at Reservoir was brought into use. The viaduct is 539 metres long and extends from 14.852 km to 15.391 km. A new station at Reservoir (15.034 km) was opened for use with an island platform 163 metres long.

The following alterations took effect:

- Automatics T391, T394, T408, T409, T421, T424, T431, T440, T440P, T445, T445P, T456, T457, T470, T471, T486, & T487 were abolished.
- Reservoir station pedestrian crossing was abolished.
- Homes RES181, RES183, RES185, RES187, RES188, RES189, RES190, RES191, RES192, RES193, RES194, RES196, & RES198 were provided. Unlike the Dandenong 'skyrail' sections all of the new signals are controlled Home signals and each can display a low speed aspect.
- Terminating facilities were provided at Reservoir. Trailing Crossover 85 was provided at the Up end of the viaduct and trailing Crossover 91 at the Down end. All points use in-bearer point machines.


Regent - Ruthven 2019
Worked from Epping
Reservoir
Regent
Ruthven
Bell (Melbourne)
Keon Park (Mernda)
65kmh
RES185
RES187
RES192
RES183
RES190
RES181
RES193
RES198
RES191
RES196
RES189
RES194
RES188
T379
T501
T504
Powell St (Ped) 13.873 km
Wild St (Ped) 13.728 km
Regent Stn (Sth) 13.560 km
Regent St 13.387 km
Oliver St Ped 13.106 km
Church St 16.836 km
Gladstone St 15.648 km

- Axle counter detection was installed on the Down line between RES190 (13.762 km) at Wild St pedestrian crossing and RES193 (16.460 km) and on the Up line between 16.628 km (228 metres in the rear of Post T504) and 13.743 km (Post RES190 at Wild St pedestrian crossing). The axle counters are provided with supervisory reset, point supervisory reset, next train reset, occupation reset, and full counting head control functionality. Automatic pedestrian gates with electromagnetic emergency gates were provided at the passive pedestrian crossing at Gladstone St (15.648 km).
- Reservoir interlocking is worked from Epping signal box. The Epping Sigview and Metrol TCMS were updated to display the new signalling at Reservoir. The data in the Epping Smartlock SMP400GP was updated to include the new Reservoir VIXL

Diagram 37/19 (Northcote – Reservoir) & 39/19 (Ruthven – Epping) replaced 7/19 & 19/19 respectively.

Clifton Hill Group Operating Procedure 1 was replaced by the following Operation Procedures 1 (Bell to Mernda – Control of Rail Traffic Movements); 1.1 (Bell); 1.2 (Reservoir); 1.3 (Keon Park – Lalor); 1.4 (Epping); 1.5 (South Morang); and 1.6 (Mernda).

17.12.2019 **Charlton** **(TON 349/19, WN 52)**

On Tuesday, 17.12., the siding (318.085 km to 318.947 km) was booked out of service due to sleeper condition. The main line points were secured normal.

19.12.2019 **Kerang** **(SW 223/19, WN 52)**

On Thursday, 19.12., No 2 Road and all yard sidings were booked out of use due to poor condition of timber turnout bearers at several yard points. The main line points are not affected. Points C and H were secured normal.

Kerang will be available for follow-on movements and will be an Intermediate Train Order Station.

20.12.2019 **Donnybrook** **(SW 222/19, WN 52)**

On Friday, 20.12., the Up platform extension (to 160 metres) was brought into use.

22.12.2019 **Ultima** **(TON 350/19, WN 52)**

On Sunday, 22.12., the Up end points were restored to use. The siding is available for use between the Up end points and the baulks at the Down end of the siding. The Down end points remain booked out of service (TON 111/17). TON 123/19 is cancelled.

23.12.2019 **Wallan** **(SW 222/19, WN 52)**

On Monday, 23.12., the Up platform extension (to 160 metres) was brought into use.

13.01.2020 **Caulfield** **(SW 636/19, WN 52)**

On Monday, 13.1., the existing computer based interlocking (an SSI) was replaced by a two new CBI interlockings - one each to control the Frankston and Dandenong sides. The Dandenong platforms were extended and the locations of a number of signals were altered. Note that the track layout was unaltered.

The following alterations took effect:

- The SSI was replaced by a Westrace MKII interlocking to control the Caulfield Local Lines and a WestLock interlocking to control the Caulfield Through Lines.
- The SigView Train Control Panel was replaced by a TCMS signal control panel.
- Automatic D307 was replaced by D309 (10.925 km)
- Dwarf CFD711 was abolished.
- Automatic F307 was renumbered CFD740
- Platform 3 was extended at the Up end to 175 metres, and Platform 4 at the Up end to 172 metres.
- The following Home signals were replaced by new masts: CFD704 (3 metres in the Up direction); CFD707 (26 metres Up); CFD708 (4 metres Down); CFD724 (6 metres Up); CFD727 (28 metres Up); CFD729 (2 metres Up); CFD744 (4 metres Up); and CFD764 (6 metres Up).
- The following Home signals were equipped with arrow type route indicators: CFD704; CFD707; CFD727; CFD744; CFD747; & CFD767.
- TPWS was provided on the following signals (all TSS, except where marked OSS which indicates TSS&OSS): CFD627, CFD702 (OSS), CFD704, CFD707, CFD708, CFD712, CFD724, CFD727, CFD728, CFD729 (OSS), CFD733 (OSS), CFD735, CFD740, CFD742, CFD744 (OSS), CFD747, CFD748, CFD765, CFD767, CFD768, CFD733, D295, D296, D309, & D308.
- Speed proving train stops were provided on the Down Caulfield Local line 87 metres on the approach side to Home CFD704, and on the Up Dandenong line 41 metres on the approach side to Home CFD733 & 14 metres on the approach side to Home CFD729.
- The diverging speed through the turnouts at the Up end has been restricted to 25 km/h and five 'diverge speed boards' have been provided.

Diagram 51/19 (Caulfield) has replaced 79/18.

End£

AUTOMATIC BLOCK SIGNALING ON THE BOSTON ELEVATED

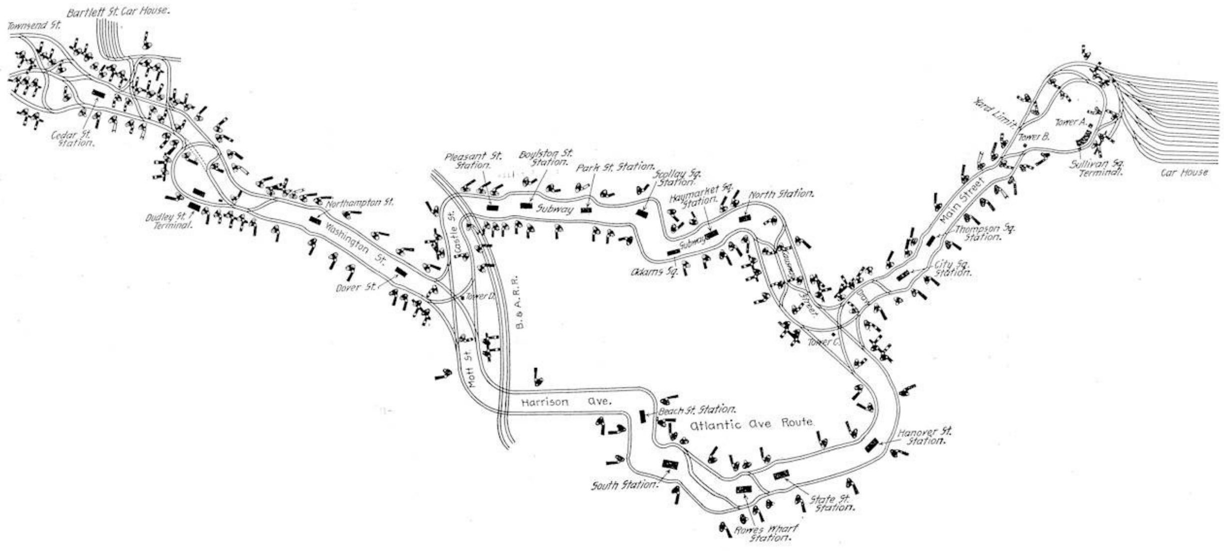


Chart for Instructing Trainmen of the Boston Elevated Railroad.

The Boston Elevated, opened in 1901, was the prototype of all modern rapid transit signalling. The El used electric multiple unit trains, and included the first section of underground railway in the US (the underground section was a portion of the upper section of the loop in the chart reproduced on this page).

For perhaps both of these reasons, the Boston Elevated was also the first rapid transit line to have a modern signalling system – automatic signalling worked by track circuits, including train stops with overlaps. It is true that the Liverpool Overhead Railway, opened in January 1893, included automatic signalling, but this detected trains by means of a trip arm mounted on the roof of the rear car of each train set. The small number of London underground lines at the time were all worked by manually operated lock & block working. The Chicago and New York elevated lines generally used no block working what-so-ever, the intensive train service was operated purely by line of sight, although junctions were interlocked and there had been an attempt to use a mechanical automatic signal system on one or two lines, and at locations with particularly bad sighting.

By 1901, automatic signalling and track circuits were routinely used on steam railways in the US. The problem of applying track circuits on electric railways, however, had not previously been solved. The conventional DC track circuit on a steam railway was powered by two gravity (zinc/copper with copper sulphate as the electrolyte) batteries giving track voltage of around 1 volt. The track relays were wound to around 5 ohms, and the operating currents were miniscule. It was not, of course, possible to use this technology over tracks that were also carrying DC traction return.

Signalling innovations on the Boston Elevated included:

- *Single rail track circuits*
- *A unique polarized DC track relay designed not to respond to traction current*
- *Train stops at each Home signal and an associated overlap*

This contemporary article describing the signalling, particularly the traction immune DC track circuit, was published in the Railroad Gazette of 11 October 1901 (p692-4) and largely draws on a Union Switch & Signal Company Bulletin. Subheadings have been added to improve the clarity.

The DC track circuit described in this article was a dead end. As far as is known, only one other installation was made; on the London Underground. The American Yerkes syndicate adopted US electrification technology on the Underground lines, and the Boston Elevated signalling system was adopted. The Ealing & South Harrow line was used as a test-bed for the proposed electrification technology, and this opened in 1903. Minor redesign occurred and the three original Yerkes tubes – the Bakerloo (1906), the Piccadilly (1906), and the Hampstead (1907) – all used a minor variation of the Boston system. The DC track circuits apparently worked successfully for many years on these lines.

It is interesting that features of the Boston Elevated signalling system were imported into the London Underground and are still evident today – such as the use of two position signals with full overlap but usually without a preceding distant.

However, the DC track circuit technology became obsolete with the development of the AC track circuit around 1902. The first trial AC track circuit installation (by US&S) was on the North Shore Railroad (California) around May 1903, and a very large scale installation was made in late 1904 on the first New York subway.

A major problem with the DC track circuit described here was that it was possible for the traction current to pick-up the track relay with a train in the section under fault conditions. The DC track circuit was based on the idea that the traction current had a specific direction – polarity – in the track as the current always flowed back to the substation. However, if a substation had failed and the track was being fed from an adjacent substation, the direction of traction current could be reversed.

Readers of the Railroad Gazette are already well acquainted with the general features of the Boston Elevated Railroad, from numerous illustrated descriptions which we have given; and the signaling has been briefly described in connection with the diagrams which were published April 19, page 269, and June 28, page 462.

Additional details of the signaling are given in a bulletin which the makers, the Union Switch & Signal Company are now issuing; and from this bulletin we are permitted to copy the following paragraphs:

Tracks circuits and electrification

Electric railway engineers are loath to surrender any portion of their installation to block signal purposes; but rail circuits[1], as employed in automatic block signaling, require the exclusive use, in an electrical sense of at least one rail of each track governed by the signals. Hence, electric railways having no other returns for their propulsion current than the running rails, would, to introduce the automatic rail circuit for signal purposes, virtually double the resistance of their power returns in surrendering the one rail of each track required for this purpose[2].

Such a procedure could not to be countenanced under ordinary conditions, since the already high resistance of the rail returns is a potent factor in preventing high economy in power distribution on most electric railways. Furthermore, the drop along such a return system must necessarily be great where traffic is heavy, and consequently measurements from terminal to terminal of a given length of track, constituting any one of a series of block sections, show an influence resulting from this general drop where one of the rails is common to the return of the propulsion system and to the rail circuit of the block system, which is the case where such a block system is installed on an electric railway of the usual construction.

This influence in the return rail naturally varies with the volume of traffic on the line, and, at its maximum, would be fatal to the successful control of automatic signals by the rail circuit method where the block sections are required of considerable length.

Serious consequences might also result to the instruments[3] of the block apparatus of such an equipment should imperfect contact occur between rails and car wheels. This would cause a sudden rise of E.M.F.[4] in the block rail far above that of the block signal apparatus did the imperfect contact occur upon the return rail only[5]. Ordinary instruments would be destroyed or badly damaged by the abnormal current thus forced through them, and a false signal indication might also be displayed at the entrance of a block so affected.

Altogether, the problem was not attractive originally, and, as applied to usual conditions, still remains so. Conditions presented themselves on the Boston Elevated lines, however, which greatly relieved the situation as usually presented, and encouraged an attempt to install on that road what has since proved to be the first and only automatic block signal system for electric lines that insures absolute and continuous control of the block signal by all pairs or any pair of wheels of a train within the block it governs.

Owing to the great capacity of the elevated structure as a return conductor one rail of each track was freely surrendered to block purposes[6], and at a relatively small loss in the electric efficiency of the power system. Owing to this great capacity, also, the drop influence within the block section became less serious in its effect upon the block apparatus. The frequent service of the elevated system made short block sections imperative, producing another favourable condition by this reducing the drop influence.

The remaining problem, that of preventing the dangerous operation of the block signal, or the destruction of its controlling mechanism, either of which seem reasonably certain to occur in the event of the propulsion current finding a return through the block rail and instruments, was next solved most effectively.

First, the block instruments were made of an electrical capacity equal to the emergency of meeting the full E.M.F. of the propulsion system at their terminals without injury. Second, these devices were polarized, so as to respond only to currents of a fixed direction. These currents are counter to those that might, in the emergency referred to, flow through the instruments from the propulsion system, and the latter could therefore cause no serious operation of the signals.

Electro-pneumatic vs electric signals

One of the most valuable features of the Westinghouse electro-pneumatic system is the ease and simplicity with which the signals are controlled automatically by trains[7]. It may seem inconsistent to use compressed air on a railroad where electric power is at hand throughout the length of

[1] 'Rail circuits' are an early name for track circuits.

[2] In a normal electrification both rails are available to carry the traction current return. If one rail is dedicated to the single rail track circuit, all of the traction current must pass through the remaining rail, which means the resistance is doubled.

[3] Track relays

[4] Electro-Motive Force – i.e. voltage.

[5] If electrical contact was lost between the wheel on the traction return rail and the rail, the traction current would pass through the wheel on the block rail and then the coils of the track relay to the traction return rail – at best destroying the relay and at worst causing it to pick-up. If the railway was really lucky, the excessive current would pick-up the track relay, fuse the contact points, and destroy the coils.

[6] The traction return rail was bonded to the steel elevated structure to provide additional return capacity. In this context, note that the London Underground used a negative conductor rail to achieve the same end – another feature still in use today.

[7] The Union Switch & Signal Company preferred to sell its electro-pneumatic (EP) signalling system, even to operate automatic signals not associated with interlockings. In this section of the bulletin they are justifying the EP system over the use of electric signal motors offered by their competitors – particularly the Hall Company. The basic argument is that in the EP system the relays only have to pass the small amount of energy necessary to operate the pneumatic valves. The actual work of moving the lower quadrant semaphore, its counterweight, any ice on the parts, and the train stop is performed by the air pressure. In a straight electric system much greater electrical power is required to be passed which quickly destroys the relay contacts.

the line; but this use is not surprising to those who know how promptly and satisfactorily enormous energies can be controlled by the simple valves of the Westinghouse system; nor to those who realize how much more readily and safely the small electric energy required for the valve magnets of air cylinders can be controlled than can the vastly greater energy that would be consumed by electric motors, were these applied to the work of the cylinders.

With the electro-pneumatic block signal, owing to the extremely small volume (0.025 ampere) and low E.M.F. (10 volts) of the current employed to operate it, no serious sparking or burning of relay contacts occurs, whereas with an electrical device of similar character these could not be avoided and frequent attention to and renewal of contacts would become necessary. On the Boston Elevated each automatic signal is equipped with an attachment to setting the air-brakes of trains should they attempt to pass the signal while in the danger position. This attachment imposes some extra service on the signal operating power[1]. This additional duty, with the normal friction of the parts and the abnormal friction due to snow, sleet and ice demands that the signal be well counterweighted toward the danger position[2], and hence an operating device that is capable of overcoming this weight. The electro-pneumatic semaphore signal, of which thousands are in use throughout the country, employs a cylinder 3 in. in diam., having a piston stroke of 4 in. The air pressure employed ranges from 60 to 80 lbs per sq. in., according to conditions, the average being 70lbs. The cylinder develops an energy per stroke of (70 x 7 x 1/3) 163.3 foot pounds. While this energy may be in excess of that required under the most adverse ordinary conditions (which it was designed to meet) the unusual conditions on the Boston Elevated line render it very desirable. Here the signal cylinder must meet the additional load represented by the rotation of the trainstop shaft, which is augmented by the fact that the counterweight of the signal must be ample to overcome the additional influence of a severe winter upon the shafts, bearings and connections. The movement of an electro-pneumatic signal from danger to safety is accomplished in two seconds, representing approximately 1/7 h.p. Electrically this is equivalent to about 106 watts, and if an electric motor were substituted for the electro-pneumatic cylinder, it must necessarily consume this energy in operating the signal in the time specified.

The contacts of track circuit relays are necessarily of a relatively delicate character, owing to the comparatively feeble energy that is, under many conditions, available for operating them, and as the pressure on these contacts varies greatly with this energy, the control of a 106 watt circuit by them is not practicable without an unwarranted amount of attention and renewals thereto. The difference between 106 watts and ¼ of a watt is, therefore the difference between the electrical energy employed by a purely electric signal, equal in capacity to the electro-pneumatic signal, and the electrical energy employed by the latter, The advantage this difference gives to the electro-pneumatic signal on the elevated lines can scarcely be overestimated.

Track circuit power supply

Upon the elevated structure during very dry weather, and in the subway where similar conditions exists at all times, the resistance between the block rail and that one common to the block and propulsion systems, is much greater than the resistance between these rails on the structure during wet weather[3]. This is a natural feature that belongs to track circuits in general. Owing to this variable resistance, which constitutes a shunt upon the relay of the block section, the source of electrical energy provided for the operation of track circuits must vary in output with the weather conditions[4]. It is also essential that some resistance exist within the generator[5], or be inserted between it and the block rail, in order that when the relay is completely shunted by the wheels and axles of a train the generator will not force an excessive current thought the short circuit thus formed, and incur an extravagant waste of energy at a time when no energy is required in the block affected.

While some waste of energy is at such time unavoidable, the limit of economy in each section is determined by the minimum resistance existing between the rails at any time when the block is unoccupied. This resistance in long sections has, in a few instances been found to be as low as 3 ohms. Sections upon which measurements were made to determine this fact showed later a resistance of 20 ohms, under a dryer condition of the ties.

It is usually the custom to employ ordinary gravity batteries[6] for supplying current to track circuits, first, on account of their simplicity and cheapness, and second, because they have within themselves the necessary resistance for holding in check the excessive waste of current which would otherwise result when they were short circuited by trains or from other causes. To substitute for gravity batteries in this service any type of battery or other generator whose internal resistance is negligibly low, would, to obtain equal results, necessitate the interposition of a resistance between them and the rails, equal to the internal resistance of the gravity type.

When two or more track circuits are to be operated by a common generator, this resistance, instead of being common to all, must be inserted as separate units in each circuit so operated, otherwise a change occurring in the

[1] The train stops on the Boston Elevated were worked by the same cylinder that operated the semaphore.

[2] The semaphores work in the lower quadrant and hence require a substantial counterweight to ensure they go to danger. Upper quadrant semaphores were still rare in the US at this time.

[3] Ballast leakage

[4] In practice, track circuits were not routinely adjusted for changes in ballast leakage.

[5] Generator is being used here in a general sense of 'source of current'. It was usually a battery in 1901, though some railways were beginning to install small petrol generators which used cables to distribute power to storage batteries at signal locations.

[6] Using zinc and copper electrodes in a copper sulphate solution. These have a relatively high internal resistance which limited the current when the terminals were short circuited. Other types of batteries did not have such a high internal resistance, and the use of an electrical distribution network certainly did not. These required the use of separate track resistances between the power source and the rails.

conditions of any one circuit would cause a variation or failure in all others, which, is, naturally, as undesirable in track circuit work as it would be in electric lighting, where a resistance common to all lamps on a multiple light system would cause the illuminating power of those burning to vary whenever a change in their number occurred.

In a number of installations made by this company in years past track circuits have operated in multiple from a single generator with eminent success. A comparatively recent installation of electro-pneumatic signals on the four tracks of the Philadelphia Division of the Pennsylvania Railroad is a most notable example of this method. There a single cell of storage battery, located in the base of each four-arm bracket signal, not only supplies current for operating the air valves of the four signals, but also for the two adjacent track circuits terminating thereat. All of these batteries are charged in series from a common 500-volt generator through a No 6 copper line 20 miles long.

Prior to the completion of the block signals on the Boston Elevated the use of dynamos for the direct operation of all track circuits and all signals had not been undertaken. As a rule, signal experts on steam railroads do not favour a signal system which depends upon the continuous motion of a generator for its operation and to introduce storage batteries for the purpose of avoiding total derangement should the generator become disabled, while eliminating its worst feature, adds materially to its cost.

On the Boston Elevated, however, as on most electrically operated roads, the fact that the signals depend on the continuous action of electric generators is not a serious matter, because these are here operated directly from the main feed wires of the propulsion system, and, any interruption of the energy in these mains would not only derange the signal system, but would stop the cars as well.

Ordinarily, relays of track circuits are made to respond to currents of extremely low potential, and are for this reason of low resistance and of diminutive proportions. A resistance of 5 ohms is common practice, though this is decreased to 2 ohms and increased to 12 ohms where extreme conditions occur. A potential difference of ¼ volt at the magnet terminals of these relays will ordinarily operate them[1], and rare indeed are the conditions which permit of one volt being maintained thereat where usual practices are followed.

The drop influence in the return rail of the Boston Elevated, previously referred to, prohibited completely the use of relays so responsive to low E.M.F. at their terminals, and compelled the use of a type that could not be operated by any potential difference that might be created at its terminals from this influence[2].

After a series of tests conducted during the erection of the signals, and while practice trains were being run for the instruction of trainmen it was decided that any relay responding to an E.M.F. of 2.5 volts at its terminals was unsafe for all conditions. To provide for future increase in the volume of traffic, which would naturally develop a somewhat higher E.M.F. at relay terminals, and to give a wide factor of safety generally, all relays were constructed so as not to respond to any E.M.F. under 5 volts. This construction included the winding of the magnets to a resistance of 50 ohms.

To maintain a minimum E.M.F. of 5 volts at the terminals of such a resistance, when shunted by the maximum leakage encountered between rails, without the use of very expensive mains, was impracticable over so extensive a system, unless the E.M.F. of the generator was made higher than that required at the relay terminals. For this reason, a comparatively high voltage machine was determined upon, and the E.M.F. maintained in the two No 6 copper lines constituting the feeders of the block system is ordinarily 90 volts, though in fair weather this may, if desired, be lowered to 60 volts without trouble ensuing.

The joint resistance[3] of a 50-ohm relay and the resistance of a 3-ohm shunt thereon (which, during wet weather, is the minimum formed by the conductivity of ties within the block controlling the relay) is practically 2.6 ohms. To secure at the terminals of this resistance (the rails of the block section) an E.M.F. of 5 volts by means of a 90-volt generator requires a resistance approximating 50 ohms between them. The maximum current delivered through this resistance is 1.8 amperes, hence, at 90 volts, each track circuit so equipped consumes an energy of 162 watts as a maximum. This however, is vastly in excess of that required by the majority of the sections, most of which are so short as to permit of 150 ohms being used in their current supply.

For comparison's sake it will be interesting to note the influence that would accompany the substitution of a 15-volt generator for the 90-volt one used. The resistance that would then have to be interposed between the generator and the block rail would, to maintain a 5-volt potential at relay terminals under the conditions stated, be but 7.8 ohms. Through this, slightly over 1.9 amperes would flow during the presence of train upon the section, while the energy consumed would represent practically but 30 watts – less than one-fifth that consumed under the 90-volt system.[4]

To maintain an E.M.F. of 15 volts in a line of the length needed and carrying the current required, would have necessitated either a vast increase in its size or else a greater number of generators at intermediate points along it than the number now in use, and this would have involved an outlay in money not warranted by the saving to be thus effected in the relatively small power consumed for block

[1] i.e. what is now known as the pick-up voltage. With a 5 ohm relay, this implies that the pick-up current is 50 milliamperes.

[2] The high traction currents in the common rail would mean that the rail would float several volts above zero – a voltage high enough to pick-up a track relay. The tests showed that a pick-up voltage of at least 5 volts was required to prevent the relay picking from this cause.

[3] i.e. effective resistance

[4] Essentially this argument is that it is necessary to drop the voltage from the signal distribution voltage – either 90V or 15V – to the 5V required by the relay. As this is DC, the only way to reduce the voltage is by a track resistance in the feed to the track circuit. For a 90V power supply, this resistance is 50 ohms, for a 15V power supply it is 7.8 ohms. The higher voltage and consequent larger resistance wastes a lot more energy.

purposes[1]. It is very apparent, however, that where separate generators are located at the end of each track circuit for supplying them individually with current, economy demands a very low E.M.F. in them; and it is partly in recognition of this fact that two cells of gravity battery constitute such generators in steam line practice.

At each terminal and at each of the two intermediate junctions of the Elevated road a motor generator is located, from which the electrical energy for the block system is derived. These machines have a capacity of 50 amperes at 110 volts (5.5 KW) and any two of them operated in parallel suffice for the energy required. Normally these deliver 40 amperes at 90 volts each, the total electrical energy generated being 7.2 KW, hence about 12 electrical HP is drawn from the main of the propulsion system – an amount insignificant in its relation to the total from which it is derived, and one producing possibly greater indirect benefits to the railroad company than any equal amount employed elsewhere in the service.

This power is applied to the operation of 175 signals, 61 switches and about 50 indicators of various types and for various purposes[2]. To this, for the total electrical energy consumed for safety appliances, should be added about 40 h.p. that is also drawn from the power mains for working air compressors.

Two Ingersoll-Sergeant, duplex class J compressors are located at each terminal, geared direct to a 40 h.p. Westinghouse 4-pole, 500-volt, DC motor, operated from the power mains. Any one of these machines is more than capable of maintaining the air supply, and each is provided with the automatic unloading device which permits the motor to run continuously, yet economically, when compression ceases. The duplication of these machines at each terminal was to avoid possible interruption to service in the event of one machine becoming disabled at a time when the pipe line under the Charles River might be damaged by dragging anchors or otherwise.

Track circuit arrangements & relay

The negative pole of the generators which develop the energy employed for propulsion purposes is that one which connects with the ground and general return system, the positive pole being connected with the third rail.

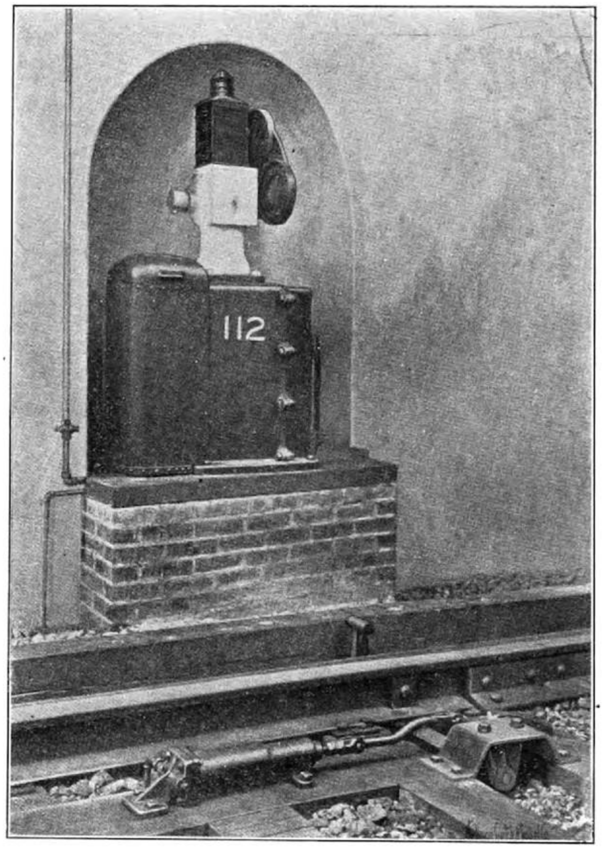


Fig. 2.—Electro-Pneumatic Block Signal in Boston Subway, With Automatic Train-Stop Attachment.

To secure the benefits for which the relays of block sections were polarized it was naturally proper to ground the positive pole of the block generators, and to connect the block feed wire to the negative pole of that generator as shown diagrammatically in Fig. 1. By this arrangement should sand or ice on the rail, or other cause, produce imperfect wheel contact with the ground rail, the propulsion current thus caused to be sent through the track relay would operate its polarized parts to hold open the

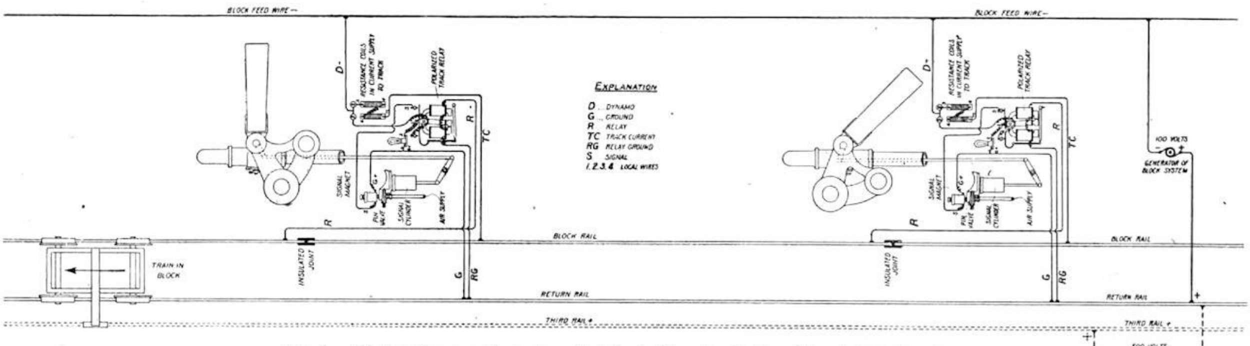


Fig. 1.—Electro-Pneumatic Automatic Block-Signals, Boston Elevated Railroad.

[1] The reason the higher distribution voltage (90V) is necessary is that it is not economically practical to use the lower voltage – the feeder wires from the central motor generators would be too expensive due to the amount of copper in them, or too many motor generators would be needed. This is one reason (of many) why AC track circuits were technically superior – voltage could be dropped using transformers with very little power loss.

[2] The electrical power does not directly operate either the switches or the signals; this is an electro-pneumatic installation. The electrical power only operates the magnetic valves.

signal circuit, and thus hold the signal at danger. With a relay not polarized such a current would close it, and thus clear the signal.

The construction of this relay is deserving of attention, being quite a departure from ordinary methods in signal work. Fig 3 gives a clear idea of it mounted in the pedestal of the signal with the resistance coils, which are inserted in a branch from the block feed wire to the rail of the track circuit as before stated. At this side of these coils are two rotary cut-out switches, by which the current may be interrupted in both the signal and the track circuits during inspection and tests. At the left is a 32 c.p.[1] lamp which is employed as a resistance only in the circuits controlling the signal. On the back side of the pedestal is located the electro-pneumatic valve and cylinder for working the signal.

Fig. 4 illustrates the polarized relay alone. Pivoted to the base is an armature having at its outer end a suitable adjustment for limiting its motion, and a link extending upwards into connection with a contact lever carrying two carbon plates at its out ends, which lie under contacts of the same substance mounted in insulated brackets secured to the top plate[2]. This armature is raised by the pair of large magnets when these are energized, and irrespective of the direction of the current flowing through them. When elevated, the armature closes that contact carried by the end of the contact plate to which it connects[3]. This plate is secured to the upper pole piece of a pair of smaller magnets mounted transversely to those first mentioned, and suspended in the top plate by trunnions formed upon the ends of the pole piece referred to[4]. The lower ends of these swinging magnets are joined together by a bar forming the lower pole piece, which lies between the extended ends of the cores of the larger fixed magnet, and is attracted by one or other of these according their respective magnetic conditions. The swinging magnets are wound to produce like poles always at like terminals of their cores, and hence, the two-pole pieces joining them constitute the actual poles of the magnets. The fixed magnets are wound in the usual manner, and are included in the track circuit, where they are ordinarily influenced by a current of one direction when the block is unoccupied – this current coming from the generator of the block system. When a train occupies the block, these are de-energized as in ordinary track relays. When influenced by abnormal currents – those from the propulsion system – they are also energized, but their poles are then reversed.

It is to prevent the clearing of a signal falsely, by the closing of the contact first mentioned, under the last stated condition, that a second contact is introduced in the signal circuit[5]. This second contact is operated by a motion of the

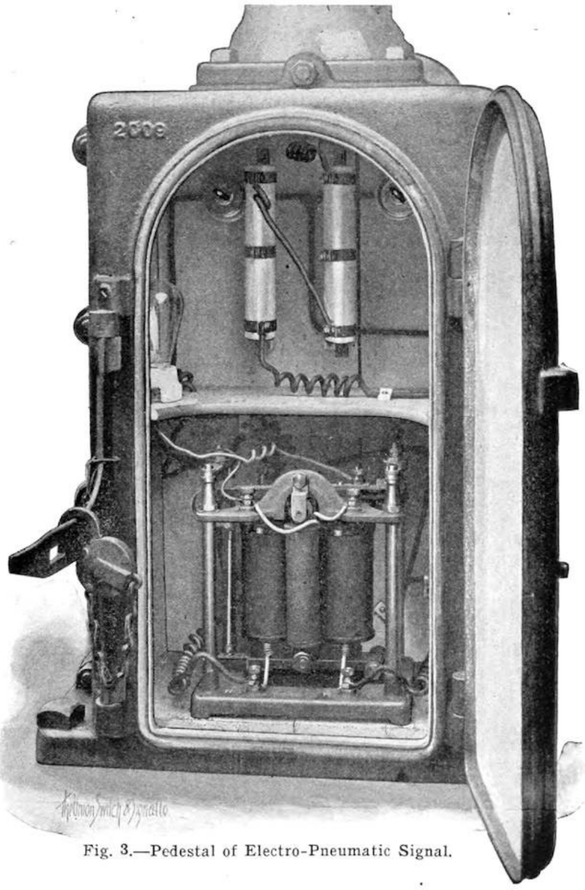


Fig. 3.—Pedestal of Electro-Pneumatic Signal.

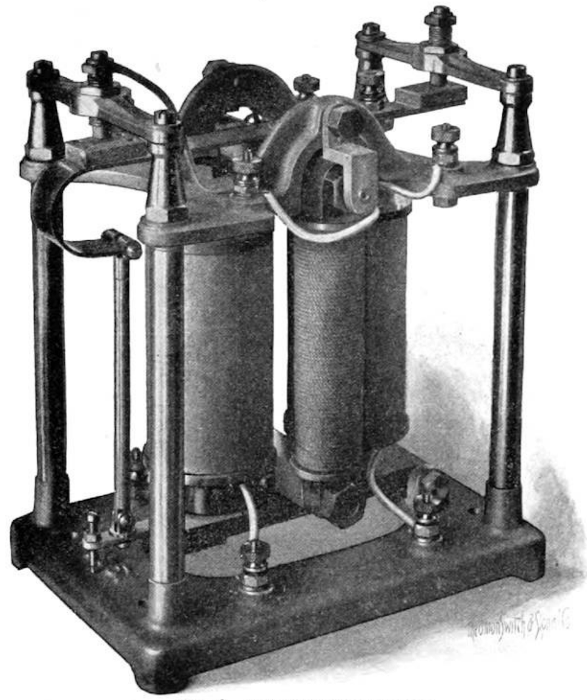


Fig. 4.—Polarized Track Relay.

[1] Candle power, a measure of the amount of light generated.
[2] These carbon/carbon contacts, formed from flat plates of carbon, rather than the usual silver, are the reason that the relay can take the full traction current across the terminals.
[3] i.e. the left hand contact in Fig. 4. Closing this contact energises the swinging polarising magnets.
[4] These sentences describe the polarizing magnets which swing between the larger fixed magnets depending on the polarity of the current flowing through the relay from the track.
[5] This second contact is the second carbon contact mounted on the armature, and it can be seen at the right of Fig. 4. The swinging of the polarized relays in the trunnions lifts or lowers the right hand end of the armature, making or breaking this second contact depending on the polarity of the current from the track. The left

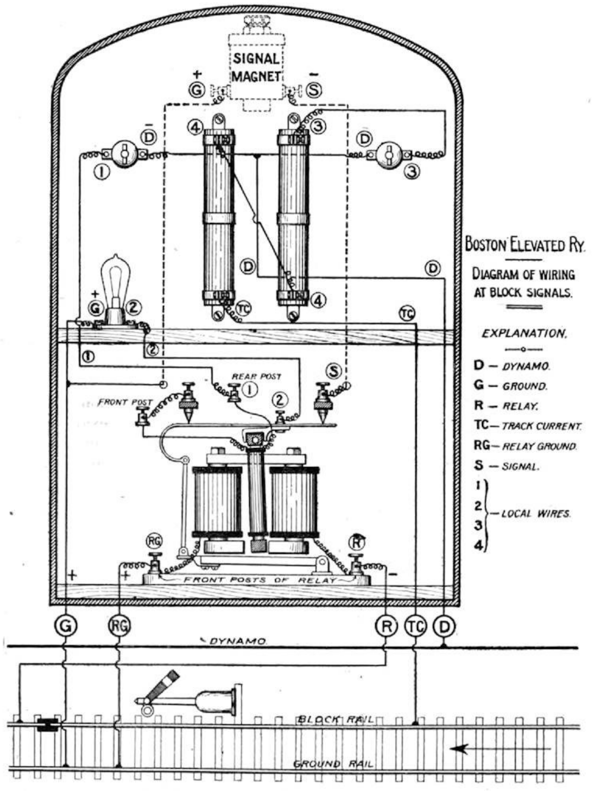


Fig. 5.

swinging magnets, which accomplish this by virtue of their constant polarity, and the reversal of the polarity of the fixed magnets when these are energized by abnormal currents. The closing of the first mentioned contact tends to open the other one, and to move the lower pole of the swinging magnets toward the pole of the left hand fixed magnet.

The instant the first mentioned contact is closed a current is sent through the coils of the swinging magnets and a lamp resistance is placed in series therewith. This current, energizing these magnets, causes their lower pole pieces to move to the opposite pole of the fixed magnet from that to which they were mechanically forced during the closure of the first contact, and thus closes the second contact in the signal circuit; and not until this is done will the signal be cleared. The mechanical effect of this electrical shifting of the swinging magnets tends to open the contact first closed by the fixed magnet, but the energy developed is not sufficient to be effective in doing this. In this feature of the relay lies one of its valuable characteristics. Ordinarily the current required to operate a relay armature must be reduced about 50 per cent. before the armature will be released. In this relay, owing to the mechanical counter effect of the swinging magnets upon the work performed by the fixed magnet, the armature of the latter drops in response to the slightest reduction of the current below that required to lift it.

This feature renders the relay extremely responsive to the shunting influence of trains within the block section, and eliminates almost completely the wide range of difference found in ordinary relays between the amount of energy required to lift the armature and that to which it must be reduced before the armature is released, this latter in many cases being fully 50 per cent. of the former. The ideal track relay should release its armature on a 1 per cent reduction of current below that required to lift it. The relay just described closely approaches these conditions by reason of the characteristics mentioned.

The electrical connections peculiar to the terminal of each block section are shown diagrammatically in Fig 5. The branch D from the main feed wire connects directly to the cut-out switches 1 and 3. The right hand switch controls the current supply to the track circuit, which flows by wire 3 through the two resistance coils and wire T.C. to the block rail. These coils have 100 ohms in each, but only on the shortest block sections is the full resistance permissible.

The left hand switch controls the current to the signal mechanism, which flows normally by wire 1 to the swinging magnets of the relay; from thence it passes to the front contact of the relay, through the contact bar to posts 2 and S, where it divides and flows from 2 to a 16-c.p. lamp and thence to the common return. From S it passes directly to the magnet of the signal air-valve, and from that to the return.

A train short-circuiting the relay causes the front contact to open, thus cutting all current from the signal and lamp and permitting the signal to move by gravity to danger. If, however, the relay should be excited by current from the propulsion system, under this condition, the closure of the front contact would not be followed by a similar condition of the rear one (S) because of the polarized feature of the device. The lamp only, under these conditions, remains in circuit with the swinging magnets.

Under normal conditions the signal circuit forms a shunt on the lamp, the coils of the swinging magnets forming a resistance common to both. By this arrangement any interruption to the current through the swinging magnets must also interrupt that holding the signal at safety, and thus cause the latter to move to danger.

It is, therefore evident that the device cannot be depolarized without producing a danger signal, a principle of great value in automatic block signaling.

Track circuit specification

Fig. 6 shows diagrammatically the controlling elements of a track section as used on the elevated road. It also illustrates a graphic method of ascertaining the minimum resistance that may occur between the rails of a block section under various conditions before a failure of the relay[1] therefrom will result.

The horizontal lines represent various E.M.F.s of the feed wire, while the vertical lines are ohm divisions. The numbers 50, 100, 150, and 200 represent the several units into which the resistance coils in the current supply to various track circuits are divided, as conditions require them.

hand contact is always closed which the armature is lifted, irrespective of the position of the polarized armature.

[1] i.e. how low the ballast resistance can fall before the track relay drops. The failure here is a right side failure.

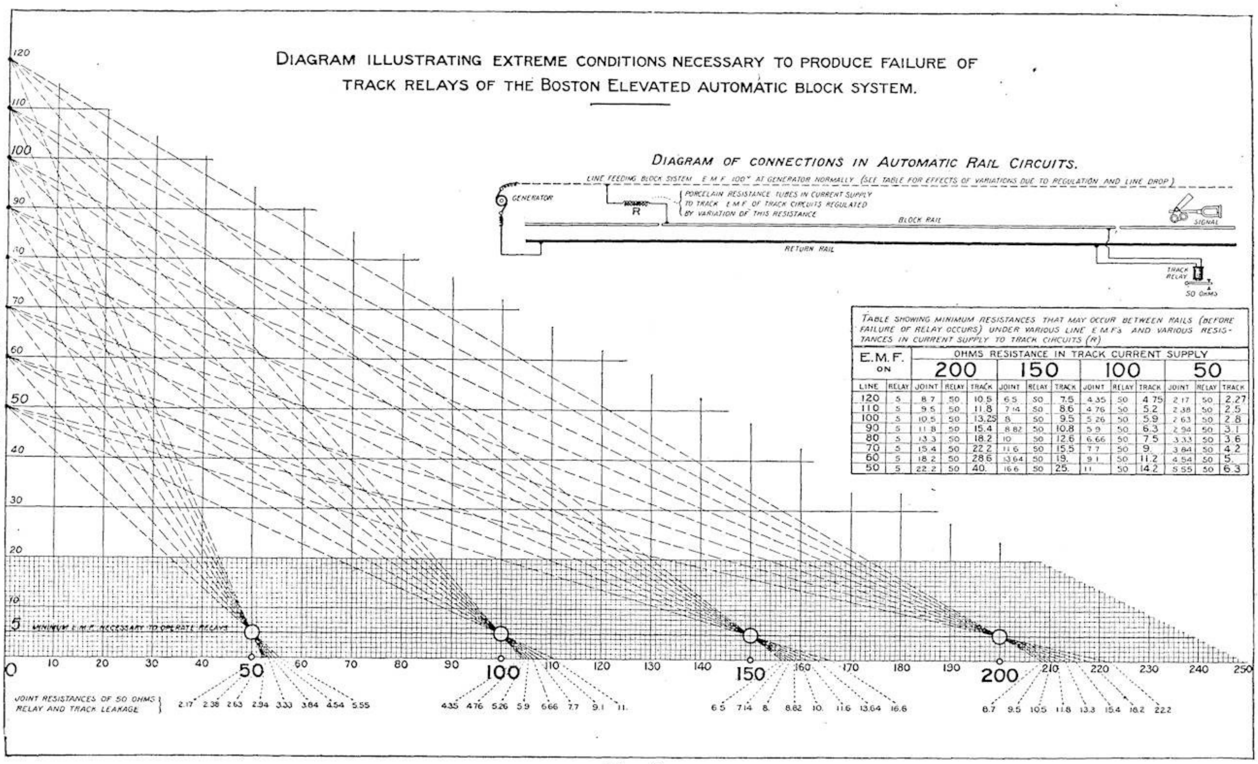


TABLE SHOWING MINIMUM RESISTANCES THAT MAY OCCUR BETWEEN RAILS (BEFORE FAILURE OF RELAY OCCURS) UNDER VARIOUS LINE E.M.F's AND VARIOUS RESISTANCES IN CURRENT SUPPLY TO TRACK CIRCUITS (R)

E.M.F. ON		OHMS RESISTANCE IN TRACK CURRENT SUPPLY											
		200			150			100			50		
LINE	RELAY	JOINT	RELAY	TRACK	JOINT	RELAY	TRACK	JOINT	RELAY	TRACK	JOINT	RELAY	TRACK
120	5	8.7	50	10.5	6.5	50	7.5	4.35	50	4.75	2.17	50	2.27
110	5	9.5	50	11.8	7.14	50	8.6	4.76	50	5.2	2.38	50	2.5
100	5	10.5	50	13.25	8.	50	9.5	5.26	50	5.9	2.63	50	2.8
90	5	11.8	50	15.4	8.82	50	10.8	5.9	50	6.3	2.94	50	3.1
80	5	13.3	50	18.2	10	50	12.6	6.66	50	7.5	3.33	50	3.6
70	5	15.4	50	22.2	11.6	50	15.5	7.7	50	9.	3.84	50	4.2
60	5	18.2	50	28.6	13.64	50	19.	9.1	50	11.2	4.54	50	5.
50	5	22.2	50	40.	16.6	50	25.	11	50	14.2	5.55	50	6.3

Fig. 6

For instance, if track conditions require the use of a 50-ohm coil in the current supply, the line 50 would mark on the diagram the terminal of such a coil. If 100 ohms are required, the line 100 indicates its terminal, etc. Having 80 volts on the line, and securing a reading of 10 volts at the terminal of a track relay, on may draw a line diagonally from 80 on the vertical marginal line to 10 on that one of the vertical lines which marks the terminal of the resistance within the coil used on the section so measured. Where the diagonal line intersects the horizontal base line may be read the resistance existing between the coil and the return rail, i.e. the joint resistance of the 50-ohm relay and the resistance between rails. This joint resistance will be represented by the base line of the triangle thus formed to the right of the line marking the terminal of the coil. Knowing the resistance of one member of the joint resistance (the relay) the other may be readily calculated. This resistance determined it may be compared with that given in the table under the number corresponding to the coil resistance which is used in that particular circuit and opposite the number corresponding with the E.M.F. of the line at the time of measurement, to determine whether or not a sufficient margin exists for reliable operation under extreme conditions.

The figures given in the table are derived from projections on the diagram through the 5-volt line at the terminal of each unit of resistance, and represent the minimum resistances possible between the rails, under the conditions indicated, before relay failures will occur as at present adjusted.

The signals are worked upon the normally clear principle, and so frequent are the trains that each is operated fully 600 times daily. There is probably not a better example in existence of the value of automatic signaling in expediting train movements than this one presented on the Boston Elevated lines; and nowhere else can the wisdom of operating automatic signals on the normally clear principle be so fully demonstrated as here, where, were the normally danger method employed frequency of train movements would virtually convert it into a normally clear one.