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# **SYDNEY TRAMWAY MUSEUM**

## **TRAMCAR MAINTENANCE MANUAL**

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## **1. Purpose**

To explain the processes and procedures necessary to maintain the tramcars at STM.

## **2. Scope**

This procedure applies to all trams operated by the Sydney Tramway Museum.

However this manual doesn't apply to Variotram 2107 and it has it's own extensive Operations and Management manual set (STM6???) with processes to be followed.

## **3. Responsibilities**

The maintenance staff at STM must follow these processes in this manual.

## **4. References**

STM6031 - Tramcar Pre-operation and Stabling Inspection Checklist

STM6075 - Lubrication Manual

STM6076 - Tramcar Registration Compliance Audit Record

STM6088 – Body Maintenance Schedule

STM6089 – Controller Inspection Schedule

STM6090 - Mechanical Inspection Sheets

STM6099 – Electrical Maintenance Schedule

STM6100 – PCC Car Inspection Schedule.

STM6106 – Westinghouse Brake Valve Maintenance Procedure

STM6131 - Hywema Vehicle - Lift Type RG – Instructions

## **5. Definitions**

STM Sydney Tramway Museum: the trading name of South Pacific Electric Railway Co-Operative Society Limited for tram activities, therefore references to STM.

H.P Horsepower

Ins Inches

Kpa Kilopascals

Lbs Pounds (weight)

Mls Millilitres

PSI Pounds (lbs) per square inch – pressure

STM Sydney Tramway Museum

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## 7. Initial Inspection

Before any restoration, overhaul or repair is contemplated a thorough inspection of the tramcar must be undertaken. This is to determine the extent of visible damage from the elements and man. As the work proceeds and items are removed from the tramcar further damage may be found. This is to be taken into consideration when inspecting the tramcar and planning the work.

Therefore when you start to inspect the tramcar use the inspections sheets as listed in Appendix A as a starting point. You may need to record more information than that which appears in the sheets, so add more sheets detailing all the defects that have been found.

If the body has to be lifted off the truck or bogies, please refer to the Hywella Vehicle Lift Instructions – STM6102 before attempting any lifts using this equipment.

If no restoration required, please go to section 8 – Inspections.

### 7.1 Restoration

After recording the total tramcar's condition, check with the Restoration and Acquisition Committee to see the style of tramcar is to represent. This simple check will need to be done so as to enable you to correctly plan what items need to be removed and not fitted and what items are missing and need to be found or manufactured. As we are a *Museum* we must properly research the STM tramcars in all their conditions over their years of operation. This may mean doors need to be removed, changing the hand rails, different floor slats, etc. Any parts that are removed must be clearly and correctly labelled, then stored safely so as to protect against any further damage for future use back on the tramcar.

After all the inspections and identifying what period the tramcar is to be restores to represent, make a detailed plan as to the work direction. That is to say work out where to start, where to finish, what specialist trades are required, what consumables are required and what items need to be manufactured.

To give an idea of how to inspect, we start with the body as this part of the complete tramcar usually takes the longest to repair or restore. Therefore the following is a list of items that need to be inspected and recorded, both for a record of condition and a historical record of the tramcars final body style.

- Side Frame
- Cabs
- End Bulkheads
- Internal Bulkheads
- Side Structure (Panels)
- Cant rails
- Ceiling Lining
- Roof Ribs
- Roof Slats
- Trolley Bridge
- Trolley Planks or Walkway
- Internal Side Lining
- Seats Glazing
- Floor Boards
- Floor Slats
- Floor Covering
- Foot Boards
- Foot Board Slats
- Bumper Bars
- Couplers
- End Aprons
- Destination Boxes
- Driver's Seats
- Communication Bell Equipment
- Standee Straps
- External and Internal Handrails

After inspecting the body above basically floor level, next go under the tramcar and thus the items that need to be looked at are:

- Bolster Condition
- Cross Members (both timber and steel)
- Cross Bolts
- Longitudinal Members
- Any Equipment support steelwork
- Coupler Fixing Point
- Cab Floor Sumners
- Rodding Wear through Cross Members
- Derailment Damage
- Accident Damage

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The last and one of the most if not the most important things to find out about the body of the tramcar is if it is still straight and is not twisted. A quick way of finding out how straight a body is, is to run a string line along each side and note any deviations from the line. To check for a body twist you will need four (4) pieces of timber say 25 mm square and longer than the diagonal of from one side's cant rail to the other side's floor side frame. Next measure the diagonals and mark the timbers at the mid point of the diagonals. The marks must be in line with each other or otherwise the body is not square. Now use the string line from the mid points of the timbers and measurements can be taken to check to body. If the body is found to be out of square, it can be straightened by placing it on four stools and jacks can be used to lift or twist it into position. A steel tramcar is very different to straighten and will need very careful thought before any remedial work takes place.

Next is the electrical inspection of the tramcar which basically is the production of the wiring diagram if there is not one in the drawings held by the Museum. Check all light fittings, equipment such as controllers, air compressors, resistance grids, circuit breakers, trolley poles and pantograph, traction motors, etc., if there are any of these items fitted. A matter of general safety of the tramcars, a policy of rewiring any tramcar that is wired with braided cotton-rubber insulation with PVC insulated cables. The old braided cotton-rubber insulation has years ago reached the end of its service life and has in very recent times caught fire or can cause failures in the wiring looms. All the electrical equipment will be removed for overhaul or refurbishment as detailed later on in this manual.

Mechanical parts to be inspected are mainly confined to the underneath of the tramcar and are items like; bogie or truck frames, axle boxes and the wear plates, axle bearings, axles, wheels and their flanges, bolsters and their centre castings, brake rigging, brake shoes, suspension bearings, drive gears, rubbing plates, springs, pivot pins and brushes, etc. As all of these and more will need to be inspected, their condition will need to be carefully determined as metal fatigue is their worst enemy which could cause a failure while in Museum service. The overhaul of these parts is also detailed later in this manual.

An important tool that must be used when looking at a restoration project is the camera. The camera, over the last hundred or so years, has recorded the comings and goings of the tramcar, so why stop recording. Keep recording the tramcar as it is being restored. It is highly recommended that you start recording the tramcar's condition before a single piece is removed and as you inspect its condition. The photographs that are taken will give you the exact condition and location of all the parts that have been removed before and during the restoration. For over the years people have started many restoration projects and because of other museum commitments have stopped the project. Years later the project is again taken up either by the original group or by other museum members and with the lapse of time memories do grow grey. So if the project was recorded by photographs the puzzle of how to put the tramcar back together would be a very much easier task.

Also when you do start to dismantle the tramcar clearly label the parts in a system and record that on the drawings or photographs as to its exact location. Then store the removed items against damage or loss near to where you are working.

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## 8. Inspections

The following is a list of general inspections which are recommended and are to be applied to practically all of the STM tramcars. For particular areas of inspection where more detail is desired, please see procedures or pages devoted to them (i.e. Lubrication, Motors, Controllers, Brakes, etc.).

Below is a guide to the period of inspection for tramcars. Most of the museum tramcars travel less than 1500 kilometres per year and most operational tramcars are inspected annually (refer to STM6076-Tramcar Registration Compliance Audit form) depending of their annual mileage. It must also be remembered that before each operating day the tram has an inspection by its crew (see STM6031-Tramcar Pre-operation and Stabling Inspection Checklist for details of this inspection).

<i>Inspection of Tramcar Equipment</i>	
Type	Period
Intermediate A - for trams that have travelled in excess of 99 kms during the previous year.	Annual
Intermediate B - for trams that have travelled less than 100 kms during the previous year	2 Yearly
Overhaul	Twenty Years

The figures above are recommended for tramcars in the Museum service, where the tramcars are rotated on a roster so that a particular tramcar is only used, say, three or four times per month. The importance of inspection cannot be under estimated, as replacement parts are in very limited supply or they have to be manufactured.

### 8.1 Intermediate Inspection

- a) Carefully examine the mechanical details such as trucks, brakes air piping, etc (*see Maintenance of Trucks and Rigging section*)
- b) Inspect the electrical equipment, wiring, batteries, etc., and check for earth and faulty operation.
- c) Motors, controllers, switch groups and all auxiliary apparatus should be cleaned thoroughly with compressed air or preferably vacuum clean where possible.
- d) All necessary repairs to tramcar body interior/exterior fittings should be made.
- e) All wearing parts of equipment such as bearings and carbon brushes (*see Traction Motor Maintenance section*); trolley wheels or skids, control contact tips and drum rings (*see Controllers section*) should be overhauled and put in smooth running condition.
- f) Gears, pinions, wheels, axles, trucks and brake details should be inspected and all worn or broken parts repaired or renewed,
- g) Examine the arc chute, electrical insulation and the wiring to see that they are in good safe operating condition.
- h) All covers on electrical apparatus and on motor bearings and journal boxes should be made to fit snugly so as to exclude dust, dirt and water.
- i) Tighten all bolts on motors, gear cases, trucks, etc., and make all necessary repairs so that the tramcars will need no other attention (other than light inspection) until the next intermediate inspection.

This inspection is recorded on the Tramcar Registration Compliance Audit Report (STM6076) when the tramcar has its inspection.

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## 8.2 Overhaul Inspection

### 8.2.1 Trucks and Brake Rigging

- i) All parts of the trucks and rigging (*see Maintenance of Trucks and Rigging section*) should be carefully gone over and badly worn hangers, pins, bolts, chafing plates, truck brake levers and brake heads should be repaired or renewed.
- ii) Bogie type trucks: radial pads and centre bearings should be rigidly attached to the bolster.
- iii) New brake shoes and adjusters should be supplied if these parts are badly worn (*see Brake Rigging part of Maintenance of Trucks and Rigging section*).
- iv) Adjust the brake release springs.
- v) Wheels (*see Wheels part of Maintenance of Trucks and Rigging section*) should be checked for fatigue (i.e. cracks), any damage, diameter and flange wear. If necessary turn the wheel to obtain the correct profile or replace the wheel if the diameter is below condemning limit.
- vi) Pairs of wheels should be kept the same diameter to prevent crowding one rail or the other, with the consequent destruction of flanges.
- vii) Pairs of wheels on the same tramcar should not vary more than 6.5 mm (*1/4 inch*) in diameter; otherwise the motor on the larger diameter wheels will be overloaded.
- viii) Gears should be checked and renewed if they will not last until the next intermediate inspection period. The teeth should not be worn to a pointed form.
- ix) Journal boxes, covers, bearings, cheek plates, etc., should be inspected, removed and replaced if badly worn;
- x) Axle collars (*see Axle Collars part of Traction Motor Maintenance section*) should be tightened and checked for proper clearances.

### 8.2.2 Air Brakes and Piping

**NOTE:** *the pressure measurements (psi – pounds per sq. inch) shown below are in imperial numbers as the gauges on the Museum trams are still in imperial measurements.*

- i) With air pressure in the system, the gauges in the two ends of the tramcar should not vary, one from the other by more than 5 psi. If gauges vary, remove both gauges and check against a 'Standard Gauge'.
- ii) Governors (*see Governors part of Brake Equipment Maintenance section*) should be adjusted, for Christenson or Westinghouse high pressure types, to cut in at 65 psi and cut out at 75 psi and, for Standard low pressure types, to cut in at 30 psi and cut out at 36 psi.
- iii) Remove the safety valve (*see Triple Valves part of Brake Equipment Maintenance section*) and adjust it on the air test bench so that it will operate at approximately 10 to 15 psi above the cut out pressure of the governor.
- iv) The governor, air cocks, air operated gong, driver's air brake valve, relay valve, double check valve (*see the valves parts of Brake Equipment Maintenance section*), etc. should be put in first class condition and given an operational test (*see the Simple Test part of Brake Equipment Maintenance section*).
- v) Test the emergency air equipment (*see the Simple Test part of Brake Equipment Maintenance section*).
- vi) Examine the dust filter on the air compressor inlet and clean the filter of any dust or if necessary replace the filter element.
- vii) Examine the air compressor motor switch and fuse and check that they are in good operation condition.
- viii) Where fitted examine the apron hose connections and hose couplings.

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- ix) Full air pressure should be applied to the brake cylinder/s in order to check the piston travel which should be limited to 63 mm (2-½ inches) usually (*see the Brake Equipment Maintenance section*), when the brakes are correctly applied.
- x) Oil and dirt should be blown out of all piping.
- xi) With pressure on the system, check for leaks and repair all defects.
- xii) Remove all dirt accumulation from the air compressor both inside and outside with compressed air (*see the Compressor part of Brake Equipment Maintenance section*).
- xiii) Inspect the air compressor's brush holders and see that the brush springs work freely. If the carbons are badly worn or broken, furnish new ones (*see the Compressor part of Brake Equipment Maintenance section*).
- xiv) Check armature clearance; (i.e. poling of the armature field coil laminations) If bearings are badly worn, replace with new ones (*see the maintenance part of Brake Equipment Maintenance section*).
- xv) All air compressor windings should be tested for earths. If insulation resistance is OK, windings should be reinsulated against water and dirt ingress with insulating varnish.
- xvi) Operate the air compressor with the inspection door/s open, and check for unusual sounds which would indicate worn bearings or defective valve operation.
- xvii) Air compressor gears and pinions should be examined to make sure that they are in sufficient condition to operate until the next intermediate inspection.

### **8.2.3 Electrical Equipment - Traction Motors:**

- i) Motors should be opened up, armatures removed (*see Removing Armatures part of Traction Motor Maintenance section*) and the field coils taken out (*see Remove and Replacing Field Coils part of Traction Motor Maintenance section*) and the inside of the motor frame cleaned out and painted using G.E Glyptal or some other suitable insulating varnish.
- ii) Test field coils for short circuits and earths (*see Re-insulating Field Coils part of Traction Motor Maintenance section*), thoroughly overhaul, revarnish and replace in the frame.
- iii) See that the wiring around the frame, leads, bushings, and connections are in first class condition; that they are cleated and that there are no loose connections. Make sure that the motor leads do not become fouled up in the brake rigging or the trucks.
- iv) Clean the brush holders and replace badly worn parts and broken shunts (*see Brush Holder Repairs part of Traction Motor Maintenance section*).
- v) Renew carbons if worn or broken (*see Carbon Brush part of Traction Motor Maintenance section*).
- vi) Bearings should be checked and if worn or defective, re-babbitt line or replace with new bearings (*see Motor Suspension Bearings and Caps part of Traction Motor Maintenance section*).
- vii) Armatures should be thoroughly blown out by dry, low pressure (less than 70 kpa (10 psi)) compressed air and tested for earths, open and short circuits (*see Armature Testing part of Traction Motor Maintenance section*).
- viii) Inspect all armature winding retaining bands and if found loose or broken, reband.
- ix) Commutators, if badly worn, should be turned, then undercut and chamfered. Front V or Cone rings should be cleaned of all carbon dust with electrical solvent. If badly pitted smooth off the pits with an epoxy resin, then re-varnished (*see Commutator Maintenance part of Traction Motor Maintenance section*).
- x) Armatures should be dried, then re-varnished and assembled in the motor frame (*see Dipping and Baking Traction Motors part of Traction Motor Maintenance section*).

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- xi) If the motor is of the split-frame type, be sure that the housings are a clamping fit between the halves of the motor frame.
- xii) See that all motor frame bolts are tight and that they are secured with lock washers.
- xiii) Oil box covers should fit tightly so as to exclude dirt, dust and water. Remove all dirt that would prevent covers from making a good fit.
- xiv) Pinions should be inspected and, if badly worn (pointed form) they must be replaced (*see Removing Pinions and Installing Pinions parts of Traction Motor Maintenance section*).
- xv) Gear Cases should be cleaned and examined for cracks and breaks. If found defective, replace or have them welded. When replacing, they should be bolted tightly to prevent all movement and consequent wearing at the supports.

### **8.2.4 Control Equipment**

- i) Controllers, main switches, switch groups, circuit interrupters, etc., should be carefully inspected and thoroughly cleaned out (*See pages on each particular type*).
- ii) All badly worn fingers and segments should be replaced (*see Inspection of Controllers part of Controllers section*).
- iii) Contacts that are badly burned should be filed smooth and adjusted or replaced by new ones (*see Inspection of Controllers part of Controllers section*).
- iv) All insulating surfaces
- v) Check and tighten up all bolted connections
- vi) On Pneumatic Control cars,
- vii) Inspect and lubricate all piston leathers (*see Lubrication part of Controllers section*).
- viii) Overhaul automatic circuit breakers, test for earths and perform function test. Check the trip current setting with an ammeter so as to protect the remainder of the equipment against overload.
- ix) Grid resistors should be thoroughly cleaned of all dust and grit. Inspect for damaged insulation.
- x) Tighten all bolts and replace cracked or broken grids.
- xi) Examine all the junction boxes, receptacles, etc. and see that all connections are tight and any broken wires are repaired.
- xii) Current-limit, over-speed, and over-voltage relays, etc. should be inspected, cleaned, repaired and properly adjusted by performing function tests.

### **8.2.5 Tramcar Detail and Body**

- i) Trolley wheels and shoes should be properly lined up and where necessary lubricate. **NOTE:** On trolley wheels fitted with carbon brushes NO lubrication is necessary. This is important as it will increase their service life.
- ii) All moveable parts of the trolley base should be inspected and well lubricated.
- iii) Springs should be adjusted to give approximately 175 to 245 kpa (*25 to 35 psi*) between the wheel (or shoe) and the overhead trolley wire.
- iv) Inspect all nuts to see that they are tight and provided with lock washers.
- v) All moving parts should be lubricated and the exposed parts painted.
- vi) Lighting arresters should be gauged and tested to make sure that they are in good working condition.

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- vii) Storage batteries should be examined for broken plates, defective separators and loose connections. Test the electrolyte for proper density and see that it covers the plates. Battery inspections should be carried as per manufacturer's recommendations.
- viii) Check and verify all control, lighting and push-button circuits and repair all defective wiring. See that all connections are tight.
- ix) Door motors should be examined, cleaned and lubricated and the brush holders fitted with new carbons.
- x) All doors should be inspected for fit and any misalignment should be corrected. Also where fitted, door canvases should be re-dressed or replaced.
- xi) If the main car wiring is not in conduit or ducting, go over it carefully to see that it is well cleated and secured from chafing. Repair all damaged parts with compatible materials and reseal surface with recommended paint or sealant.
- xii) Repair all body defects such as wood rot, rust, corrosion and accident damage.
- xiii) Inspect roof covering and repair or replace, then seal.
- xiv) Repaint entire tramcar.

For Body, Mechanical, Controller and Electrical Maintenance Schedules see Appendix A. For Lubrication Schedules, see Lubrication Manual (STM6075).

### **9. Lubrication**

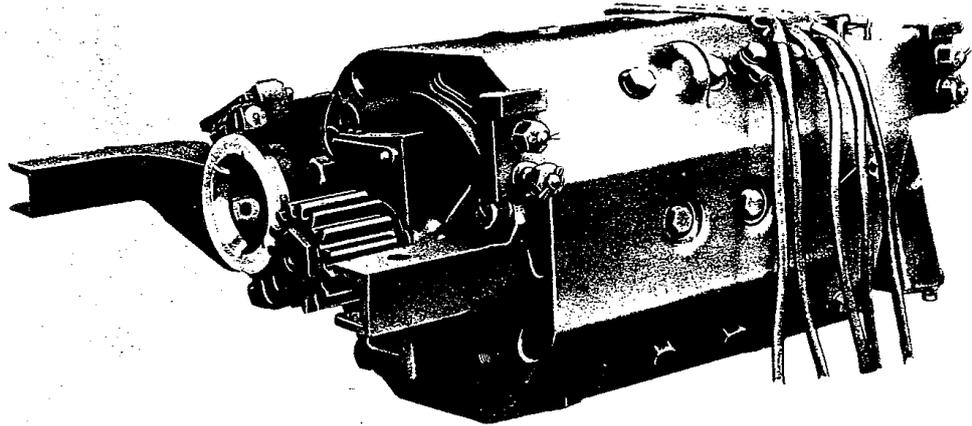
See Lubrication Manual (STM6075) for details and schedule.

## 10. Traction Motor Maintenance

### 10.1 Traction Motor Construction

A traction motor is constructed of the following parts:

Armature, Field coils, interpoles on later motors brush holders, carbon brushes, armature bearings, motor frame, nose suspension, axle suspension.



*Figure 1 - TYPICAL TRACTION MOTOR*

To describe each of the above listed parts fully would take an entire book to allow a full understanding of the design features and principles of D.C. motor theory. Therefore the following few paragraphs is a brief outline of the main parts of traction motor. Some of the parts are more fully described later in this section.

**MOTOR FRAME:** - is manufactured from high permeability steel, such as cast steel or fabricated rolled steel and is part of the magnetic circuit of the motor. The motor frame has the supports for the armature bearings, the suspension bearings and the nose suspension.

**FIELD COILS:** - are fixed windings mounted on the motor frame with the pole pieces through them. These coils magnetise the pole pieces to induce a magnetic field direction that the same as the adjacent armature magnetic field and this causes the armature to rotate. The field pole pieces are of laminated construction, to stop eddy currents, and usually bolted to the motor frame.

**Interpoles:** - are fixed windings fitted between the main field poles, are a part of the armature circuit & aid in commutation in the direction of rotation.

**ARMATURE:** - is constructed on a laminated core to reduce eddy currents, completes the magnetic circuit and is slotted to carry the armature wiring (coils). The laminations are mounted on a steel shaft which has the bearing/s surfaces for holding the armature in its correct position in the motor frame and allowing it to rotate. Also on the armature shaft is mounted the drive pinion or coupling and the commutator which allows the armature windings to be connected together plus it allows current to be passed into the windings from the external supply while the armature is rotating.

**BRUSH HOLDERS OR BRUSH BOXES:** - as the name suggests they hold the carbon brushes in the correct position for the armature and are insulated from the motor frame. They contain tensioning devices that hold the brushes at a constant pressure against the commutator.

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CARBON BRUSHES: - are usually manufactured from a carbon based material with additives for wear and lubrication characteristics. They carry the current from the armature supply leads to the commutator and the armature windings.

ARMATURE BEARINGS: - carry the armature and allow it to freely rotate. The armature bearings also locate the armature in the centre of the magnetic field paths that are created by the field coils.

NOSE SUSPENSION: - is the side of the motor frame that is supported on the truck or bogie frame through the use of springs, etc.

AXLE SUSPENSION: - is the other side of the motor frame that is supported on the axle that is being driven by the motor. To allow for wear, the axle suspension is fitted with renewable bearings to allow for free rotation of the axle while still supporting the weight and torque of the motor.

The main reason for laminating both the field pole pieces and the armature core is to stop the eddy currents that flow as the armature rotates and cuts the magnetic field paths. This cutting of the magnetic field paths induces an electromotive force in the cores. If the cores were of a solid design there would be build up of large circulating currents causing a large waste of power and over heat the core, thereby damaging the winding insulation. Laminated cores are built up from thin oriented steel which is electrically insulated from each other; this insulation reduces the eddy currents to a minimum.

Further to the above it should be mentioned that there is two basic styles winding the armatures which are LAP and WAVE. To identify a particular style of winding is to count the number of brush boxes for a lap wound armature requires the same number of brush boxes as there is field poles. For example a four pole motor has four brush boxes. A wave wound motor only requires two brush boxes regardless of the number of poles. A diagrammatic representation of each type of winding is shown in *Figures 9 and 10*.

Normally most D.C. generators, locomotive type traction motor and rotor converters have lap wound armatures as they are very heavy current machines. Being lap wound armatures the current density per brush is kept as low as possible to save any possible damage to the commutator. Smaller lower current D.C. machines have their armatures wave wound for economy of manufacture.

Nearly all the traction motors in the Museum's collection are series wound machines. The most notable exception is the trolley bus's motor which is compound wound which means that both a shunt field and a series field are built into the motor. It also should be noted that most of the traction motors are wave wound with the exception of the PCC motors which are lap wound. These PCC motors are high performance, high current and are of a very small frame size, they therefore have four brush holders compared to a conventional traction motors two brush holders.

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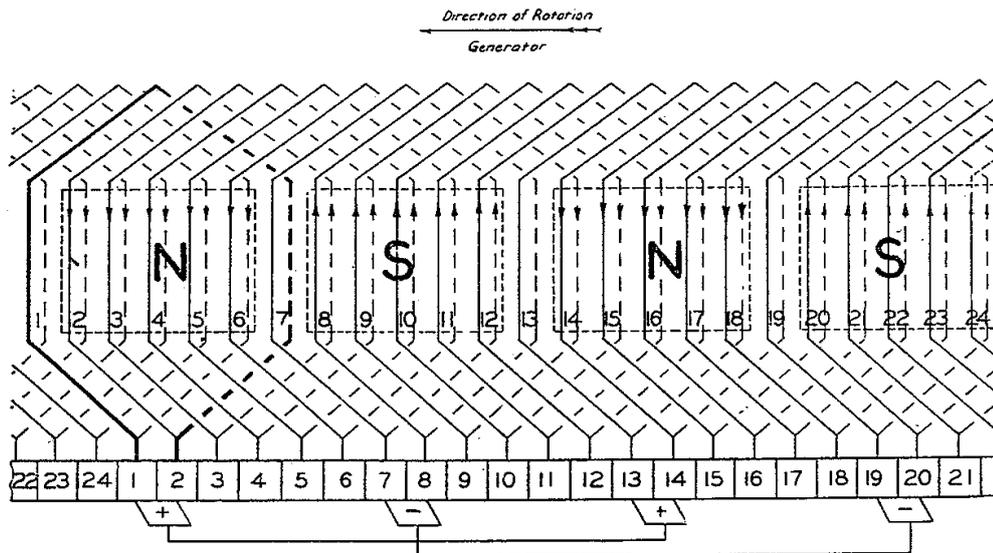


Figure 2 – LAP WINDING

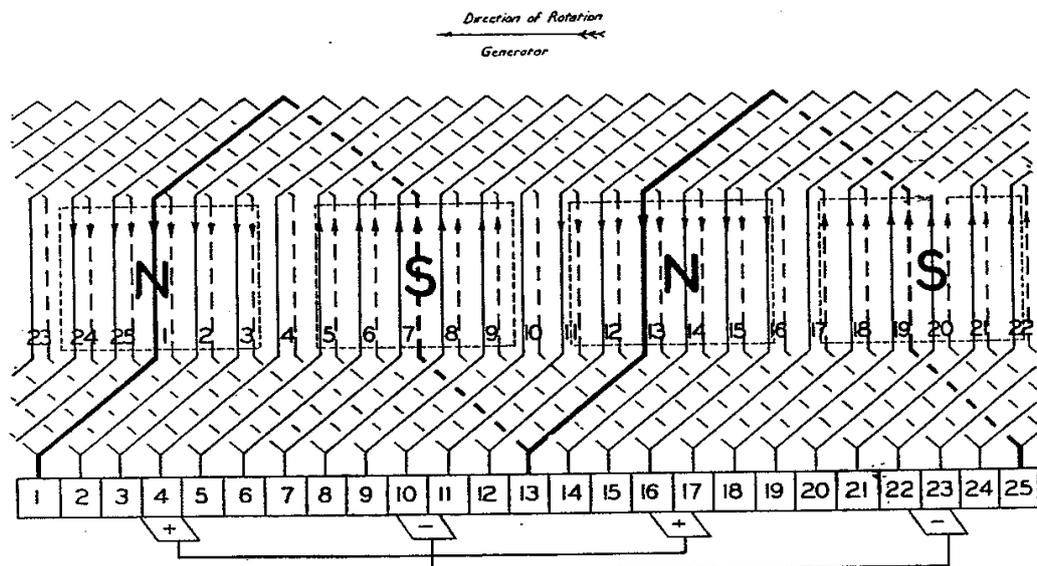


Figure 3 – WAVE WINDING

## Brush Holders

Two brush holders are bolted to the motor frame and are located so as to span one quarter of the commutator bars. A brush holder complete includes the carbon way, finger, finger spring arrangement, shunt, carbon brush and clamping arrangement. Some of the older motors have the brush holders bolted to a yoke which in turn is bolted to the frame.

## Brush Holder Repairs

- a) Clean carefully with a fine grit blast or preferably dip in a good cleaning solvent solution.
- b) Porcelain insulators should be cleaned with solvent and sealed tight on supporting pins by putting pieces of insulation paper between the tube and porcelain if loose. Use air dry insulation varnish to hold in place.

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- c) Smooth up inside of the carbon box if oversize, repair and regauge. No more than 1 mm (*1/32 inch*) clearance all round the brush should be allowed.
- d) Contact tips should be adjusted to make maximum contact on the new carbons at the top of the brush box.
- e) With steel ratchets, use phosphor bronze spindles to prevent sticking.
- f) When moving parts are stiff, apply a little light machine type oil or preferably graphite powder to reduce friction.
- g) Keep shunts in good condition.
- h) When two or more springs are used, adjust the pressure of each to about 20.7 Kilopascals (*3 pounds per square inch*) of brush contact area. Later, after the brush has been installed, adjust the spring pressure to that shown in the Traction tables on the following pages.
- i) When one spring is used, the pressure should be measured at the centre of the contact point, again the spring pressure should be about 20.7 Kilopascals (*3 pounds per square inch*) of brush contact area.
- j) All spring pressures should be measured at the centre of the contact tip and at the top of the brush box using a spring balance.

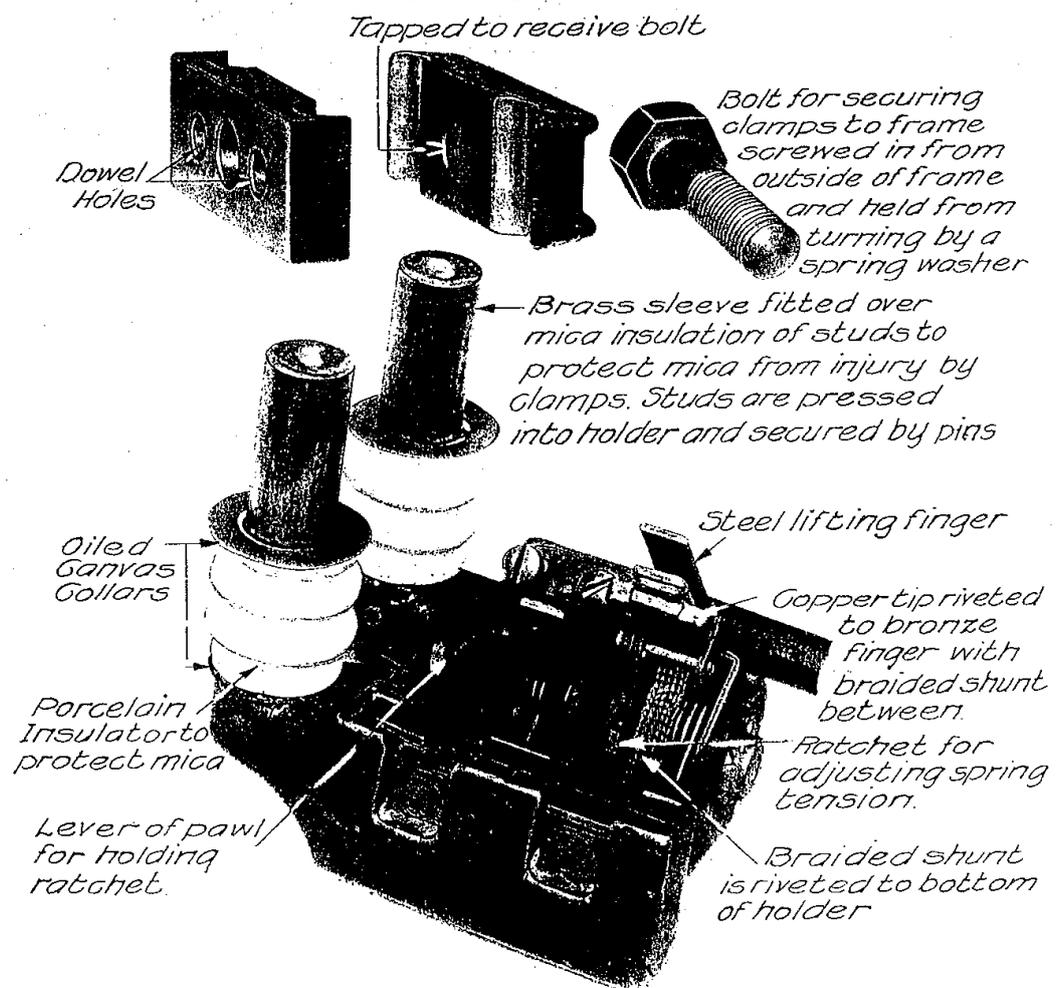


Figure 4 – TYPICAL BRUSH HOLDER

### Mounting Brush Holders in Motor Frames

- a) Clamping bolts should be drawn up tight and secured by lock washers.

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- b) Pressure mechanism should work freely.
- c) Spring tension should be checked with valves given in the following tables on the following pages. A good rule for those motors not included in the table in 20.7 to 24.1 Kilopascals (3 to 3.5 psi) of brush contact surface area.
- d) The distance between brush holders should span one quarter of the number of commutator bars around the face of the commutator.
- e) The underside of the carbon box should be kept within 3 to 6 mm ( $\frac{1}{8}$  to  $\frac{1}{4}$  inch) of the commutator surface, so as to give maximum support to the brush and prevent breakage. This is done by loosening the clamping block and moving the brush holder until the correct setting is obtained. A piece of fibre 3 to 6 mm ( $\frac{1}{8}$  to  $\frac{1}{4}$  inch) thick makes a handy gauge.
- f) Carbon ways should line up parallel with commutator bars.
- g) Carbons should have a smooth sliding fit in the boxes.
- h) See that wiring around the leads is securely fastened to the brush holder terminals. Use a brass or copper sleeve soldered onto the wire to insure good contact.
- i) Always seat the carbon to the surface of the commutator (curve surface) before putting the motor back in service.
- j) Brush holder castings should at least 19 mm ( $\frac{3}{4}$  inch) air clearance from the motor frame.

### CARBON BRUSH INFORMATION ON TRACTION MOTORS

Armature ratings are for one hour.  
Continuous ratings are much lower.

Adjust tension to values given for satisfactory brush service. Measure these pressures on the centre of the contact tip and at the top of the carbon box.

Number of commutator bars means the number of bars between the near sides of the carbons plus the number covered by one carbon. This gives the number of commutator bars between the centre lines of the brushes.

Westinghouse Motors							
Type of Motor	K.W. (H.P.)	One Hour Rating Amps	RPM	Size of Carbon Brush mm (inch)	Amps/sq. inch Carbon	Kilopascals (Lbs./sq.) Pressure	Comm. Bars Between Carbon
202							
205							
225							
510	26 (35)	52	1070	16 x 25 x 6 mm ( $\frac{5}{8}$ x 1 x $\frac{1}{4}$ inch)	34	55.16 (8)	36- $\frac{1}{4}$

General Electric Motors							
Type of Motor	K.W. (H.P.)	One Hour Rating Amps	RPM	Size of Carbon Brush mm (inch)	Amps/sq. inch Carbon	Kilopascals (Lbs./sq.) Pressure	Comm. Bars Between Carbon

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67	26 (35)		340				
90	37 (50)		590				
201	41 (55)		750	57 x 41 x 16 mm (2 ¼ x 1 ⅝ x ⅝ inch)		48.3 to 55.2 (7 to 8)	
203	37 (50)		635	57 x 44 x 14 mm (2 ¼ x 1 ¾ x 9/16 inch)		48.3 to 55.2 (7 to 8)	
247A/D	30 (40)		715	57 x 32 x 13 mm (2 ¼ x 1 ¼ x ½ inch)		48.3 to 55.2 (7 to 8)	
275F	37 (50)		727	57 x 41 x 16 mm (2 ¼ x 1 ⅝ x ⅝ inch)		48.3 to 55.2 (7 to 8)	
1000	26 (35)						

Metropolitan Vickers Motors							
Type of Motor	K.W. (H.P.)	One Hour Rating Amps	RPM	Size of Carbon Brush mm (inch)	Amps/sq. inch Carbon	Kilopascals (Lbs./sq.) Pressure	Comm. Bars Between Carbon
101	30 (40)						

Miscellaneous Manufacturers Traction Motors							
Type of Motor	K.W. (H.P.)	One Hour Rating Amps	RPM	Size of Carbon Brush mm (inch)	Amps/sq. inch Carbon	Kilopascals (Lbs./sq.) Pressure	Comm. Bars Between Carbon
DK11E	37 (50)						
DK83							

### Carbon Brushes

When putting in a new brush in the brush holder it is desirable to work the commutator side of the brush to the shape of the commutator. This is to produce a good electrical contact from the start so as to stop very high currents flowing through a small area, which can cause damage to both the brush and the commutator. To set a brush to the contour of the commutator, a piece of glass paper or garnet paper is cut to the width of the commutator face and is at least half the circumference of the commutator. The paper is placed with the abrasive side up on the commutator and the brush to be set inserted into the brush holder and onto the paper. Next the paper is held firmly against the commutator and moved back and forth abrading the end face of the carbon to the contour of the commutator, be extremely careful as the carbon is quickly cut to shape.

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**NOTE:** *do not* use sand paper as the abrasive particles are easily removed from the paper and can be deposited in the undercut of the commutator and wear the brush away very quickly, also damage to the commutator can occur such as scoring. When finishing setting the brushes, vacuum away the excess carbon particles from the commutator and the inside of the motor frame.

High mica in a commutator is very detrimental to the carbon brushes in that the mica is harder than carbon. There is a tendency for the high mica to break off the corners and the edges of the carbon brush thereby decreasing the life of the brush.

It is very important at each inspection to remove the carbon brushes to make sure that they are not chipped.

Spring tension on the brushes is a very important factor. When the brush is not held firmly to the commutator, sparking will surely result. Also if the spring tension is too great, the brush will be rapidly worn away. Consult the tables above for the proper tension.

Length - for use in the more modern (*post year 1919*) brush holders, the carbon should not be over 57 mm (*2-¼ inch*) long, i.e. when new, they should not extend above the top of the carbon box for these reasons:

- a) If longer, they are subjected to a greater side pressure due to the action of the contact tip which increases the side wear, tends to bind the carbon in the box, and reduce the direct pressure on the surface of the commutator.
- b) If longer, they are discarded due to excessive side wear before the added length can be used up in the end wear.
- c) Replace brushes when they are worn to within 6 mm (*¼ inch*) of the limit of the brush holder spring travel.

Width – The width is not so popular; they can have as much as 1 mm (*1/16 inch*) clearance in the box without causing any trouble in service.

Thickness – The thickness is very important, as the initial clearance between the carbon and the carbon box should be approximately from 15 to 20 microns (*0.0006 to 0.0008 inch*). If it is much less, the carbon will tend to stick in the box and bind; if greater it will soon rattle in the box, wearing away the side. It will also tend to chip and break, thus reducing the life of the carbon.

### **10.2 Motor Suspension Bearings and Caps**

Excessive wear on the axle (suspension) bearings is not as serious as on armature bearings as it only subjects the frame axle cap and axle cap bolts to increased shocks and strains. It also tends to spread the gear centres, with resulting less efficient gear operation and rapid wear. The wear limits for axle bearings have not been definitely set, but when the radial wear for an axle bearing is 3 mm (*⅛ inch*) or alternatively a 3 mm (*⅛ inch*) feeler gauge can be placed between the axle bearing and the axle, the bearing should be replaced. Also when the flange of a bearing has worn by 6 mm (*¼ inch*), the bearing should be replaced.

This wear can readily be checked with a feeler gauge from the inspection pit. If necessary, remove the axle shield to make the inspection.

Do not use shims in back of the bearing to make a tight fit in the motor frame, use a correct fitting bearing.

The following points should be noted when replacing axle bearings:

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- a) Bearing shells should preferably be made from bronze, tinned and babbitt lined. The Babbitt lining may possibly chip and break out in a split bearing, therefore extreme care must be exercised in the use and handling.
- b) Chamfer all bearings at the oil window to remove the sharp edge which would have the effect of scraping the lubricant off before it could go onto the bearing face. Lightly chamfer at the halves for the same reason.
- c) Oil grooves are required; they should leave the window at 45 degree to either side of the horizontal axis. This is to allow quick lubrication of the bearing as Museum tramcars can remain stationary for long periods of time between uses.
- d) New axle bearings, where possible in times passed, were brought from the original motor manufacturers and finish bored to size. Now in Australia, there is little possibility of original manufacturer purchase. So to overcome this, the Australian Tramway Museums have manufactured or obtained from local tramway systems the patterns for many parts. Then a local foundry is called in to cast the new bearings. In all cases it is recommended that the bearing should be brought undersize to allow for finishing and ample metal to fit the new bearings to worn axles.
- e) Allowances and variations should be made as follows:

<u>Normal Bore</u>	<u>Allowances and Variations</u>
Up to and incl. 127 mm (5 inch)	Plus 38 microns to plus 43 microns (Plus 0.0015 inch to plus 0.0017 inch)
Over 127 mm (5 inch)	Plus 71 microns to plus 76 microns (Plus 0.0028 inch to plus 0.0030 inch)
- f) Keep bearings from working loose by maintaining the dowels or keys tight and in good condition.
- g) The outside of all shells should be given a tolerance of plus 0 microns to plus 8 microns (plus 0.000 inch to plus 0.003 inch).
- h) Bearing shells should be a tight clamping fit in the motor frame and axle cap, not onto the axle.
- i) Do not mix axle caps from different motor frames. Whenever possible, use the ones that were originally furnished with the motor frames.
- j) Carefully clean all of the surfaces of the housings, axle caps and frames at the point of fit when assembling.
- k) Heat treated high grade special bolts should be used to hold the bearing housings in place. Use only lock washers. See Lubrication Manual (STM6075).

### **10.3 Removing Axle Bearings**

In case it becomes necessary to remove the axle bearings whilst the motor is still in the truck, proceed as follows:

- a) Run the tramcar over a pit. Locate it to the best advantage for working on the under side of the axle.

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- b) Remove the axle dust shield from between the axle bearings by taking out the four bolts which hold it in place.
- c) If the bearing being removed is on the gear side, it will be necessary to take out the two gear case bolts and drop the lower half of the gear case.
- d) Take out the four axle bearing cap bolts and remove the cap. If the cap sticks, it can be loosened by carefully tapping a flat cold chisel in the crack between the cap and the motor frame. First on one side and then on the other. Care should be taken to see that the cap is properly supported by leaving two of the bolts in place but held by at least two threads (turns) of the nuts onto the bolts. An assistant holding the cap or pack up the cap with wood blocks in order to prevent personal injury when it is being loosened. The lower half of the axle bearing will drop down with the cap and can readily be knocked out with a hide, or equivalent type of hammer. To remove the upper half of the bearing, jack up under the motor frame by a sufficient amount to remove the weight on the bearing. Then revolve the upper half around the axle until it can be slipped off below. If the bearing sticks to the frame, it can be knocked loose by driving down on the flange with a hammer and wooden block.

### **10.4 Hot Axle Bearings**

Hot axle bearings can be caused by any one of the following causes:

- a) Lack of oil in bearings.
- b) Imperfectly packed bearings.
- c) Grit or foreign matter working into bearings.
- d) New bearings with insufficient clearances.
- e) Motor nose clamped.
- f) Excessive wear and end play on the axles.

The strap holding the motor nose should not be applied in such a way that it produces a clamping action, as severe stress on the nose and axle bearings may be produced.

### **10.5 Axle Collars**

The function of an axle collar is to keep the motor properly located sideways on the axle so that the centre of the pinion on the motor shaft will line up with the centre line of the gear on the tramcar axle. Some collars have one adjusting bolt, most commonly found, other have two. The head of the adjusting bolt backs up against the wheel hub, and can be adjusted whenever the flange of the axle bearing wears so as to cause excessive side play. The axle collar should be adjusted whenever the end play on the tramcar axle is greater than 6 mm ( $\frac{1}{4}$  inch). The adjusting bolt in addition to the lock washer has a cotter pin which prevents the adjusting bolt from the turning out in opposition.

The face of all collars should be given a smooth machined finish to minimise friction and wear. The maximum value of the end play on motors up to 37.3 kilowatts (*50 horsepower*) should be 6 mm ( $\frac{1}{4}$  inch) and above 37.3 kilowatts (*50 horsepower*), 8 mm ( $\frac{3}{8}$  inch).

### **10.6 Armature Bearings**

The proper maintenance of motor armature bearings requires careful inspection and gauging to determine when armatures should have new bearings in order to keep the motors in good operating condition. In armature bearings, this is very important because when inspections are neglected, worn bearings may cause the armature windings to become earthed or damage the entire armature and field poles.

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As it is common practice to check the armature bearing radial wear by measuring the air gap of the motor. That is the space in between the outside of the armature and the nearest field pole. The measurement is usually taken at the 12 o'clock position and if possible the 6 o'clock position. Below is given a range of air gaps for some typical motors.

Motor Type	Air Gap
Westinghouse type 510-A	3 mm ( $\frac{1}{8}$ inch)
General Electric type 247	As above
Metropolitan Vickers type 101	As above

Armature bearings sometimes become loose in their housings. Although the looseness may be only a few thousandths of an inch, it proves to be very troublesome. A “pumping action” is set up by the excessive vibration which pumps the oil out of the bearing window. Looseness of this kind is usually indicated by an unusually low oil level. It can be detected by tapping the bearing lightly with the end of a small hammer. If it moves in its housing, it is loose and should be repaired.

It is considered a safe working rule to replace the bearings after they have worn approximately 1 mm to 2 mm ( $\frac{1}{16}$  to  $\frac{3}{32}$  inch), for with this wear, added to the initial clearance allowed on the new bearings, there is considerable pounding of the armature which tends to rapidly increase the bearing wear to the danger point and hammer out of Babbitt.

If the wear on the flange is as much as 3 mms ( $\frac{1}{8}$  inch), the bearing should be replaced. Wear on the flange causes a good deal of end play on the motor armature. The armature in this case is thrown back and forth, either by magnetic field in the motor or the external drive force from the wheels which causes shocks to the bearing faces. Helical gears have a tendency to force the armature to one side which causes excessive end wear.

### 10.6.1 Checking Bearing Wear

A very common method of checking end wear and radial wear of small motors is to put a bar under the fan of the armature and raise the armature up and down. This gives some idea of radial wear. At the same time the armature can be pushed back and forth to get some idea of end wear. Many motors, however, cannot be checked this way and so it is necessary to pull out some of the waste to get the radial wear at the bearing by putting in a gauging tool. End wear can be obtained by pushing the armature back and forth by a bar through the commutator cover on the motor.

### 10.6.2 Other Methods of Bearing Wear

Light Test – Applicable to motor frames that have inspection holes so located that a light can be held at one end of the motor and the clearance in the air gap checked by the servicing person. This method depends largely upon judgement and cannot be entirely relied upon.

Sweep Gauge on Underside – This method, very commonly used by operators, requires a sweep gauge made of varying thickness of hardboard, bakelite, soft metal or sometimes a long steel feeler gauge. These gauges are inserted in the air gap at the lower side of the motor. When the minimum gauge cannot be entered, the bearings show the maximum allowable wear and should be renewed. In general, this method requires that the lower commutator cover be removed in order to apply the gauge.

Feeler Gauge – When the motor is off the tramcar and the pinion is removed, the pinion end bearing wear can be measured with a feeler gauge. This method is accurate but not practical for in service inspections as it requires too much work to check the bearings

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under these conditions. This method can be used to check the commutator end of the motor on the tramcar by removing the commutator dust cover. With experience, the condition of the wear on the pinion end can be estimated from the wear on the commutator end.

A final check on the bearing is to go into the pit and look at the clearance between the armature and the main coils.

### 10.6.3 Checking and Installing New Armature Bearings

- a) Bronze bearing Babbitt lined should preferably be used.
- b) Bearings that are properly Babbitt lined should give out a bell-like tone when suspended and struck with a hammer.
- c) New armature bearings
- d) The finish on the outside of shells should be smooth and slick, and from 51 microns to 102 microns (*0.002 inch to 0.004 inch*) oversize to insure a tight fit in the housings.
- e) The bore of bearings should be as follows:-

<u>Nominal Bore Of Bearings</u>	<u>Allowance and Variations Before Pressing into Housing</u>
51 to 76 mm ( <i>2" to 3"</i> ) inclusive	plus 152 to 203 microns ( <i>0.006" to 0.008"</i> )
76 to 102 mm ( <i>3" to 4"</i> ) inclusive	plus 203 to 254 microns ( <i>0.008" to 0.010"</i> )
102 to 127 mm ( <i>4" to 5"</i> ) inclusive	plus 305 to 356 microns ( <i>0.012" to 0.014"</i> )

- f) All armature bearings should be provided with oil grooves, one of which should extend to the face of the collar.
- g) All rubbing surfaces, such as the bore and the end of the flanges, should be given a smooth finish to keep down friction.
- h) Chamfer the sides of all windows.
- i) New bearings should be forced into the bushings with a pressure ranging from 3 to 7 tonnes, depending upon the size of the bearings. Old bearings that require less than 1 tonne to press into the housing should not be placed back in service.
- j) Bearings should be forced into the housing using a press rather than pounding with a sledge hammer as the practice can distort the bearing shape.
- k) Bearings that are finish bored after being pressed into the housings give a more accurate alignment of the armature.

### 10.6.4 Removal of Armature Bearings

To remove an armature bearing, it is necessary to take the motor out of the truck (*see Removing Motor Armature section*). Take off the end housing in which the bearing is located and press the bearing shell out with a screw or hydraulic press. The bearings are pressed in with from 3 to 7 tonnes and the pressure to remove them is generally 3 to 8 tonnes.

The shaft should be carefully examined for surface condition and circularity. Smooth up, if any surface roughness exists or, return the journal face to circular form before putting on the new bearing.

After pressing a new bearing into the housing it should be slipped over the armature and checked for clearance. The clearance should be measured on the bottom of the shaft with a narrow feeler gauge with the weight of the housing resting on the bearing. If the clearance is not sufficient the bearing should be carefully scraped until the necessary clearance is obtained.

A little oil should be spread over the surface of the shaft and bearing before assembly.

## **10.7 Commutator Maintenance**

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### 10.7.1 Smoothing a Commutator Face

Flat spots, high or low bars, ridges, burned spots on the trailing edges, oil leakage, etc., should be cleaned and smoothed up. When these are not bad, the motor need not be removed from the tramcar. A tool can be used called a “dressing stone” which is mounted on a block of wood, the face of the block being shaped to the radius of the commutator. The tramcar is run, with the “worked on” motor being electrically isolated, by using the other motors. The dressing stone being held against the commutator will smooth up the rough spots.

If the face is very rough, the armature should be removed from the tramcar and placed in a lathe for turning of the commutator. After turning down, the mica between the segments must be undercut.

### 10.7.2 Undercutting the Commutator

The commutator should be re-undercut before it is worn flush since the groove left will guide the saw and make the work much easier.

The object of undercutting commutators is to clean out the mica between the copper segments from the face of the commutator to a depth of 0.4 mm to 1.2mm. If not kept undercut, the mica soon wears the carbons of the brush away causing flashing.

If the commutator trouble is frequent, it is good practice to use a V-shaped tool to round the edges of the undercut grooves between the bars to 0.25mm to 0.5 mm radius. This can be done with the motors in the tramcar. All particles of mica, copper or dirt must be removed from the grooves after undercutting.

The general method of undercutting consists of placing the armature in the lathe and with a lathe mounted undercutting machine which can be guided absolutely parallel with the slots, cutting away the mica between the segments. The blade should be between 0.00mm and 0.05 mm larger than the slot.

### 10.7.3 General Commutator Care

Don't forget to keep:

- a) Commutator well undercut - 1.2 mm maximum and 0.4 mm minimum;
- b) Edges of commutator face rounded – 4.8 mm radius front and 1.6 mm radius at the rear;
- c) Front V-ring clean and well painted;
- d) Commutator free from oil;
- e) Rear of commutator free from dirt and moisture;
- f) Commutator tight;
- g) Face of commutator smooth; and
- h) Free from all earths and shorts.

## **10.8 Motor Flash Overs**

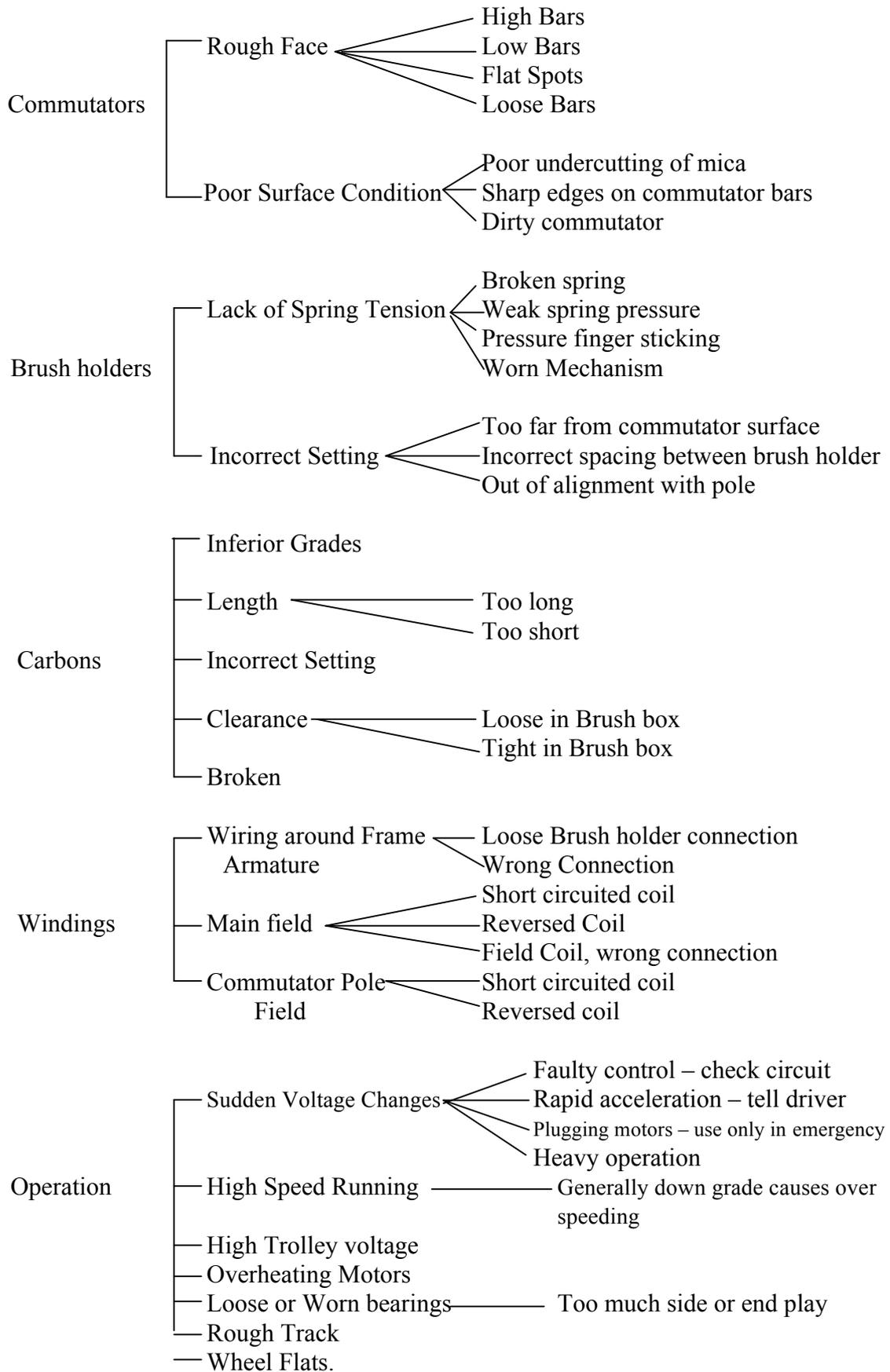
Motor flashovers are also known as bucking or blowing. Flashovers are primarily caused by poor commutation which results in a sudden breakdown of the insulation over the face of the commutator or to earth. As a result, there is a sudden rush of heavy current which will either open the circuit breaker, or hang on as a high resistance arc and badly burn the parts short circuited. Poor commutation can be caused by the wheels spinning at an uncontrolled speed, i.e. due to excessive wheel slip on wet or greasy rails.

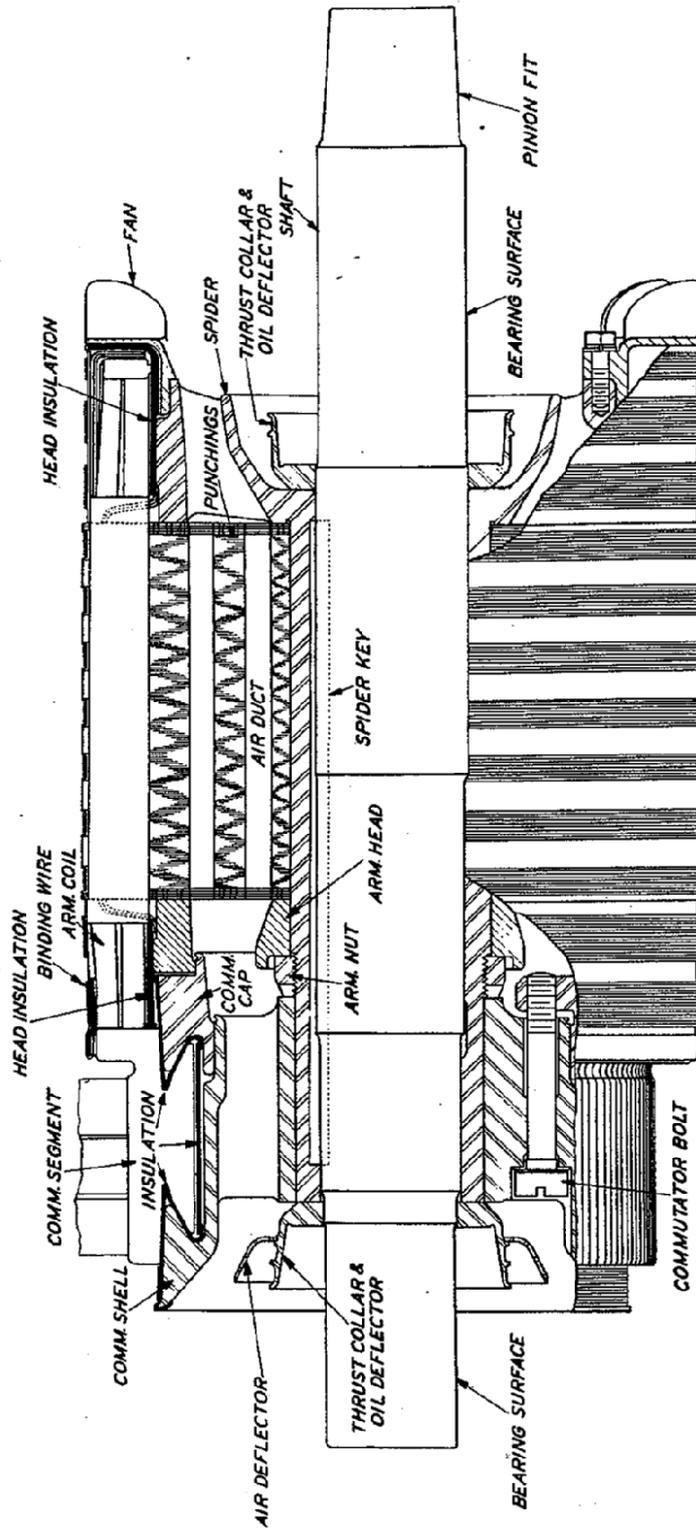
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After this flashover has occurred, a motor can generally continue in service to finish the run, but should be given careful inspection for damaged parts that need attention.

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## Conditions that Tend to Produce Flashovers.





*Figure 5 – CROSS SECTION OF AN ARMATURE*

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### **10.9 Removing Traction Motors**

- a) The leads from each motor are attached to the tramcar body by two wooden cleats. Remove these cleats and slide the insulating tubes which cover the connections along the motor leads, taking care to see that all connections are plainly marked so that there will be no trouble when they are connected. Or colour code the leads on both motor & frame cables. Red for A, blue for AA, green for F & yellow for FF.
- b) Remove the king pin securing pin and disconnect the brake rigging, sanding equipment and any other connections between the truck and the tramcar body. Jack the body up a sufficient amount to clear and run the trucks out from under.
- c) Remove the bolt which secures the axle end gear case to the arm, which is cast on the axle cap. Then remove the bolt which secures the opposite end of the gear case to the lug on the motor frame. Pull out the gear case clips and the lower half of the gear case will drop down and the upper half can then be lifted off.
- d) Remove the axle shield.
- e) Remove the bolts/straps which hold the motor nose in place on the truck transom.
- f) Remove the motor axle cap bolts and take off the motor axle caps. Then remove the axle bearings and store with their respective caps.
- g) Lift the motor out of the truck with the appropriate lifting equipment, hooking the lifting chains onto the bales that are cast on the motor frame for that purpose. When hooking up the lifting chains, care must be taken to so adjust the lengths that the motor will be lifted first on the side next to the truck centre. Allowing it to rotate around the axle a sufficient amount so that the lower lip of the axle bearing housing will clear the axle, so as not damage the journal face.

### **10.10 Removing Motor Armatures for other than split frame motors**

- a) Remove the motor from the truck (see above).
- b) With the motor sitting safely on the floor, remove the pinion (see below).
- c) Remove the oil and wool waste from the bearings. Place the waste in a covered bucket or other container where it is protected from dust and dirt ingress. Inspect the waste for water and other contamination.
- d) Remove all of the brushes, inspect the condition and length. If the brushes are reusable, store the brushes carefully and identify as to which brush holder they were removed from. If the motor has roller bearings remove comm. End grease cap & undo the bearing alignment equipment.
- e) Lift the motor into a secure vertical position, with the pinion end up. Then remove the end housing bolts. The end housing can be loosened from the motor frame by using the “jacking screw holes” provided. As you screw the jacking screws in, the end housing is moved away from the motor frame without the use of hammers and wedges which damages the machined faces of the motor case & end shields.
- f) Secure a lifting eye to the armature shaft and attached the hook of the lifting gear to it. Lift the armature out of the motor together with the pinion end housing. Extreme care must be taken to ensure that the lifting gear is directly above the armature shaft’s centre before the lift is started. The armature must be guided out to stop any scraping of the armature against the field poles. When setting the armature down, a hardwood stand should be used with two vertical supports, with ends notched, to take the armature journals. A thick piece of felt or equivalent could be used between the journal and the timber. Using this type of stand allows the armature to be rotated for inspection or to affect any repairs necessary.

### **10.11 Removing Pinions**

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In order to remove a pinion, the motor must first be removed from the truck. Use a pinion puller of suitable capacity as pinions tend to grow onto the armature shaft. They then require, at times, a great amount of force to remove them.

Remove the pinion nut and lock washer, then assemble the puller around the pinion. There are a number of pullers available, but they fall into basically two types which are the split plate type and the two or three leg type. The split plate type pullers can then be split into two basic types which are the centre bolt type and the multi bolt type. The single bolt type is mainly used for small bearings, with the multi bolt type being used where a large force is required to move the bearing or pinion. What ever type of puller is used, when the puller is used do not stand in front of the puller as it and the pinion can suddenly let go and may cause injury.

In taking off *worn out* pinions that are to be scrapped and very hard to remove, the following method could be used:

- The pinion is heated with an oxy-acetylene torch to expand the metal and relieve the fit. **NOTE:** for a pinion that is going to be reused, heat should not be applied as this has a tendency to destroy any heat treatment of the pinion surface. When an old pinion is heated, extreme care must be exercised to prevent heating of the armature shaft and damaging it.
- A pinion can be removed by using a “fuller” (a blunt chisel shaped tool) in the trough of the pinion and striking a series of heavy blows with a sledge hammer. This operation is repeated if necessary in a number of troughs around the pinion.
- In extreme cases a pinion can be pulled off, either with a heavy hammer and cold chisel or an abrasive disc grinder, then finish cutting with a hammer and a cold chisel. If using an abrasive disc grinder, cut most of the way through the pinion and finish cutting through with the hammer and cold chisel.

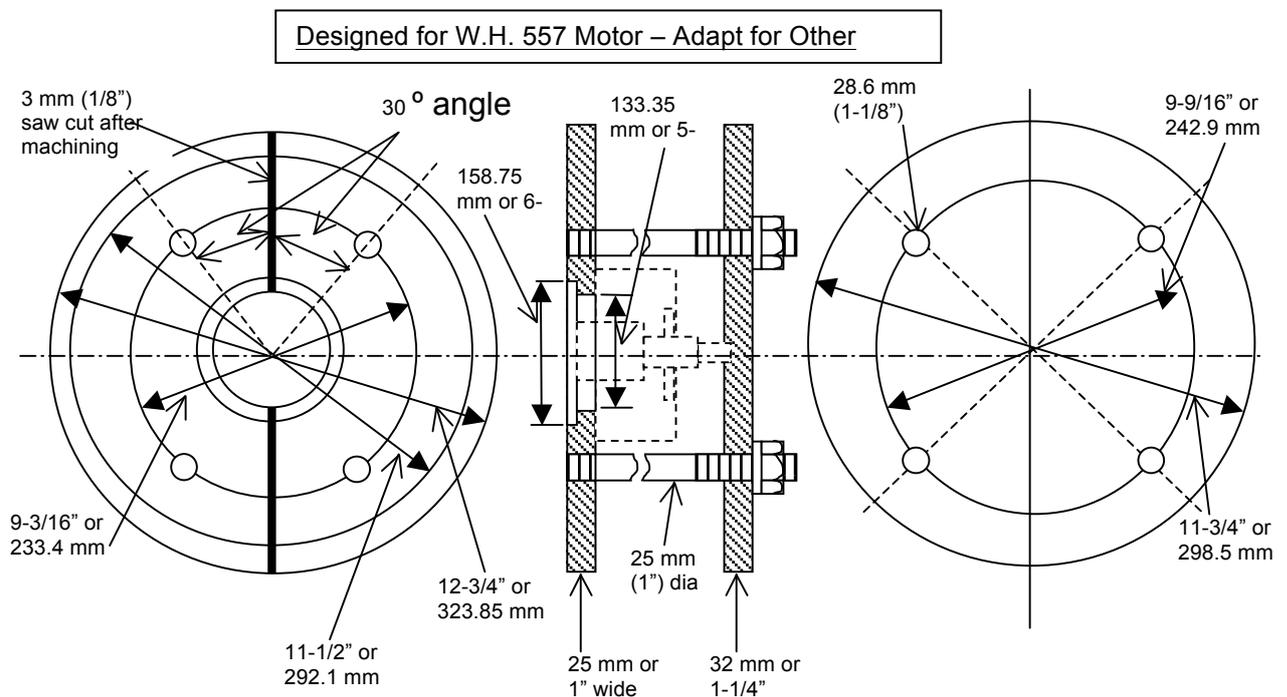


Figure 6 – PINION PULLER

### 10.12 Installing Pinions

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When installing a pinion onto a shaft it must be a “press” fit or a “shrink” fit. This is because it is bad practice to allow a pinion to drive its gear through its key. The pinion key is for safety in case the pinion accidentally loosens. If the pinion is fitted correctly, it will give years of service without any trouble.

- a) Inspect the shaft for any imperfections such as burrs or blisters, clean the shaft with solvent and remove same.
- b) Check the bore of the pinion for any burrs or blisters and that it is of the correct taper (clean the shaft with solvent).
- c) Lightly cover the shaft where the pinion is to sit with “bearing blue” (Prussian Blue) and slide the pinion onto the shaft. Remove the pinion and inspect the shaft for the removal of the “blue”; as if 75% or more has been moved or removed then the pinion is a good fit onto the shaft. If not, lap the pinion onto the shaft using a medium grade of lapping compound, remove the pinion, clean the surfaces and test again. Continue the process until a satisfactory contact area is achieved.
- d) After checking the fit of the pinion, the shaft and bore should be wiped perfectly clean, the key put into place and the pinion slipped onto the shaft cold to check the key clearances. The pinion should not ride up or bind on the top or sides of the key. The keyway on the pinion should be 0.56mm (*0.002 inch*) larger, but not less than the key. There should be 0.4 mm (*1/64 inch*) clearance between the top of the key and the bottom of the keyway in the pinion. The corners of the key should be rounded so that they will not bind in the fillet of the keyways.
- e) After check fitting, the pinion should be heated in oil for about one (1) hour. Remove the pinion from the oil and wipe the bore dry. Without allowing the pinion to cool, place it into position on the shaft. Then tap it home using a 3 or 4kg hammer with a hardwood or brass drift against the pinion to strike it on. A few taps evenly distributed around the pinion should be enough to assure that it is properly seated. Then the lock washer and nut are then put on. Setting the nut with a correct fitting ring spanner (flogging type) using a lever arm of about one 1 metre (*3 feet*) in length.

### **10.13 Removing and Replacing Field Coils**

#### 10.13.1 Removing

In case of the field coils have not been removed from the motor, it will be necessary to first remove the motor from the truck (*see Removing Traction Motors section*). Secondly remove the armature from the motor (*see Removing Motor Armatures section*).

Assuming the motor to be on the floor of the work area with the armature taken out, proceed as follows:

- a) Place the motor onto two heavy (150 x 150 mm) hardwood timbers which are longer than the motor case so that it can be conveniently rolled into different positions.
- b) Strip the insulation off the connections of the leads, of the coil to be removed, that lead to the adjacent coil/s and unsolder or unbolt the connections. Take care, if a naked flame is used, not to damage the insulation of the remaining coil/s.
- c) Remove the nuts from the studs which hold the pole piece of the main coil which is being removed and lift out the pole as shown in Figure 7 below.
- d) Remove the nuts from the studs of the adjacent commutating pole from which the coil leads have been unsoldered. Tap on the ends of the commutating pole studs with a wooden block until the commutating pole stands up enough on the inner side so that it can be taken hold of and lifted out, (*see Figure 8*) below. The commutating coil can now be taken out past the tip of the adjacent pole by keeping it close to the adjacent loose main coil (*see Figure 9*). The main field coil can now be swung out past the remaining commutating coil as shown in *Figure 10* below.

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If, only the commutating coil is to be removed, it will be necessary to remove an adjacent main field pole, but it will not be necessary to remove the main coil or disturb its connections (*see Figures 7 to 9 below*)

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## FIELD COIL REMOVAL

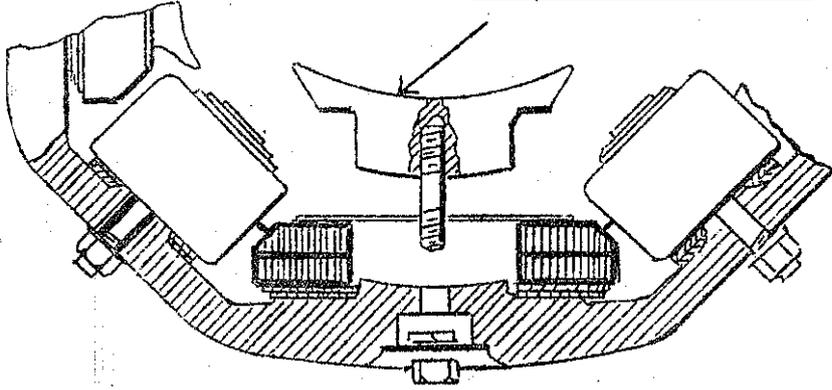


Figure 7 – REMOVING MAIN POLE

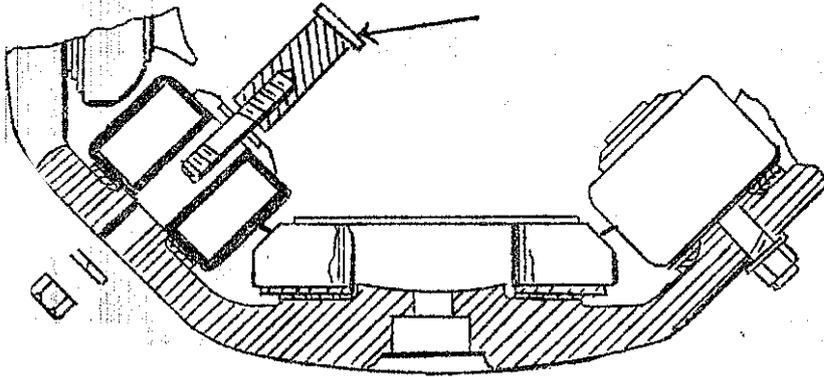


Figure 8 – REMOVING COMMUTATING POLE

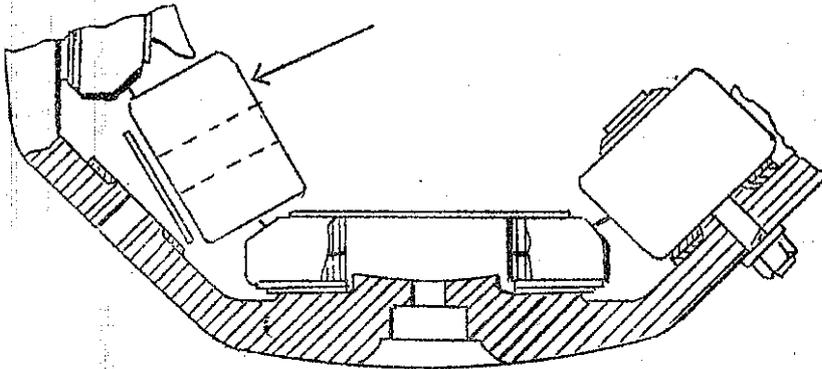


Figure 9 – REMOVING COMMUTATING POLE COIL

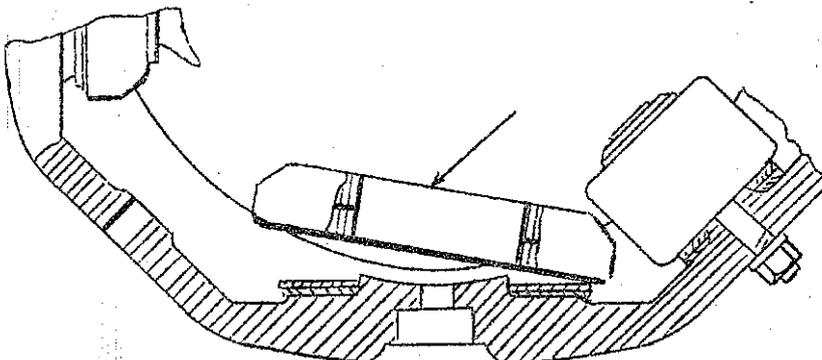


Figure 10 – REMOVING MAIN FIELD COIL

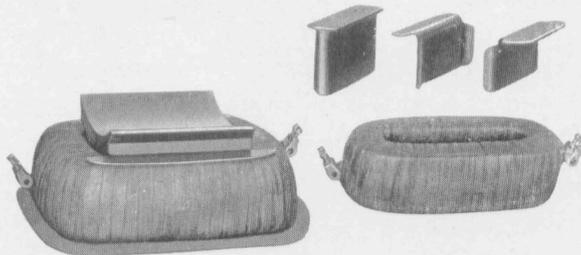
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## *44406A-2 GE-247 Ventilated Commutating-Pole Railway Motor*

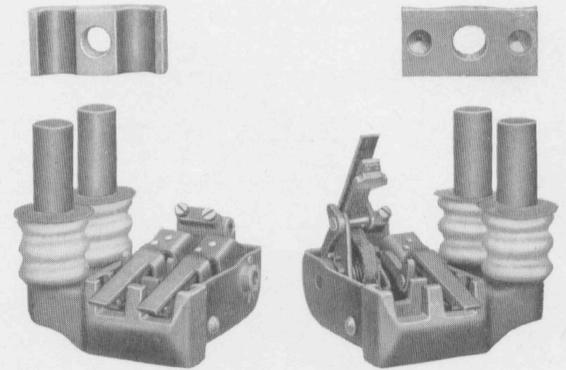
hot binding process is employed in banding the armature, this process having largely eliminated the possibility of loose coils.

The field coils are thoroughly impregnated with insulating compound by the vacuum process and are securely held in place by

closed by springs. The axle is enclosed between bearings by a sheet steel dust guard.



EXCITING AND COMMUTATING FIELD COILS

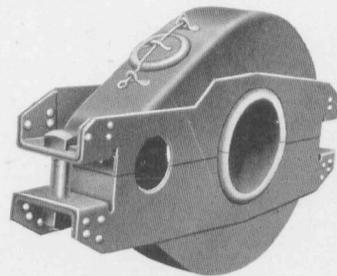


BRUSH HOLDERS

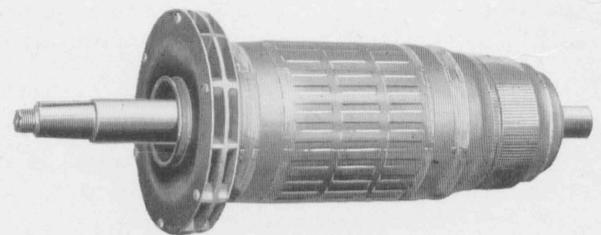
spring steel angle flanges. The gear case is of specially light and strong construction each half being pressed to shape from a steel plate, and welded to a supporting cradle. These are carried by a lug on the frame head and a horn made integral with the pinion end axle cap.

### Ventilation

All parts of the motor are effectively cooled by air drawn into the motor by a double or multiple fan on the armature shaft. The cooling air passes through the motor in two parallel streams, one through the commutator shell and armature core, the other over and



PRESSED STEEL GEAR CASE



ARMATURE

### Lubrication

Oil and waste are used throughout. Oil boxes are provided with auxiliary oil wells, and have felt lined, deep lipped covers held

around the armature and field coils. The air inlets are screened and are located to afford protection to the interior of the motor when operating under unfavorable conditions.

Figure 11 – TYPICAL BRUSH HOLDER

### 10.13.2 Assembling

- Clean off all sharp burrs and edges on all poles and pole seats.
- Paint the inside of the frame at the coil seats and generally inside the frame with red insulating varnish.
- Use steel springs and washers between the field coils and the motor frame.
- Wipe clean the surface of the pole seats and pole tips at the joints before reassembling.

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- e) Be sure to place the coil spring and washer back on the coil before putting it in place. Take care that these items do not slip in between the pole and its seat when it is being bolted in. Taping the coil, spring and washers together at several points temporarily helps avoid this trouble.
- f) Make sure that the coils are turned right side up and correct orientation when placing them into position.
- g) Tighten the pole bolts until they are pulled down solid to the pole seats.
- h) When the bolts are pulled up tight, test by hitting the pole tip lightly with a hammer.
- i) Make sure that the lock washers are used under the nuts on the pole bolts.
- j) A Template made to the diameter of the armature plus twice the single air gap to the main field pole should be used to check the assembled poles of the box-type motors (non split frame type). *See table in section 10.6 Armature Bearings.*
- k) Check the polarity of the assembled main and commutating field coils to insure that they are properly connected. *See test sections below.*

## FIELD COIL CONNECTIONS

*Figure 12 – LOWERING FIELD COILS*

Figure 13 – LOWERING COMMUTATING POLE

*Figure 14 – LOWERING COMMUTATING COIL*

*Figure 15 – LOWER MAIN FIELD COIL*

## **10.14 Re-insulating Field Coils**

Damaged field coils that have had all the insulating tape and reinforcing pieces removed, and are stripped down to the varnished impregnated wound coil, should be re-insulated as follows:

- a) Apply three layers of 254 microns (0.010”) cotton tape, with a half overlap. Place the required protecting pieces over the coil at points where the pole tip rests and then tape with one layer of 508 microns (0.020”) cotton tape, with a half overlap.
- b) Dip and bake three times as follows:
  - i. Dry in an oven at a temperature of 110° C for between three to five hours.
  - ii. Dip in varnish recommended by the motor manufacturer for 20 to 40 minutes or use ISONEL 31 Red Insulating Varnish or equivalent.
  - iii. Hang and drain for about 30 minutes.
  - iv. Bake at a temperature of 150° C for 1 to 4 hours.
- c) Remember to:
  - i. Keep the specific gravity of the varnish at about 0.850.
  - ii. Trim the tape to about half width with scissors while applying around inside corners to keep from piling up at these points.
  - iii. The tapes most generally used are 254 microns (0.010”) cotton cloth 25 mm (1 inch) wide and 508 microns (0.020”) cotton cloth braid 32 mm (1 ¼ inch) wide.

## **10.15 Dipping and Baking Traction Motors**

### **10.15.1 Purpose**

Dipping in insulating varnish, then baking thoroughly fills the cracks and pores in the insulation. This greatly reduces the possibility of breakdown which might be caused by moisture or other conducting materials filling the voids. This treatment acts as an effective bond to prevent vibration of motor parts.

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### **10.15.2 Equipment**

- a) A tank to contain the dipping solution;
- b) An oven in which to bake; and
- c) A means of handling the apparatus.

### **10.15.3 Cleaning**

First protect the polished surfaces, such as the journals and commutator faces, with insulation tape or similar material. Remove all oil and dirt with solvent after first blowing the parts thoroughly with low pressure compressed air to remove all loose dirt.

### **10.15.4 Drying**

Heat the desired part in an oven at 95° to 105° C for 12 to 24 hours depending on the size of the armature or coil. This heating is to insure that all moisture in the armature or coil is driven off and to warm it for dipping. If possible a vacuum oven is preferable to remove any liberated moisture with an air drier for letting air in when opening the oven. It is to be noted that a dry coil should have an insulation resistance of greater than 100 Mega ohms.

### **10.15.5 Dipping**

Dip in an oil-proof, moisture-proof baking and insulating varnish at approximately 0.840 specific gravity such as ISONEL 31. This depends however, upon the varnish and the thickness of the coat desired. If the varnish is too heavy, then thin it.

Dip the armature in the varnish in a vertical position, pinion end down, and to such a depth that the varnish will come to the commutator neck. Allow to soak for approximately 5 minutes.

If a tank is not obtainable, results (though not so good) may be obtained by turning the armature in a shallow pan with the varnish deep enough so that the bottom of the slots will be completely immersed. If this is done, the insulated creepage surface at the end of the commutator should be treated by repeated paintings of varnish. Turn until all of the coils have been thoroughly soaked.

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## FIELD WIRING DIAGRAMS

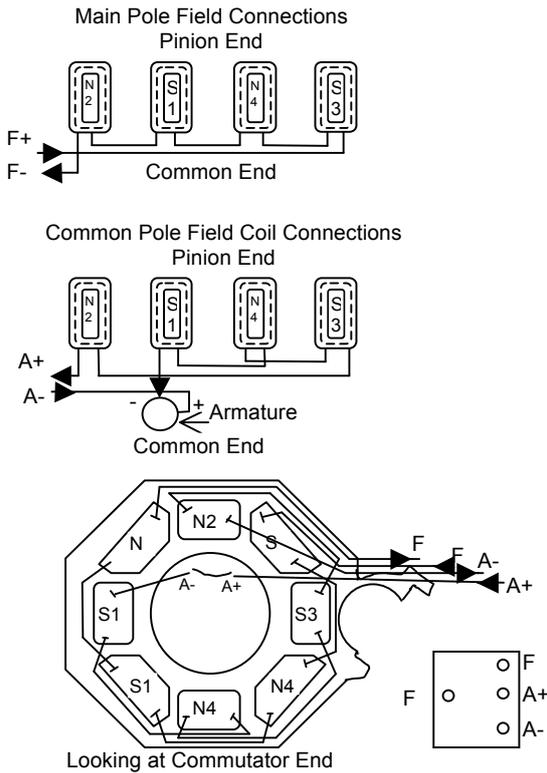


Figure 16 –

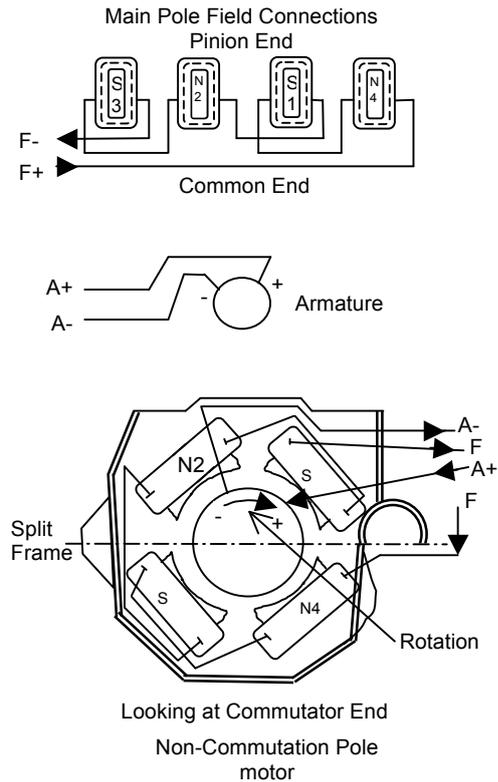


Figure 17 – NON-COMMUTATING POLE MOTOR

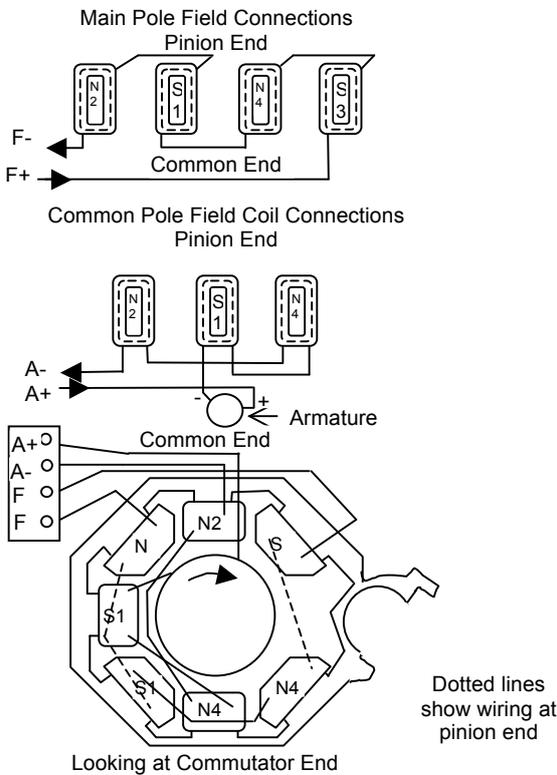


Figure 18 – MOTOR WITH THREE COMMUTATING-FIELD COILS

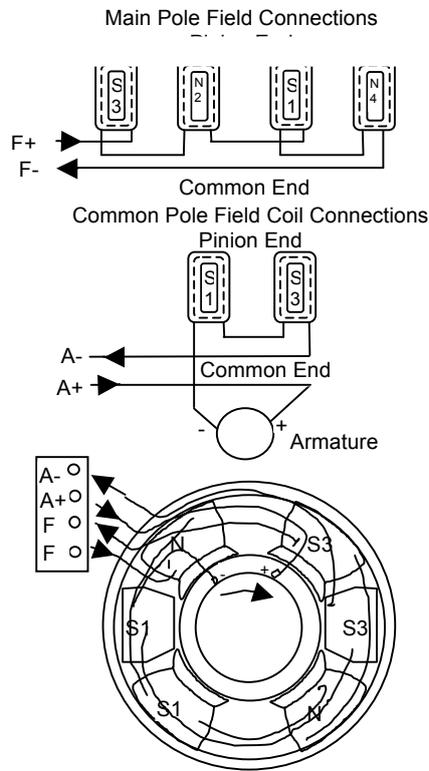


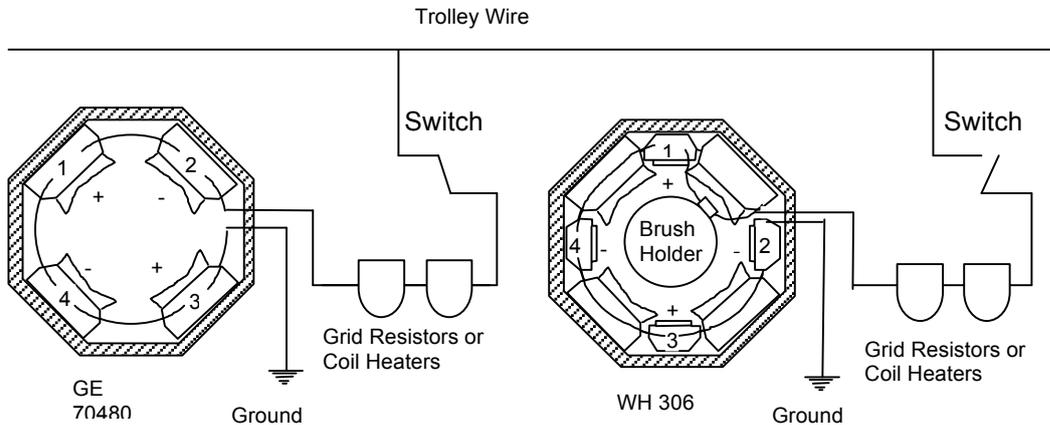
Figure 19 – COMMUTATING-POLE MOTOR WITH TWO COMMUTATING-POLES

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## 10.15.6 Method

The motor may be either on the truck or out on the floor. It may have the armature in or out of the frame and if a split-frame motor, may be opened or closed. With the coils all connected in series as shown in *Figure 20* below, connect the two field coil leads to the test circuit.

The diagram below could be used to test polarities however it is safer to use a low voltage D.C. supply as generated by the workshop M.G.set. a voltage of between 115V to 120V is adequate to give polarity indications during this procedure.



*Figure 20*

*Figure 21*

When the switch is closed, current passes through the field coils producing the magnetic fields. If the coils are connected properly, by holding the polarity indicator close to the ends of the coil or to the pole stud bolts on the outside of the frame, the polarity indicator will reverse at alternate poles; i.e., if No. 1 pole attracts the marked end of the polarity indicator, No. 2 pole should attract the unmarked end, No. 3 – the marked end and No. 4 – the unmarked end. This test can be made by rubbing a screw driver on the pole bolts and then holding it to the compass needle or polarity indicator. If the same conditions are not obtained, the field winding connections should be changed.

If the frame has commutating poles, two separate tests should be made, one on the main field as previously described and the other on the commutating-pole coils. The latter test is made in the same manner, with connections as shown in *Figure 21* below. In this case, only one of the motor leads (the negative armature lead) can be used, as the other lead from the commutating coils goes to the brush holders. Four-pole traction motors with only two commutating coils, which are located directly opposite to each other, also four-pole motors with three commutating coils, are tested in the same manner (*see figures 16, 17, 18 and 19*). In the case of the two-pole motor, the polarity of both coils should be the same, while in the three-pole motor the two coils that are diametrically opposite should be the same polarity, while the intervening coil should have the opposite polarity.

Precautions in making this test:

- Hold the pivoted compass in a horizontal position; or the suspended polarity by the free end of the suspension string.
- Test for polarity at the same end of all coils – either the commutator end or the pinion end, whichever is more convenient.
- Never consider the results final until they have been checked for a second time, as there is a possibility of the indicator having its polarity reversed.
- It is necessary that a certain pole have a definite polarity of either plus or minus, but it is essential that the polarity of adjacent poles be different.

## 10.15.7 Relation of Commutating-Pole to Main Pole Polarity

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In the case of the commutating-pole motor, it is important to have the proper relation of polarity between the main and commutating-field coils. To check this, connect the negative (-) armature lead of the motor to the positive (+) field lead, the positive (+) armature lead to the positive supply side of the test circuit and the negative (-) field lead to the negative supply side of the test circuit and close the switch and apply the test supply. If the armature is in the frame and the brushes make contact on the commutator, current will flow through the windings; if the armature is not in the frame, then it will be necessary to short circuit (bridge out) the brush holders. With these conditions, the polarity of the main pole should be the same as the polarity of the commutating-pole next to it in a clockwise direction when facing the commutator end of the motor.

### **10.16 Armature Testing**

In the case when a motor flash over has occurred it is the indicator of trouble - *see the list of "Conditions that Tend to Produce Flashovers" in the Motor Flash Over section on previous pages-* on causes of motor flash overs.

#### **10.16.1 Commutators**

- a) Short Circuits – This test can be made by using a multimeter set on the lowest resistance range. By testing adjacent commutator bars the meter will show a resistance on healthy bars and no resistance on short circuited bars.
- b) Earths – In testing for an earth with all commutator bars, short circuited by a piece of fuse wire wound tightly around it, use an insulation resistance testing device (Megger) or a multimeter set on the lowest resistance range. An insulation testing device will give you a resistance value that gives an indication of the armature insulation condition. An insulation testing device's output voltage is usually twice the service voltage, therefore on a 600 volt traction motor a 1000 volt testing device is usually used. Using a multimeter will only indicate if you have an earthed commutator or not. The minimum value of insulation resistance for a healthy commutator should be in the "Hundreds of Mega ohms".

#### **10.16.2 Armature Coils**

- a) Short Circuits between Coils – All leads are separated at both ends and the insulation between adjacent coils is tested with an insulation resistance testing device (usually a Megger). The minimum value of insulation resistance for a healthy commutator should be in the "Hundreds of Meg ohms".
- b) Earth Coils – As above, the leads are separated at both ends and the insulation between adjacent coils is tested with an insulation resistance testing device. The minimum value of insulation resistance for a healthy commutator should be in the "Hundreds of Meg ohms".

#### **10.16.3 Completed Armatures**

Connect the armature across a low voltage, direct current and current limited supply such as 100 volts with a current output set to 10 amperes for a 20 h.p. or larger motor or 2 amperes for an air compressor motor. Feed the current into the armature exactly one pole pitch apart and adjust the current until the multimeter set on a suitable voltage, say 20 volt range, to give a mid scale reading on a normal coil. Now take a series of voltage readings between bars 1-2, 2-3, 3-4, etc., and record their values. If all the coils are healthy, then all the readings will be approximately the same. Higher voltage readings indicate high resistance connections, usually caused by poor soldering to the commutator, while lower voltage readings show shorted coils or commutator segments. The following eight tests will determine the exact nature of faults in the completed armature.

- a) Open Circuited Coil – To prevent injury to the meter, this test must precede all others when the millivolt method is used. Set the meter on the multimeter to the 20 volt range and with current flowing through the armature as above, take readings between bars 1-2, 2-3, 3-4, etc., until all pairs of segments have been covered. A high reading between any

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pairs of bars indicates an open circuit coil. Note that this method of testing the meter is used to measure the voltage drop in each armature coil, and that this is done by taking readings between commutator segments (*See Figure 22 below*).

- b) Short Circuited Coil – For this test set the multimeter to a range that gives the best deflection starting with the 200 volt setting and work down to the lowest range needed, if necessary. Adjust the current through the armature until approximately mid-scale deflection is obtained on a normal coil and make a bar to bar test on all segments. The defective coil will give a low or zero reading depending upon how many turns are shorted out. It should be understood that this method of testing is merely a comparative one, for it is how the readings compare that is important (*see figure 23 below*).
- c) Earthed Coil – To make this test, send a current of suitable value through the armature and measure the voltage difference between each segment and the shaft. If the winding is earthed, a reading will be obtained that becomes gradually less as the bars to which the earthed coil is connected are approached. The reading will be lowest on the bars to which the earthed coil is connected. It should also be noted that as the earthed coil is passed the meter reading will reverse. To determine if the bar is earthed, disconnect the coil leads and repeat (*see figure 24 below*).
- d) Reversed Coil Leads – Usually on armatures that have just been rewound, this fault requires a different testing method. Set the meter of the 50 volt range, select the first coil to be tested and find the segments to which the ends of this coil are connected. With the meter leads on these bars draw a bar magnet swiftly across the slot in which one side of the coil lies and note the deflection on the meter. Repeat this test on all other coils, always moving the magnet in the same direction. When drawn across a reversed coil, the meter will read in the opposite way (*see figure 25 below*).
- e) Reversed Coil Loops – Usually found in rewound motors, this fault is checked by the regular bar to bar test. Proceed in exactly the same manner as used for locating shorted coils since the current in passing from segment 10 to segment 11 must flow through the two coils. It follows that the voltage drop between bars 10 and 11 will be double the value obtained on a normal coil. The same is true for bars 12 and 13. Bars 11 and 12 will give a normal indication; thus reversed coil loops are indicated by a double reading, a normal reading and a double normal reading (*see figure 26 below*).
- f) Short Bars – Make the same test as for shorted coil. With current flowing through the armature, measure the voltage drop between segments. When the shorted bars are encountered, the meter will read zero. In as much as the same indication would be obtained if the coil leads were shorted, it will be necessary to disconnect the leads from the commutator segments before it can be determined whether the low reading was caused by shorted bars or shorted coil leads. If after the coil is disconnected a zero reading is obtained, the bars are shorted (*see figure 26 below*).
- g) Earthed Bars – Test for this defect is the same as for an earthed coil. Meter reading from the bar to the shaft will be zero when the earthed bar is connected. To determine whether the bar or the coil is earthed, disconnect the coil from the bar and test again. If the bar now tests clear, the coil is earthed. When making this test, the meter readings may change so rapidly as the earth is approached, that a satisfactory deflection cannot be obtained without turning to a different range. Therefore, as the reading falls, the meter switch should be moved to a lower range (*see figure 26 below*).
- h) Poor Connections – Trouble frequently develops in armatures as the result of poor electrical connections between the coil leads and the commutator segments due either to poor soldering or to over heating of the armature while in service. High resistance connections of this type are indicated by high readings on the multimeter. To positively locate which bar has the poor connection, make the test indicated in *figure 27 below*. A poorly soldered joint will produce a reasonable deflection on the meter; where as a good joint will give no reading.

*Figure 22*

Figure 23

*Figure 24*

Figure 25

*Figure 26*

Figure 27

## **10.17 Simple Indications of and Correction for Motor Circuit Troubles**

### **10.17.1 Open Circuits**

An open circuit can readily be detected by scarred commutator bars, which occur at points diametrically opposite. To find the defective coil, raise the two leads at each of the scarred bars, and with a multimeter set on resistance range, test between them and all other bars of the commutator. The multimeter will show high resistance when connected with one of the leads, (i.e., the lead of the defective coil). If the defect is a broken lead, it can easily be spliced with a wire of the same size and connected as before. If it is not in the lead, the open circuited is probably due to a short circuit or earth, which has burnt off one or more turns of the coil. In which case the coil will have to be cut out or replaced by a new one.

### **10.17.2 Short Circuits**

A short circuit can sometimes be detected by the smell of burnt insulation, or the charred condition of the insulation of the coil. The shorted coil can only be repaired by cutting out or replacing the coil.

### **10.17.3 Earths**

Earths may sometimes be seen on the surface, where the insulation and often the coil or iron coil is burnt. If it cannot be located in this manner, test the armature core for an earth with an insulation testing device (*see Armature Testing section*). If the arcing to the core cannot be seen or heard, raise a few upper leads at different points on the commutator, thus dividing the winding into several parts. When the earth division is located, raise the upper leads and test them for earths separately. If all the coils appear earthed, it is usually the commutator that is defective (*see Armature Testing section*).

### **10.17.4 Cutting Out a Damaged Armature Coil**

Disconnect the damaged coil from the commutator, and after cutting off the leads, insulate the exposed parts with insulation tape. Then connect the commutator bars, to which the leads of the damaged coil were connected, with a wire or jumper of the same size as used in the winding.

If it can be avoided, armatures should not be run with more than four (4) coils cut out, but may be used with more, if the defective cut-out coils are distributed evenly around the armature but it is strongly recommended to rewind the armature if four or more coils are damaged.

### **10.17.5 Removing a Damaged Coil**

It will be necessary to cut off the band and remove the slot wedges, and raise a sufficient number of leads and coils to allow the removal of the defective coil. The new coil can then be put into place and the slot wedges restored and a new band installed. If you are going to this much trouble to replace a few damaged coils it is recommended that the armature be totally rewound with all new insulation material and coils.

## **10.18 Testing Other Parts of the Motor**

In overhauling or repairing traction motor frames or fields, it is advisable to test certain detail parts before they are placed in the frames to ensure against unnecessary work during rebuilding the motor. A very good precaution is to paint the inside of the motor frame thoroughly with a good air drying insulation varnish (GE Glyptal) after thoroughly cleaning

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the frame. The painting is done before putting the field coils in place, taking care not to get any paint on the pole seat which would tend to weaken the magnetic field's path.

### 10.18.1 Brush Holders – Earthed

Brush holders of the insulated type should be given a test for earths with an insulation testing device, placing one lead on the brush holder and the other on the brass support. The minimum insulation resistance that is acceptable is one (1) Meg ohm, but the result should be much higher.

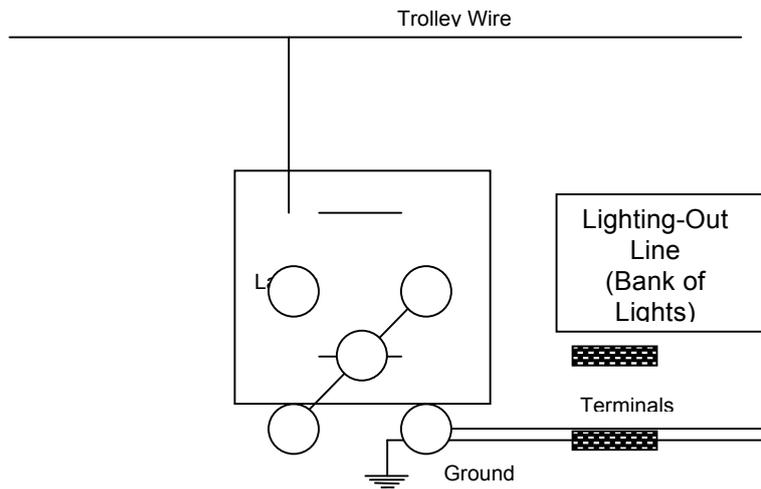


Figure 28

### 10.18.2 Main or Commutating Pole Field Coils

Using the multimeter set to the resistance range and measure the resistance of the coil and compare the known resistance of a healthy coil. Record the resistance values obtained for future reference when next time the motor is overhauled.

### 10.18.3 Completed Fields

- a) Earths – After the coils and brush holders are in the frame, and bolted down tight in place and all connections made, use the insulation testing device to test the insulation resistance. On an overhauled motor the insulation resistance should be 100 Mega ohms or greater.
- b) Short Circuits – The individual field coils should be tested for short circuits by the methods previously discussed before the connections are taped.
- c) Open Circuits – Test the coils and wiring around the frame for open circuits with a multimeter set on the resistance range or an insulation testing device. In either case the value of resistance should be very low, normally less than 10 ohms.
- d) Polarity Test – *see page 93(old page numbers)*

## 10.19 Testing Assembled Motors

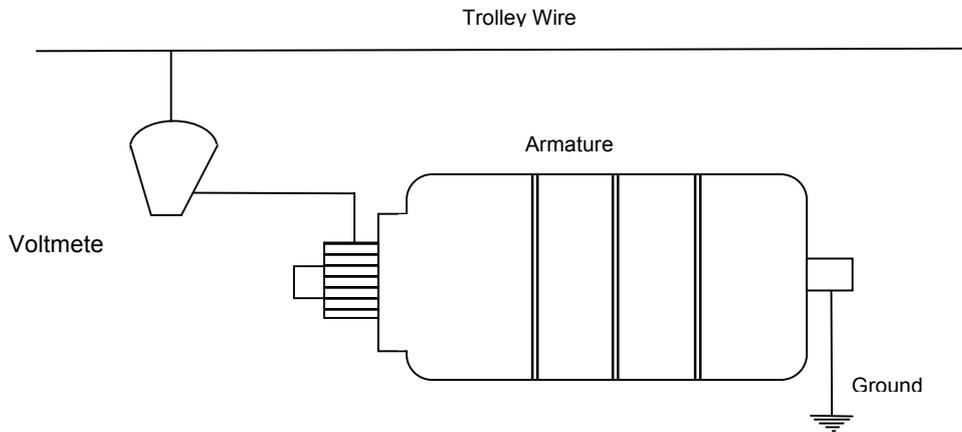
### 10.19.1 Insulation Resistance

- a) Object - It is best to measure the insulation resistance of the electrical apparatus, as this test will give an indication of the condition of the insulation's moisture content. In general, insulation materials are more or less affected by moisture, and if given an earth leakage (insulation resistance) test while damp and having a low resistance value, they are more likely to break down than when dried out and having a higher resistance value. Another test that is used very often these days after checking the insulation resistance, is Dissipation Factor (D.F.) (sometimes known as Dielectric Loss Angle, Dielectric Dissipation Factor or Tan Delta). The measurement of D.F. gives you the value of A.C.

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leakage current and the angle of the insulation viz a standard capacitor. The test instrument for this measurement can cost many thousands of dollars but used properly an insulation testing device will give the Museum reasonably accurate indication of the condition.

- b) Apparatus – Insulation Testing device commonly called a “Megger” which is a trade name). See Figure 29 below.



*Figure 29 – Connections for Insulation Resistance*

- c) Method – The motor to be tested is connected to the test leads, i.e., the “Line” lead is connected to all of the motor leads, which are shorted together and the “Earth” lead resistance is above 1 Meg ohm after 30 seconds keep testing for ten (10) minutes. Record the 30 second reading, then every minute after which in turn are plotted on a graph (see figure 30 for example). It can be determined from the graph the moisture content of the insulation. That is if you have a constant rise in resistance the insulation is dry but if you have a sharp rise in resistance when it levels out there is some moisture in the insulation. Temperature of the windings also effect the insulation resistance reading for as the temperature increases the insulation resistance decreases, therefore a motor just removed from an oven will have a lower resistance than one at ambient temperature.

### **10.20 Test Running on Tramcar**

- a) Object – To check the connections of motors to the tramcar’s wiring after they are placed in the trucks under the tramcar. This test is necessary to make sure that all of the motors, when taking current from the trolley wire, rotate in the same direction and pull together.
- b) Apparatus – The tramcar equipment.
- c) Method – One pair of motors on a four motor tramcar or one motor on a two motor tramcar are cut-out with the controller at the No. 1 end in the “forward” position. The wheels of the motors in the circuit are spun and the direction of the motor of the tramcar is checked and made to correspond to the direction of the controllers. This operation is to be repeated for the “reverse” position of the No. 1 end controller as a further check.

An equivalent test is then performed on the other motors. The controller at the No. 2 end is checked in a similar manner to correct motor operation but opposite function to the No. 1 end controller (i.e. forward and reverse direction of the motors).

- d) Precautions – In making these tests, be absolutely sure that there is sufficient clearance on the track at both ends of the tramcar to allow for the movement of the tramcar. Also all bystanders must be warned of the tests and possible movement of the tramcar.

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**NOTE: Before starting the test inspect the brakes and check their operation.**

Figure 30 – INSULATION MOISTURE CONTENT

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## 11 Controllers

### 11.1 Types of Control

There are several types of control systems in use in tramcars which can be divided into two basic classes:

1. Direct Control - This is usually used for single tramcar operation and where the total capacity of the motors does not exceed 300 horsepower.
2. Multiple Unit Control – This is used wherever train operation of motored tramcars is required and where the total capacity of the motors exceeds 300 horsepower.

#### 11.1.1 Direct Control

Direct Control is subdivided into several classes which include:

1. “R” Type Controller in which the starting of the tramcar is controlled entirely by resistance. The only examples of this type the Museum has are the Essance Grinder.
2. “K” Type Controller – a series-parallel controller in which the power to some or all of the motors is connected while the change from series to parallel is made. The change-over period is called transition. Examples of this type are Ballarat tramcars 37, 12. Brisbane tramcars 71, 180 and 295, Melbourne tramcars 249, 611 and Sydney tramcars 12, 29, 42u, 154, 290, 393, 529-530, 728, 1296, 1740, 1971, 1979, etc – **See Appendix D.**
3. “B” Type Controller - a series-parallel controller to which has been added the feature of electric braking. The examples of this type is the Nagasaki Tram 1054. Berlin cars & Munich cars.
4. R.C. type control. Brisbane 548 and Melbourne W7 1036 have what is known as R.C. control where the motoring steps are controlled by contactors beneath the floor driven by the cab controllers. The cab controllers are fitted with full current reversers. This is not M.U. control as these cars cannot be run with similar cars due to the reverser situation.

#### 11.1.2 Multiple Unit Control

Multiple Unit Control is of several types. It may be divided into:

1. Automatic multiple unit control, in which the rate of resistance is removed from the motors circuit controlled by current dependant relays instead of by the rate at which the master controller is manually “notched up”. Examples of this type are “P” tramcars 1497, 1573, 1729
2. Non-automatic multiple unit control, in which the rate of feeding power to the motors is controlled by the rate at which the operator “notches up”. Examples of this type are tramcars Brisbane tram , Sydney trams 957, 1030, 1089, 1111, 93u and 99u.

In Multiple Unit Control, the power circuits are handled by contactors mounted beneath the tramcar. An auxiliary control circuit is required for the operation of these contactors. The contactors can be operated by air or by magnetic. These may be divided into three types:

1. Magnetic Type in which the contactors are operated by large magnets. This type is called “M” control. These are found on the “O” type Sydney tramcars and the U4 type Ballast Motors. A later development was the “RC” (Remote Control) type controller which are basically similar to the “M” type control. An example of the “RC” type controller is to be found on Brisbane tramcar 548 and W7 1036.
2. Electro-pneumatic in which air valves are operated by small electro-magnets and again can be automatic or non-automatic. Automatic is called “PC” (Pneumatic Cam) as found on Sydney trams 1497, 1573 and 1729. These are manufactured by G.E.

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3. Commutator Type is a type of controller driven by a low voltage pilot motor. As the pilot motor drives the commutator type controller around, it shorts out resistances that are attached to the commutator, by the use of brushes. An example of this type controller is in use in PCC tramcar 1014. This is also manufactured by G.E.

### 11.1.3 Rheostatic or Resistor Control

The earliest form of control of traction motors was of the rheostatic type. Rheostatic we mean resistance arranged so that it can be cut-out or in, in small steps. A very simple form of rheostatic control is shown below in *Figure 30*.

Any switch that is used to regulate the speed of an electric tramcar is called a controller. In *figure 30* the iron shaft (a) has projecting lugs (b) on which are mounted copper segments (c). The two lower segments are of the same length, but the others are of different lengths. The shaft is insulated from the handle (d) and the base (e) by insulating couplings (f). The fingers make contact with the segments when the handle is turned. The fingers are marked R1, R2, R3, R4 and (m). The motor is earthed at (G). The dotted lines 1, 2, 3, 4 indicate the positions of the fingers on the segments when the segments are turned into contact with the fingers on the first, second, third and fourth notches of the controller.

The "OFF" position is indicated in *figure 30*. At the notch 1, fingers R1 and (m) are in contact with the segments (c) and since all of the segments in this controller are all electrically connected together, the circuit to the motor is complete. All of the resistance is cut in on the first point which holds back the power until the motor gets started. As the motor speed increases, part of the resistance is cut-out by the controller allowing the motor to further increase its speed and more resistance can be cut-out. When notch 4 is reached, all of the resistance is cut-out which makes notch 4 a running notch. It should be noted that there is no provision for reversing the motor here.

It can be seen from observations of the diagram and of the regular "K" type of controller that there is great similarity between the operation of these two types, with the exception of the series-parallel features and of reversing.

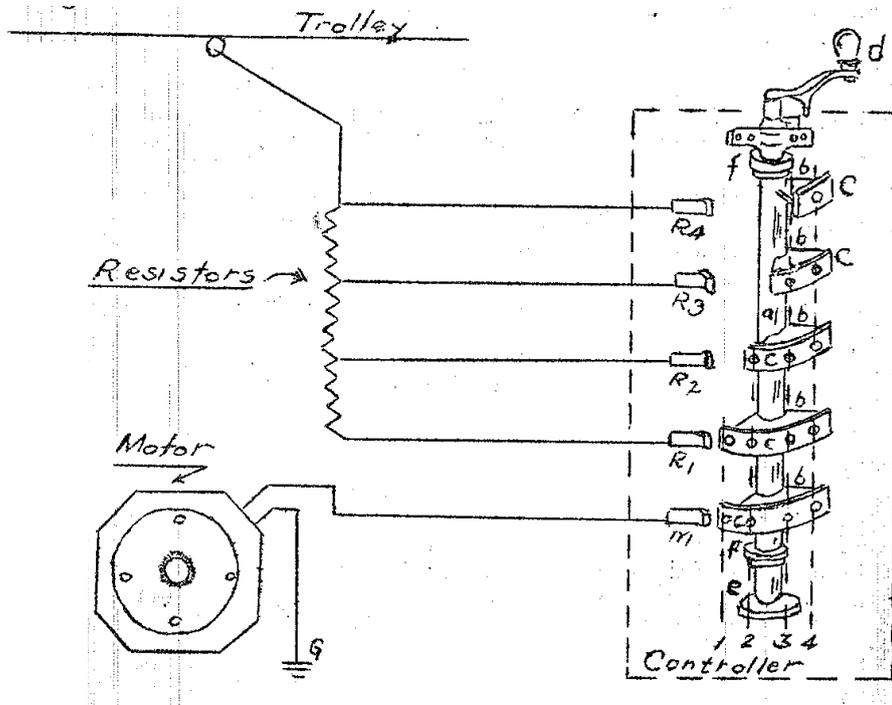


Figure 31 – RHEOSTATIC CONTROL

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### 11.1.4 “B” Type Control

As mentioned before, “B” type control has the same electrical duties to perform as the “K” type control, except that an additional connection is made for electric braking. “B” type controllers were commonly used this century on interstate tramcars; but seldom on Sydney tramcars. The exceptions in Sydney were some of the “D” and “N” classes of trams. At the Museum there are examples of this type of control – Nagasaki 1054, Berlin cars and Munich cars.

By means of the braking controllers, positive and graduated electric braking is secured. The controller relieves the driver of a large part of the braking, i.e., the frequent starting and stopping at points, coupling, etc. and operates so that the tramcar is stopped by its own momentum. This is accomplished by providing on the controller’s main drum a set of connections that turn the motors into self-excited generators and the energy developed by them is absorbed in the main resistors. The amount of this energy and consequently the degree of braking effort, is governed by the position of the main drum of the controller, that is simply the braking effort is merely moving the controller handle backwards (anticlockwise) past the off position. The more resistance cut-out of the circuit, the more quickly the stop will be made.

The degree of braking is under the driver’s control at all times for it is found that the tramcar is stopping too quickly, the driver merely has to return the controller towards the OFF position of the main drum and permit the tramcar to continue to brake but at reduced braking effort.

On a level track it is sometimes possible for the driver to bring the tramcar to a dead stop without using the hand brake at all. The driver can also bring it to a stop on a grade, but since there is no energy developed when the wheels have stopped turning, the hand brakes must be applied to hold the tramcar at rest. With electric braking the hand brakes need be used very little and, as a result, there is a great reduction in the wear of brake shoes and wheel treads. Further, since the braking effect is zero as soon as the wheels have stopped turning, there is practically no skidding of the wheels and consequently, there will be few, if any, flat spots developed from this cause.

The electric braking controller is a positive insurance against the practice, all too prevalent amongst drivers of bygone times, of reversing the motors to save braking effort in stopping. Stopping in this way gives the motors a heavy rush of current and the gearing and other parts of the mechanical equipment receive severe shocks tending to shorten their life and run up the maintenance costs.

### 11.1.5 “K” Type Control

The rheostatic control as previously described was used almost entirely for one-motor equipped tramcars. As the two and four motor equipped tramcars came into general use, the attention of the tramway industry was centred on the control system. It was found that if (with two-motor equipment) the motors could be connected in series at the start and later connected in parallel, a control system could be arranged that required less resistance and more economical than the rheostatic control. The connection of motors in series for low speed and in parallel for high speed gave the name series-parallel which for short has been called “K” type control.

For example, the two motors (*figure 32*) in series across a 600 volt circuit, the voltage drop across each motor is only 300 volts and each motor will run at about half its full speed without resistance in the circuit. For higher speed, the connections are changed from series to parallel by means of the controller, thus impressing on each motor 600 volts as indicated in *figure 33* and resulting in full speed. Some resistance is used in starting and in passing from series to parallel connections, but no resistance is in circuit on the running notch of series or parallel position.

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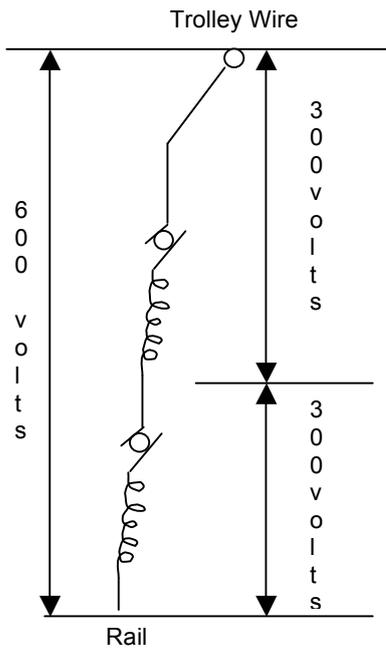


Figure 32 – TWO MOTOR

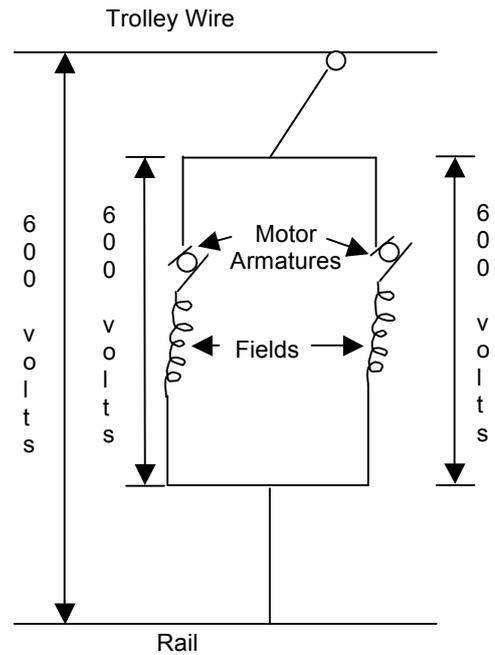


Figure 33 – FULL SPEED

## 11.1.6 Control Resistance

The resistors or resistance frames are a very important part of the control equipment on a tramcar. Every type of control requires some form of rheostat for starting the tramcar and bringing it up to speed smoothly. The rheostats or resistors used for this purpose are several types, although the underlying principles are the same.

The rheostats on early tramcars had a great number of steps between resistance cut-in and cut-out. The amount of resistance in the motor circuit at any time depended upon the position of a sliding contact shoe on iron grids. Modern resistors, however, are of the “sectional” type. This means that resistance is cut-out in the motor circuit in steps or sections. The number of resistance sections depends on the connections made by the controller drum segments and the main fingers.

The resistance of each section must be a proper portion of the total resistance value. Sometimes the proper sections are decided on by trying out various combinations on a tramcar and choosing the best one. The best way of selecting a resistance is based on the performance of a motor. As a guide to this, the following table is helpful. The percent of the total resistance for a K-35 controller is given for each step or section.

<u>Section</u>	<u>Percentage of Total Resistance</u>
R1 – R2	26.6
R2 – R3	20.9
R3 – R4	15.8
R5 – R6	20.9
R6 – R7	15.8

It will be noted that R2 – R3 is the same as R5 – R6 and R3 – R4 is the same as R6 – R7.

## 11.1.7 Electrical Diagrams

In order to assist in servicing personnel who have to install, connect and fault find the electrical equipment on a tramcar, there are three types of electrical diagrams. They are the schematic diagram, the wiring diagram and the connection or termination diagram. All the drawings are drawn in the de-energised, switch normally open positions. The schematic is a line drawing which shows

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the electrical connections of the equipment working from the positive supply connection through all the circuits to the negative supply connection in the order of first function to last function. A schematic is usually read in logic progression, from left to right. The exact location of the wiring on the tramcar is not indicated. The wiring diagram shows the connections to the motors, controller, lighting, and any auxiliary circuits as it is actually installed in the tramcar. In the case of Sydney tramcars, the wiring diagram does indicate the actual size of the cables used, remember that the cables are in imperial sizes and need to be converted to the new Metric sizes available today. The third type of diagram is the connection or termination diagram, with shows the connection points and the wiring connections. All cabling between connection points is usually shown as a single line and does not show the actual layout of wiring on the tramcar.

The method of drawing the controller and the various positions of the controller is usually the most difficult to understand when learning to read the schematic diagram. *Figure 34* shows a very simple controller drawn in the schematic diagram style. The speed roll, or the connections made on the controller drum, is represented by the shaded parts. In this example there are two body castings on the speed roll. The top two segments make up the top section and the lower four segments make up the second section. All segments in one section are connected together through the speed roll body castings. The connection between segments is represented on the drawing by shaded lines or wide lines. *Figure 34* shows where the disc insulator would be located on the speed roll. In this case, the fact that no lines connect the second segment to the third segment will leave it to be understood that the insulator is located here.

The small circles T-A1-FF1-R1-R2-R3 represent the six fingers in this controller shown in *figure 34*. The zig-zag lines represent the resistance, with the armature and field coils of the motor are also indicated. The OFF position of the controller is shown in *figure 34*. The lines marked 1, 2 and 3 that pass through the segments represent the location of the fingers on the segment when the controller speed roll handle is moved to any of these positions.

*Figure 34* shows the controller now in first notch. Current passes from the trolley wire to the trolley finger (T). In first notch, the trolley finger touches the segment marked (m) which is connected to segment (n). The finger (A1) touches segment (n). Since there is no connection between segments (n) and (o), the current will have to pass through the armature and then the field coming out of the motor at (FF1). The finger (FF1) touches segment (o) which is connected to segments (p), (q) and (s). The current entering segment (o) passes through the resistance (R1-R2) and (r2-R3) to earth thereby completing the circuit. Current cannot pass out at fingers (R2) or (R3) because in first notch these fingers do not touch the segments.

*Figure 35* shows the controller in the last notch. In this notch all the resistance is cut-out. A bit of practice reading the connections shown in *figures 34, 35 and 36* will make the reading of electrical diagrams of four motor equipped tramcars easy.

*Figure 41* on the following pages is a diagram of the connections that the controller makes for series and parallel connections. The diagram shows the interrelationship between the resistances, the controller (type K-35) positions and the four traction motors. Note that the connections are not shown for reversing the traction motor direction. Now to explain the operation, first let us assume that the controller is placed in first notch series, this allows the current to flow from the trolley wire through the trolley pole or pantograph, etc., passing into the speed roll through contact T and out in finger R4. The current then flows through the total resistance of R4-R3, R3-R2 and R2-R1, and passes back through the speed roll through finger R1, coming out at +1 and passes to +1 at the motor cut-out switch. Current then goes through one blade of switch coming out at A1-3 and then goes to a point between the motors. At this point, the current divides; one half going through No. 1 motor's armature and goes to -1 at the cut-out switch. Passing through the blade the current goes to R7 and is forced to pass through the resistance R7-R6 and R6-R5. The current again enters the current to +2 at the cut-out switch. The current then passes through the single blade cut-out switch and again divides where A2-4 is connected. The current comes together after passing through No.s 2 and 4 motors and goes to earth completing the circuit.

The same procedure can be followed for the other positions of the controller. When the parallel position "6" of the controller is reached, finger R2 is important for at this point the current divides and two separate parallel circuits are formed to earth.

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Figure 40 on later pages shows a number of diagrams of the resistance and motor connections in the simplest form possible. The eight positions of the controller in addition to the three connections during transition are shown. Figure 41 should be studied along with figure 40 taking one notch at a time. A complete understanding of these figures will make the actual schematic diagram a very simple matter.

It must be remembered that figures 40 and 41 are simplified diagrams that make it easier to understand a full schematic diagram and do not fully represent actual function. The points marked A, AA, F and FF on an actual schematic diagram are the wires that run to the reverser to make the connections as shown in figure 37.

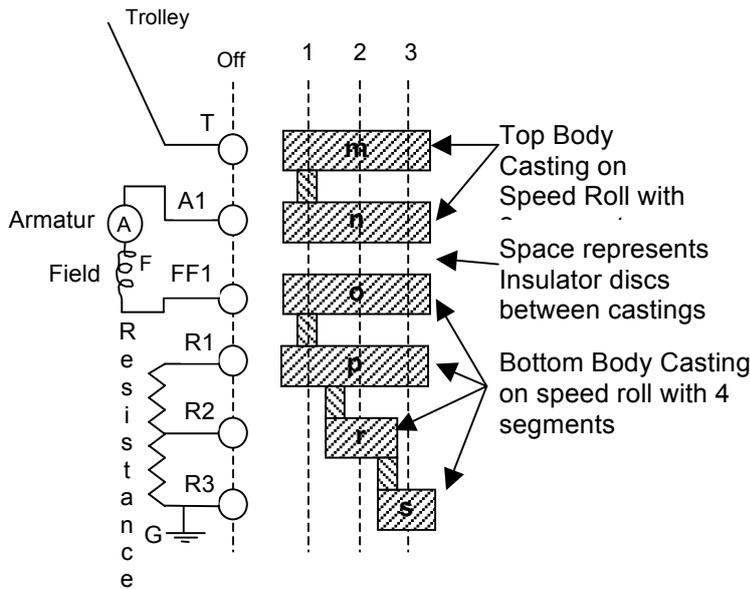


Figure 34

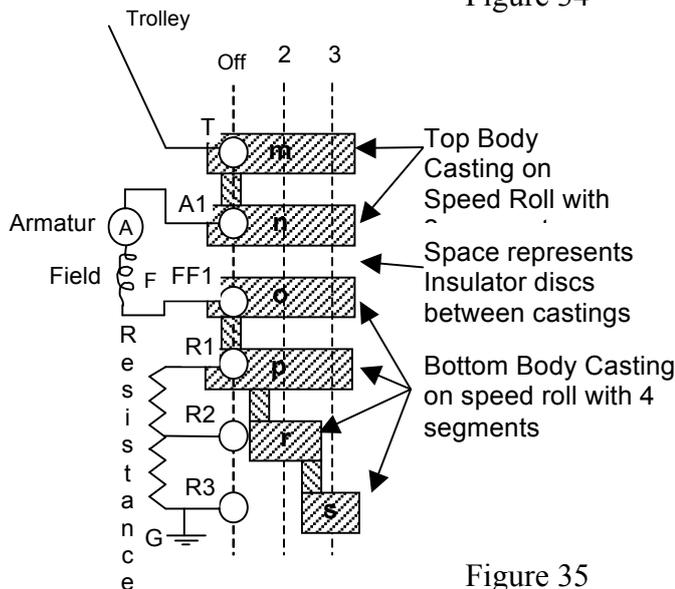


Figure 35

Figure BBP (31)

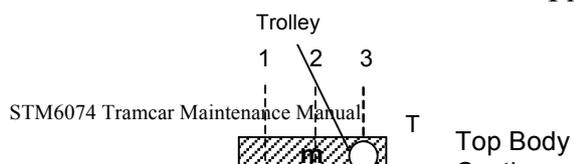


Figure 36

## 11.1.8 Reversing Motors

On *page 114* reversing motors is mentioned, the following paragraphs will help to understand the actual schematic diagrams used for the STM tramcars.

*Figure 37* shows two motors that are being fed with current from a +2 wire. The current divides at this point, half going through to one motor, and the other half going through the other motor. There are eight reverse fingers in *figure 37* in the “OFF” position. One armature wire from each motor is connected to a reverse finger. Both field wires are connected to reverse fingers. This leaves two fingers that are connected to earth. *Figure 37* shows the reverse roll of a controller as it is usually shown on a schematic diagram. Servicing personnel must imagine the reverser in either forward or reverse positions.

If the motors are to be connected in the forward position, the simplified diagram of *figure 37* must be imagined to be in the position shown in *figure 38*. In *figure 38* current comes from +2, divides with half of the current out at AA2, is connected to the F2 wire by the reverser drum and so the current going into field of No. 2 motor comes from AA2. F2 then brings the current to field No. 2 and the current goes out at FF2. FF2 is connected to earth by the small plate on the reverser drum.

The other half of the current that comes from +2 enters the No. 4 armature at A4 and leaves at AA4. AA4 is connected to F4 (*figure 38*) and F4 then carries the current to the field of No. 4 motor. The current then goes from FF4 to earth. In other words, we can say that the current that divided at +2 comes together again at the earth fingers of the reverser. This is the same as shown in *Figure 40*.

It so happens that when a motor is to be reversed, a very simple change in connections will do. If the current is reversed in the armature and the field, the motor will not reverse the direction of rotation, but if the armature or the field is alone reversed, then the armature will rotate in the opposite direction. With the K-35 controller the fields are reversed and the armatures are left alone when the motors are to be reversed.

*Figure 39* shows the way in which *figure 37* looks with the motors reversed. Current comes into armature 2, the same as before, but AA2 is now connected to FF2, which means that FF2 is going to bring the current to the field instead of F2 and that F2 is leading the current out of field No. 2 which is the reverse of *figure 38*. A4 brings the current from +2 to armature 4 as before but AA4 is connected to FF4 so that FF4 is now the entering point instead of F4 which is the reverse of *figure 38*. This should make clear the method of reversing motors on a “K” type controller. A study of *figures 37, 38 and 39* will aid in an understanding of the schematic diagram.

# SYDNEY TRAMWAY MUSEUM

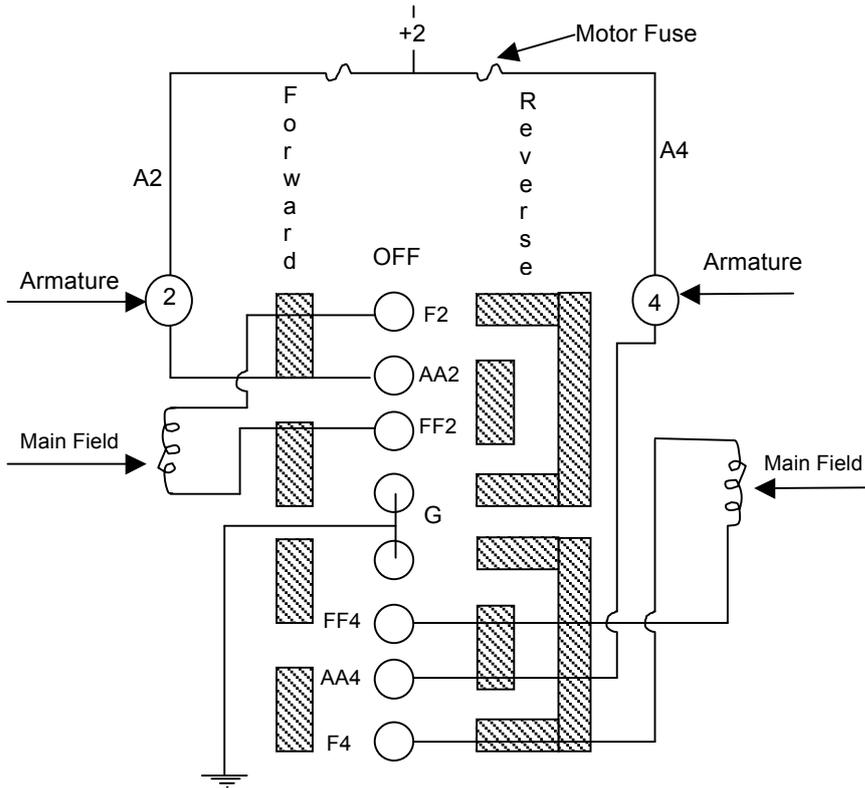


Figure 37

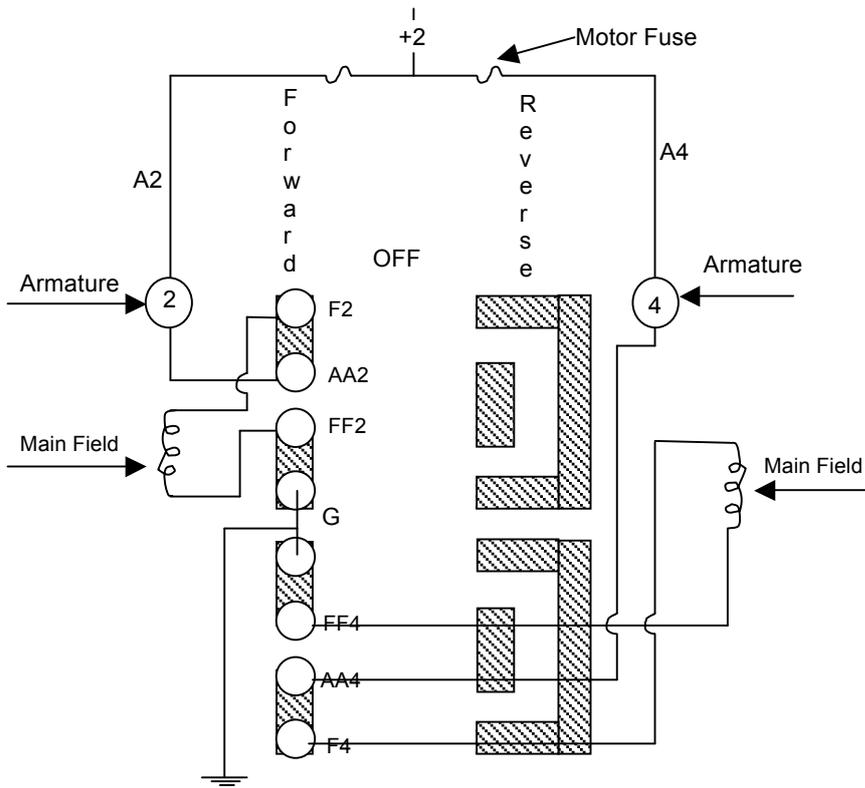


Figure 38

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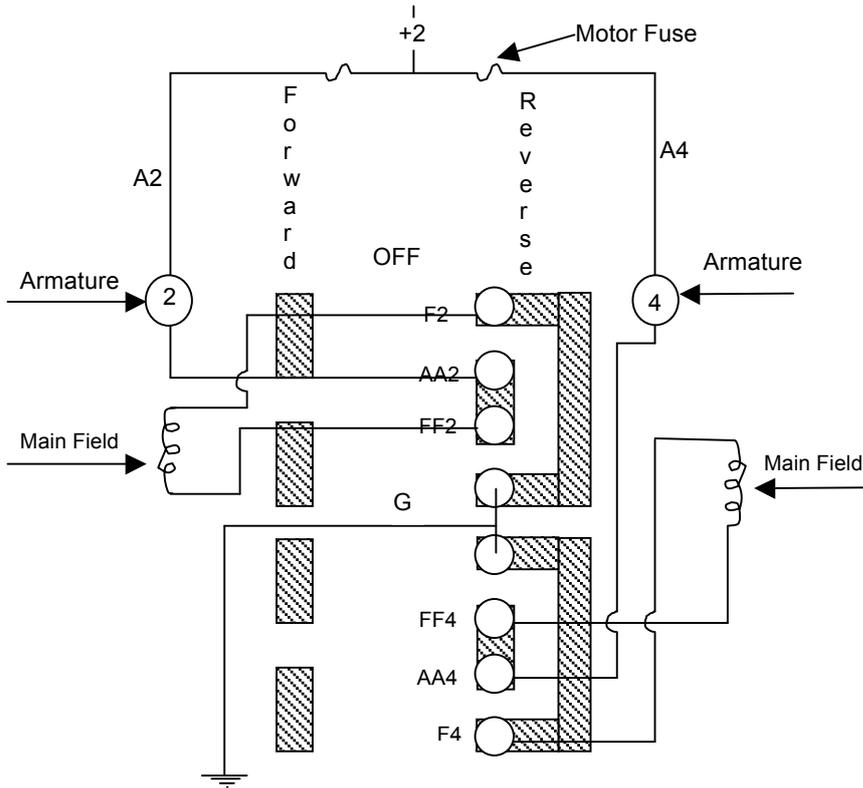


Figure 39

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## 11.1.9 Motor Connections

The functions of a controller are:-

- a) In the starting sequence to place resistance in the main power circuit thereby limiting the current to the motors;
- b) To allow the motors to be reversed; and
- c) On some types of controllers to cut-out a defective motor.

In (a) resistance grids are cut-out of the circuit; that is the resistance value in series with the motors is reduced. The resistance in circuit with the motors limits the large current that flows to the motors as a D.C. motor at rest has very little internal resistance. The internal resistance of the motor at rest is so low that it is seen by the power supply as short circuit, so a large current flows and if it is not limited in size it will damage the conductors in the motor. As the motor starts to rotate it creates what is called back electromotive force this limits the motor's ability to allow the current to pass through the windings. The controller also changes the connections to the motor, i.e., series – parallel. In cutting out the resistance grids, the part of the controller that do this job are:- the speed roll or drum, controller fingers and a controller handle to remove the drum. Separate to this, and taking care of the second function of the controller, is a reverser handle, reverse roll or drum, and smaller fingers that take care of this function of reversing motor connections. In a “K” type controller the wires connected to the reverser drum are: - AA1 – F1 – FF1 – AA2 – F2 – Ff2 – AA3 – F3 – FF3 – AA4 – F4 – FF4 (-1) and G. The last function of the controller is to isolate defective motors and this is performed by small knife switches at the bottom of the controller or by the reverser drum itself being mechanically separated in the centre of the drum.

The significant of the letters used above is standard for the entire controller wiring and is thus:-

A – armature -	AA- armature –	
- going to the motors	- coming from the motors	
F – field -	FF – field -	
G – Earth or negative		

1, 2, 3 and 4 are numbers of the motors which are numbered in sequence, starting from the No. 1 end of the tramcar. This is usually marked in the driver's cab or in the case of Sydney tramcars there are cast plates attached to either side of the vehicle at the centre specifying the side “Left” or “Right” and the end number.

Motors numbered 1 and 2 are on the first truck and motors 3 and 4 are on the second truck. Motors 1 and 3 are permanently connected in parallel. Motors 2 and 4 are also permanently connected in parallel. Each pair of motors thus connected is called a unit. Unit No. 1 consists of motors 1 and 3 and Unit No. 2 consists of motors 2 and 4. From this it should be clear that Unit 1 has a motor on each truck and Unit 2 also has a motor on each truck. *Figure 40* shows the connections of the two units.

*Figure 40* shows how the power is applied to the motors and how the motors are connected and reconnected as the motors are sped up. It should be noted that at start, the two units are connected in series. Notches 1 to 5 on the controller are called the series notches or series-parallel. After this the units are connected in parallel and the notches 6 to 8 are called the parallel notches. Notch 5 is called the series running notch where all of the resistance is cut-out with the units connected in series. Notch 8 is called the parallel running notch with all of the resistance cut-out and the motors in parallel.

A K-35 type controller is illustrated because it is typical of many four motor tramcars preserved. The principles illustrated here may be readily to other controller arrangements such as two motor controller and automatic controllers as the basic theory is the same.

*Figure 41* shows a simplified diagram of the motor, field and armature connections. The actual connections are made at the controller reverser roll. Since there are four leads to each motor and since, for this example, we have four motors in this tramcar, we can expect to find 16 fingers for the

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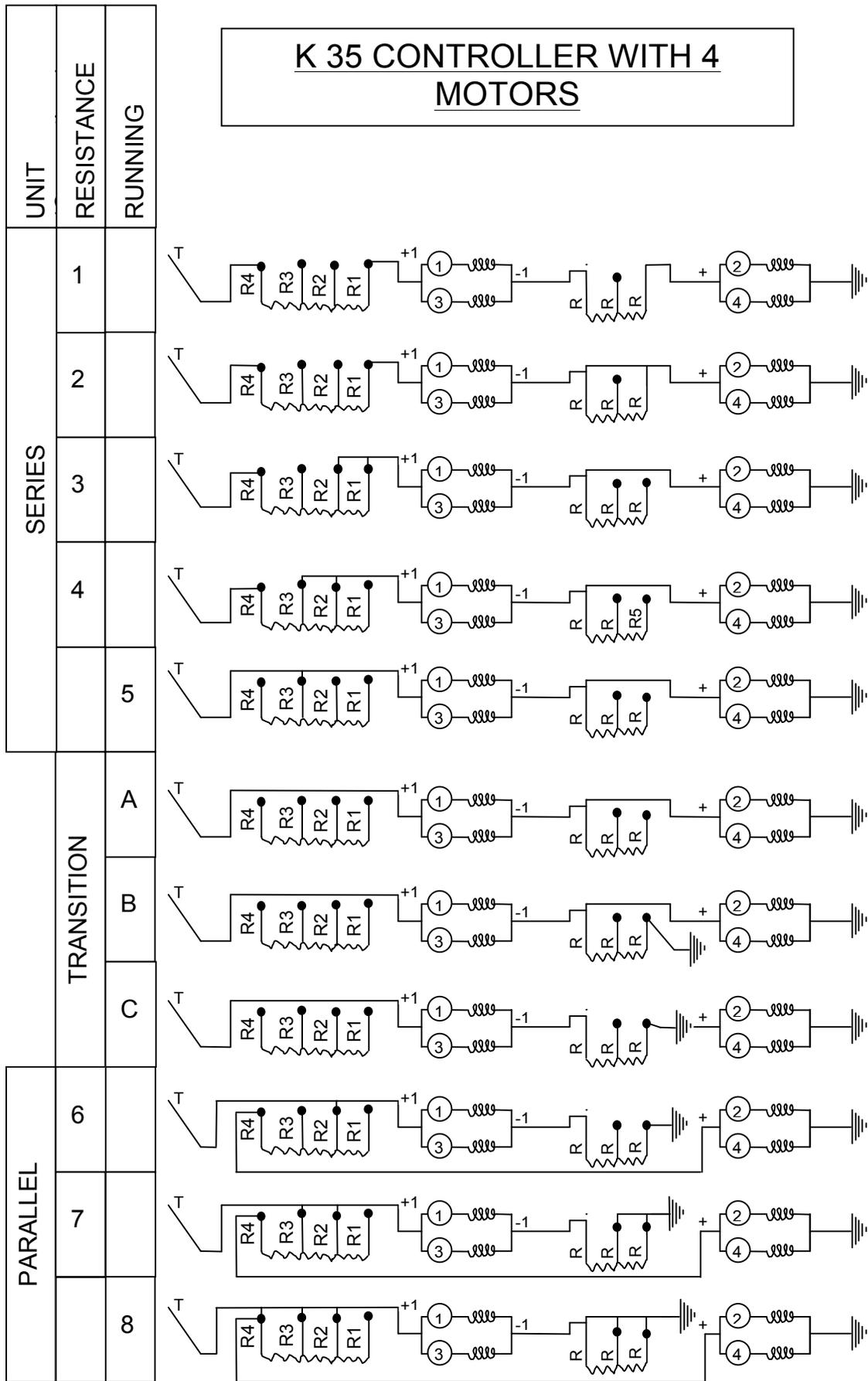
reverser roll to connect the motor leads. This does not mean that there are four AA wires, four F wires and four FF wires, but there are a total of 16 fingers.

*Figure 42* is drawn without any resistor grids for clarity. Following the circuit through from the trolley pole or pantograph connection, the first item shown is a fuse (or circuit breaker), then to the A wire. Now to operate the motor let us assume that we are controlling the motor from No. 1 controller. In order to get the current to flow from the AA wire, it will be necessary to connect AA to F which is done by moving the reverser key to the forward position. Then the current enters F at the reverser and goes to F at the motor. After passing through the field, current comes out of FF at the motor and goes to FF at the reverser. The movement of the reverser roll should connect FF to ground at the same time the AA wire is connected to F. This completes the circuit to ground and the motor will turn. If we want the motor to go in the opposite direction, we must reverse the field connections by throwing the reverser key to reverse position and connecting AA to FF and F is connected to ground. It will be noticed in the diagram that the F wire in No. 1 controller is connected to the FF finger in No. 2 controller and that the FF wire in controller No. 1 is connected to the F finger in the controller No. 2. This means that the fields are reversed when the operator goes to No. 2 end to operate. (Reversing the fields is one way to reverse a traction motor).

In *Figure 41* it will be noticed that the feed for each pair of motors comes from the cut-out switches and the return goes back to the cut-out switches. If now we were to locate 16 fingers on each of the two controllers, and connect wires between them, we could connect the motors and then study the belling out of motors, fields and armatures.

*Figure 43* shows the reverse fingers in order from top to bottom, the cut-out switches and motor fuses on a K-35 controller. The oblong squares to the left of the No. 1 controller represent the plates on the reverser roll for the forward position of the reverse key. With the reverser key on the No. 1 controller in the forward position, this figure is exactly the same as *figure 41*.

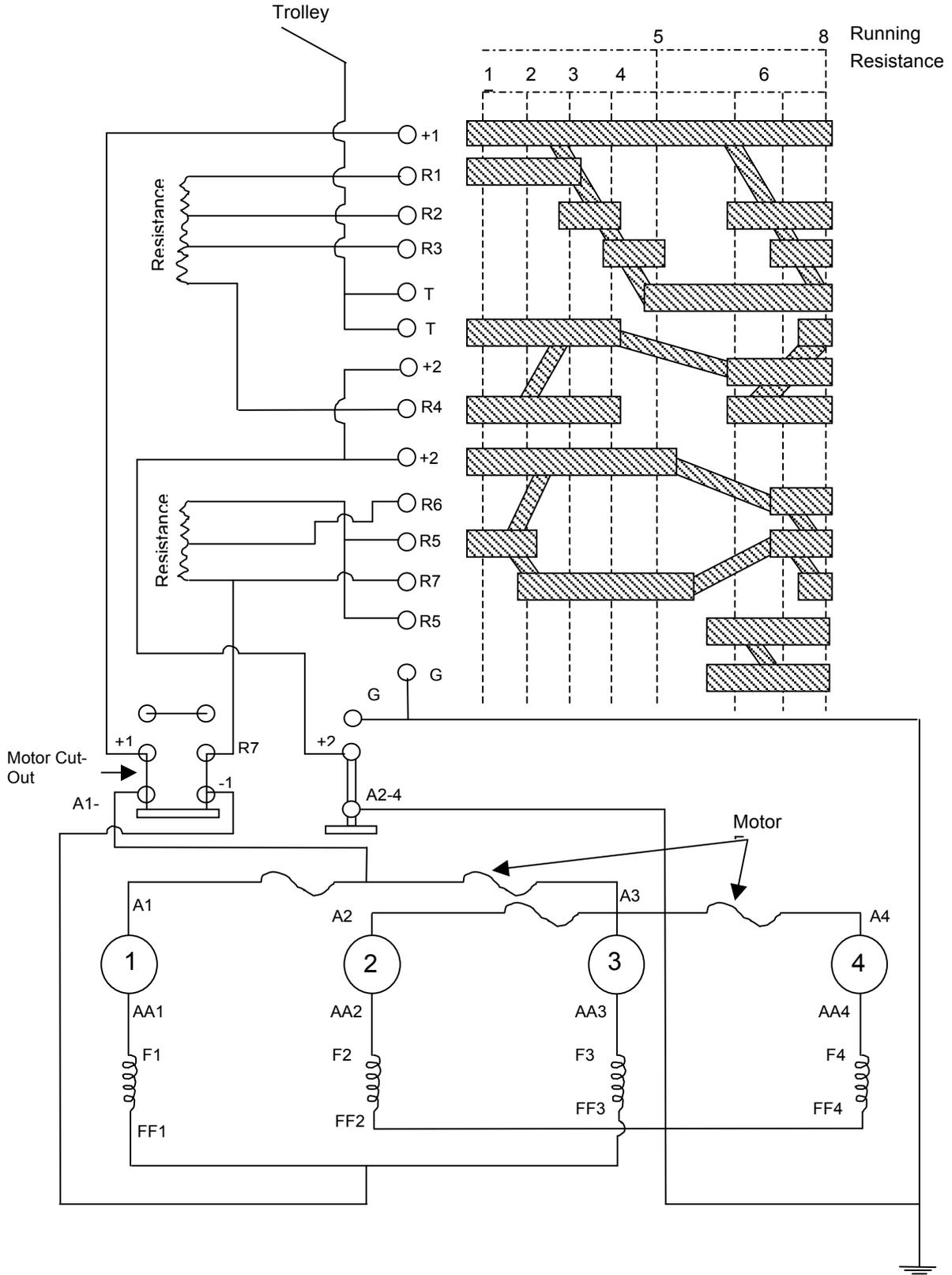
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*Figure 40 - 4 MOTOR, K-35 CONTROL*

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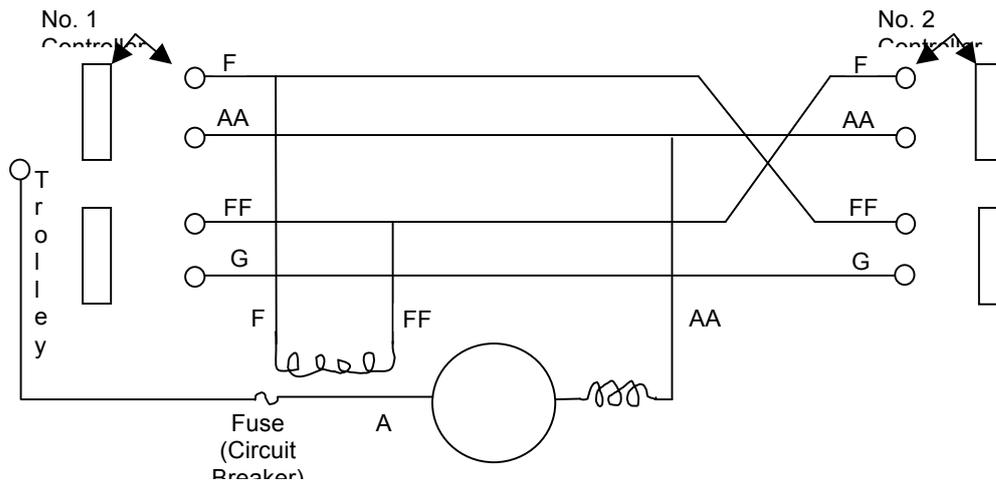
## K35 CONTROLLER



*Figure 41 – K-35 CONTROLLER*

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Below is a simple diagram of a one motor tramcar connected to two controllers.



*Figure 42*

If we wish to test the armature circuit of the No. 1 motor, we connect a multimeter, set on the lowest resistance range, across from A 1-3 at the cut-out switch to AA1 at the reverser finger. If no reading is obtained, your first guess is that perhaps the brushes were taken out of the motor. If the brushes are OK, then perhaps there is a wire disconnected. There are five places where a wire could be disconnected, and each place should be located. After the circuit has been tested for being complete, a test for earths might be made by placing the multimeter from earth to AA1 at the reverser finger. The field circuit can be tested by touching the f1 finger and the FF1 finger at the reverser roll. Motors 2, 3 and 4 can be tested in a similar manner to the one described above.

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## MOTOR CONNECTIONS TO REVERSE FINGERS FOR K-35 CONTROLLER

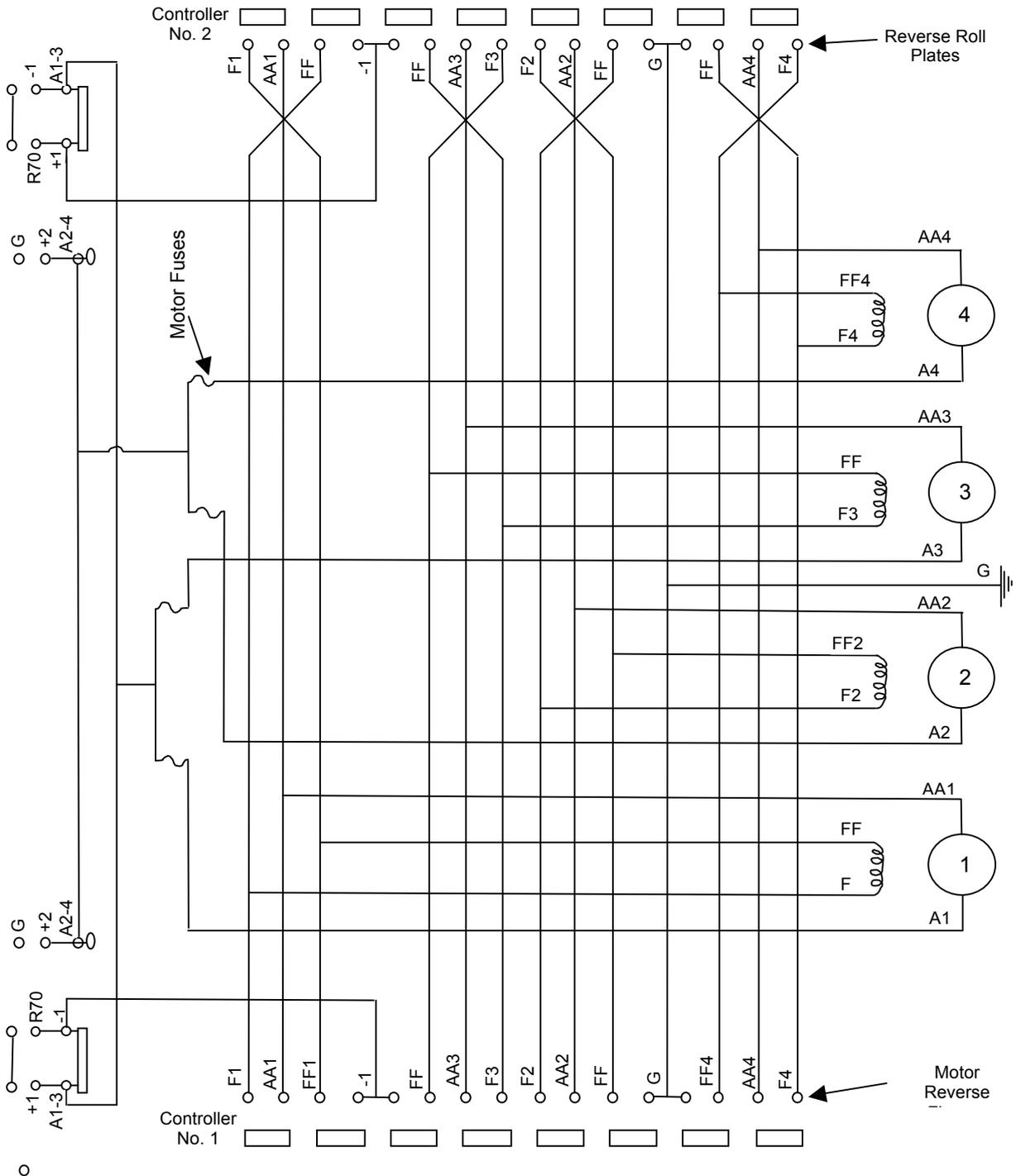


Figure 43

## 11.2 Tests and Testing Equipment

### 11.2.1 Voltage Testing

Testing for trolley power with a multimeter or voltmeter set on a D.C. voltage range greater than 600 volts is now the expected practise for testing a power circuit. If one of the test probes is touched to a part that is supposed to be alive and the other test probe is placed on an earth, the meter will show a deflection indicating that the circuit is live. If no deflection occurs, then circuit is dead.

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Suppose we are testing the trolley (T) finger of a controller for trolley power. By closing all of the switches ahead of the finger and seeing that all fuses are in and the trolley poles is up, we can put one test probe on the trolley (T) finger and the other on an earthed part of the tramcar. If the meter indicates the trolley wire voltage (normal 600 volts), then the trolley finger is supplied with power. If there is no deflection, then the circuit is open ahead of the trolley finger. When the meter reads greater than 0 volts but less than the trolley wire voltage, then the insulation is breaking down somewhere and part of the power is lost before it gets to the trolley finger.

### **11.2.2 Insulation Resistance Tester (Megger)**

The device used for testing high resistance circuits such as the insulation of cables or motors is called an insulation resistance tester or commonly called by the company name of "Megger". This device produces a high voltage, usually the tramway work of 1000 volts D.C., which tries to send a current through the insulation and a reading on the meter (calibrated in ohms) shows the leakage current of the insulation.

## **11.3 General Controller Maintenance**

### **11.3.1 Fingers and Contacts**

Large capacity fingers (18 mm to 25 mm ( $\frac{3}{4}$ " and 1") in width) such as those used in the K type of controller are made of copper and slide over copper segments. Both the finger and segment, being of the same composition and comparatively soft, will wear excessively unless lubricated. Petroleum Jelly is usually satisfactory for this purpose.

### **11.3.2 Contact Pressure**

The safe current load on a finger depends on the width of the contact surface, the pressure at the point of contact, and the mass and radiation of the finger and segment. The capacity for a given width increases with pressure, but too heavy a pressure causes excessive wear and stiff drum.

Average practicable finger pressures for general service (copper on copper) are listed below. For different contact materials, these values may be increased somewhat.

<u>Size of Finger</u>	<u>Kilopascals (<i>lbs/sq inch</i>) pressure</u>
25 mm (1")	55 (8 <i>psi</i> )
18 mm ( $\frac{3}{4}$ ")	42 (6 <i>psi</i> )
12 mm ( $\frac{1}{2}$ ")	28 (4 <i>psi</i> )
6 mm ( $\frac{1}{4}$ ")	14 (2 <i>psi</i> )

By means of a small spring balance and a wire stirrup, the pressure is easily checked and the inspector soon becomes accustomed to the feel of a finger with the correct pressure.

Pressure may be varied by changing the bend in the flat finger spring. After bending, see that the finger is making contact along its full width.

Most fingers have an adjustable stop which limits the drop of the finger tip when it leaves the contact, but this stop does not vary the finger pressure. Its sole purpose is to prevent stubbing. The drop should be set at between 1.5 mm ( $\frac{1}{16}$  inch) and 3mm ( $\frac{1}{8}$  inch) or enough to allow the finger to lift entirely free from the stop when the finger is in contact. This allows full pressure on the contact surface. The lift should be checked in all positions of the drum as an eccentric drum or one having worn bearings may have good finger pressure in one position and weak pressure in another.

The considerations mentioned above are equally important when installing new fingers or contact segments. A new finger should be ground in with emery cloth to give a contact area of at least 3 mm ( $\frac{1}{8}$  inch) in width along the contact line and the finger should make contact over at least  $\frac{3}{4}$  of its breadth.

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## 11.4 Inspection of Controllers

### 11.4.1 Intermediate Inspection

General: Perform the following inspections, see appendix A for a sample inspection form.

- a) Remove trolley pole or poles **or pantograph** from the overhead wire and secure it in the down position, affix warning rags “**Do Not Raise Trolley Pole**”. Open all circuit breakers and line breaker control switch.
- b) Remove controller cover noting condition of handles or catches.
- c) Vacuum out all the dust and dirt.

#### Reverser Drum and Fingers:

- d) Check the reverser fingers for broken or badly burnt fingers, also check condition of segments. Tighten all screws mounting cap screws with a box spanner. Check and tighten all screws holding segments onto the reverser drum.
- e) Remove the fibre filter strip from the reverser drum and permit fingers to “drop” into this space. Move the Drum to see that the fingers “wipe in” with sufficient contact. Renew fingers that do not have proper tension.
- f) Clean fingers and segments with fine second cut file and lightly coat them with Petroleum Jelly.
- g) Check the motor lead connections at reverser fingers for loose connections or broken screws; tighten or repair all connections.

#### Main Drum and Fingers:

- h) Check the main fingers for broken or badly burnt fingers. Renew where necessary. Smooth up the tips of fingers with a fine second cut file.
- i) Check the main fingers for proper free play of 1.5 mm to 3 mm (*1/16” to 1/8”*). Adjust fingers to obtain contact on all contact points. Replace burned tips or segments on the cylinder with new ones where necessary.
- j) Tighten fingers and connections to the fingers with box spanner.
- k) Clean segments with a fine second cut file. Tighten all segments and apply a thin coating of petroleum jelly to the fingers and segments (see Lubrication Manual STM6075).
- l) Check the condition of fibre spacing
- m) Wipe the spacing discs clean and apply a coating of insulating varnish.

#### Star Wheels and Pawls:

- n) Observe operation of check pawl and star wheel on each notch. See that the reverser interlock pawl operates properly.
- o) Where fitted, check the operation of the line breaker switch interlock.

#### Motor Cut-out switches:

- p) Check the motor cut-out switches for loose connections. See that the switch blades work properly in their contacts.
- q) On a “K” type controller, throw the No. 1 switch out, then the No. 2 switch. See that series stopping lever prevents the main drum from being moved past the full series position with either switch out. On controllers with the motor cut-outs incorporated in the reverser drum operate the top or bottom sections and check that the main drum does not move past full series.

#### Arc Chutes:

- r) See that arcing plates in the controller insulating trough are in good condition, and that the grooves do properly fit the tapered edge of the arc suppressor plate. If necessary renew.

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- s) Wipe off the plates of the arc deflector, close deflector and see that it clears the fingers and drum segments as the main drum is operated.
- t) Replace cover on controller, check handles or catches for proper fit and operation.

### **11.4.2 Overhaul Inspection**

Perform all steps on the intermediate inspection plus the following; see Appendix A for a sample inspection form.

#### Reverser Drum and Fingers:

- a) Remove fingers from the block and smooth them with a fine second cut file. Clean segments with a fine second cut file, then replace the fingers, set and tighten them.
- b) Remove the fibre filler strip from the reverser drum and check the fingers for proper “wipe” on the contact segments. Renew the fingers which do not have proper pressure.

#### Main Drum and Fingers:

- c) Check the condition of top and bottom bearings of the main drum, replace if necessary and lubricate with oil through the oil tubes.
- d) Check the tightness of the drum segments to the body casting and replace any damaged screws. Replace the burnt tips of the drum segments with new ones where necessary. Clean off all segments with solvent and smooth them with a fine second cut file.
- e) Check the tightness of the screws holding the drum castings to the controller shaft.
- f) Align the main drum fingers with the drum segments; reset the fingers to wipe the segments with adequate pressure and surface contact.
- g) Check the controller fingers notch to notch to see that they make full contact with segments in all positions. See that the fingers “wipe” in the proper sequence.

#### Star Wheels and Pawls:

- h) See that the wheel is securely tightened to the drum shaft.
- i) Check the pawl bearing for excessive play and renew pawl if necessary. Renew badly worn rollers. Observe the operation of the check pawl and star wheel on each notch, adjust as necessary.
- j) See that the reverser interlock pawl works properly. Check the condition of the roller and renew if necessary.
- k) Check the operation of the line breaker interlock switch, if fitted, and adjust for accurate and proper operation. See that “G1” finger contact closes after the main drum segments have closed against their fingers on the first notch. Apply a thin coating of petroleum jelly to the contact faces.

#### Motor Cut-out Switches:

- l) Clean the blade assemblies with fine emery paper and coats them lightly with petroleum jelly.

#### Arc Chutes:

- m) Examine the arc chute plates and clean them. Check the arc chutes for alignment with fingers and segments, repair as necessary. Close the arc chutes.
- n) Replace the cover on the controller, check the handles or catches for proper fit and operation,

### **11.4.3 Testing**

The following insulation resistance tests are to be made after each overhaul inspection, with the trolley poles **or pantograph** down and tagged.

- a) Open the air compressor and light circuits at their switches.
- b) Open the lightning arrestor circuit.

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- c) Close the circuit breakers and “scotch” the line breaker with a block of wood.
- d) Using a 1000 volt insulation resistance tester, test the following points to earth for one minute:
  - i. Each of the drum castings;
  - ii. Trolley finger;
  - iii. R1 finger;
  - iv. -1 finger;
  - v. F2 reverser finger;
  - vi. FF2 reverser finger;
  - vii. AA2 reverser finger;
  - viii. F1 reverser finger;
  - ix. FF1 reverser finger;
  - x. AA1 reverser finger;
  - xi. A1 on motor cut-out switch;
  - xii. A2 on motor cut-out switch; and
  - xiii. S1 and S2 finger contacts of Line Breaker control device.

**NOTE:** the insulation level of any of the above mentioned test points must be greater than ONE (1) Meg ohm, if not investigate and repair.

### **11.5 PC Controller Maintenance**

P.C control is an electro-pneumatic form of automatic control applied to either single tramcars or multiple units. P.C. stands for Pneumatic Cam, i.e. the cam arrangements in the motor controller, pneumatically operated, which throws the various main switches. The acceleration is automatic, being controlled by an accelerating relay. On the master controller there are three positions that are:

#### **SHUNTING                      SERIES                      PARALLEL**

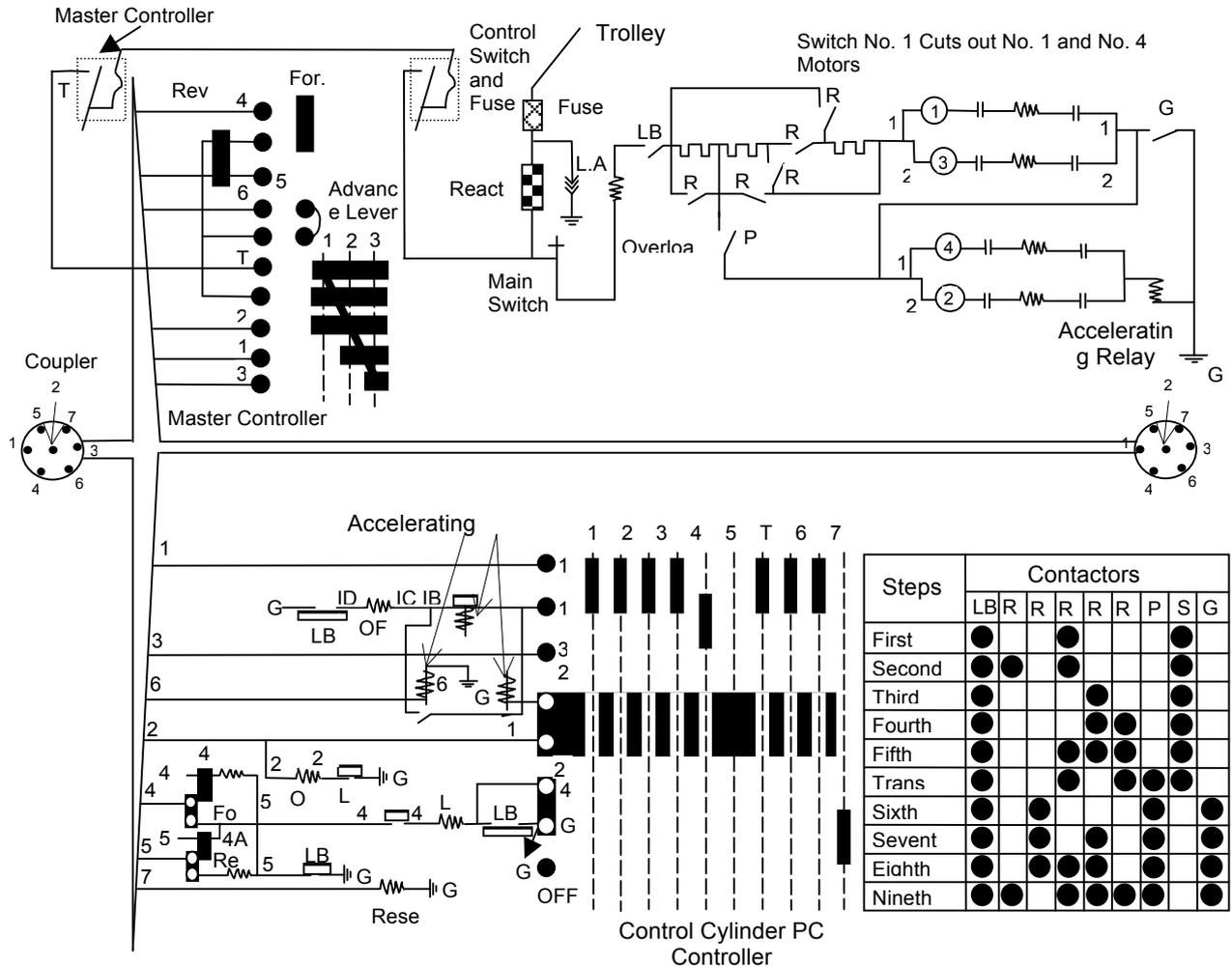
On the first position, or notch, slow movement of the tramcar is obtained, due to the current passing through the full resistance of the grids. This position is not a running position.

On the second position, it allows the main controller to move through all the series notches up to the full series notch, i.e., all resistance is cut-out. This is the running position.

There is a small lever on the right front of the master controller which is the advance lever commonly called “the ticker” which is used in case the automatic relay does not feed sufficient current to the motors, which would be most likely to occur on sharp curves. In operation put the controller handle to full series position, pull the lever back and hold it for two seconds. If the tramcar does not start, repeat the operation until the car starts and full series obtained. The controller handle must be kept on full series at the time that the advance lever is being used.

This style of controller is very vulnerable to poor maintenance and lack of use. Trouble in operation of tramcars equipped with this controller has been found in the past when the vehicle was left idle for extended periods. The air motor as originally fitted had leather cup washers which had a tendency to go hard. So the tramcar was used on a very regular basis to ensure that it was kept in satisfactory working condition. The cup washers have since been replaced with neoprene rubber cups which have increased the controller’s reliability.

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*Figure 44 - CONNECTIONS OF PC-5 CONTROLLER WITH FOUR MOTORS*

## 11.5.1 Operating test

At each inspection the main switch group covers should be opened and, with air pressure of not less than **60 psi**, the PC controller operated from each master controller and with the reverser being operated in both directions. This test allows observation of the switch group, thereby immediately informing the inspector as to the controller condition.

The master controller should be held on notches 1 and 2 long enough to ensure that the P.C. controller definitely stops in the corresponding positions. The controller should be advanced a step at a time as during acceleration by using the advance (“tickler”) lever on the master controller or by repeating the current limit relay by hand. The overload relay should be tripped by hand and reset from the cab.

## 11.5.2 Inspection

### a) Master Controller

- i. Inspect for weak fingers, imperfect contacts and loose connections.
- ii. Clean the contacts and apply a small quantity of petroleum jelly to the drum with a piece of lint free cloth.

### b) P.C. Controller

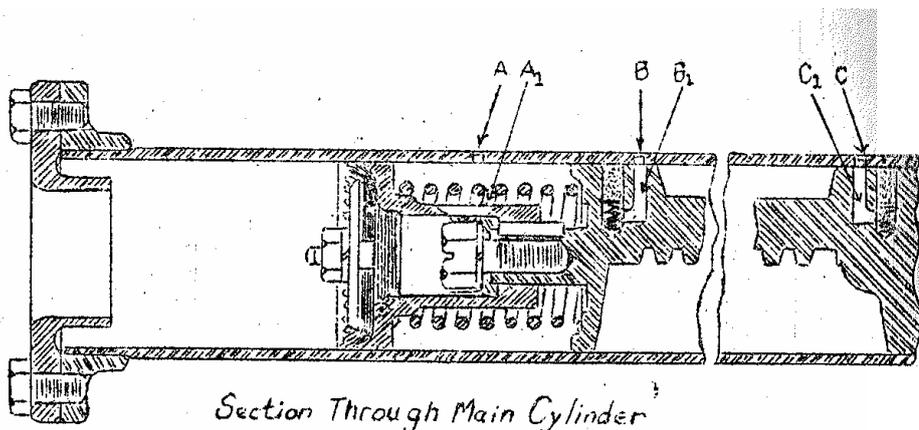
- i. Examine the contact tips and tighten screws holding them, if loose.

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- ii. Remove the contact tips when worn half way through.
- iii. When renewing a contact tip, if the surface against which it rests has become rough or pitted due to poor contact from a loose screw or similar cause, it should be smoothed up or a new part installed.
- iv. Screws holding the contactor and line breaker shunts should be examined to see that they are tight.
- v. Test the operation of the line breaker by pressing the valve operating pin. It should operate quickly, either closing or opening in less than 200 milliseconds. If sluggish, the cylinder should be oiled by placing approximately 1 tea spoon of thin, non-freezing oil such as P.C. controller lubricant No. 1 through the hole above the piston. This should be done at least every twelve months or sooner if the breaker shows signs of sluggishness.
- vi. Oil all bearings, rollers and hinge pins with a thin lubricating oil such as P.C. controller lubricant No. 1.
- vii. The main controller should be oiled at least once every twelve months by removing the heads and placing a thin film of non-freezing oil such as P.C. controller lubricant No. 2 on the walls.

### c) Reverser

- i. Inspect for weak fingers, poor contact and loose connections.
- ii. Clean contacts and lubricate with petroleum jelly



*Figure 45 - SECTION THROUGH MAIN CYLINDER*

- iii. Operate the reverser by pressing the valve pin. It should throw in less than one second. If slow, with the segments and bearings being well lubricated, the cylinder should be lubricated. The cylinder should be lubricated every twelve months by removing the heads and placing a thin film of non-freezing oil such as PC controller lubricant No. 2 on the walls.

### d) Control Fingers

- i. At each inspection, the control fingers on the reverser, line breaker, control drum and their segments should be wiped clean with a piece of lint free cloth that has been moistened with a thin lubricating oil.
- ii. The control fingers, when the contact with a segment, should have sufficient pressure to make a good contact refer to the chart on **page 120**.

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### e) Overload Relay

- i. Clean the contacts
- ii. Trip the relay and see that the armatures move easily.

### f) Current Limit Relay

- i. Clean the contacts.
- ii. Move armature by hand and see that they are free and easy to move.

### g) Star Wheels

The star wheels of the P.C. controller, like those on a “K” type controller, locate the controller notches. If the pawl springs are broken or become weak, the controller notches are not as definitely located as when the pressure is maintained at normal.

Pressure of the pawl against the star wheel in the “OFF” position for PC 5 type controller is between 6 to 11 kgs (*13 to 25 lbs*).

### h) Line Breaker

The arc chute is removed by taking out two caps screws. These cap screws are accessible from the bottom of the controller and are located in the arc chute pole pieces on the outside of the arc adjacent to the contact tip.

To remove the line breaker packing it is necessary to first take off the arc chute, then remove one of the transit barriers. This allows the pins through the operating and contact levers plus the levers to be removed. The cylinder head may now be taken off and the piston packing removed, see *Lubrication Manual STM6075* and the lubrication section later.

### i) Reverser Removal

The reverser cylinder may be removed by disconnecting and removing the cut-out switch and end bearing of the reverser. Then the reverser cylinder may be taken out through the door that covers the cut-out switch.

### j) Control Drum Removal

In order to remove the control drum, take out the cap screws holding the bearing at the line breaker end of the cylinder. Then slip the bearing off the shaft and the drum can be easily disengaged from the clutch and removed.

It is possible to put the control drum in place 180° from its correct position and to prevent this, the two parts of the clutch between the drum and cam shaft are witness marked.

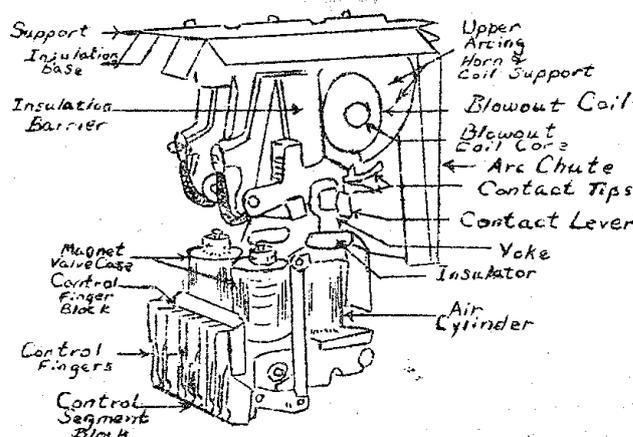


Figure 46 – LINE BREAKER UNIT (PC 5 only)

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### k) Cam Shaft and Pinion

To remove the cam shaft, first take out the control drum, then take off the steel strap used as a stop for the covers. The cap bolts holding the cam shaft bearings can now be taken out and the cam shaft removed.

In order that the cam shaft and pinion be assembled on the rack, the best method is to mark the pinion and rack before taking these parts out. In case this is not done, the rack and pistons should be pushed toward the "ON" magnet valve as far as they will go. The cam shaft and pinion are then put in place so that none of the cams touch the cam rollers on the contactors.

### l) Removing the Piston Spring

Read the General Electric PC Control Book #GEH-328 on page 21.

### m) Magnet Valves

When the valves are sticky, wash them thoroughly in solvent as well as washing the valve seats inside the magnetic core. When the valves are returned, each must be returned to its own seat, as each stem is ground to fit its own seat. Therefore it is recommended, that when the magnet valves are to be dismantled, that one magnet valve is to be worked on at a time.

Whenever a new valve is installed or a valve leaks, it must be ground in, lapped. After a good seat is obtained, wash out all grinding materials with solvent. Further details on magnet valves may be found in the *Magnet Valve section* later.

## 11.5.3 Lubrication

### a) Pneumatic Cylinders.

Not less than once ever two years perform the following:

- i. Remove the cotter pin, nut, lock washer and pressure distributing washer from the end of the piston, then remove the piston packing by first running the piston to the open end of the cylinder, then back, this will probably back the centre stud out of the packing and it can be removed by hooking a heavy wire hook through the centre hole. Do not, unless absolutely necessary, try to remove the piston packing and expanding washer by running a knife or other sharp instrument between the packing and the cylinder wall, as this may damage the packing. The main cylinder and reverser pistons, on which the metal heads are not removable, should be pushed in the cylinder to the extreme end of the stroke exposing the cylinder walls.
- ii. Wash all metal parts thoroughly in solvent. Wipe the piston packing off with lint free cloth to remove the lubricant.
- iii. If the piston washer is in good condition, not scored or the wearing edge otherwise damaged, it should be rubbed over with a small amount of PC Controller Lubricant and held to assemble. If it is very hard or shows a tendency to crack when bent slightly, the piston washer should be replaced. Do not attempt to replace a damaged disc from one set of three with a disc from another set, because each set is made together and should not be so used. If one is damaged, replace the whole packing, otherwise a "leaky" piston will probably result, necessitating removal immediately after assembly. Originally the piston washer was of leather but over the years in Museum service these washers grow old and hard, a decision was made to replace them with a modern, low maintenance material and a neoprene rubber washer selected and used. Since installation, the maintenance on the piston washers has considerably lessened.
- iv. When the walls of the cylinder are clean and the solvent has been thoroughly wiped out or has evaporated, lubricate with PC Control Lubricant. Too much lubricant should not be used: 3.5 grams ( $\frac{1}{8}$  oz) is sufficient for a cylinder. This lubricant should be applied in an even film over the entire surface of the cylinder walls with a swab. In case the piston is entirely removed from the cylinder or reverser, it should not be replaced with the piston packing on both ends because the packing that must pass over the opening at the centre between the two cylinders will be damaged. The packing should be left off the piston that is

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put into the cylinder first and put in the opposite end of the cylinder after the piston is in place.

- v. After reassembling the piston and replacing the cylinder head, apply normal air pressure and operate the piston through the full stroke several times, then test both the piston and the cylinder head for leaks.

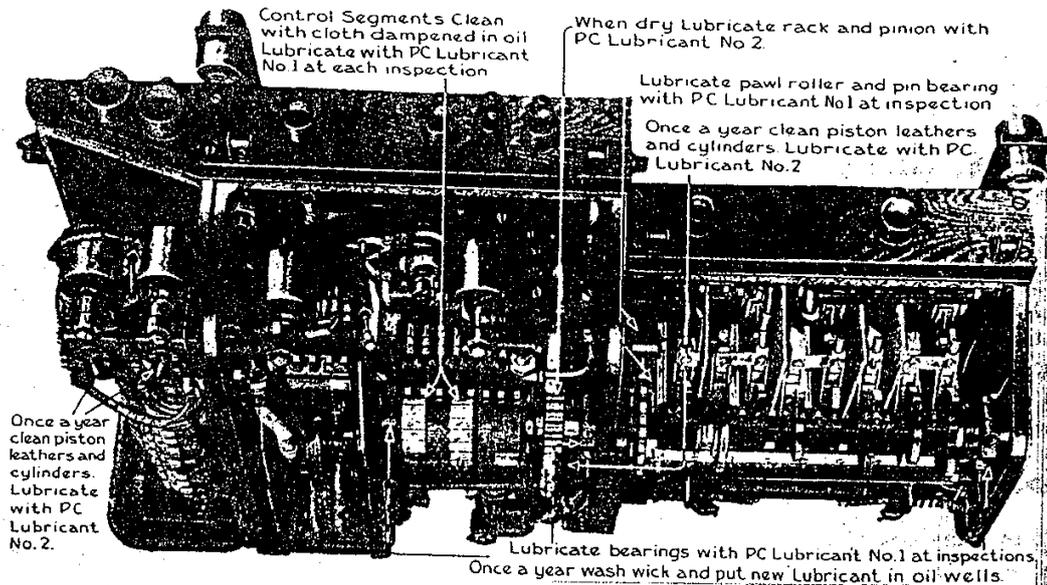


Figure 47 – LUBRICATION FOR PC-5 CONTROLLER

### **b) Lubricating of Bearings**

Lubricate at intermediate inspections.

- i. Remove the control cylinder and cam shaft from the controller.
- ii. When the cam shaft and control cylinder are reassembled in the controller, the oil wells in the main bearings should be filled through the oil hole in the side of the bearing housing with PC Controller Lubricant oil.
- iii. The roller bearings on the contactor units and star wheel pawls should be lubricated with a small amount of PC Controller Lubricant oil applied to each end, and the bearing rotated to cause oil enter between the end washer and the outside roller way.
- iv. The hinge bearings of the contactor units (three per contactor) should be lubricated with a small amount of PC Controller Lubricant oil.
- v. Lubricate the reverser main bearings with a small amount of PC Controller Lubricant oil.

### **c) Lubricating of Contacts**

At every intermediate inspection.

- i. Motor Contacts
  - a. Cover wearing surface of the contactor units with a thin film of petroleum jelly.
  - b. Cover the motor circuit segments of the reverser with a thin film of petroleum jelly.
- ii. Control Circuit Contacts

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Clean and lubricate the segments as above.

It is particularly important to keep the control segments clean and well lubricated when low control voltage (32 volts) are used for the following reasons:

- a. The electrical contact resistance is less, provided the lubricant is not so heavy as to actually separate the finger from the contact segment, and
- b. The presence of lubrication tends to form a hard insulating film on the surface of the segments.

### **d) Air Engine**

- i. Dismantle the air operating cylinders sufficiently so that the cylinder walls and piston parts may be thoroughly cleaned. When reassembling, lubricate with PC Controller Lubricant oil.
- ii. If the piston packing is pliable, rub it over the PC lubricant. If the packing is dry and hard, replace it with new neoprene rubber packing.
- iii. Apply to the clean cylinder walls with a swab or brush, an even film of PC Controller lubricant of about 3.5 grams ( $\frac{1}{8}$  oz).

### **e) Sleeve and Spherical Bearings (Wick Oiled)**

Clean oil wells and bearings, wash the felt in solvent and allow to dry. Fill with PC Controller Lubricant oil.

## **11.6 Magnetic Valves**

### **11.6.1 Inlet Valve Leakage**

Occasionally a valve will “blow” (i.e., give out a hissing sound) due to leakage of air. If this occurs when the magnetic coil is de-energised and the air blows out of the magnet valve exhaust port (f) it is indication that the lower (inlet) valve is not seating properly. The trouble is generally caused by a little dirt in the valve seat and in most cases can be cured by pressing down the pin in the top of the magnet valve and releasing it quickly several times. If the blowing persists, shut the air off from the apparatus by closing the control reservoir cut-off valve and bleed the air from the control reservoir, then unscrew the plug at the bottom of the magnet valve. Lower the plug carefully straight down, the spring and lower valve will drop down with it. Wipe the valve perfectly clean, and with a small wooden dowel and a piece of lint free cloth, also clean the valve seat.

When replacing the lower valve, spring and plug, first remove the cap over the armature so that in case the valve stem does not properly enter the hole in the stem (k), it is free to be lifted by the advancing stem instead of being damaged. If the inlet or exhaust valve is not tight, the difficult can sometimes be cured by inserting a small screw driver in the top slot and rotate it several times on the seat.

### **11.6.2 Exhaust Valve Leakage**

In case the valve “blows” through the exhaust port when the coil is energised, it is a sign that the exhaust valve (d) is not sealing properly on the seat (e). This may be due to any one of the following causes which are mentioned in order of their usual sequence of operation:

- a) Dirt in the valve seat (e).
- b) Dirt under magnet armature (h).
- c) Valve stem (k) worn down so that the armature strikes the pole (m) before the valve seats.

To remove the stem (k) it is not necessary to shut off the air. First remove the cap over the armature and lift out the armature which is not fastened in any way. Temporarily seal the magnet valve exhaust port (f) and press down on top of the valve stem with a finger and then raise the finger quickly. The valve stem will be raised by the air pressure and can be readily be lifted out and the end of the valve be wiped clean.

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Another possible cause of a blowing exhaust valve, i.e., a worn down stem, is very unlikely to occur until after the equipment has been in service for many years.

### **11.6.3 Grinding Valves**

It is occasionally necessary to grind in leaky valves. Use a prepared grinding paste (compound) for this purpose. Apply a little grinding paste onto the valve seat, put the valve in place and rotate back and forth with a screw driver.

When grinding the lower valve, the upper stem should be in place to act as a guide. After grinding the stem and valve seats, they should be thoroughly cleaned by using a little solvent and blowing out with air.

## **11.7 Type “M” Control**

### **11.7.1 Intermediate Inspection**

#### **a) General**

- i. Remove the trolley pole or pantograph from the trolley wire, open the circuit breakers and master control, then affix warning tags to the trolley ropes and elsewhere as required for personal safety.
- ii. Remove the cover from the contactor box and vacuum the dust and dirt out. Wipe out any dirt that remains with a clean cloth.

#### **b) Reverser Drum and Fingers**

- i. Check the reverser fingers for positive contact.
- ii. Inspect reverser fingers for broken springs.
- iii. Replace any badly worn segments.
- iv. Charred segment blocks should be scraped and repainted or if badly damaged replacement should be considered.
- v. Inspect the blow out coils for open circuits.
- vi. See that the operating arm works freely.
- vii. Apply a thin coating of petroleum jelly to segments.

#### **c) Contact Box and Contactors**

- i. Inspect contact tip for excessive wear, renew when they are worn half way through.
- ii. Inspect the arc chutes for burning, when holes are burnt halfway through they should be replaced, or repaired with arc resisting cement.
- iii. Replace arcing horns when badly burnt.
- iv. Replace badly worn shunts.
- v. See that the plunger works freely in the brass sleeve of the operating coil.
- vi. Check all moveable parts for excessive wear.
- vii. See that all wiping springs are in good condition.
- viii. Check all interlock rods, discs and posts for excessive wear and proper tension.

#### **d) Motor Cut-Out Switches**

- i. Check the motor cut-out switches for loose connections.
- ii. Check the function of the motor cut-out switches and proper sealing in their contacts.

#### **e) Master Controller**

- i. Remove the cover and vacuum out the dust and dirt.
- ii. Check all fingers for excessive wear, replace fingers when three quarters ( $\frac{3}{4}$ ) worn.
- iii. See that all finger supporting screws are tight.
- iv. See that the reverser fingers have proper tension.
- v. See that both operate freely.??

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### **11.7.2 Overhaul**

- a) Remove all contactors from the box.
- b) Test the operating coils for short circuits.
- c) Inspect all moveable parts for excessive wear. Renew parts where necessary.
- d) Reline the interior of the box if necessary and paint with insulating varnish.

### **11.7.3 Reverser**

- e) Remove and test operating coils. Inspect all moveable parts for excessive wear and renew where necessary.
- f) If necessary, reline the interior of the box and paint with insulating varnish.

### **11.7.4 Interlocks**

- g) Remove all interlocking rods from the back of the magnet frame.
- h) Inspect all rods, discs and posts for excessive wear, renew where necessary.

### **11.7.5 Master Controller**

- i) Remove the controller from the tramcar.
- j) Remove all parts from the controller.
- k) Revarnish the inside of the controller.
- l) Renew all worn parts.
- m) After reassembly, paint the outside of the controller.

### **11.7.6 Testing**

- a) After all parts are reassembled in the contactor box, use an insulation resistance tester of 1000 volt capacity and test between the contactor frames and the contactor box.
- b) After all parts are reassembled in the reverser box, again use an insulation resistance tester of 1000 volts capacity and apply the test between the reverser frame and the reverser box.

## 12 Automatic Circuit Breakers

### 12.1 Maintenance and Inspection

An automatic circuit breaker can be maintained with very little trouble, if cared for systemically at inspection periods. It should be opened and examined carefully for wear, dirt loose parts or damage of any kind. During inspections the automatic circuit breaker must be carefully examined for any evidence of mud or other type wasp nests which must be removed to allow correct operation of the circuit breaker. Blow-out coils should be examined for evidence of heating, should be dusted off and tighten if loose or chafed. Contacts should be smoothed up with a fine second cut file, after which they should be lubricated slightly by applying a thin coating of petroleum jelly. Shunts should be examined for fraying or breakage. Arc chutes should be examined for burning and dirt. The mechanical parts should work freely and positively and badly worn pieces should be replaced. A drop or two of oil should be used to lubricate the parts to prevent rusting of the bearing pins, care being taken to see that no surplus oil is left to gather dirt and dust, therefore any surplus oil is to be removed with a lint free cloth. The automatic circuit breaker tripping mechanism should be inspected for good order and the setting should be checked and set for the correct value.

### 12.2 Overhauling

The automatic circuit breaker should be removed from the tramcar and taken to a bench where it can be taken apart comfortably. The blow-out coil must be thoroughly cleaned and repainted using insulating varnish; the box should be cleaned thoroughly and also be repainted using insulating varnish. All mechanical parts are to be inspected for wear and repaired or replaced if necessary, with all other parts being thoroughly cleaned.

### 12.3 Setting

The effectiveness of an automatic circuit breaker is increased by setting the trip limit as accurately as possible. Settings for the tramcars in the Museum's collection can be seen *in table 2 in Appendix D*. If the setting is unknown, a good approximation can be used of 150% of the combined "one hour rating" current when the motors are connected in parallel. With a setting of 150% of the normal rating, the current per motor cannot exceed 150% of the normal rating when the motors are in parallel without tripping the breaker. In series, however, the current may reach a dangerous value of three times the rating before the circuit breaker opens. For an automatic circuit breaker to operate it needs an overload (high) current and time, therefore the higher the overload current the shorter the operating time for the circuit breaker. This serves to illustrate the relative lack of protection even when the circuit breaker is set as low as possible and emphasises the necessity of proper training of the drivers in handling the controller and speed of acceleration.

For the "one hour rating" of the traction motors – see the tables in section *Traction Motor Maintenance*.

## **13 Resistance Grids**

With proper design, application and installation, the maintenance of grid resistance should be negligible. However, under the best of conditions, troubles such as breakages are likely to occur. When replacing broken or burned out grids, be sure that there sufficient insulation, at the proper places, between the new and old grids. It may be necessary in a number of cases to renew a considerable portion of the mica tube around the main suspension bolts.

At the time of an overhaul inspection, and when installing new grid frames; the clamping bolts should be tightened to take any shrinkage that may have occurred. The terminals should be checked to see that the cable connections are satisfactory. All leads should be carried up close to the floor of the tramcar until it is necessary to bend them down for the terminals. This prevents the cables from resting on top of the grids and damaging the insulation.

When inserting new plates into the grid frame be sure to have a smooth contact surface between the connecting plates and a good amount of insulation between those not connecting. It is necessary to file these surfaces flat, using a course type file. If they can not be made perfectly flat, use soft copper washers to take up the difference.

## **14 Brake Equipment Maintenance**

### **14.1 Compressors**

For their lubrication see Lubrication Manual (STM6075). These are general rules for all types of compressors.

#### **14.1.1 Overhaul**

*The overhaul should be every 10 years for tramcars in general museum service.*

Field coils and armatures should be given a solvent good bath, followed by a thorough drying out and a liberal application of insulating varnish. Bearings should be maintained to prevent noisy operations particularly on the connecting rod. Valves and valve heads must be thoroughly cleaned and the valves lapped into their seats. The suction strainer must be kept clean; otherwise the dirt accumulated in the filter will be drawn into the compressor and increases the wear rate. In either case the efficiency of the compressor will be greatly reduced, therefore the filter should be regularly washed in solvent to remove the dirt.

The compressor should be entirely dismantled and thoroughly cleaned out with solvent. Particular attention should be given to all wearing parts and proper adjustments made to eliminate lost motion due to wear. It is important that the rings and ring grooves be cleaned and that the rings have a good bearing on the cylinder wall and the groove.

#### **14.1.2 Inspection**

On an inspection the following should be done:-

- a) Blow out the compressor motor with low pressured compressed air, to avoid damaging the insulation.
- b) Wipe off with a lint free cloth the brush holders, insulators, commutator front V-ring band, and the inside of the cover.
- c) See that the wires connected to the brush holders are secured and in good condition.
- d) Take hold of the brush holders and see that they are secure.
- e) See that the holder can not move than 3 mm ( $\frac{1}{8}$  inch) or less than 1.5 mm ( $1/16$  inch) from the commutator surface.
- f) Remove and check the brushes to see that they are free from cracks and chips.
- g) Replace the brushes with the trade marks facing each other.  
See that the brushes are long enough to last until the next inspection.  
See that the hammers exert between 14 to 21 kilopascals (2 and 3 psi) on the brushes.
- h) Check the fuse to see that it is a 10 ampere rated fuse when used to protect a DH16, CP 27 types or similar sized compressors.

#### **14.1.3 Maintenance of Westinghouse DH Type Compressors**

- a) The air gap should be checked at intervals in order to preclude any possibility of bearings wearing sufficiently to permit the armature to hit the field poles (poling) causing damage or possibly destroying the windings.
- b) When the brushes are changed, they should be seated to the commutator shape by using a strip of glass paper held on the surface of the commutator under the brushes with the abrasive surface against the brushes. This strip of glass paper should be long enough to encircle the commutator. To set the brushes move the paper backwards and forwards around the commutator a few times then check the brushes, for it takes little time to bed in the brushes. This bedding in of the brushes will prevent excessive sparking which would result from an improper brush bearing, as the current will be evenly distributed across the brush face, and thus preserve the commutator glaze.

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- c) If pounding develops in the compressor, take off the crank case cover (if possible), examine the connecting rod gap where lost motion likely to occur and remove the necessary shims to take up the wear in the bearing. Never leave an unfilled gap between the cap and the rod, as it could lead to the bearing binding on the crank pin. Be sure to tighten the lock nuts evenly and replace the cotter pin.
- d) The best results are obtained when the valves have lifts of 4 mm (*5/32 inch*) for inlet valves and 3 mm (*1/8 inch*) for the outlet valves on DH16 compressors.
- e) If the compressor blows its fuse frequently and the motor is found to be in good order, it may be assumed that the compressor is not working freely. It should be examined for tight or stuck valves, hot or tight bearings, or tight pistons and the trouble repaired.

### 14.1.4 Maintenance of General Electric Compressors

- a) Oil level is normally 3 mm (*1/8 inch*) below the top of the filling elbow. Add more oil when 9 mm (*3/8 inch*) below the top of the elbow.
- b) The vent pipe is located in the bottom of the compressor between the motor and the piston casting and it is a safety drain. An accumulation of oil around this is an indication that the vent pipe requires immediate attention. Remove the cleaning with a socket spanner and replace with the threads well taped with plumbing (Teflon) tape.

The condition of the vent pipe can be determined by holding the hand under it. If there is no signs of air coming from it, it is probably clogged with dirt, but if light puffs of air come from it all is well.

If the vent pipe is clogged, oil from the armature bearing cannot return to the crankcase as it should but should be discharged through the safety drain and wasted. If it is found clogged, the 12 mm (*1/2 inch*) pipe plug at the bottom of the oil return should be removed and the oil return passage thoroughly cleaned. The 18 mm (*3/4 inch*) pipe plug at the bottom of the settling well should be removed and any sediment which may have collected drawn off at least once a year or more often if the tramcar is used very frequently.

- c) Clean the air intake strainer as often as necessary. It should be inspected at every twelve months. The motor frame cover should be removed and the outer end of the motor, including the brush holders, field coils, armature and the cover should be should be thoroughly cleaned. If compressed air is used to blow the motor out, a bent nozzle should be used so that the dirt will be blown away from the interior of the motor and out the exposed end. It is important that is using compressed ait to blow out any motor it **must be** of low pressure to avoid damaging the insulation.
- d) Brush holders must be inspected for accumulation of carbon dust and this must be cleaned away from the insulators, etc. The brushes must be checked for wear and replaced, if necessary, and the brush spring tension should be checked that it is between 17 to 21 Kilopascals (*2-1/2 to 3 psi*) {type CP 27}.

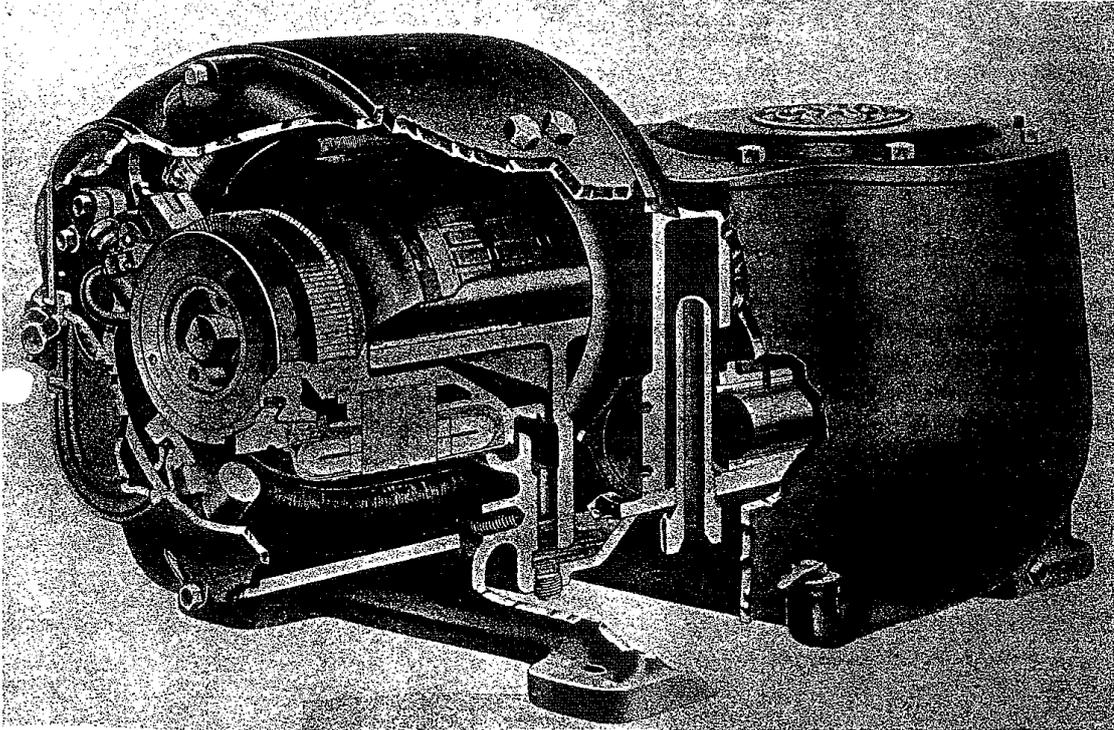


Figure 48 – CP27 COMPRESSOR SHOWING OIL RETURN FROM THE MOTOR TO THE COMPRESSOR AND CRANK CHAMBER VENT PIPE.

## 14.1.5 Maintenance of National Type Compressors

*Inspect weekly, if tramcar is used weekly otherwise intermediately. Check at elbow nearly to the top and drain oil about every 10 years.*

Oil the armature bearing on the gear end when filling by removing the plug. It does not need filling after the compressor has run. The bearing on the commutator end should be lubricated occasionally through the filling opening or through the opening in the end of the bearing cap.

If the suction and discharge valves work irregularly, they as well as their chambers must be thoroughly cleaned with solvent. Never put oil on the valves.

Leave about 0.4 mm (*1/64 inch*) play between the gear teeth when assembling.

## 14.2 Governors

Settings must be	Cut in	Cut out
Christensen Type	65 psi	75 psi
Standard Type	30 psi	36 psi

*(NB the pressures shown above are in imperial measurements because the gauges are in imperial)*

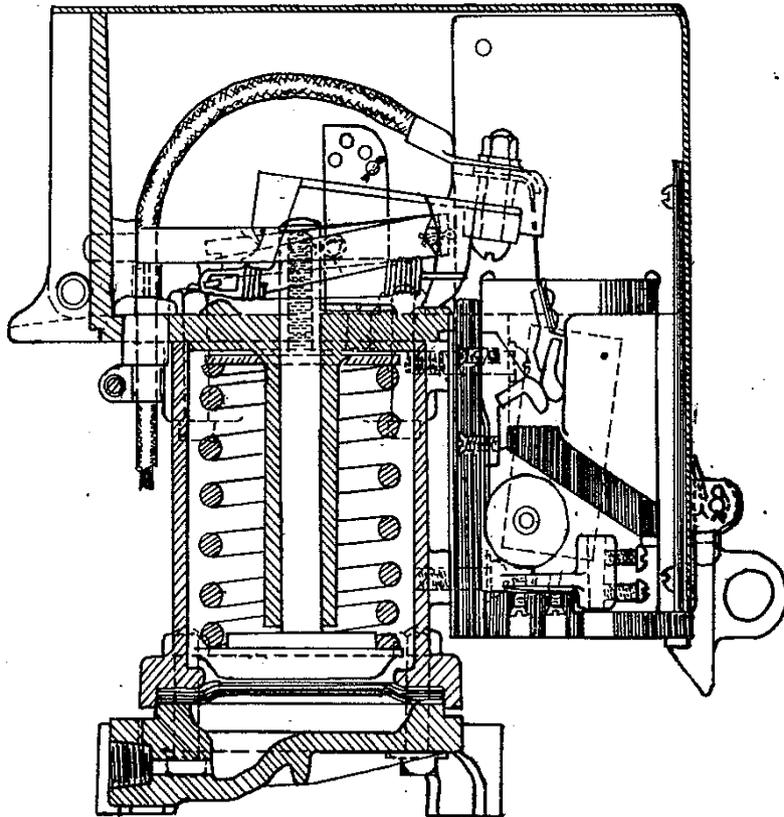
- Remove the governor cover.
- Check that the regulating screw lock nuts are tight.
- Check the condition of the wiring and that the insulation pieces are in good condition and properly secured.
- Check that the contact finger, finger base and contact shunts are in good condition. Dress the contact surfaces if required and lubricate with petroleum jelly.
- Check the contact finger adjustment so that it allows the finger to drop clear of fixed contact when maximum operating pressure is reached.

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- f) If cut-out pressure setting has to be changed, adjust both pressure adjusting screws exactly the same amount, **DO NOT** adjust one screw only.
- g) Wipe out any dust and dirt.
- h) Lightly lubricate operating mechanism with light lubricating oil.

When installing a new governor, never assume that it works properly. Always watch the pressure gauges carefully and be ready to turn the compressor off, if necessary, to stop over pressurisation of the system. To adjust the cut-out pressure, move both adjusting screws at the same time. The cut-in pressure is adjusted by moving the cotter pin, on the contact finger framework, into a different hole.

If the governor cannot be adjusted for cut-out pressure, it is possible that the diaphragm has ruptured and must be replaced.



*Figure 49 – “ML” TYPE COMPRESSOR GOVERNOR*

### 14.3 Reservoirs

- a) All reservoirs must be drained daily.
- b) Always install with the seam at 135° to the drain valve. This keeps moisture out of the seam and the rivets (when fitted).
- c) Reservoirs should be hydrostatically tested to at least twice the operating pressure or if possible a minimum of 1100 kpa (160 psi) and left for a minimum of one hour under pressure with no loss of pressure.
- d) The reservoir must comply with current regulations for mobile pressure vessels and should have an inspection hole so as to inspect the internal condition of the reservoir.
- e) Remove any rust and clean the outside of the reservoir, then paint the entire surface with a good ferrous metal primer such as red zinc chromate.

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## **14.4 Safety Valves**

- a) Make sure that all the vent holes are clear of any obstructions and air clean.
- b) The safety valve should be set at the most *10 lbs (70 kpa)* above the tramcars cut-out pressure.

## **14.5 Air Pressure Gauges**

- a) Must be clean and easily read. If the hand/s or the numbers are illegible it will be necessary to repaint them.
- b) The gauges must not vary from one end to the other by more than *5 lbs per sq. inch (35 kpa)* or from a standard gauge.

## **14.6 Driver's Brake Valve**

### **14.6.1 Lubrication**

Every 12 months (with no air in the system) remove the oiling screw either in the body of the valve or in the stem and apply several drops of compressor oil. Then replace the screw and make certain there are no air leaks. On self lapping valves some are fitted with a grease nipple, therefore with no air in the system apply one or two pumps of general purpose grease.

Also refer to STM6106 – Westinghouse Brake Valve Maintenance Procedure.

### **14.6.2 Testing**

With the valve installed in the tramcar and full air pressure in the reservoirs, use a container of soapy water to detect any leakage (indicated by soap bubbles forming) as follows:

- a) Install a short length of 12 mm (*½ inch*) pipe or tube into the exhaust connection, with the other end of the pipe submerged in the water. As the valve handle is moved through all positions except release (on manual lapping air valves), there should be no leakage.
- b) Pour a small amount of the soapy water around the top position of the valve stem and bonnet brushing as the handle is moved through all positions. Observe for the formation of bubbles.
- c) With the handle in **LAP** position, disconnect the brake cylinder connection and inspect for leakage.
- d) With the system fully charged with air, i.e., the brakes fully applied, check all of the pipework for leaks.

### **14.6.3 Repairing**

- a) If adjoining faces of the body and rotary valve are scored, grind and lap these surfaces. When regrinding the faces use a trued grinding plate and good quality grinding paste. After grinding reassemble the parts into the valve and use a good quality lapping paste to lap the parts.
- b) After lapping, wash the parts with solvent to remove all traces lapping paste.
- c) Apply a coating of petroleum jelly to the valve stem.
- d) Replace the gasket if necessary.
- e) Make sure the valve works correctly before leaving the job. Check the action of the piston in the brake cylinder.

## **14.7 Brake Cylinders**

### **14.7.1 Inspection and Maintenance.**

- a) Disassembly
  - i. Making completely sure that the air has been completely drained from the system. Remove the nuts from the non-pressure head bolts, taking care that the spring is not released inside the cylinder. Then remove the piston from the cylinder.

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- ii. Scrape the old lubricant from the cylinder wall and leakage grooves and wipe surfaces clean and dry. Kerosene may be used to assist cylinder cleaning, but must be removed completely to prevent damage to the gasket and packing washer.
  - iii. If rusted, clean cylinder with emery cloth and remove the dust.
  - iv. Remove the expander ring from the piston.
  - v. Scrape all the old lubricant from the metal part of the packing washer.
  - vi. Replace the packing washer if brittle or thin or cracked. Order the new washer by cylinder diameter, i.e., 200 mm, 225 mm, 250 mm (8", 9" 10"), etc.
  - vii. Examine the piston and follower plate for cracks and tighten up the following nuts.
    - viii Examine the follower studs for tightness in the piston.
  - ix Place the brake packing washer centrally on the piston with the cup side away from the piston. Apply the nuts, bringing them uniformly into contact with the follower without tightening. Then draw them down.
- b) Reassembly
- i. The piston with the spring and non-pressure head should be stood on end with the flat side of the non-pressure head flange and the opening of the expander ring toward the work person.
  - ii. With the piston in this position, enter it into the cylinder.
  - iii. The sleeve or rod should then be slowly raised and the piston moved into the cylinder until the upper portion of the washer engages the cylinder walls.
  - iv. Enter this portion of the washer into the cylinder with a dull-edged, round cornered putty knife or similar instrument while the sleeve rod is being gradually raised, taking special care not to crimp or otherwise damage the washer.
  - v. Pull upward and outward on the sleeve rod until it is in a horizontal position.
  - vi. Push the piston into its release position and then raise the sleeve and rod to the top of the cylinder to determine whether the expander is in the proper position which will be indicated by freedom of movement.

These instructions for assembly apply particularly when the brake cylinder is in a horizontal position; however, for other positions, the method must be changed as required to produce a similar result.

**Special Note:** If the leather packing washers are used they should be kept soft and pliable, so that it will be tight and yet move easily in the cylinder, (the modern replacement is a neoprene rubber compound). To this end, a small quantity of Neatsfoot Oil should be applied by filling the space between the leather and the follower. In removing the cylinder head for this work, the piston should first be forced outward by a slight application, and a nail or a piece of wire inserted in a hole provided for that purpose in the piston-rod pipe to prevent the spring from forcing the piston out when the cylinder head is removed. A syringe with a capacity of 71mls ( $\frac{1}{8}$  pint) may also be used for injecting the oil into the brake cylinder as there is a 12 mm ( $\frac{1}{2}$  inch) pipe plug provided for this purpose in the back head of the brake cylinder.

### 14.8 Some Basic Types of Air Brake Systems

In order to know about braking systems and their operation, it is very helpful to understand the significance of their names. These are some of the more common types:

- a) Straight Air Brake – most common and simplest system. It is a system where the air that is allowed through the driver's brake valve, is the air that goes to all the brake cylinders no matter how many tramcars that are connected together and under the driver's control.
- b) Manual Lap Brake Valve - is a driver's brake valve with three positions. In Sydney tramcars, the positions are: **OFF** – to the extreme right.

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**LAP** – in the centre of the movement,  
**ON** - to the extreme left.

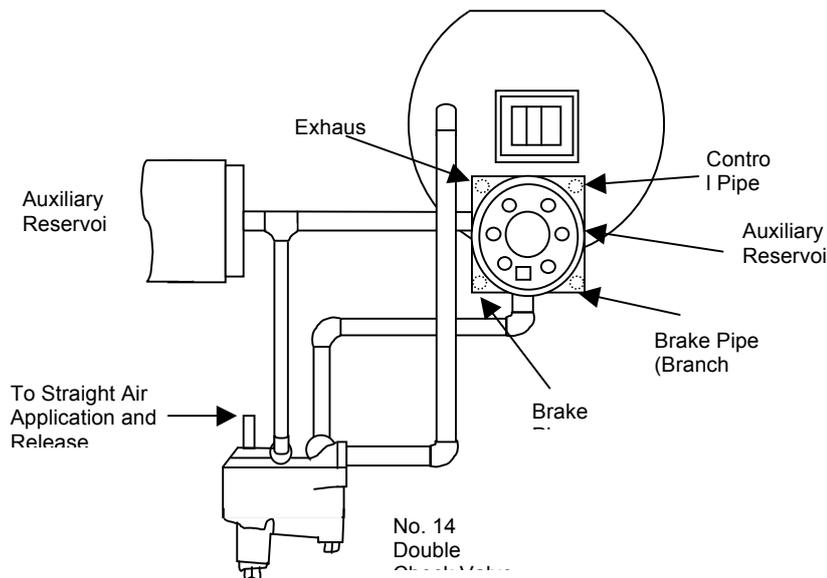
- c) Self Lapping brake – is a driver's brake valve again with three positions but this time in Sydney tramcars the position are:  
**OFF** – to the extreme right.  
**ON** - between the extreme right and left, i.e., infinitely variable.  
**Emergency ON/Handle Release** – to the extreme left.  
**Normal full application of the brakes** - is just before extreme left position.
- d) S.M.E. or Safety Tramcar Air Brake System – is a straight air brake system with an emergency valve added to it. "S" means straight air, "M" means for a motor and "E" means with an emergency valve.

On most tramcars, there is some kind of automatic valve, the operation of which is often confusing. Several of these are explained in the following paragraphs.

### 14.8.1 Piston Travel

Piston travel should be adjusted to 100 mm (4 inches), standing, as nearly as practicable with automatic brake equipment. This is important for if the piston travel is too short, a high braking power will be obtained when only a low braking power is desired, the equalisation of the auxiliary reservoir and brake cylinder will occur sooner, and the time in which the driver can perform the operation is greatly reduced. On the other hand, if the piston travel is too long, a proper braking effort is not obtained for a given reduction and the final equalisation pressure is lowered. If some brake cylinders in a coupled set have a long piston travel and others short, a very uneven braking power will be developed for any given brake pipe pressure which will cause wheel slip.

The correct operation of the brakes can be secured only by maintaining a uniform piston travel on all tramcars. Keep the slack adjusters in proper operation.



View showing pipe Connections to Brake Cylinder

*Figure 53 – TYPE "M" TRIPLE VALVE*

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### 14.8.2 Type “E” Relay Valve

- a) Operation – The “E” relay is used with the air brake equipment where a more prompt action is desirable. The object of the “E” relay valve is to reduce the volume of air which has to flow through the brake valve and straight air pipe to the brake cylinder and vice-versa, thus ensuring a quick application or release of the brakes.

This device performs three functions:

- i. Supplies main reservoir air to the brake cylinder in the same time as a small volume of straight air pipe is built up.
- ii. Releases brake cylinder pressure in the same time as a small volume of straight air pipe is released.
- iii. Maintains a brake cylinder pressure equal to that in the straight air pipe when the brake valve is in the lap position.

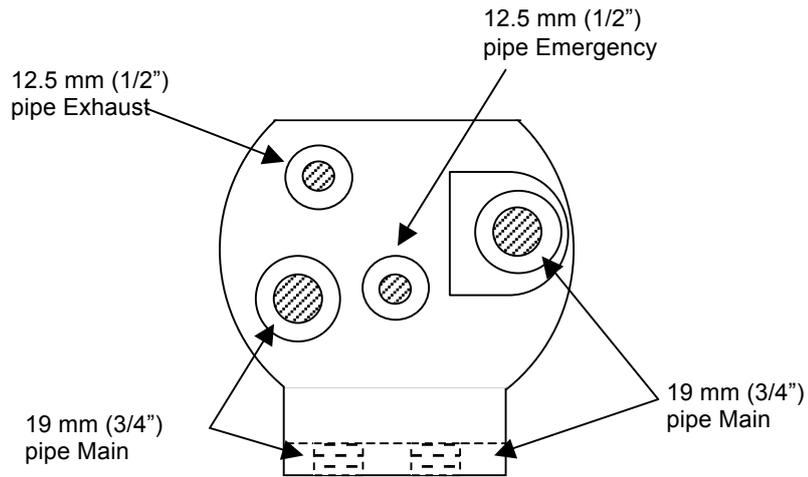
This valve is located between the brake cylinder and the emergency valve in the brake cylinder pipe. The valve functions in application, to open a direct connection between the main reservoir/s and the brake cylinder/s.

In release, this valve opens a direct passage between the brake cylinder/s and the atmosphere, thus eliminating the time ordinarily expended in passing the air volume contained in the brake cylinder/s, through the brake pipe to exhaust to the atmosphere.

- b) Maintenance:

- i. Remove the four mounting bolts and dismantle from the pipe bracket.
- ii. Remove the piston and slide valve assembly in a clean environment.
- iii. Extract the piston from the slide valve bushing.
- iv. Inspect the slide valve spring for wear. If worn more than 20%, replace it.
- v. Inspect the piston screw for excessive wear or fatigue cracks. If it is damaged in any way, replace it.
- vi. Inspect the three piston rings for fatigue cracks, if any, replace them.
- vii. Place the valve housing in a vice and remove the end nut with the appropriate spanner.
- viii. Remove the application valve and spring.
- ix. Inspect the application valve gasket faces and note any indication that might be air leakage. If any indication, inspect the faces of the relay valve for damage or other irregularities and repair same. Fit a new gasket.
- x. Inspect the spring for wear or damage, replace if necessary.
- xi. Clean the application valve with a clean, lint free cloth.
- xii. Lubricate the application valve seat with petroleum jelly.
- xiii. Reassemble the application valve and spring; then replace the end nut.
- xiv. Fit the new slide valve bushing gasket.
- xv. Lubricate the piston rings, slide valve, spring and bushing with petroleum jelly.
- xvi. Replace the piston into its housing with a turning motion. Take extreme care when replacing the piston to avoid breakage if it jams.
- xvii. Place the piston and slide valve bushing back into the housing. Be sure to have the gasket in its correct position at the forward end.
- xviii. Inspect the housing gasket faces for any air leakage or damage, repair if necessary. Fit a new gasket.
- xix. Replace the valve on the bracket with four bolts.
- xx. Listen and test for air leaks at the relay valve as soon as there is full air pressure in the air tanks and the compressor has stopped.
- xxi. Test the relay valve by applying the brakes.

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*Figure 54 – PIPE BRACKET FOR “E” RELAY (showing connections)*



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- ON** - To the extreme left of the brake valve's operating positions. In this position the valve directly connects the air reservoir to the brake cylinder/s allowing the reservoir air pressure to be applied to the brake system.
- LAP**- This position is midway between the ON and OFF positions and is also the position for removing the brake valve handle. With the valve in this position it will hold the air being applied to the brake system (i.e., it stops the air flowing into or out of the brake cylinder/s).

To make a service stop, move the brake valve handle from the "OFF" position to the "ON" position and when the required brake cylinder pressure is obtained, move the handle back to the "LAP" position. The brake cylinder pressure should be reduced as the speed of the tramcar decreases, with a final brief release just as the tramcar comes to a stop. This is achieved by quickly moving the handle between the "LAP" and the "OFF" positions, thereby releasing air from the brake system to the atmosphere but not releasing all of the air pressure. If a stop is made on a grade, sufficient brake cylinder pressure should be retained to hold the tramcar. To release the brakes, move the handle to the extreme right, which is release and running position. The only emergency position on this valve is at the extreme left, the "ON" position.



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the brake cylinder/s or from the brake cylinder/s to atmosphere. The valve is a rotary type valve with three distinct operating positions (*see figure 57*). The positions are:

**OFF** – to the extreme right with the brake handle, exhausts the air from the brake system to the atmosphere thereby releasing the brake pressure and the brakes. This is also the position the handle must be in for normal running when the brakes are not required.

**ON** - The handle is moved from the right hand side towards the left. In doing this movement the amount of air admitted to the brake cylinder/s is increased, the air pressure in the brake cylinder/s is increased, the closer the handle gets to the left hand side. Just before the handle actually reaches the extreme left end of movement, a mechanical stop is felt; this is the actual position where the normal maximum air pressure is admitted to the brake cylinder/s. At this position full reservoir pressure is **NOT** applied to the brake cylinder/s.

**EMERGENCY** - To the extreme left of the brake valve's operating positions. In this position the valve directly connects the air reservoir to the brake cylinder/s allowing the reservoir air pressure to be applied to the brake system. This position for removing the brake valve handle.

To make a service stop, move the brake valve handle from the "OFF" position to the "ON" position until the required brake cylinder pressure is obtained. The brake cylinder pressure should be reduced as speed of the tramcar decreases, with a final release just as the tramcar comes to a stop. This is achieved by moving the handle, slightly, back towards the right hand end, the "OFF" positions, thereby releasing air from the brake system to the atmosphere but not releasing all of the air pressure. If a stop is made on a grade, sufficient brake cylinder pressure should be retained to hold the tramcar. To release the brakes, move the handle to the extreme right, which is release and running position. The only emergency position on this valve is at the extreme left, the "EMERGENCY" position.

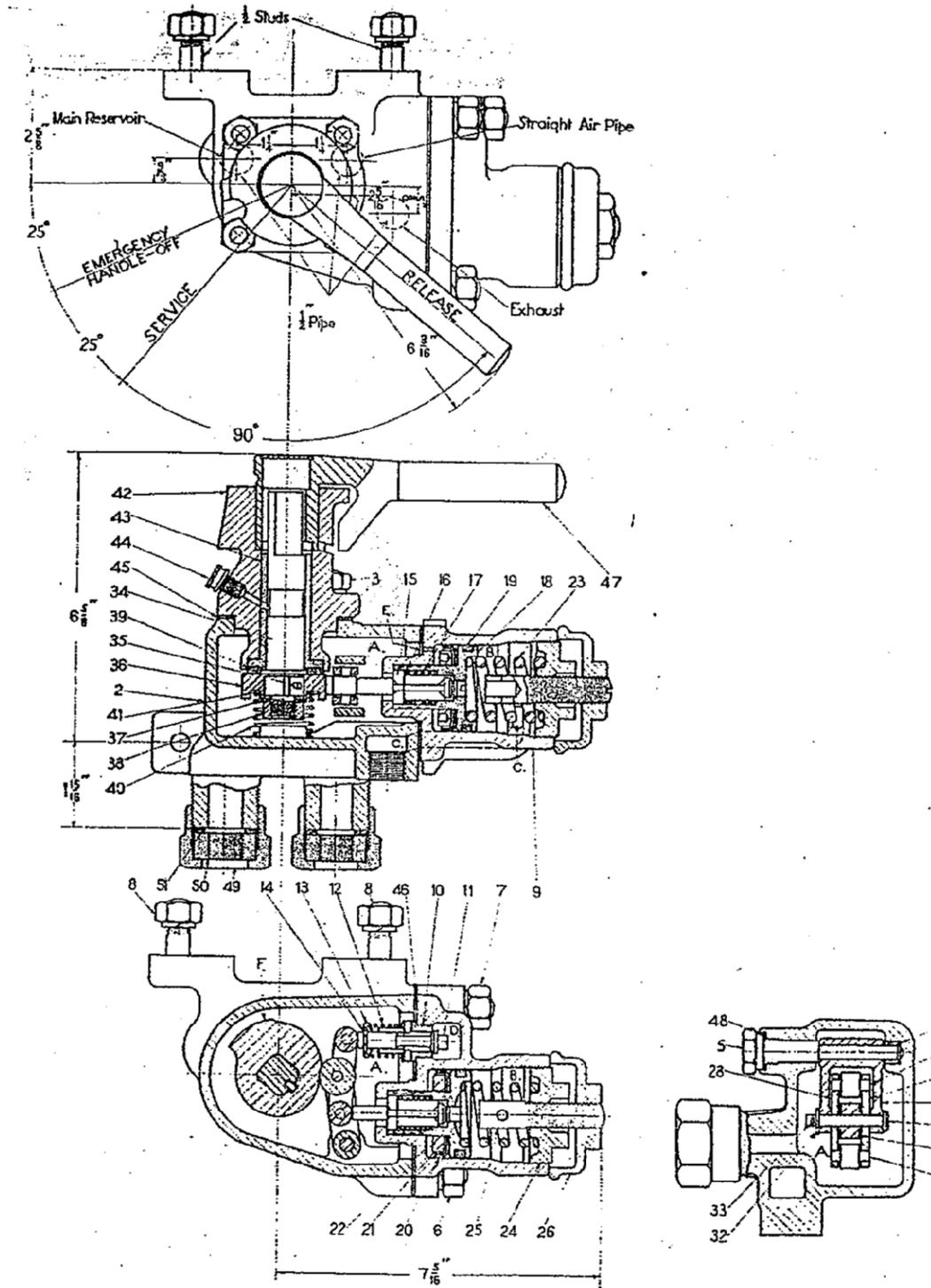


Figure 57 – SELF LAPPING BRAKE VALVE

**14.8.5 Simple Tests on a Straight Air System**

In the operation of the straight air system, whether controlled by a manual lapping or self lapping brake valve, on a tramcar some simple checks must be performed.

a) Test No. 1

When the air system is fully charged and the governor stops the compressor, apply the brakes and on a manual lapping valve return the brake handle to the LAP position or on a

## SYDNEY TRAMWAY MUSEUM

self lapping valve leave the handle in the full service position. Now inspect that the brake piston has moved out a distance to indicate that the brakes are properly applied. If the brake releases after the service application has been applied for, say, ten minutes, it may be caused by any of the following reasons:-

- i. Brake valve not properly “lapped”.
- ii. Leaky rotary valve.
- iii. Leaky brake cylinder/s packing washer.
- iv. Piston travel is so short that the piston did not travel beyond the leakage groove.
- v. Leakage in the brake cylinder/s pipe.
- vi. Leakage in the air application and release pipe or its branch to the double check valve.

If the brakes do not operate properly during this test, the trouble should be locate and remedied before proceeding to the next test.

### b) Test No. 2

After test No. 1, having noted that the brakes apply after a service application, release the brakes by placing the brake valve handle in the “OFF” or “RELEASE” position. Leave the handle in this position, and examine the push rod to see that it has moved back to the “fully released” position and that all the brake shoes hang free from the wheels.

### c) Test No. 3

On some of the tramcars in the Museum’s collection, there is an emergency application valve, sometimes called the ‘conductor’s valve’, inside the passenger compartment. This valve, when operated, causes the brake cylinder/s to be connected directly to the air reservoir and therefore an emergency application of the brakes occurs. This valve, where fitted, must be inspected and tested to make sure that there is no obscure cause or reason to exist which could interfere with this safety feature.

**NOTE:** Where tramcars are fitted for coupled operation or multiple unit operation, all features of that system must be tested for correct operation. That is to include the possibility of the tramcars becoming uncoupled during operation and the brakes applying to stop runaways.

### 14.8.6 General Overhaul and Inspection of Air Brake Systems

The following is an elaboration of the general inspection section previously. The “starred” items below should be performed only on overhauls or on tramcars that have never been inspected before at the Museum.

- 1) For safety, remove the trolley pole **or pantograph** from the trolley wire and secure it ~~under the trolley hook~~, if fitted, and attached warning signs “**DO NOT RAISE TROLLEY POLE**”. Open the compressor switch and drain the air.
- 2) Inspect, clean and adjust the electrical contacts of the governor, replace worn or burnt parts (see *Reservoirs* section previously).
- 3) Inspect, clean and adjust the compressor motor brushes and holder, replace parts where necessary (see *Compressor* section previously).
- 4) Inspect and clean the commutator, string bands and cone rings.
- 5) Check the compressor and suspension for loose or broken parts, tighten or replace where necessary.
- 6) Check the oil level of the compressor, replenish supply if necessary.

**NOTE:** *The following tests should be made with the trolley pole **or pantograph** up and full air pressure. For safety reasons notify all other working staff on the tramcar or in the near area before the trolley pole **or pantograph** is raised or the brakes applied.*

- 7) Check the brake valves for ease of operation and if necessary lubricate with light oil (see *Brake Cylinder* section previously).

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- 8) Check the gauges with the standard test gauge. Adjust or replace if variation exceeds 5 psi (35 kpa).
- 9) Check the air brake system for standard pressures.
- 10) Check the brake cylinder for leakage which should not exceed more than 3 psi (20 kpa) per minute.
- 11) The main reservoir should be drained.
- 12) On self lapping equipment, relay valves should be checked for leakage at the exhaust with the valve in all positions (see *Brake Valve* sections previously).
- 13) Check the feed valves for proper operating range. If operation is irregular, replace (usually set for 70 psi {490 kpa}).
- 14) Check the air hose for condition of rubber, fitting and gasket.
- 15) Check the non return valve and isolation valves for leakage or broken parts, replace when necessary.
- 16) Apply and release the hand brakes, clean, oil and adjust where necessary to ensure proper operation.
- 17) Check the sander system for proper operation and replenish sand supply.
- 18) Check the air operated gong for proper operation (if applicable).
- 19) Test conductor's valve by duplicating service conditions.
- 20) Remove all valves and replace with repaired and tested valves. Stencil or paint, the date when the work was performed and by whom (see **pages 146, 149, 155, 158 & 163**).
- 21) Remove and clean all strainers.
- 22) Clean any dirt collectors.
- 23) Clean and lubricate brake cylinder and replace defective or worn packing or other parts if necessary. Stencil or paint, the date when the work was performed and by whom (see **pages 147 & 148**)
- 24) Remove air compressor and replace with a repaired and tested one.
- 25) Remove all air tanks and subject them to a full hydrostatic test and any other tests required by the relevant Government authorities. Hydrostatic pressure should be at least 25% above the normal operating pressure.
- 26) Paint the air tanks and hangers with good rust proofing paint (see *Governors* section previously)
- 27) Inspect all piping for deteriorated condition and proper cleating. Test all points and fittings for leakage by application of soapy water when the system is under full pressure.

***SEE APPENDIX A AND FORMS STM6090 MECHANICAL INSPECTION SHEETS.***

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## 15 Maintenance of Trucks and Rigging

### Inspections

#### 15.1.1 Intermediate Inspection

- 1) The tramcar to be inspected is to be located over the inspection pit and it is to be secured against movement.
- 2) Inspect all wheels for cracks and other damage.
- 3) Check the wheels for the proper back to back clearance, flange size, shape, tread contour and wear. This check should be made with a set of standard gauges which are made especially for this inspection. Record wheel profiles.
- 4) Inspect the equalising bars, where fitted, for cracks.
- 5) Check every detail of the bogie or truck for loose bolts or rivets.
- 6) Inspect all springs, whether coil or leaf, for breaks or cracks and check that they are not dislocated from their seats.
- 7) Inspect spring planks, swing links, swing link pins, bolster, side and centre bearings, rubbing plates for cracks, excessive wear and other irregularities.
- 8) Check side bearing clearances and record the clearances.  
**NOTE:** The tramcar must be standing on level track for this check.
- 9) Check the motor nose suspension for loose bolts, broken springs or damaged rubber mounting and excessive play. On the nose type suspension, 1.5 mm (*1/16 inch*) is the recommended clearance.
- 10) Inspect all journal boxes for tight fitting lids, broken covers, springs, check axle keeper plates and bearings.
- 11) Inspect all brake rods, levers, hangers, etc. for cracked, bent, worn, broken or missing parts; tighten all loose nuts and replace any missing keys or cotter pins. Also inspect the body where any of the brake rods pass through any timber work or support brackets for thinning of the rods or any wear in body parts.
- 12) Replace all worn brake shoes and adjust the brakes.
- 13) Inspect release springs for damage or wear; that they are free to deflect through their full travel and are not fouling on any bogie or truck parts.
- 14) Lubricate all parts in accordance with the lubrication instructions (*see Lubrication Manual – STM6075*).
- 16) On bogie tramcars, check that the rubbing plate clearances and adjust to the correct tolerance.  
**NOTE:** The tramcar must be standing on level track for this check.
- 17) Tighten any loose axle box shims or replace excessively worn shims. Clearance of the axle box to the shims should be 1.5 mm (*1/16 inch*) minimum to a maximum 4.5 mm (*3/16 inch*).
- 18) Remove and inspect the axle bearings and keeper plates for excessive wear or damage. Replace if necessary.
- 19) Check the motor bearing and axle collar for excessive wear and adjust if possible.
- 20) Inspect all pins, bushings brake levers and floating brake rigging on the bogies or truck. Replace excessively worn parts, maximum wear is a 1/3 reduction in diameter.

#### 15.1.2 Overhaul Inspection

When dismantling the truck or bogie, great care shall be exercised to mark all parts to ensure re-assembly in their correct position.

- 1) Repair and reset all springs.

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- 2) Remove, inspect and repair all worn brake rigging parts.
- 3) Remove the bolster, swing links and spring planks. Inspect and replace all defective parts.
- 4) Inspect all axle boxes for excessive wear. Where shims are not used, restore pedestals to the original dimensions by welding and machining
- 5) Remove the bogie or truck shims and check for squareness or twisting. The usual method of tramming consists of stamping the centres of the journals on the frame and measuring the diagonals. The difference between the diagonals shall not vary by more than 3 mm ( $\frac{1}{8}$  inch). A distance greater than this may result in excessive wheel flange wear.
- 6) Remove all temporary shims from the rubbing plates. Inspect the bearings, repair or replace defective ones.
- 7) Check the clearance between the bolster and the truck transom chafing plates. This distance should not exceed 1.5 mm ( $\frac{1}{16}$  inch) per side or a total of 3 mm ( $\frac{1}{8}$  inch). The minimum allowable clearance should not be less than 1.5 mm ( $\frac{1}{16}$  inch) in total.
- 8) Where fitted, remove the equaliser bars and inspect for cracks and excessive wear.
- 9) Clean and inspect the bogie or truck frames for cracks, loose or worn rivets and bolts, replacing defective parts.
- 10) Inspect motor suspension supports and safety hangers for broken parts, worn or loose rivets and bolts. Replace or repair defective parts.
- 11) When re-assembling the bogie or truck all parts shall be restored to their original position and original tolerance specification, all wearing surfaces should be well lubricated and all contact surfaces should be greased

### **15.1.3 Wheels**

The following is an example from the New South Wales Government Tramways (NSWGT) and will give some ideas as to the proper wheel maintenance.

The profile of a wheel is the shape of the flange and tread. The NSWGT standard profile No. 8 is shown in figures 58, 59 and 60 for 514 mm ( $20\frac{1}{4}$ "), 686 mm (27 ") and 838 mm (33") Electric tramcar wheels.

There are a few terms that need to be described, they are:

- Gauge - is a line which is a specified distance from the back of the wheel and is the root of the fillet curve between the flange and the tread.
- Wheel Gauge - is the distance between the gauge lines of the wheels on the same axle, which is 1432.56 mm (4' 8.4").
- Wheel Hub - is the wheel centre to which the steel tyre is heat shrunk onto then the combined wheel is then pressed onto the axle.
- Tread - It is the part of the wheel on which the tramcar actually runs on.
- Flange - is the part of the tyre that guides the wheel along the rails.

The mileage obtained from steel wheels is about 16,000 kms (10,000 miles) for each 3 mm ( $\frac{1}{8}$  inch) of wear on the radius, i.e., a reduction of 6 mm ( $\frac{1}{4}$  inch) in diameter per 16,000 kms (10,000 miles) travelled. When the flange wears too thin; a great deal of metal has to be removed from the tread to obtain the standard profile, which means that the life of the wheel is greatly reduced. When the wheels are turned, the entire axle is mounted on the lathe or grinding machine and both wheels are turned at the same time to the same diameter and profile. A witness mark is usually left on the flange to show that too much metal has not been removed from the wheel.

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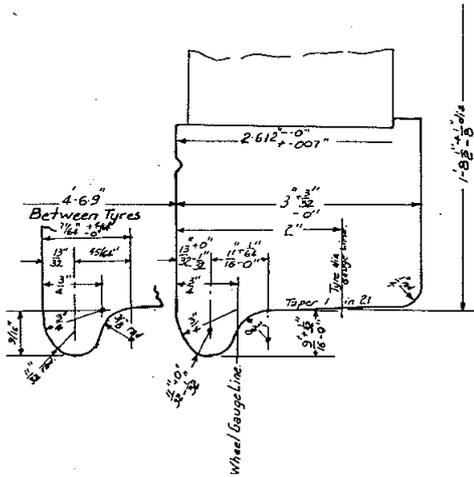


Figure 58 - STANDARD 20-1/2" WHEEL

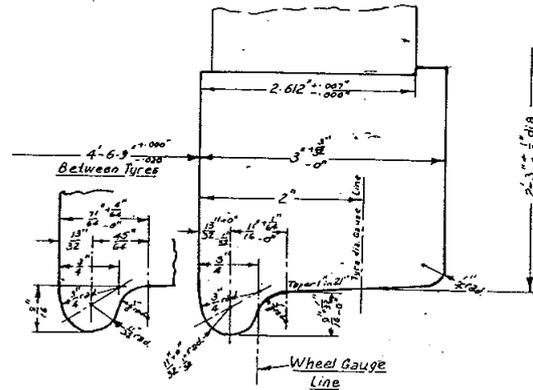


Figure 59 - STANDARD 27" WHEEL

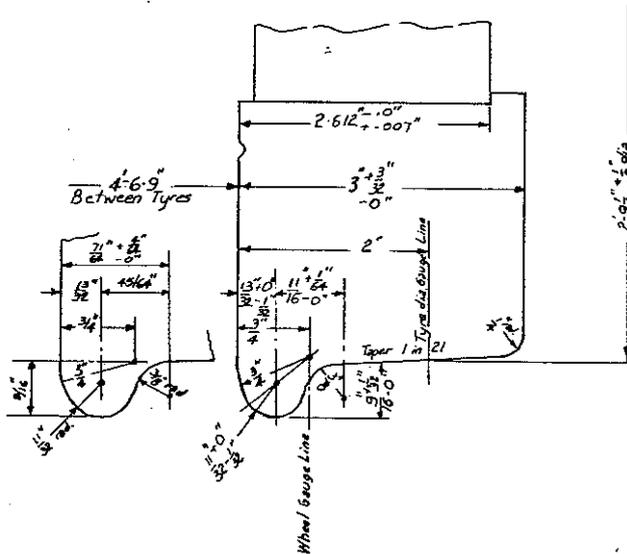


Figure 60 - STANDARD 33" WHEEL

## 15.2 Pedestals

The pedestal jaws on equalised side frame bogies move up and down along the sides of the axle boxes. The wear of the pedestals is usually taken care of by the use of chafing plates which can be replaced when worn. The chafing plates should be greased at every inspection to reduce wear.

## 15.3 Rubbing Plates

Sliding – The rubbing plates are steel plates, some times brass or bronze, usually mounted on shims and bolted to the bolster near the ends. The clearance between the rubbing plates when the body is on the bogie should be about 3 mm ( $\frac{1}{8}$  inch). It is very difficult to lubricate rubbing plates, but the ease with which the bearing surfaces slide has a great deal to do with the wear of the flanges on the wheels especially when going around curves in the track. Sometimes the friction between the rubbing plates is so great that the bogies will not turn and the wheels simply ride up over the rail and a derailment results.

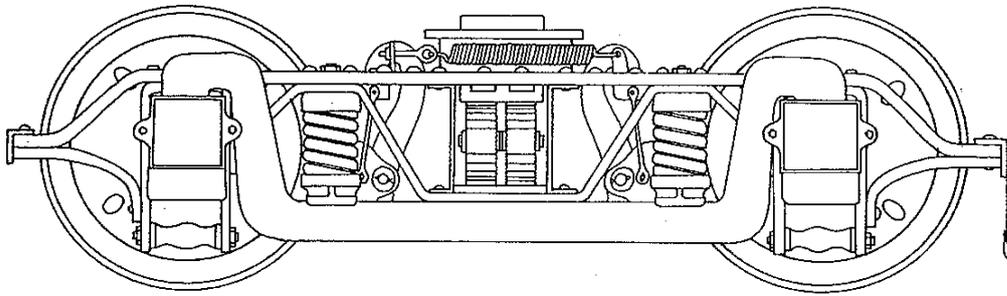
## SYDNEY TRAMWAY MUSEUM

### 15.4 Centre Bearings or Castings

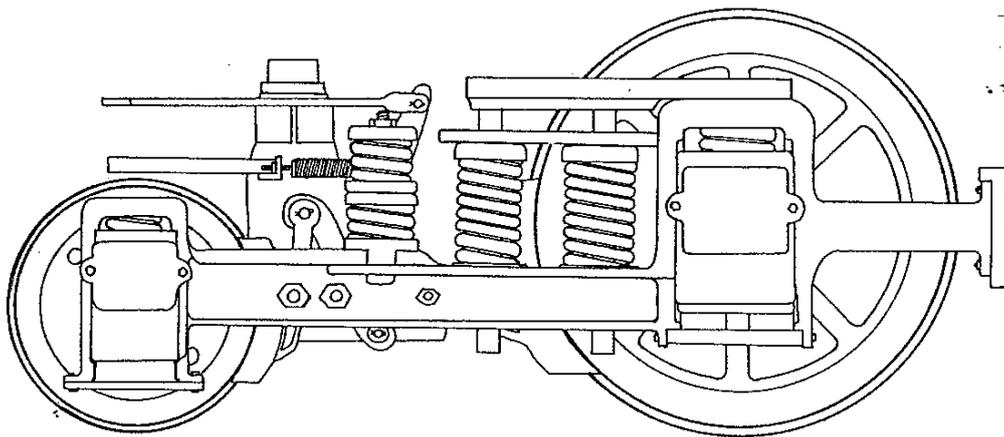
The bogie centre casting is a cup shaped piece of steel on flat plate, forged or cast in one piece. In the bottom of the cup there usually is a bronze washer, sometimes a non metallic friction material is used, called a wear plate on which the body's centre bearing rests. The entire bearing cup is either oiled or greased depending on the designer's intention by supplying an oil feed path or greasing only when the body is lifted (sometimes a grease nipple may have been fitted for ease of lubricating. As the wear plate wears down, the rubbing plates, of course, come closer and closer together. When the clearance is reduced to minimal, shims must be removed from under the rubbing plates or a new centre bearing wear plate is inserted. The bronze, or non metallic friction material, wear plates wear faster than steel and by the use of this plate; it is possible to get a long life out of the centre casting.

### 15.5 Bogie Bolsters

The bolster slides up and down between the transoms and is guided at the ends by wear plates on the bolster and the transoms. The clearance between the transom and the bolster should not be less than 1.5mm (*1/16 inch*) or much more than 3 mm (*1/8 inch*) at any time. These guides should be lubricated when ever possible to grease. The two ends of the bolster should be at least 63 mm (*2-1/2 inches*) from the side frame to allow for side movement of the bolster.

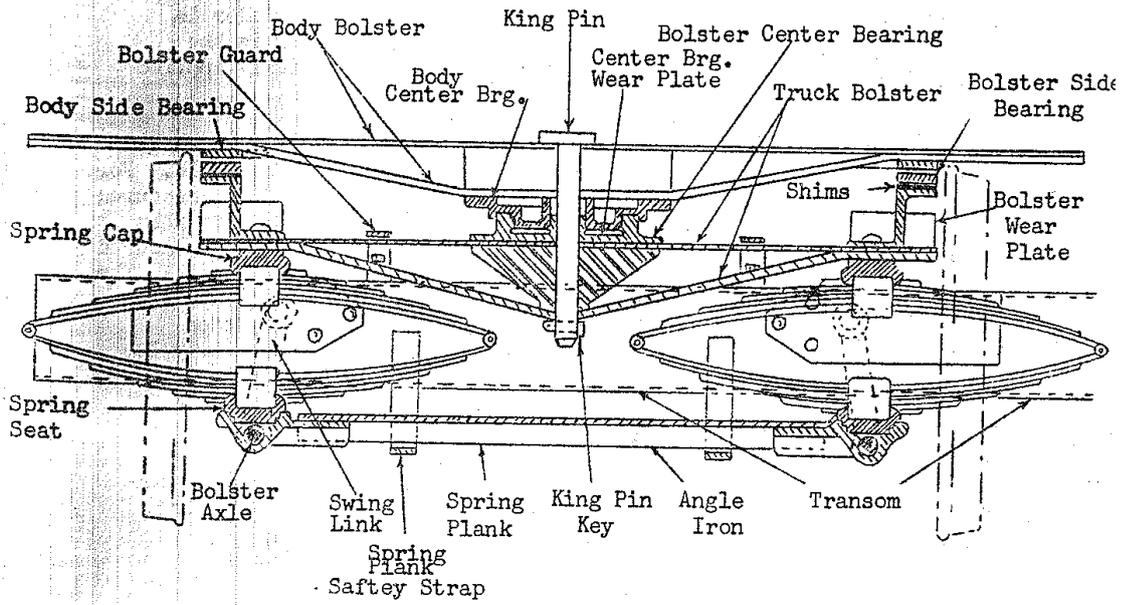


*Figure 61 - EQUAL WHEELED BOGIE*

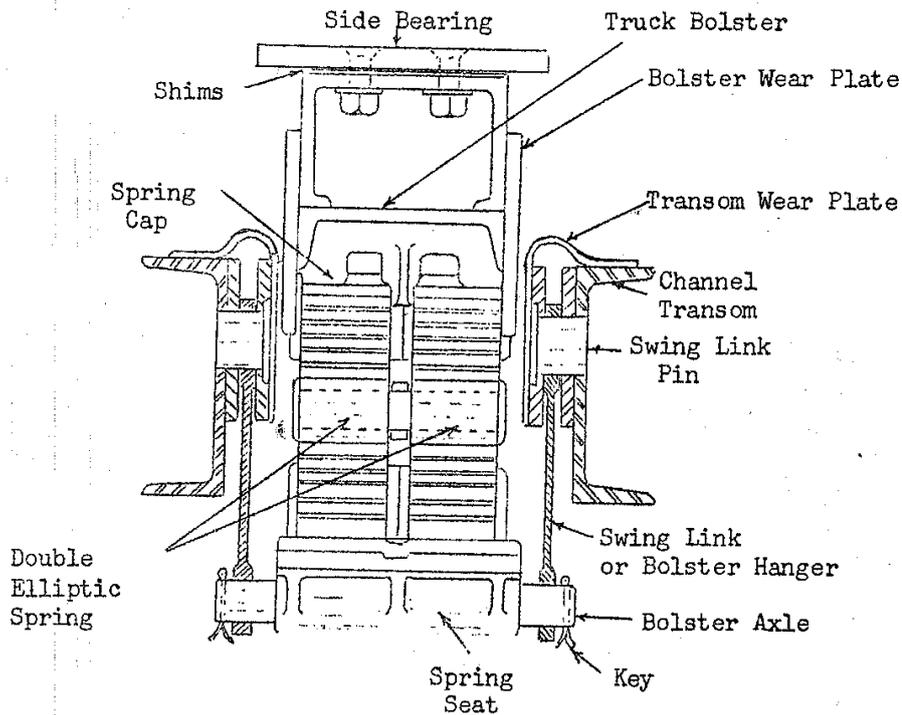


*Figure 62 - MAXIMUM TRACTION BOGIE*

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*Figure 63 – CROSS SECTION OF EQUAL WHEELED BOGIE*



*Figure 64 – DETAIL OF BOGIE BOLSTER ARRANGEMENT*

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## **15.6 Brake Rigging**

### **15.6.1 Piston Travel**

The movement of the piston rod in and out of the brake cylinder is called piston travel, but the correct meaning of piston travel is the distance in millimetres (inches) the piston moves from the release position to the brake fully applied, in a service application.

With the straight air brake, the pressure in the brake cylinder should equal the governor cut-out pressure when the piston travel is measured. The piston travel measured when the tramcar is in motion is more than the travel when the tramcar is stationary. The jarring of the tramcar in motion reduces the friction between the pins in the brake rigging and the tramcar axles and journal bearings. Running piston travel is usually from 12 to 25 mm (*½ to 1 inch*) greater than standing piston travel. Brake shoe clearance of 3mm (*1/8 inch*) is usually requires 100 mm (4 inches) of piston travel.

### **15.6.2 Brake Shoes**

Wearing limits on brake shoes are usually indicated by a notch or a line in the side of the shoe. When the shoe has worn down, the indicator is also gone.

Unevenly worn shoes should be reversed if possible.

Brakes are adjusted by loosening the bottom rods on bogies or on single truckers and some bogies by decreasing the bottom rods, while the air pressure is OFF.

### **15.6.3 Slack Adjustments**

The purpose of the automatic

### **15.6.4 Hand Brakes**

During inspection of the brake rigging, these operations should be performed:

- 1) Check the chains to see that there are no worn or stretched links.
- 2) Binding of the chain on the staff or body work should be watched and corrected.
- 3) Check the connection of the chain on the staff.
- 4) When air brake is inspected, the hand brakes at either end of the tramcar must be in the release position, but after the air brakes have been inspected, excessive slack should be taken out of the hand brake rigging. This keeps the chains out of obstructions.
- 5) Oil all moving parts and rubbing surfaces.
- 6) Every ten years remove the chains and heat to an even red heat to anneal and allow to cool slowly to stop any crystallisation of the chain metal.

*See figure 68 on page 167*

*Figure 65 – BRAKE RIGGING WITH SLACK ADJUSTERS FITTED*

*See figure 69 on page 167*

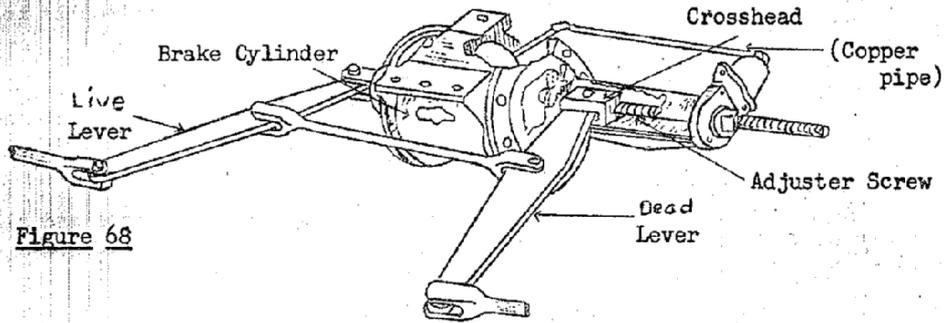
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*Figure 66 – SLACK ADJUSTER WITH BRAKE PRESSURE RELEASED*

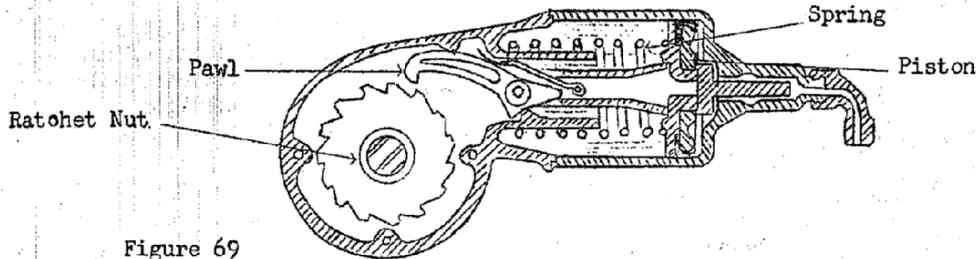
*See figure 70 on page 167*

*Figure 67 – SLACK ADJUSTER WITH BRAKE PRESSURE APPLIED*

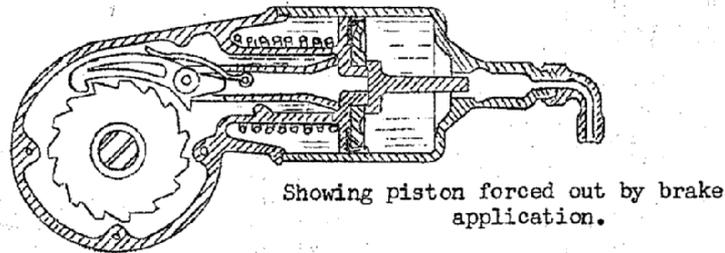
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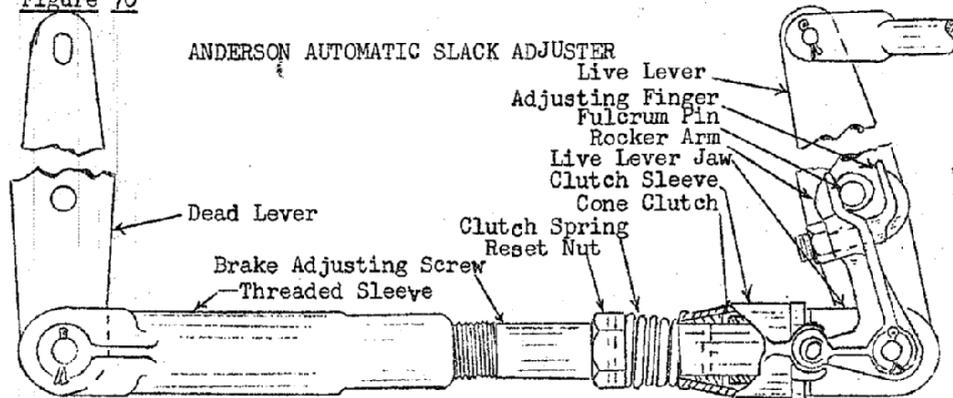
**Figure 68**



**Figure 69**



**Figure 70**



**Figure 68 – ANDERSON AUTOMATIC SLACK ADJUSTER**

## 16 PCC All Electric Tramcar

### 16.6 Regulating Relay Type 17LV23

#### 16.6.1 Description

The regulating relay consists of a frame mounting a shunt coil and series coil wound on the same spool, and an armature carrying a moveable contact which operates between two fixed contacts. The contacts are connected to resistor tubes and arranged to vary the current flowing in the generator shunt field to maintain constant voltage.

#### 16.6.2 Operation

The series coil is connected in the battery circuit so that it carries the charging current to the battery from the generator. The shunt coil is connected in series with a 20 ohm control resistor directly across the generator terminals and so varies in strength as generator voltage.

There are three possible circuit combinations depending on the position of the relay armature which in turn depends on the relation between the pull of the armature calibrating spring and the combination of the shunt and series coils. With low trolley voltage resulting in lower M.G. speed, or heavy generator load, the generated voltage will drop, allowing contact on **RR** to contact point 2. This produces the maximum generator field to raise the voltage since there will be only 10.5 ohms resistance in the circuit from **GA** through the generator field. For intermediate load and speed the moving contacts on **RR** may float between points 2 and 3 inserting an additional 13 ohms in the field circuit. For light loads and higher speeds the moving contact may contact point 3 reducing the generator field still further by shunting the generator field with 5.65 ohms resistance. In actual operation, since the relay armature is very light weight and moves only a small amount, a minute voltage will move the armature, so it vibrates very rapidly to produce a steady voltage regardless of the load or the speed conditions.

The series coil on the regulating relay carries only the charging current to the battery and normally has very little effect on the relay armature since this charging current is very small with a fully charged battery. If, however, the battery becomes discharged, the charging current would try to go very high since the shunt coil on the relay tries to hold full voltage. To protect the battery and generator from damage, the charging current through the series coil produces a pull which limits the charging current by reducing the generator voltage in the same manner as an increase in voltage previously described.

#### 16.6.3 Adjustments

Ordinarily all necessary adjustments can be made on the regulating relay by changing the tension of the calibrating spring. Increase spring tension to raise the setting. The relay should be set to hold 35.5 volts if the equipment is cold; and 36.5 volts if the equipment has been running enough to heat up to normal operating temperature.

If any parts of the regulating relay are disassembled, or replaced, or if any new resistor tubes are installed, the contact adjustment should be checked as indicated on drawing and setting of relay rechecked.

The battery floats on the motor-generator set, the latter supplying all load requirements. The battery is considered more or less as a standby and supplies low voltage power under emergency conditions, such as loss of line voltage or trouble with the motor generator set.

The figure of 36.5 volts mentioned in the foregoing applies to a 16 cell lead acid battery.

*Figure 69 – VOLTAGE REGULATOR*

## **16.6.4 Inspection and Data**

### **a) Contact Adjustment**

- i. Set the moveable core so there is at least 1.5 mm (*1/16 inch*) clearance between the core and the armature. This adjustment is required so that the overhanging edge of the armature will not strike the flange on the operating coil.
- ii. With stationary contacts free, push the armature in until the core bottoms and hold it there while screwing up the front contact until it touches moveable contact.
- iii. Screw the front contact one more turn towards the centre to provide about 762 microns (*0.030"*) wear allowance before the core can bottom.
- iv. Screw the front contact until there is no gap between front and back contacts, then back off one turn and lock. This will provide total gap of 762 microns (*0.030"*) between the front and back contacts.

### **b) Voltage Adjustment**

Set voltage by the calibrating screw. If the regulated voltage differs by more than ½ volt between front and back contacts, change core position slightly, to correct.

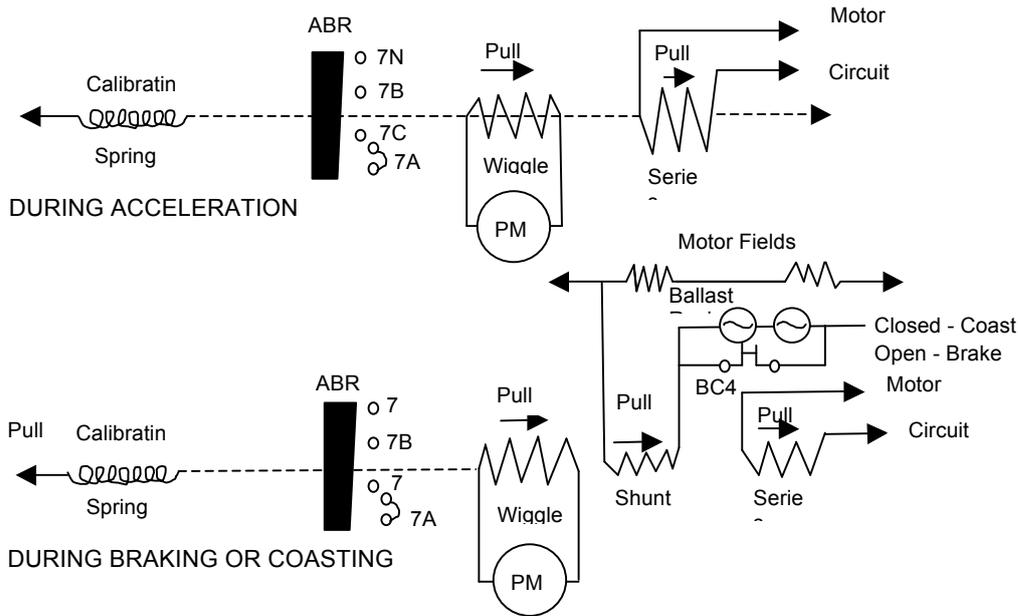
## **16.7 Acceleration and Braking Relays**

In coasting and for minimum rates, the tension of the calibrating spring is determined by the stop screw adjustment, as the cam on the master controller (power and brake) is not striking the roller on the relay arm to stretch the spring. When higher rates of speed are desired by the operator, depressing the pedal turns the controller on and causes the rate cam to stretch the relay calibrating spring and increases the rate in proportion to the pedal movement up to the maximum rates.

When the relay is operating to hold some current value, a state of approximate balance is obtained between the tension of the calibrating spring and the combined pull of the series, shunt and wiggle coils.

During braking the pull of the shunt coil is added to that of the wiggle and series coils. KC25-10 being open and ballast resistors and in series with the shunt coil. In coasting the KC25-10 finger closes to increase the current in the shunt coil which allows the relay to regulate for low motor current values. The current through the motor fields produces a voltage across the fields proportional to the current across the fields, this voltage being applied to the shunt coil.

# SYDNEY TRAMWAY MUSEUM



*Figure 70 – OPERATION OF ACCELERATION AND BRAKING RELAY*

By connecting the wiggle coil across the pilot motor armature, both the “wiggle action” and “anticipation” are obtained. Wiggle action results from the fact that as the relay starts to pick up and closes contacts 7A, 7C, 7B and 7N, closing of these contacts results in a reduction of voltage on wiggle coil, tending to allow armature to drop out. In opening of the relay contacts a similar opposing action takes place. The result of this wiggle action is the vibrating of the relay armature producing an average motor voltage to give the motor speed required to hold the current that the tramcar operator is requesting.

## 16.8 Adjustments of Accelerating and Braking Relays.

- 1) Set correct tramcar pedal travel – approximately 1.5 mm (1/16 inch) clearance measured at the controller stops in the maximum positions.
- 2) Make mechanical adjustments as per the diagram. Measurements may be made at point “A” with a dial indicator.
- 3) Set the maximum rates by the cam arm eccentric with brake or power pedal full on by weighing armature spring or checking shunt coil drop out amperes as per the table following.
- 4) With both controllers off, set coasting and minimum rates with a stop screw adjustment.
- 5) Set C2 pick up rate with adjustable KC24 cam.

	Brake Full ON	Power Full ON	Minimum Power *	Coast	C2 Pick-up
<b>A for 4-¾ MI/Hr/Sec Acceleration and 4 MI/Hr/Sec Braking</b>					
Spring Tension	40 oz	42 oz	8-½ oz	8-½ oz	10-½ oz
Shunt Coil D.O. Amps	7.5	7.8	3.8	3.8	4.6
Single Motor Amps	180	250	112	20	135
<b>B for 4-¾ MI/Hr/Sec Acceleration and 4 MI/Hr/Sec Braking</b>					
Spring Tension	35 oz	40 oz	8-½ oz	8-½ oz	10-½ oz
Shunt Coil D.O. Amps	6.6	7.4	3.8	3.8	4.6
Single Motor Amps	160	234	112	20	135

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\* Set the minimum power accurately with an ammeter during the test run. Rate varies slightly with voltage conditions.

All values given above are approximately due to many factors affecting rates. Values are for a 17,273 kilos (38,000 lb) tramcar with 635 mm (25 inch) diameter wheels. For worn wheels, 584 mm (23 inch) diameter average, reduce maximum values by 5 percent for the same rates.

*Figure 71 – FIELD ADJUSTMENTS OF ACCELERATING & BRAKING RELAY*

# MASTER CONTROLLER CONTACTS

**POWER 1100**

**OOMSOOOOM**

**BRAKE OFF**

**OOMOMMSOOM**

**LOCKED**

**MMOMOMSOOO**

## **17 PCC Tramcar Inspections**

All inspections shall include the inspection, adjustment, and repair of all units and items as outlined in this manual. Each item on the inspection form will be checked as “O.K., repaired or replaced” as indicated. Any unusual condition as noted defect will be recorded and reported in the defects reports.

Safety rules and regulations will be observed at all times in performing work on any type of electrical or mechanical equipment. Report any hazardous or unsafe condition to the maintenance supervisor as soon as possible.

**CAUTION:** When working on a PCC car:

- 1) Always stand on the rubber matting when on the roof of the vehicle.
- 2) If possible, place the pole under its hold-down hook before climbing onto the roof of the car and after making adjustments, before climbing down from the roof.

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- 3) When working on 600 volt circuits always pull poles down, secure and place warning signs on the ropes.

### **17.1 Inspection Notes**

These inspection notes shall be used in conjunction with the Tramcar Inspection Schedules as listed in Appendix A. The procedures detailed in this chapter shall be for each inspection item noted on the sheets. When an item has been inspected, adjusted, or repaired by the maintenance person, so that the person considers that no further work is required, the person shall initial in the column provided beside that item. If further repair work is required, a note to that fact shall be made at the end of the inspection sheets in the space provided as well as marking that item.

A condition or defect which could cause a vehicle to be unsafe or failed for service shall be promptly reported to the maintenance supervisor, who shall arrange for its correction as soon as possible. All defects and repairs shall be noted and reported to the supervisor who shall arrange their handling when convenient.

Throughout this chapter the terms “lubricate”, “grease” and “oil” are used. In applying any of these materials, discipline must be used in the use of the list of approved lubricants.

### **17.2 PCC Car Inspection**

Carry out the work outlined in the various Inspection Schedules as listed in Appendix A.

#### **17.2.1 Topside Inspections**

- 1) Passenger Signal
  - a. Check the operation of the passenger signal. Make any necessary adjustments.
  - b. Test pull the switches for binding; check all pull cords for being too loose or too tight, and fraying at the support rings.
  - c. Make the necessary repairs or adjustments.
- 2) Gong
  - a. Check the operation of the gong by operating the toggle switch.
  - b. Release the toggle switch and check the operation by applying “Emergency Brake”.
  - c. Make necessary adjustments or replacements to ensure the efficient operation of the gong.
- 3) Sanders
  - a. Check the operation of the sanders, both from the sander switch and by applying the “Emergency Brake”. Sand must flow freely and drop onto both rails.
  - b. Make necessary adjustments to electrical equipment.
  - c. Report any mechanical defects or blocked sander to the supervisor if unable to repair.
- 4) Foot Pedals and Reverser Lever
  - a. Check the operation of the reverser lever, accelerator pedal, brake pedal and foot interlock. Reverser lever and foot pedals must operate freely with no indication of sticking or binding in any of their operating or emergency positions.
  - b. Make necessary adjustments to provide trouble free operation.
  - c. Lubricate the front side of the brake pedal with a film of approved grease to prevent the pedal from binding on its latching mechanism.
  - d. Check the condition of the rubber foot pads, replace if necessary.
- 5) Spare Fuses

Check that there are spare fuses of the correct type, current rating and number off.
- 6) Windshield Wipers

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- a. Check that the electric windshield wipers operate at 50 to 60 full strokes per minute. If the wiper speed varies from this rate, the motor is defective and must be changed.
  - b. Inspect the wiper blades to see that the rubber is clean and pliable and that their entire length bears firmly on the glass; change the blades if defective.
  - c. Using the approved tools, test all of the wiper clamps and set screws, making certain they are tight.
  - d. Check that the wiper blade is held to the arm with approved fasteners.
  - e. Check the left side parallelogram pins and bushings, for evidence of wearing to the point where the arm might contact the glass. Change the arm if required or install new bushings.
- 7) Signal Lights
- a. Check the operation of all door, warning, track and drum brake signal lights.
  - b. Make the necessary adjustments or replacements.

### **17.2.2 Interior**

- 8) General
- Carefully check the interior of the tramcar for sharp projections, loose screws or plating on the seat frames that may cause damage to clothing. Any projections or loose plating must be filed or sand-papered smooth.
- 9) Upholstery
- Check upholstery for cuts or badly sagged seat backs and cushions. Make the necessary repairs or replacements
- 10) Window Glass
- Check all window glass. Cracked glass must be changed.
- 11) Moveable Windows
- Check all moveable windows, replace defective window regulators or lifts,
- 12) Front and Side Vents
- Check the front and side vents for operation, seals, threaded shafts, etc. Make the necessary repairs or replacements.
- 13) Route and Destination Signs
- Check the operation of route, destination and run number signs. Make any necessary repairs.
- 14) Door/Draft Rubbers
- a. Check the condition of all door rubber draft guards and rubber edging. Make the necessary repairs or replacements.
  - b. Check the bottom rubbers and replace worn or damaged bottom draft rubbers.
- 15) Point Operating Bar
- Check and replace with one in good condition if necessary.
- 16) Sand Container
- Check the condition and fill with clean, dry sand.
- 17) Transfer Cutters

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- a. Check the tension of both springs. Make certain that the minute cutting points offer some resistance when moved on their adjusting bar and that both points are firmly in contact with the cutter body plate.
- b. Check that the hour cutting knife fully contacts the cutting body plate.
- c. Defective must be changed.
- d. Lubricate mirror fitting with approved lubricant.

### 18) Lubricate Doors

- a. Lubricate the top guide tracks with approved lubricant applied sparingly.
- b. Tighten loose roller guide screws.
- c. Lubricate the door drive arm pins with approved oil.

### 19) Door Relays

- a. Check the operation of all door relays. If contacts are dirty, clean with a fine file or contact abrading strip.
- b. Check the armature shunt for evidence of breakage of wire strands.
- c. Change the relay if it does not function or if the shunt is defective.

### 20) Door Operation

- a. Check operation of all doors to see that they open and close smoothly
- b. Check the operation of the entrance relay.
- c. Using a stop watch, time the opening and closing and make any necessary speed adjustments as described hereunder.
- d. Door speeds:-

Entrance Door: from the moment of operating the switch

Opening – As close to 1-½ to 2 seconds as possible.

Closing – 1-½ to 2 seconds.

### 21) Door Cam-Switch

- a. Check the door cam-switch settings as per instructions in the following sections.
- b. Make adjustments as required.
- c. Setting for Door Cam-Switches.

The following is a description of the settings for the cam-switches, exit warning light, line switch interlock (D.I.R.) and the exit door interlock. Measurements indicated are to be the length of a line perpendicular to the rubber seal on the door jam to the edge of the door leaf at the hinge point:

#### 1. Entrance Doors

- i. Opening and closing speeds should be set in accordance with the data in the PCC Car Inspection Manual. The following items illustrate the door controlled cam-switch settings.
- ii. On the closing cycle, the line switch interlock (or D.I.R. interlock) must close before the closing limit switch opens. The line switch interlock (or D.I.R. interlock) should be set to make at a measurement of 76 mms (3 inches) and the closing limit switch should be set to break at a measurement of about 25 mms (1 inch). The closing limit switch must be open when the doors are fully closed with power on the motor.
- iii. On the closing cycle, the front door controlled door interlock cam-switches should break when the angle between the door leaves is 90°. This corresponds to a measurement of 10° to 11°.

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2. Exit Doors
  - i. Opening and closing speeds should be set in accordance with the data in the PCC Car Inspection Manual. The following items illustrate the exit door controlled cam-switch settings.
  - ii. On the closing cycle, the line switch interlock (or D.I.R. interlock) should be set to make a measurement of 76 mm (*3 inches*), and the closing limit switch should be set to break at a measurement of about 25 mm (*1 inch*). The closing limit switch must be open when the door is fully closed with power on the motor.
  - iii. On the closing cycle, the exit door controlled door interlock cam-switch should be set to break at a measurement of 101 mm (*4 inches*).
  - iv. The exit warning cam-switch should be set to break at a measurement of 76 mm (*3 inches*).

### **17.2.3 Body**

#### 22) General

Check the general condition of the exterior and interior of the tramcar body. Report any unusual conditions, such as worn tread plates, broken seat legs, or collision damage that presents an unsightly appearance.

#### 23) Body and Auxiliary Lights

- a. Check the body, sign, stop, marker and head lights.
- b. Make any necessary repairs or replacements.

#### 24) Battery Inspection

- a. Open battery compartment door and slide the batteries out, remove filler plugs and check the liquid levels in each cell. Add sufficient water to bring the level of the liquid halfway up the filler tubes.
- b. Clean top of batteries and check condition of connections.
- c. Defective or badly-corroded batteries must be changed.

#### 25) Battery Condition Test

NOTE: For tramcars equipped with a voltmeter use the tramcar voltmeter, but check the tramcar voltmeter against a standard voltmeter.

- a. Test the condition of the battery by moving the M.G. switch to its OFF position energising the track brakes by releasing the foot interlock pedal to its upper emergency position. Observe the voltmeter – if the battery voltmeter drops more than 6 volts either the battery is defective, or one or more of the track brake shoe coils is short circuited. Report defects to the supervisor.
- b. With the M.G. switch is OFF apply the brake pedal to the EMERGENCY position, track brakes should be ENERGISED. Observe the voltmeter – if the battery voltage drops more than 6 volts, either the battery is defective, or one or more of the track brake shoe coils is short circuited. Reports defects to the supervisor.

#### 26) Trolley Catcher

- a. Lubricate the trolley catcher drum bearing with compressor oil.
- b. Adjust lateral motion of drum to a minimum by tightening spindle screw, taking care not to cause drum to bind.
- c. Check the operation of the catcher, change if defective.

#### 27) Trolley Harp

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- a. Lubricate the trolley harp saddle bearing with approved lubricant, using grease gun supplied for this purpose.
  - b. Wipe surplus grease from the saddle or harp.
- 28) Trolley Base Hinge Pin
- a. Lubricate the trolley base hinge pin with approved lubricant.
  - b. Wipe the surplus grease from the trolley base.
- 29) Trolley Base Lock Down Latch.
- Test the operation of the trolley base gag by placing the pole under the hold down hook, and see that the gag can be freely installed and released.
- 30) Trolley Base Shunt and Connections
- a. Inspect the shunt for evidence of loose connections or broken strands.
  - b. Check the shunt if wire strands are frayed or broken.
  - c. Check main trolley connections to make certain they are tightened securely.
- 31) Trolley Base Rubber Mounts
- Check for evidence of collapsing. Report the defects to the supervisor.
- 32) Roof
- Check the condition of the tramcar roof, trolley timbers, rubber mats, metal shrouds and climbing steps. Report any unusual conditions to the supervisor.
- 33) Track Brakes
- Inspect and replace defective side bumpers.
- 34) Emergency Draw-Bar Equipment
- a. Remove and replace emergency draw-bar from its box.
  - b. Check the operation of the catches on the containers.
  - c. Lubricate the catches and hinge pin with compressor oil.
  - d. Raise and lower both emergency draw-bar anchor pins to make certain they move freely in the anchor holes, repair any broken anchor chains.

### **17.2.4 Lubrication and Truck Inspection**

- 35) H.G. Lifeguard
- a. Check to ensure that both of the lifeguard trip gates and cradle are centred in relation to the rails.
    - i. Inspect the trip gate and cradle, tighten or replace any loose or broken bolts;
    - ii. Replace distorted or broken slats;
    - iii. Change any trip gate or cradle that cannot be really repaired in position;
    - iv. Check the tension spring to make certain that it holds the cradle in firm contact with the rails when the cradle is tripped.
    - v. See that the split pins are installed through both trip gate suspension arms, to prevent the gate from becoming displaced on its shaft by contacting objects on the roadway.
  - b. Lubricate all shaft bearings and clevis pins with a small amount of compressor oil.
  - c. Using the approved gauge, check the height as follows:

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- i. The cradle, in normal running position, to be adjusted to a height of 139 mm (*5-½ inches*) above the rails, measured from the underside of both skid plates.
  - ii. The trip gate, in normal running position, to be adjusted to a height of 139 mm (*5-½ inches*) above the rails, measured from the underside of the lowest slat.
  - iii. The angle of the toggle lever is to be adjusted so that the cradle will drop when the trip gate is moved backward and upward to a height of 164 mm (*6-½ inches*) above the rails, measured from the front lower edge of the bottom slat.
  - iv. Trip the lifeguard and reset it from the inside of the tramcar. Make the necessary adjustments to the reset lever, so as to ensure easy resetting of the lifeguard by operating personnel.
- 36) Emergency Lifeguard Hold-up
- a. Inspect the spring and operating lever, to make certain that the hold-up device will be in good working order and ready for instant use in the event of a storm or other emergency.
  - b. Hold-up cables exposed to the weather should be coated with approved grease.
- 37) Swing Link and Bolster Bearings
- a. Using an approved lubricant, lubricate the entire swing link and bolster trunnion bearings. Then: using jacks, raise the tramcar body high enough to relieve the body weight from the truck bearing surfaces, and AGAIN apply lubricant to all swing links and bolster bearings.
  - b. Apply sufficient lubricant to ensure complete lubrication of all bearing surfaces.
- 38) Journal Bearings
- Lubricate with SAE 40 oil, applied at the front filler plug hole with a pump type oil can until the oil starts to run out of the filler hole. Let the excess oil drain out before replacing the plug.
- NOTE: Any discolouration of the oil indicates contamination which might ruin the lubricating qualities of the oil. If the oil is milky, it indicates that water has been drawn into the journal bearing housing through the outer seals. If the oil is black, it indicates that the oil from the gear case is getting past the inner journal housing seal. It is most important that contaminated oil be drained off and the journal bearing refilled with new SAE 40 oil.
- 39) Brake Shoe Fulcrum Lubrication
- Lubricate all brake shoe fulcrum points with approved lubricant.
- 40) Gear Cases
- a. Check the lubricant level in the gear cases.
  - b. Fill level with the filler hole with approved lubricant and report defects to the supervisor.
  - c. Remove and clean the breather unit, if necessary, to ensure the pin is loose and will move freely in the breather hole.
- 41) Drive Shaft Universal Joints
- a. Lubricate all universal joints and drive shaft splines with approved lubricant.
- 42) Centre Bearings
- a. Remove the lower centre bearing dust cap. Jack up the body clear of the centre bearings; check the condition of the upper and lower bearings.
  - b. Check the condition of the felt dust rings and replace with new ones, if necessary.
  - c. Lubricate the surfaces of the upper and lower bearings, with approved lubricant, by means of the special attachment for this purpose.
  - d. Report unusual conditions such as evidence of galling, poor lubrication and cracks in the upper king pin castings, to the supervisor.

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### 43) Lower King Pin Bearings

- a. Using approved lubricant, lubricate the lower king pin bearing, with sufficient lubricant to ensure complete lubrication.

### 17.2.5 Switch Group Inspection

#### 44) Control Apparatus

Remove the accelerator, contactor, line switch and controller compartment covers and inspect the control apparatuses follows:

#### 45) Rotor and Permanent Resistors Westinghouse unit only not fitted to 1014

- a. Check the rotor and all permanent resistors for evidence of loose connections, burnt or distorted ribbons; make necessary repairs or replacement.
- b. Inspect the rotor drum interlock cam switch moving and stationary contacts; clean blisters from the contact surfaces using a fine file.
- c. Change the cam switches and stationary contacts on which the silver has worn to 1 mm (*1/32 inch*) thickness.
- d. Check the cam switch shunts for indication of frayed or broken strands.
- e. Change the defective shunts.
- f. Change switches that show excessive wear in the roller axle pins or any other defect that might interfere with trouble free operation.

#### 46) Master and Brake Controllers

- a. Inspect the cam switches, stationary contacts and the KM brushes. Remove and replace the KM brushes if they are chipped or worn below the mark. Clean the blisters from the contacts using a fine file. Change the contacts on which silver has worn to 1mm (*1/32 inch*) or less in thickness. Change the cam switch shunts that show indication of frayed or broken strands.
- b. Inspect the track brake cam switches and stationary contacts. Clean the blisters from the contact using a fine file. Change the contacts that are badly burnt. Change the contacts on which silver is worn to 1mm (*1/32 inch*) or less in thickness.
- c. Inspect the cam switch shunts; change the shunts that show an indication of frayed or broken strands. Check the KM arm shunt and brush holder shunts.
- d. Report any unusual conditions to the supervisor.

#### 47) Contacts and Line Switch

- a. Inspect all control contactors and the line switch.
- b. Check the main contact tip screws to make certain that they are tight. Change the contactor main tips, when worn to less than 6 mm (*1/4 inch*) in total thickness. Change the line switch main tips when worn to less than 8 mm (*5/16 inch*) in total thickness.
- c. Inspect the interlock moving and stationary contacts; clean any blisters from the contact surfaces using a fine file; change the contacts on which silver has worn to 1mm (*1/32 inch*) or less in thickness. The interlock compression springs should compress for a distance of 2.5 mm (*3/32 inch*) when the interlock makes full contact. Test the interlock drag links to make certain they do not bind in the interlock rocker arms or their hinge pins.
- d. Change any armature shunts that show evidence of having broken wire strands; check the shunt screws to make certain that they are tight.

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- e. Clean the inside walls of the arc chutes; change any broken or badly burnt arc chutes. By hand, carefully close and open each contactor and line switch to make certain that armatures do not bind on the hinge pins, armature stop arms, arc chutes, or due to improperly adjusted drag links.
- f. Make any necessary adjustments, or replace the complete contactor unit.

NOTE: A binding contactor will result in service failures that will only be prevented by carefully carrying out the foregoing inspection. Whenever Main Contact Tips are changed on the line switch, the line switch is to be checked for pick-up and seating at 24 volts.

### 48) Accelerating and Brake Relays

- a. Inspect and clean the relay contacts.
- b. Measure the gap between the moveable contacts and the contacts on the stationary contact block. The maximum gap at the upper end of the stationary contact block should not exceed 254 microns (*0.010 inch*). The maximum gap at the lower end of the stationary contact block should not exceed 1mm (*1/16" or 0.062"*). If the gaps exceed these values, remove the accelerator and braking relay unit for bench repairs and adjustments.

### 49) Drum Brake Lock Out Relay

- a. Check the operation of the drum brake lock-out relay. Using a fine file, clean all contact tips. Adjust "IN" interlock contact gap by loosening the lock nut on the stationary and moving the contact; then tighten the lock nut securely.

### 50) Auxiliary Relays

- a. Inspect all auxiliary relays and contactors for worn tips, worn interlock or loose connections. Move each relay in and out by hand to make certain there is no binding action and that the contacts have good compression.

### 51) Voltage Regulator

- a. Check the voltage regulator's stationary contacts and moveable bar for wear, blistering, or signs of damage. Replace the contacts or bars if necessary then adjust as outlined below (see figure 68 previously).
  - i. Set the moveable core so there is at least 1.5 mm (*1/16 inch*) clearance between the core and the armature. This adjustment is required so that the overhanging edge of the armature will not strike the flange on the operating coil.
  - ii. With stationary contacts free, push the armature in until the core bottoms and hold it there while screwing up the front contact until it touches the moveable contact.
  - iii. Screw the front contact one more turn towards the centre to provide about 762 microns (*0.030"*) wear allowance before the core can bottom.
  - iv. Screw out the back contact until there is no gap between the front and the back contacts, then back off one turn and look. This will provide total gap of 762 microns (*0.030"*) between the front and the back contacts.

### 52) Voltage Adjustment

Set the voltage to 36 volts by the calibrating screw. If regulated voltage differs more than ½ volt between the front and back contacts, change the core position slightly to correct.

### 53) Equipment Covers

Remove dust, dirt and foreign objects from the accelerator contactor, line switch and controller compartment covers before re-installing.

### 54) Wiring

- a. Inspect the motor, track brake and the drum brake wiring for chaffing on the drive shafts or adjacent truck parts.

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- b. Make the necessary repairs or replacements.

### 55) Control Sequence Test

- a. Connect the master voltmeter to GA and GAA
- b. Place the motor cut-out switch to A-L OUT position.
- c. Place the trolley pole **or pantograph** on the trolley wire.
- d. Start the M.G. set.
- e. Disconnect the battery switch.
- f. Reduce the battery voltage to 24 volts.
- g. Close the entrance and exit doors and check the operation of the control equipment as follows:
  - i. Move the accelerator slowly to the full ON position by the lever provided for this purpose.
  - ii. Check to see that all of the contactors pick up and seal in their correct sequence.
  - iii. Refer to “Sequence Diagram” (figure 71 previously) for the control sequence being tested.

### 17.2.6 All Motor Brushes

All carbon brushes for motors must be inspected. The worn brush must be measured according to the detailed instructions on the following pages. If the brush length exceeds these instructions and is otherwise in good condition, it should be reinstated, if not, it should be discarded and replaced with a new brush.

### 56) Traction Motors

- a. Check the carbon brushes. Change the brushes that bind in the brush holder box or are worn to the wear line.
- b. Check the commutators for evidence of flat bars, flashovers, etc.
- c. Check that the inspection cover gaskets are in good condition and that the latches hold the covers tightly closed to minimise the entrance of water into the motor frames.
- d. Check the condition of the motor bellows. Report any broken bellow springs or torn canvas to the supervisor. Report any unusual conditions to the supervisor.

### 57) Motor Generator Set

- a. Check the carbon brushes. Change the brushes that bind in the brush holder box or are worn to their scrapping limit.
- b. Change the MOTOR end brushes when worn to 32 mm (*1-1/4 inch*) in length.
- c. Check the GENERATOR end brushes when worn to 22 mm (*7/8 inch*) in length
- d. Check the commutators for evidence of flat bars, flashovers, etc.
- e. Check the motor and generator leads for chaffing or being broken. Make repairs or replacements. Report any unusual conditions to the supervisor.

### 58) Pilot Motor

- a. Remove and inspect the pilot motor carbons for wear or for binding in the brush holder. Change the brushes that are worn to less than 17 mm (*11/16 inch*) in length.
- b. Clean the carbon and brush gear with lint free cloth before replacing.

### 59) Voltmeter

- a. Move the M.G. and the battery switches to their **OFF** position and move the headlight switch to the **ON** position.

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- b. By means of the calibration adjusting screw, set the meter pointer to zero.
- c. Move the headlight switch back to the **OFF** position.

### ST.LOUIS / G.E. P.C.C.

#### FUSE RATINGS

	15 AMPS	25 AMPS	30 AMPS	50 AMPS	60 AMPS
MOTOR GENERATOR 25 AMPS 600 VOLTS		✓			
NO. 2 TRUCK BRAKE ACTUATORS 15 AMPS 600 VOLTS	✓				
NO. 1 TRUCK BRAKE ACTUATORS 15 AMPS 600 VOLTS	✓				
AUXILIARY 50 AMPS 600 VOLTS				✓	
GENERATOR 60 AMPS 32 VOLTS					✓
NO. 2 TRUCK DRUM BRAKES 32 VOLTS			✓		
NO. 1 TRUCK DRUM BRAKES 32 VOLTS			✓		
NO. 2 TRUCK TRACK BRAKES			✓		
NO. 1 TRUCK TRACK BRAKES			✓		

## **18 Paint Removing**

### **Methods**

#### **18.1 Initial Surface Preparation (cleaning)**

Before starting to remove paint, the surface must be cleaned of all greases and dirt which has been encrusted, caked on, over the years. By cleaning the surface first the application/action of some of the following methods will be greatly improved. It will also stop staining of wooden surfaces when they are exposed. The use of degreasing agents or strong detergents as the cleaning agent, then wash off with water are probably the best and easiest to use to obtain a clean surface.

#### **18.2 Scraping (for wood or metal)**

Scraping paint can be accomplished best when the paint has dried out and is hard or brittle, with the paint coat starting to flake or chip. A smooth finish can be obtained when the scrapped area is sanded using a coarse to fine grade of sanding papers to feather or smooth out the surrounding paint to blend in the damaged paint area. Various types of scrapers can be purchased from the local hardware or paint suppliers such as putty knives, triangular scrapers, hook scrapers, multi-shaped scrapers, etc. All of these scrapers are good to use on wood or metal if a slight downwards pressure is used, too much pressure on the scraper will damage the surface. Extreme care must be taken when working on wood as it is very easy to pick up the grain of the timber and remove a large sliver permanently destroying the surface. An excellent scraper for use on metal work can be made from an old file; the end of the file can be heated and forged to the required shape or simply ground to the shape. When using an old file as a scraper it must be fitted with a correctly fitting file hand and it must be remembered that you now have a fair amount of leverage using this type of scraper on the surface and damage can be easily be done.

#### **18.3 Paint Stripper (for wood or metal)**

Paint stripper or as sometimes called paint remover is a way of removing paint layer by layer or in bulk. To remove paint layer by layer a thin coating of paint stripper is applied. When the top layer of paint starts to bubble a sponge which has been thoroughly soaked in water is then wiped across the surface to dilute the stripper. This process is continued until the chemical has been stopped. Then the underlying paint detail can be observed and details recorded.

When the paint is to be removed to provide a total bare surface a thick layer of stripper is applied but not too excessive as this is wasteful. The stripper is then allowed to react with the paint until the paint stops bubbling. A paint scraper is then used to remove the soft paint and spent stripper leaving an unaffected surface. More stripper is then applied and the process is continued until a bare surface is produced.

There are many brand name paint strippers available in Australia and it is best left for the person doing the job to try the local brands to find out the best one. Remember to read the directions on the container for any possible problems that may occur with the parent material that the paint is applied to. It must be noted that the paint stripper is caustic based material and is very harmful to human skin and eyes, therefore proper protection must be worn. If accidental contact with the skin a bucket of water is very handy to wash the effected area.

##### **18.3.1 Techniques**

- a. Use an old brush to apply the stripper to the paint surface from a tin not the bulk container as this stops contamination of the bulk supply and waste. Make sure that the stripper is spread evenly and to the thickness required, brushing in one direction only. Leave the stripper for 10 minutes or as directed on the container.
- b. After the reaction has stopped, as the paint stops bubbling use a paint scraper to remove the old paint. The paint that has been removed must be put into a metal container as it still contains some weak stripper and is still active for sometime to come.

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- c. Repeat steps “a” and “b” above until the surface is as required. Note: when the stripping paint that is many years old (e.g. 60 years old say), the paint is very hard and therefore the action of the stripper does not penetrate as far into the surface.
- d. When finished stripping the paint always wash the surface down to remove any traces of the stripper away. If the paint stripper is not removed and the new paint is applied over it, in a very short time the new painted surface will be damaged from the stripper becoming active again. Therefore to remove all traces of stripper use water on the metal surfaces and some wooden surfaces. When some woods are washed with water the grain becomes raised, so instead of using water, try turpentine or paint thinners.

After the surface has been washed clean it is then ready for sanding, bleaching or painting. When stripping paint from the corners care must be exercised to remove all traces of the old paint and the paint stripper, for as already mentioned the new paint will blister or peel in a very short time and ruin the finish that has been so carefully created.

### **18.4 Heat Removal (for wood only)**

Burning or heat removal of paint is a long established way of removing thick, damaged and brittle paint. It is a highly satisfactory way for quickly removing paint for wooden surfaces that are to be sanded, possibly filled, before re-painting where a little charring of the surface can be withstood. In recent years the old kerosene, propane or spirit burning torch has been replaced by electric heat gun, which is far safer as there are no flames to ignite the paint, just a slight possibility of ignition for excessive heating.

The procedure is to use heat gun to preheat the paint on the wood to just before the flat blade scraper, that is used to the paint by scraping and the heat gun is then moved across the paint just in front of the scraper. Removal of the paint is as fast as the paint softens and not when it chars as this means that you have heated the paint too long. The experienced operator can remove everything in one pass and not damage or char the wood's surface.

Heat removal of paint on metal surfaces is not very effective because the metal is a very efficient conductor of heat and therefore to remove any paint a large amount of heat will be required to remove a small quantity of paint. If heat removal of paint is to be tried on metal panels buckling of them may occur.

Caution: never heat paint to be removed when there is say less than one hour before leaving the job, for it may be possible that the paint may actually smoulder for an hour or longer. A bucket of water or a fire extinguisher must be readily available at all times in case there is a fire, the bucket of water is the cheapest and most effective for such an occurrence.

### **18.5 Sanding**

Paint can be removed from metal and wood by using sanding paper coated with various compounds such as sand, glass, aluminium oxide, carborundum, etc. When using sanding paper it must be used wrapped around a block of wood approximately 50 mm X 30 mm X 10 mm long or larger, to rub down paint or the surface being prepared to stop any possibility of forming hollows in the finished surface. When sanding around rivets or other details extreme care must be used so as not to damage the detail or create a crater around the rivet.

After heat removal of paint the surface must be sanded smooth before the application of the paint system to be used.

NOTE: when sanding try to use long strokes as this stops removal of too much surface material in one spot. Also when sanding near glass, protect that glass by removing the glass or by covering the glass with an abrasive resistant material such as thick masking tape.

### **18.6 Wire Brush (for ferrous type metals only)**

Wire brushes are only to be used on ferrous type metal surfaces as the wires tend to gouge wooden or aluminium surfaces. The brushes, whether handheld or attached to a power drive, only remove loose paint and rust. They do not work well on heavy coats of paint.

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### **18.7 Chipping or Needling (for ferrous type metals only)**

To remove paint, scale or rust by chipping or needling, first clean the surface of all oil and grease. Then you can use a hammer and punch/chisel or ball peen hammer or scaling hammer to chip the material to be removed. Chipping is a slow process and is mainly used in small, tight to get to areas.

Needling or common called “needle gunning”, is a process where you use a tool called a needle gun being electrically or pneumatic powered. At the work end of the tool there are a number of steel rods or needles that are moved in and out of the barrel at a fairly high speed. The tool with the needles reciprocating is slowly brought into contact with the surface to be cleaned. The distance that the tool is held away from the surface is determined by the tool itself, it will labour very heavily and very little material will be removed. It should be noted that if the tool is not introduced close enough to the surface very little material will be removed. Care must be taken that the tool is held firmly to stop any possibility of injury to the operator.

### **18.8 Sandblasting (for metal only)**

Sandblasting or more correctly abrasive blasting is a process whereby all traces of paint, rust and dirt will be removed. There are two ways of abrasive blasting, they are wet or water and air. These two mediums are not the main removal agent but the carrying or transporting medium the actual surface cleaning agent is an abrasive sand or grit. Abrasive material comes in various grades and sizes to suit the material to be cleaned and their shape.

When abrasive blasting, the carrying medium causes a partial vacuum to be created in the suction tube in the blasting material. This vacuum draws the blasting material up and into the path of the carrying medium and onto the surface to be cleaned. As the abrasive material hits the surface it removes the material (paint, rust or dirt) by grinding action. If the carrying medium is air, the operator needs to be supplied with a fresh air supply because a large dust pawl or cloud is created stopping fresh air to the operator. The use of water for abrasive cleaning can be used on many materials for it is easier to control the dust pawl as it is practically none existent.

A problem that does exist with the use of water cleaning is that once ferrous type metals are cleaned they start to corrode almost immediately. Therefore the surface must be dried quickly and painted.

Once the surface has been cleaned, whether by water or air as the carrying medium, it is always very vulnerable to corrosion and just be protected as soon as possible. The maximum time span between cleaning and painting is four hours; after that time has elapsed the surface must be re-cleaned then painted. See the *Painting Section* for the correct application of paint.

### **18.9 Water Blasting (for wood or metal)**

Water blasting as mentioned in the previous section can be used for abrasive blasting of a surface; it can also be used by itself. When a water blaster is used by itself it is primarily used for cleaning dirt and dust off of parts not for paint preparation, it can be used for degreasing, cleaning, etc., by the use of the correct suction apparatus to draw a cleaning agent up into the water path.

NOTE: When using water blasting machine the water that is coming out of the nozzle is at a very high pressure and will damage human tissue.

In cleaning timber the operator must take extreme care not to lift any pieces off the timber work as it is easily done. Also it should be noted that after the timber is cleaned, the grain of the timber will stand proud of the surface.

### **18.10 For Partial Paint Removal**

With all of the Museum’s old tramcars the original paint schemes are still in place under many layers of paint, unless the panels were replaced after accident damage. Therefore to reveal the different lining, number or lettering the paint must be carefully removed layer by layer for recording the details for later use. To do a partial paint removal follow the steps as outlined in method 3 (Paint Stripper) above but make sure that as soon as the paint has started to soften the action of the paint stripper is neutralised. Then carefully remove the first layer of paint to reveal the next layer. Repeat the procedure until the designs or what ever is revealed. Next use non soaped steel wool to carefully

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clean the surface and even it up as much as possible. You can now record the colour, the application of the revealed design, etc.

**SPECIAL NOTE:** When preparing a surface for painting by removing the original surface protection are some Australian Standards that may be useful in reading before starting. The standards are:

<b>AS 1627</b>	<b>Part 1 – 1974</b>	Degreasing of metal surfaces using solvent or alkaline solutions.
	<b>Part 2 – 1975</b>	Power tool cleaning of steel surfaces.
	<b>Part 4 – 1974</b>	Abrasive blast cleaning of steel surfaces.
	<b>Part 7 – 1977</b>	Hand cleaning of steel surfaces.
	<b>Part 9 – 1974</b>	Pictorial surface preparation standards for painting of steel surfaces.
<b>AS 1433</b>	<b>1972</b>	Paint colours for building purposes.

**Also before commencing any painting on Museum tramcars or omnibuses, consult the Museum's colour chart to ensure the correct colours are used.**

## 19 Surface Preparation

### 19.1 General

After the surface has been cleaned of paint, rust or other surface covering, the clean exposed surface must be sealed against any possible weathering, rusting or staining. If any of these damaging agents are allowed to occur you will have to start all over again cleaning the surface with the possibility of changing the surface details.

Therefore all freshly cleaned surfaces need to be protected by the application of prime type or varnish in the case of feature type timber work. Surface primers give a good key for the following coats of paint to adhere to and the surface that is being covered or protected. If primers are not used, the finish of the surface will be of poor quality and will soon fail.

### 19.2 Preparing Wood Surfaces

1. Sand until a smooth surface has been obtained using hand sanding (with a sanding block), orbital sanders or belt sanders. Belt sanders must be used with extreme care as the surface can be easily gouged. Blow or dust away all sanding dust that has accumulated on the surface; then lightly and slowly rub your hand over the surface in opposing directions. When the hand feels no blemishes or there is none visible sanding can be stopped.
2. After sanding, fill all cracks and holes with a good quality exterior grade wood putty or filler. The putty or filler should be applied using a putty knife or wide blade scraper pushing the putty or filler into the cracks and holes. Allow the putty or filler to dry, sand, then refill with more putty or filler. If the cracks or holes are very deep, care must be exercised to key the filler agent into the surface to stop any possibility of it falling out.

Where large areas are badly damaged or rotted consideration must be given to replacing the piece. Do not attempt to fill these areas as the filling will fall out. It should be noted that there are many types of putty or fillers on the market, whether they be linseed oil based or two part epoxy types. You will have to try each for its best application of use and for a list of the preferred jobs viz putty or filler.

3. When the grain of the wood has become raised, the grain can be filled with “Wood Stop” type putty or fillers. After the repair material has been applied and has dried, it can then be sanded smooth. It is important to read the instructions on the usage of the repair material as some of them are applied over a clean surface where others are applied over a prime coat.
4. Priming the surface is very important as if the surface is not sealed before the colour coats of paint are applied the final surface and colour will be of an inferior standard. The most common primer for timber surfaces is commonly called “Pink Timber Primer” and is manufactured by many paint companies. After the primer has dried it is important that the surface is lightly sanded to remove any brush marks.
5. Stop putty is one product that is used to fill the minor imperfections that are left in the surface after the primer has been applied and lightly sanded. The normal way to apply stop putty is to use a spray gun designed for spraying putty. You must follow the manufacturer’s directions for air pressure, distance to the surface, etc. as there are many different brands with their own differences in application. Once the surface has been coated and has dried, it is then sanded down usually with a paper called wet and dry (see point 7 below) to obtain a good surface for the next stage.
6. Undercoating is the next stage in the surface preparation where a coat of undercoat type paint is applied which is basically an inter-prime which is white or light grey in colour. The undercoat seals the primer and the stop putty for the application of the finish coats.
7. Colour-coating or colour undercoating is the paint coat that is applied next. This is a coat of undercoat type paint which has been tinted to the colour of the finish coat. If you are painting a new surface or a surface that has been totally strip back to as a new surface it is recommended that you use a coating of enamel finish that has been cut to produce a flat matt

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finish. This is achieved by putting in 500 ml of turpentine to four (4) litres of paint. The colour-coat seals the colour of the undercoat and provides a colour base for the finish coats.

8. Wet sanding is an important operation that must be done to produce a smooth surface, free from brush marks, paint runs or if spraying the different spray faults. If the sanding is not done between coats of paint a very poor finish will be obtained which spoils all the effort that has been put into the restoration of the tramcar.

The type of sanding paper that is used is called “Wet and Dry Paper” which is a type of emery grit paper that is waterproof. In using the paper it is soaked in water, which acts as a lubricant, the paint surface is then sanded until the paper is full of paint and then it is rinsed in water, usually frequently. If the paper is rinsed frequently and not allowed to clog up a very smooth surface is produced.

The most commonly used grit size papers are 260 and 320. When working on a surface the coarser paper is used first, then the finer one. In this way a very smooth surface is produced, thereby producing better finished surfaces.

Before sanding is started the paint must be dry, allow at least 48 hours, as wet paint clogs the paper and makes it useless, also damaging the previous applied surface. By using different colour primers and undercoats as you sand the surface, the depth of sanding can be gauged. If the timber or original surface appears, the area will have to be repainted and then re-sanded. When the surface is to the condition that you require, it must be thoroughly washed down to remove all traces of the dust that was created. This washing is easily done by using a good sponge and plenty of clean water which has had a dash of detergent added.

### **19.3 Preparing Metal Surfaces**

1. Any rust that is present on ferrous surfaces after cleaning must be neutralised before any paint steps can be started. Rust that is present on the surface will slowly keep working on the metal destroying it. Therefore before any painting is commenced the surface must be passivated to stop the formation of ferrous oxide. There are many products on the market, but the main agent in nearly all of the products is phosphoric acid which converts the surface to iron phosphate which is a neutral substance. If the treated surface is not damaged by the paint, corrosion will not occur. Remember the human eye cannot see the first signs of rust forming. For in the end there is nothing uglier and soul destroying than a panel or frame that has been destroyed by rust.
2. Etch primer is a very important paint on metal surfaces. It forms the key that will hold the rest of the paint system onto the surface. It is usually applied by spraying. As soon as the etch paint has dried, the metal primer must be applied.
3. Metal primer is the next coating to be applied to the surface, usually in the Museum’s cases on tramcars by brushing. The metal primer is a paint that is high in zinc, commonly called “Red Zinc Chromate Primer”. One good even coat of primer is usually all that is required, but depending on the amount of sanding that has been performed a second coat may be needed.

On brass and associated type metals use “Yellow Zinc Chromate Primer” instead of the “red”.

Some points to remember that *too thick* a coating of primer will cause runs to appear in the paint and will be easily chipped off the surface. Also the primer must be sealed against any possibility of water damage by finishing the section being painted up to the stage of having one final coat applied.

4. Stop Putty as per the method that was described in the Timber section.
5. Undercoat as per the method that was described in the Timber section.
6. Colour-coating as per the method that was described in the Timber section.
7. Wet sanding as per the method that was described in the Timber section.

## 20 Painting

### 20.1 General

The application of paint determines the appearance of the finished restoration job. There is basically three ways of applying paint to any surface and they are brushing, rolling and spraying. Application of paint by roller is not to be used as it does not produce an acceptable finish on the STM exhibits and was not used by the Tramways as a standard painting practice. The different types of paint suitable for each method of application are explained in the following paragraphs with some tips for each method.

### 20.2 Brushing

Brushing is the most commonly used method and the only method that was used by the Sydney Tramway Department for the application of paint. For the application of paint onto a surface whether it be wood or metal surfaces as it requires a minimal amount of masking. Thereby making it a quick job to put many different colours onto the surface in their correct positions, with only the drying time of the paint between colour applications. Brushing works best with all normal house type paints whether they be enamels or acrylics as these are slow drying paints. Those paints that are intended for spraying have very volatile solvents, giving quick drying, than those used for brushing. With the use of slow drying solvents, the paint has the time to spread out over the surface trying to smooth out the brush marks.

To save paint as it is becoming more expensive every year; please follow the steps listed below:

- a. Before opening any **new** can of paint, turn it upside down (after checking that the lid is secure) and shake it for one minute. Then place it right side up and carefully remove the lid with a paint-can lid removing tool. Then using a sharp point small chisel or screw driver punch three or four holes in the groove excess paint is allowed to drain back into the can before it runs over the side or fills the groove and stops the lid sitting down properly. If paint is in the groove the lid does not sit down tightly and allows air to get to paint and sets it drying forming a skin over the paint.
- b. If the paint tin has not been used recently and has settled, mix it thoroughly in this manner.
  - i. Remove from storage shelf right side up, **DO NOT TURN OVER**. Open the tin and inspect the condition of the paint. If upon opening the paint tin you find a skin has formed over the surface carefully peel it off and dispose of it first, never stir the skin into the paint.
  - ii. Pour off about three quarters of the paint into a clean paint tin.
  - iii. Mix the remaining paint into a smooth soft paste with a rectangular cross section paint stirrer about 5 mm by 25 mm.
  - iv. Gradually add more of the paint until the whole tin of paint is thoroughly and evenly stirred.
  - v. While using the paint, you must keep the paint stirred. This will give you an even pigmentation of the applied paint.
- c. Before using the stirred paint it must be strained through a very fine sieve (say an old pair of stockings makes a good sieve). By straining the paint, any lumps or pieces of skin that have remained will be removed.
- d. It is a good practice to never paint directly out of a new paint tin. Pour off what is needed for the job into a painter's tin (a four litre tin with a wire handle and no rim on the top edge) or at least a smaller tin. This will remove any chance of spilling a whole four litre tin of paint. Using a clean or new brush, run the bristles of the brush around the rim of the paint tin to remove surplus paint in the rim area before replacing the lid.
- e. When loading the brush with paint only dip approximately 12 mm (½ inch) into the paint. Next gently tap the metal band of the brush on the top edge of the paint tin. This avoids over

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loading the brush and thereby allowing the paint to drip from the brush onto the surfaces below spoiling them and wasting paint. Never push a brush into a surface as this causes a great number of brush marks to appear in the paint when dry. By always gently and lightly applying the paint you will get the best results.

- f. When applying paint to long horizontal surfaces always work in approximately one metre sections at a time. Starting at one top corner and applying the paint from top to bottom, working your way across the section. After the section has had the paint applied, gently wipe the brush on the rim of the paint tin removing any excess paint, then lightly wipe the brush across the painted section from left to right. Start in the top corner opposite from the direction you are going to continue painting from and finish at the bottom corner next to the section that is to be painted next.

**Note:** On the omnibuses in the STM collection the exterior panels must be painted opposite to that as just previously described. That is; apply the paint from the left to right starting at the top and working down. When finishing the panel it must be wiped from top to bottom.

- g. After you have finished painting and returned any excess paint to the bulk container always wipe out the groove thoroughly. Then replace the lid tightly using a rubber or wooden mallet, but do not hammer the lid down too heavily as this will deform the tin and the lid will not seal. Next clean the outside of the tin, this will allow everyone to read the label clearly and identify the paint that is inside.
- h. One important consideration that a lot of people forget when trying to paint is to ambient temperature of the day. For the best results it is strongly recommended to only paint when the temperature of the day is between 10°C and 30°C. Also if the humidity is too high, above 80% do not paint as the surface is now covered when a very fine coating of moisture which will spoil the paint's adhesion to the surface.
- i. Another important point and is very important to produce a good finish is the paint brush. Some people insist on purchasing cheap, short stiff bristled and narrow brushes and this shows in the finished surface as very badly damaged with brush marks. Therefore to obtain the best finish use a very good quality brush. A good brush is one that has long, soft bristles and is as large as possible to paint the area being coated. That is to say the normal width of brushes to paint both tramcars and omnibuses is 1 X 100 mm and 1 X 150 mm paint brushes.

The 100 mm brush is used for cutting into corners, around details and applying the 40 mm or wider black lines that are used in some of the colour schemes. Where the black line is less than 40 mm narrower brushes or lining brushes will be required. The 150 mm brush is used for almost all the work for applying the main colour areas. One of the main reasons for using large brushes is to achieve a smoother finish and cut down painting time. Another is that there will be less brush strokes required to paint a surface, therefore the painter will be less tired towards the end of the job.

The painters who were painting the Museum's vehicles many years ago were supplied with sable hair brushes. Although these brushes are still available the cost of their use is very prohibitive, so good quality, synthetic hair brushes should be used in their place.

Another important point is the pressure that is applied to the brush; it should be a gentle even pressure throughout the entire stroke. Also the paint is on the end of the brush bristles and that is the part of the brush that must only be in contact with the surface. If you only paint with the end of the brush bristles the paint has less tendency to be pushed up the brush to the butt and this stops the brush from dripping.

### **20.3 Spraying**

This method of painting may be the fastest way of applying paint but it takes more time to correctly mask the surface to stop over spray. Large areas can be quickly painted in a very short time and the areas such as the under sides of the tramcars which would be extremely difficult to paint by brush are easy with spraying. Most paints can be sprayed, except the paint (Naval Dressing) for the roofs of tramcars that are canvas covered. Spray painting was used by the Omnibus Division of the Department of Road Transport and Tramways in the 1930's when they were absorbing private

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omnibus operators but they changed over to brush painting. The Brisbane Tramways were one Tramway Authority that spray painted their trams, mainly because the tramcars were mostly painted in one colour.

The most common paints/materials that are sprayed are:

- Etch primers
- Metal primers
- Primer-surfaces (stop putty)
- Automotive enamels
- Automotive acrylics
- Spraying enamels.

To spray the above they may need to be thinned or reduced to a thinner consistency. Therefore before spraying read the manufacturers instructions very carefully and use the correct thinner for the product.

### **20.4 Spraying Techniques**

#### **20.4.1 Air pressure**

When a regular siphon gun is used, the pressure should be set at 455 kpa (*65 psi*) in order to properly atomise spraying synthetic enamels or acrylics. Figure about a 70 kpa (*10 psi*) pressure drop between the regulator and the gun due to the hose friction, if you use 8.5 mm (*5/16 inch*) I.D. hose. It is advisable to use as short a hose as possible in order to avoid this excessive pressure drop which can become quite large in long, small bore hoses.

When a heavy fog or overspray fills the air surrounding the object being sprayed, the chances are that the air and fluid pressures are out of adjustment. The illusion that high pressures ensure speed is a fallacy. There is a correct, economical air and fluid pressure for each type of finishing material. One of the greatest single factors in sound finishing practice is the use of the correct pressures for a given material.

#### **20.4.2 Connection of the Spray Gun**

Connect an air line to an air compressor or the air system through a regulator and water/oil trap. Set the regulator to the pressure required and inspect the trap for water and oil. Release any found and while spraying, periodically drain the regulator of condensed moisture as this may ruin any paint job.

There is a pressure drop of approximately 31.5 kpa (*4-1/2 psi*) per 3 metres (*10 feet*) of 8.5 mm (*5/16 inch*) I.D. hose (while the air flowing at 420 kpa (*60 psi*)), this must be taken into consideration when making regulator settings.

#### **20.4.3 Masking**

This is an absolute essential in spray painting as the overspray will cover a large area. Newspaper or brown wrapping paper and a cheap grade of 20 mm masking tape are best for the job. When applying the tape put most of it on the paper and just an edge on the surface itself. Seal all joints in the newspaper to prevent leaks. Always remove the masking as soon as possible (*1/2 to 1 hour* but no longer than 24 hours) after the job is completed or else it becomes very difficult to remove and may cause peeling of the other coats of paint. When masking a two or more colour job, wait at least a day between colours to avoid peeling off the first colour and then remove the tape as soon as possible,

#### **20.4.4 Filling the Spray Gun**

Always strain the paint – either through the spray gun strainer cups which can be obtained from a paint supplier or at least through a stocking. If this is not done, the spray gun will become clogged very quickly providing great annoyance and will have to be cleaned.

#### **20.4.5 Amount of Enamel**

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The greatest error made in spraying enamel is putting too much on. A thick film is not more durable than a normal film thickness and it usually produces a poor finish with many paint runs and surface defects. Two or three thin coats will usually satisfactorily cover any colour. Spray a good covering, but thin, coat first and allow this first coat to get quite tacky (from 10 to 30 minutes depending on the temperature and humidity) and then spray the next coat. Repeat the time waiting period if a third coat is required.

Keep the gun held at a perpendicular to the surface and approximately 250 mm away. If the gun is held too close, it will cause poor distribution of the paint and if too far away, dry spray will result. Never move the gun in arcs as it gives poor distribution of paint, move it parallel to the surface. When the gun is arced 45° away from the surface approximately 65% of the material is lost. Always lap each stroke by 50% over the preceding one. Less than a 50% overlap will result in streaks on the finished surface. Move the gun at a constant speed while the trigger is pulled since the material flows at a constant rate. It is good practice to try the settings out by spraying on a scrap panel first. Also practice holding the gun too close and too far from the work to determine the correct distance necessary.

### **20.4.6 Technique**

Techniques to Remember when spraying:

- a. You must always strain the paint.
- b. Always use the correct pressure.
- c. Always keep the proper distance from the work – 200 mm to 200 mm (8 to 12 inches)
- d. Keep the proper angle with the work (Perpendicular and parallel)
- e. Use smooth even strokes, shutting off the trigger just before reaching the end of the stroke and turning on just before beginning of each stroke.
- f. Lap strokes evenly. Aim the nozzle at the edge of the previous stroke.
- g. Always keep the spray gun moving. Avoid runs.

### **20.4.7 General Spraying Difficulties**

General spraying difficulties and cures:

- a. Overspray – dry spray – too high pressure – improper paint thinning.
- b. Spitting of Gun – Leakage in the spray gun – moisture in the paint – siphon breather hole clogged.
- c. Runs – Over reduction – too slow thinning solvents – cold surface being painted – improperly cleaned surface.  
– REMEDY – refinish.
- d. Sags – Under reduction – applying successive coats without allowing time to dry between coats – low air pressure (Lack of atomisation) – gun too close – gun out of adjustment.  
– REMEDY – sand off and refinish.
- e. Orange Peel - Under reduction – improper thinning solvent – lack of proper flow – surface drying too fast – improper air pressure.  
– REMEDY – rub with mild polishing compound or sand and refinish.
- f. Wrinkling - Under reduction or air pressure too low causing excessive film thickness – excessive coats – fast reducers creating overloading – surface drying trapping solvents – fresh film subjected to heat too soon.  
– REMEDY – sand and refinish.
- g. Pin holing – moisture in spray lines – trapped solvents – insufficient atomisation or breaking up of material – settling of pigment in the cup.  
– REMEDY – sand down and refinish.

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- h. Blushing – (the finish turns milky looking) – fast thinners in high humidity – unbalanced thinners – condensation on the old surface.
- REMEDY – add retarder to the thinners and respray – sand and refinish.
  - PFREVENTATION – keep paint and surface at room temperate – select a good quality thinner – use a retarder or reflow solvent when spraying in high humidity and warm temperatures.

In order to secure a really good finish, all of the precautions mentioned before must be taken into consideration.

**Note:** While spraying use a respirator type mask covering both the mouth and nose plus correct protective clothing. Also there are other problems that can occur with dirty main and side nozzles. It is recommended that you at least obtain instructions on how to use a spray gun before you attempt to spray paint for the first time.

### **20.4.8 Cleaning the Spray Gun**

This is one of the simplest and easiest jobs ever. Put about 300 mm of thinners, which can be used for cleaning-up, into the paint cup. Point the spray gun onto a scrap panel or similar and spray until there is no paint coming out of the nozzle. While spraying, shake the gun, to rinse the paint out of the cup. Dump out this thinner and repeat using clean thinner but a smaller quantity. Next loosen the cup and hold with the fluid tube in the cup, unscrew the air cap about two turns, hold a cloth over the air cap and pull the trigger. The air is now divided into the fluid passageways forcing material back into the container. When finished, wipe the nozzle and the paint cup with a clean cloth dampened with thinner. Save the thinner by pouring the remaining thinners into a container such as an empty thinners tin.

Be sure to clean the gun completely immediately after use. It is very difficult to properly clean it after the paint has dried inside.

#### Various Types of Paints and General Methods of Applying them:

1. *Pink Timber Primer.*

Use a brush to apply a good even coat. Allow 24 hours to dry.

2. *Timber Undercoat*

Use a brush to apply a good even coat. Allow 24 hours to dry.

3. *Colour Coat*

Use a brush to apply a good even coat. Allow 24 hours to dry.

4. *Finish Colour Coat – Brush Enamel*

Use a brush to apply a good even coat. Allow 24 hours to dry. Check the coverage as putting light colour over a darker one will allow the darker one to show through. If the darker colour shows through, apply another coat and allow 24 hours to dry. Coverage of the enamel type paints of the present day manufacture are not as good as enamel paints that were manufactured 40 years ago, this is because the present day enamels are of a synthetic base to replace the lead base pigments that were used up to 1951.

5. *Varnishes*

Usually brush applied, best when used on interior timberwork. On tramcars up to the 1920's after the last enamel coat was applied the whole exterior of the tramcar was given a coating of varnish. This gave the paint a higher gloss and helped protect the colour of the finished surface. Normally not thinned, except on the first coat on new timber, and slightly sanded between coats. After the second last coat use clean, soap free steel wool to lightly abrade the surface before applying the last coat of varnish. Try to maintain, as best as possible, a dust free work and surrounding areas as any dust becomes very noticeable on the finished product. Allow 24 hours between coats.

6. *Stop Putty*

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This putty is normally applied by using a special spray gun for the application of stop putty only. Dries within one hour.

7. Etch Primer

8. *Metal Primer – Brush Applied.*

Use a brush to apply a good even coat. Allow 24 hours to dry.

9. *Metal Primer – Spray Gun Applied*

Use a spray gun to apply a light coat of primer to the surface. Then allow about 10 minutes to dry and apply another light coat, fully covering the first coat. Follow the manufacturer's recommended time as shown on the tin before applying undercoat, colour coat and finish coats.

10. *Sprayed Undercoat, Colour Coat and Colour Coat.*

Whether the paint used is enamel or acrylic the best advice is to follow the paint manufacturer's instructions as set out on the label of the paint tin. Follow their times, pressures and coverage to obtain the best results with sanding the coats after they have dried by the wet sanding method as outlined in the *Surface Preparation Section*.

11. Roof Paint – Naval Dressing.

Apply with as large a brush as possible. On the first and second coats, on new canvas, thin to 50% with the manufacturer's recommended thinners, usually turpentine. On the third coat thin to about 75% dressing, 25% thinners and fourth to seventh coats the dressing is at full strength. This allows the canvas to be impregnated as much as possible before the dressing becomes too thick to soak into the canvas, thereby producing a good water tight roof. Also as the different coats of dressing are applied and allowed to dry the canvas becomes tighter and the roof should have a good drumming sound to it. Remember to make sure that you seal the area where the canvas goes under the gutter rail, as this is one of the first areas of failure of the roof covering.

Drying time for this paint varies from about one week for the first to third coats. The last coats should only get a crust on them in a week as the dressing should not dry out for a very long time, about six months or more. Therefore the last coats should be spaced apart as the roof is safe to walk on, usually one month apart.

### **20.5 Painting Particular Parts**

#### **20.5.1 Trucks**

- a. Degrease, clean, remove and loosen the paint. Remove any loose rust and scrape or wire brush any remaining rust off the surface. Next treat the rusted areas with phosphoric acid or equivalent.
- b. Coat all of the truck with zinc rich metal primer.
- c. Apply at least two coats of the finish colour enamel.

#### **20.5.2 Steps and Side Frames**

- a. Degrease, clean, remove and loosen the paint, making sure that all dust and dirt is removed. . Treat the metal parts that have any signs of corrosion with phosphoric acid or equivalent.
- b. Sand smooth all wood work and give it a good rubbing of linseed oil, applied with a rag. This helps to preserve the timber from rotting and shrinkage.
- c. Apply pink wood primer to the wooden parts and finish as already described earlier. With the metal parts use metal primer and finish as described previously.

#### **20.5.3 Window Frames and Doors**

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- a. Repair any damaged door or window frames and make sure that all the corners are secure.
- b. Sand the surface until smooth or if required remove all the paint as described in the *Paint Removal Section*. When sanding near the glass extreme care must be exercised as it is very to scratch the glass and ruin it for all times. In the past some members have been a little over enthusiastic while sanding and have badly scratched many window panes in a few of the tramcars.
- c. If glazing putty was used around the glass repair or replace as required to maintain water tightness.
- d. Apply pink wood primer to the wooden parts and finish as already described earlier. With the metal parts use metal primer and finish as described above.
- e. When finished painting around the windows and the paint has dried, scrape off the excess paint that has covered the glass with a safety razor blade.

### **20.5.4 Roofs**

- a. Remove any damaged canvas and repair any damaged roof slats.
- b. Apply pink wood primer and apply new canvas to repaired area while the primer is wet. Make sure that the topside of the canvas is tacked down first, then stretch the canvas to the lower side and tack down, then stretch the two sides and tack down.
- c. When the wood primer has dried apply Naval Dressing as described in the *Painting Section – Painting Particular Parts*.
- d. On roofs of metal construction, clean the roof, repair as necessary, prime and apply the finish coats of roofing enamel or similar.
- e. On malthoid roofs, repair the damaged areas by cutting back the damaged area or lifting malthoid. Next cut a piece of malthoid that is about 100 mm larger than the damaged area. Paint the area with malthoid paint and apply the patch centrally to the damaged area. Tack down the patch making sure that the patch does not have any bubbles under it, and then paint the patch and surrounding area with malthoid paint. When dry coat area with finish colour malthoid paint.

### **20.5.5 Handrails and Other External Metalwork**

- a. Steel work.
  - i. Remove the old paint and remove any loose rust, scrape or wire brush any remaining rust off the surface. Next treat the rusted areas with phosphoric acid or equivalent.
  - ii. Sand smooth with an emery cloth.
  - iii. Prime with zinc rich primer and finish as described earlier.
- b. Brass work
  - i. Remove any loose or flaking paint.
  - ii. Sand any remaining paint smooth using an emery cloth.
  - iii. Prime with zinc rich primer of the yellow zinc chromatic variety.

### **20.5.6 Seats**

- a. Wood
  - i. Remove any loose or flaking paint. Make sure that the areas between the slats are also treated. If necessary remove all the paint from the slat which may cause you to dismantle the seat to get to all the areas to produce a quality job.

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- ii. Sand the slats down, producing a good smooth surface using a good quality glass or sand paper or if available aluminium oxide paper is also suitable as it tends to last longer.
- iii. Next apply a coating of varnish. After the varnish has dried, the seat can be wood primed and finished with enamel paints. One reason to apply a coat of varnish is if in the future the period in which the tramcar is painted is changed, the seats may need to be varnished. It is an easy matter to remove the paint without the wood primer showing in the grain of the timber when the timber is varnished. As it is very difficult to remove paint out of the grain of the timber. Another reason is to help to preserve the timber as the varnish is a very good sealant of timber.

### b. Metal

- i. Remove the old paint and remove any loose rust, scrape or wire brush any remaining rust off the surface. Next treat the rusted areas with phosphoric acid or equivalent.
- ii. Sand smooth with an emery cloth.
- iii. Prime with zinc rich primer and finish as described earlier.

### **20.5.7 Varnish Surfaces**

- a. Remove all of the old paint by using paint stripper only as varnish chars very easily with heat.
- b. Sand the surface smooth and apply a thinned down coating of varnish. The varnish is usually thinned to 50%.
- c. When dry lightly sand the surface and apply a full strength coat of varnish. Then wait until dry, usually 24 hours, lightly sand the surface and apply another coat of varnish. Apply three coats of varnish in this manner.
- d. A fourth coat of varnish is usually applied but the surface is first rubbed down with clean, soap free steel wool. This produces a fine finish. Remember to make sure that the area you are working on is free of dust as possible.
- e. To touch up or repair damaged varnished surfaces first lightly sand. Then clean off any dust and apply one or two coats of varnish.

### **20.5.8 Ceilings**

- a. On painted timber surfaces, prepare and paint as any other timber surface. Be careful not to splash or drip paint onto the seats or walls of the tramcar.
- b. On varnish timber surfaces, prepare and varnish as per any other varnished surface.
- c. Some ceilings are lined with metal panels and were originally spray painted. Therefore if you are to restore to original condition inspect the surface to determine the original application method and reapply the paint the same way.

### **20.5.9 Floors**

- a. On timber floors, clean the floor with a vacuum cleaner and prime where necessary. Apply two coats of flooring paint.
- b. Malthoid floors are usually painted red or black with “Solpar” flooring type paints.

## 21 Repairing Roofs

### 21.1 General

When considering how to conserve a tramcar or to protect it from the elements the roof is the most important part of the body structure. The roof of the tramcar, when it is in good condition stops the ingress of water into the structure of the body and the interior trim. Therefore any tramcar's roof must be kept in good at all times to minimise repair costs to the Museum.

There are a number of different types of coverings that have been applied to the roofs. The main types of coverings used are: painted canvas, malthoid felt and sheet metal. On the tramcars in the STM collection each of these types of coverings or a derivation of it, is used by itself or in combination with one of the other coverings.

The coverings can be explained as follows:

- a. Canvas – used on a timber slatted roof secured to the timber roof ribs painted with a thick coating of wood primer. While the paint is still wet, a good quality of sail canvas is stretched over the roof and tacked down on the vertical edge at the side of the roof using copper tacks only.

**NOTE:** Never use steel tacks as these rust and destroy the canvas. The canvas, as described in the *Roof area of the Painting Section*, is painted with naval dressing to tighten the canvas, by shrinking it and to make it water tight. With this method of roof protection, the canvas must be painted from time to time so as not to allow the dressing to dry out. Also the canvas must be in one piece fro side to side and end to end, all the seams or joints are to be double stitched for strength.

When the roof is measured allow 300 mm on each side and end, so as to allow you and your helpers to be able to hold onto the canvas when putting it on. Also with this excess of canvas it allows something to be put under the gutter board or under the canvas retaining beading.

The main problem with a canvas roof is that pf looking after the dressing and not allowing it to dry out. Once the dressing has dried out it can and will crack. This cracking then allows water, dust and dirt to get to the canvas, thereby setting up a corrosive mixture that destroys the canvas. As the canvas is destroyed, water is allowed to penetrate to the roof slats. Water when it is observed dripping from the interior of the roof means there is a fair amount of damage to the roof seal and it needs urgent attention.

- b. Malthoid felt – was used to replace canvas, mainly found on the STM Brisbane tramcars. It is fibrous, rubberised tar material, usually obtained in rolls. The usual way that the malthoid felt is installed on the roof was from side to side on the full malthoid felt protected roofs.

To apply it to the roof surface, first the roof is given a coating of malthoid paint slightly wider than the roll width. Only paint where the malthoid felt is to be placed as the paint must be wet to apply the malthoid felt. Next roll out the malthoid felt starting on one side of the tramcar, after tacking it down first. Unroll it to the other side and pull it reasonably tight and tack down that edge. The next strip is applied in the same way but with a lap of about 30 to 40 mm, making sure that the lap area on the first sheet is now painted. Double tack the lap with the rows of tacks about 10 to 15 mm from an edge of the lap and staggered.

The rest of the tramcar roof is covered in the same way with all the edges being tacked down with the tacks being placed about 30 to 40 mm apart. When the roof is fully covered with malthoid, then apply a minimum of two full coats of malthoid paint.

- c. Sheet Metal – this type of roof is usually applied over the roof ribs and is the only thing between these ribs. Therefore it can be easily damaged if you walk on the wrong section of the roof. To paint and protect this type of roof covering, it is to be treated as any other metal surface. Therefore it is to be painted in accordance with the method set out in the *Painting Section* for painting metallic surfaces.

### 21.2 Roof Preparation

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Roof preparation is a very important task and must be done correctly to obtain a good surface to seal. Therefore the discussion will be on how to achieve the best possible roof surface so it can be sealed by one of the above mentioned methods. The main repair work that is required is to the roofs that have slats as metal finished roofs need no roof slats, only ribs to attach to.

So at the start, it will be assumed that the roof is of timber construction (slats and ribs) covered with canvas, the most common covering, and requires to be removed. First remove the existing canvas. This may and probably will entail the removal of the gutter boards or at least the retaining beading. Next the roof has to be stripped of all trolley equipment i.e., trolley poles, trolley bases or pantograph and bridges, hooks, insulators, cable and cable cleats. Before you actually remove any equipment or roof equipment, find the manufacturing drawings or if they are unavailable a drawing must be produced that locates all of the equipment with accurate dimensions. After all of the equipment has been removed a start can then be made on removing the canvas by cutting through to the timber slats below, but not cutting into the slats. Then lift an edge and pull the canvas off the surface. This may work on old, weathered and dried out canvas but may not work on a roof that has been protected from the weather. If the canvas will not lift off the slats, a very strong metal scraper will need to be used to scrape the canvas off. When scraping the canvas off, at the same time scrape off the binding agent that was or is holding the canvas down as it needs to be removed any way after the canvas has been removed. Whilst removing the canvas beware of the copper tacks that were used to hold the edges of the canvas down as these must also be removed.

After all the canvas has been removed and the surface has been scrapped clean, all the slats must be inspected for condition. Any slats that have bowed excessively or have badly cracked may need to be considered for replacement so mark them. Next check all the screws that hold the slats to the ribs, cant rails and end rails for corrosion. This is easily visible if steel screws were used as rust stains the timber. If the screw is badly corroded the timber around the screw has probably rotted, thereby letting the slat move on the remains of the screw and the screw is no longer doing its job. Rusted screws can be replaced by putting in a new one if the slat can accommodate another screw hole and the rusted screw, if possible, be removed or at least try to cover the rust and metal prime it.

If the slats have bowed try to add extra screws to pull them down and finish by sanding. If the slats have bowed or cracked beyond repair they will need to be replaced. This is not easy as the slats are tongue and groove boards, having been laid from the centre to the outside. Therefore to replace a small area, say on or two slats, it will need to cut off one tongue to remove the boards and to install the new slats. On larger areas it may be possible to work the boards into the area intact. A point to remember is that the slats need to be replaced from one rib to another, so they must be cut off in the middle of the rib to allow an area for the replacement slat to be attached.

Damaged cab end roof slats are the most difficult to replace as the most common cab roofs have a double curve built into them. That is the slats are curved down and around to meet the end of the car. The way these slats were installed was by securing the centre slat first, the next slats on either side were slightly shaved on both sides, having a small triangular piece removed. This process is continued as you work outwards, producing the double curve to the roof end. I have over simplified the process as it is not easy to produce this compound shape, especially as the slats do retain their tongues and grooves to lock the slats together. You will need to work out the amount of timber to be removed off each slat in turn. I suggest that you practice using scrap slats until you can obtain the correct roof end shape.

Once the slats have been repaired and the roof has been cleaned to the bare timber, prime the surface. After this coating has dried, apply another and much thicker coating on which the new canvas must be immediately applied. The canvas is now stretched over the entire roof and secured at the edges on a doubled over edge of approximately 40 mm. This double over edge will stop the canvas tearing away from the tacks and is hidden under the gutter rail or the beading. Make sure that the doubled edge is turned under not over as the water and dust/dirt could accumulate in the groove that is formed if it was turned out.

If the canvas only needs a patch to be applied, the area needs to be cleaned the edges of the existing canvas needed to be tacked down. Then cut a patch of 100 to 150 mm larger than the damaged area. Apply a coating of Naval Dressing to the area and tack down the patch making sure that the patch is stretched before finish tacking it down. Finally apply a thinned coating of Naval Dressing to the new canvas. After the dressing has dried, recoat with full strength dressing for about two coats.

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If repairing or replacing a malthoid covered roof, follow the same basic steps as a canvas covered roof. After the roof slats have received the primer coat, malthoid paint is now applied. Then the roof is covered, as described, with the malthoid felt.

### **21.3 Refitting The Roof**

As the roof equipment is refitted, check that all of the cable cleats, the trolley base planks or supports and where fitted, the trolley pole bump timbers are in sound condition. If they are to be replaced, as always, use the originals as patterns and the timber to be used is:

- a. PINE for the cleats,
- b. OREGON for the trolley pole roof bumpers and trolley bridge board supports, and
- c. HARDWOOD for the trolley bridge or pantograph boards.

When refitting the main traction cable ensure that where the cable enters or passes through the roof that it is sealed against any possible entry of water.

If refitting a roof of a tramcar that was totally stripped of all roof equipment, start with positioning the trolley base or pantograph and carefully work out where the roof has supports for the equipment. Remember that most of the equipment would have been set out on a balanced or proportioned basis. The best way is to obtain, if possible, the manufacturing drawings, if they exist.

When you start to refit the gutter rails, always start at the end of the tramcar and work towards the middle as the end gutters are steam bent and fitted to the end profile of the roof. Usually the gutter timbers are replaced as they have rotted or are badly damaged when removed. This will cause you to manufacture the new end gutter rails, they are usually steam bent to shape and this is a specialist trade and the Museum has, in the past, contracted this work out. Sometimes the ends can be made from laminating pieces together with using water proof glue to hold them in the correct shape. To obtain the correct shape of the ends for the gutter rails, cut the required shape out of stiff cardboard and this is used for a pattern. It has been found that both ends of the same tramcar are not exactly the same, so it is important to make the patterns for both ends. After the ends have been fitted, the fill-in pieces are fitted to complete the gutter rail.

If the tramcar has beading and no gutter this makes for a very easy job to complete the roof. For the two most difficult parts are the obtaining of the correct shape beading and bending it to the roof shape. To bend it to shape, start securing it to the very middle of the end of the tramcar and work it evenly both ways around the roof.

## **22 Ceiling Lining Repairs**

### **21.1 General**

On some of the STM tramcars the underside of the roof has had a lining fitted. This is to complement the internal finish of the body and to present a modern clean interior finish. As for the older tramcar bodies, the underside of the roof was mainly varnished, sometimes painted. Over the years different types of linings have been used and there are three basic types which are: tongue and groove slats, veneer/masonite and sheet metal. Also over the years the linings could possibly have come damaged with the ingress of water, either by condensation or leaking rook. Therefore in this section we will describe the replacement of the linings.

### **21.2 Lining removal**

- a. Measure and record by producing a drawing of the layout of the fittings such as lights, handrails, advertising racks, destination boxes, any mouldings, etc., that are fitted to the lining. This will help you when it becomes time to refit them. Even take photographs of the interior as all this adds to the record of how the tramcars were manufactured or altered over their years of service with their original operators.
- b. Now carefully remove all handrails, advertising racks, destination boxes, any mouldings, etc. As you remove an item record its exact location on the drawings that you have produced and mark the items on a non visible side with your part recording system.
- c. After the lining has been cleared of fittings that would hinder or stop its removal, now stop and inspect how the lining is attached to the roof ribs. On some of the Sydney tramcars, the lining which has tongue and groove slats is secured to the ribs by the hidden nail method. This is where the nails are put through the back edge groove into the rib and this does make the job of removing the slats without damaging them slightly more difficult.

Veneer or Masonite linings also present similar problems as they were originally secured to the ribs so as not to show the securing method. So care must be exercised in their removal, more so with the veneer as it may be possible to restore it and use it again. Masonite is still available, so if it is too difficult to remove it without damaging it you will have to replace it.

The sheet metal lining is probably the most easiest to remove as its fixing is almost always clearly visible and easy to undo.

- d. Now the lining has been removed inspect it and obtain the replacement material either for part or full replacement. Use the original as a pattern to mark out the new lining. With the slatted lining the centre slat is the odd one out as it is double grooved to allow the slats on either side to be laid into it. While at this stage inspect the underside of the roof and any evidence of water ingress and repair the same if the roof has not been recovered. Also inspect the attachment points for the roof ribs to the cant rails for any signs of deterioration. If any deterioration is found, repair it.

### **21.3 Lining Replacement**

- a. To reinstall the lining start by cleaning the underside of the roof and give it a coating of appropriate primer. Then find the longitudinal centre line and mark it. Now after refurbishing or making a new lining start to refit it. If you are going to use Masonite, use a tempered grade and follow its installation instructions.
- b. With sheet metal, veneer or Masonite lining the refitting is a relatively easy job. To refit these types of linings use the original as a pattern to mark out the replacement sheet. Then cut the sheet to size and cut out light fitting holes, also drill any holes required for fitting of any handrails, etc. Locate the longitudinal centre of the sheet and mark the two edges. Now put the sheet into its general location and gently push it up into its position. Secure it in place, making sure that there is about 5 mm gap between adjoining sheets and 2 to 3 mm at

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either end. These gaps are for expansion and any movement of the tramcar and are covered with a cover strip.

As mentioned earlier, slatted linings are started from the centre slat. Therefore install this centre slat along the entire length of the body. Next inspect all of the slats that you have and measure their width. The reason for knowing their widths is to install the same width slat along the entire length of the body. Any variation in widths if not checked and allowed for will be very visible when you look down the length of the tramcar. It is seen as the slats being out of alignment and this spoils the finish of the appearance of the ceiling. All of the slats are nailed into place by the hidden nailing method. Ensure that the slats have been pushed or clamped together as tight as possible as they have a tendency to shrink as they age. An important point to remember is to varnish the backside of the veneer and primer the backside of the other linings before they are installed. This sealing of the non visible side will extend the life of the lining as it will not allow condensation or water to penetrate.

- c. After the lining has been installed finish painting or varnishing it before you proceed further. The Masonite lining as with the other linings will need to be lightly sanded before painting.
- d. Now furnish all mouldings and cover strips. Paint or varnish them to their finished state.
- e. Reinstall all mouldings and cover strips to their correct positions. Making sure that when the screws are used that the slots are in line with the grain of the timber.
- f. Replacing all of the fittings, handrails, advertising racks and any other miscellaneous items. Make sure that the lighting circuits are in working order by having an electrician who is experienced in tramcar wiring to do the job.
- g. After installing all of the fittings, mouldings, etc. inspect the finish of the painted surfaces and check for any abrasions or scratches. Repair the same if any found.

## **22 General Body Repairs**

### **22.1 General**

Body repairs are probably the most time consuming part of any restoration or repair work that is undertaken at the Museum. As most of the STM tramcars are built in the main or in the most part of timber, the skills of a coach builder are required. Coach building is now a dying art, it is not just carpentry. As building or repairing timber framed vehicles must be done with extreme care as you do not use spirit levels to obtain a straight and square finished body. You must use the method as outlined in the Initial Inspection section which uses diagonal timbers and string lines to obtain a square body.

In the main the Museum has employed a coach builder to do the restoration of the most badly damaged bodies. The minor body repairs can be done by the Museum's workforce. These minor repairs can be quite major in scope. For the amount of work involved in the repair of internal linings, mouldings, etc. and the external panels has in the past taken 2 to 3 years to restore a single tramcar body. Therefore we will look at the minor body type repairs.

As mentioned above the minor repairs will possibly include the following:

- Internal and External Moulding Replacement or Repair
- Internal and External Handrails Replacement or Repair
- Window Replacement
- Replacement of Canvas Doors and Blinds
- Door repairs
- Door Runnier Repairs
- Internal Bulkhead Repairs
- Seat Repairs or Rebuilds
- Bumper Bar Repairs
- Coupler Repairs
- Driver Cab Apron Repairs
- External Side Sheeting Repairs
- Destination and Route Number Boxes Repairs
- Floor Renewal
- Footboard Replacement
- Floor and Footboard Slat Replacement;
- And may other minor items.

All the items listed above, in themselves are all minor repairs but if they are to be performed on one tramcar at the one time, they soon make it a major project.

To talk about the actual art of replacing or refurbishing would take quite a large book to explain all of the methods and procedures. It is very easy to say "however the part was made and fitted in the first place is how it must be done, now". Thus saying may be laughed at but as we are trying to preserve the past, we therefore should and must try to copy exactly what was done in the past. Therefore if the part was installed with the mortice and tenon joint, it must be reinstalled with a mortice and tenon joint and not use modern steel jointing strips or other practices. The same goes for how timber grains were laid; the normal way was that the grain was in line with the length of the timber. On some parts the grain has been found across the timber but these parts are usually only for finish not for strength.

### **22.2 Timber Installation**

When you are installing replacement timber into the body of a tramcar, the grain of the replacement timber must be in the same direction as the same timber component in the rest of the tramcar. The replacement timber also must be installed the same way as the original, for if modern timber working techniques are used you will be destroyed the historical accuracy of the body. Therefore if

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the original timber was morticed and tenoned, with wooded dowels locking into position you must copy the same method as close as possible.

As you will be using wood screws to secure the timber in place, the slot of the screw head must be in line with the grain. After the timber work is installed and the vehicle is finished, the finish looks more pleasing to the eye if all of the slots are in one direction and in line with the grain. The same goes when installing the slats on the floors and footboards.

### **22.3 Glazing**

A note on glazing used on Sydney tramcars. The glass used in the Sydney tramcars was installed into its position without the aid of glazing putty. Timber frame windows and bulkhead glass is held in place in a rebated frame with a quad type beading nailed or screwed into the open side of the frame, thereby locking the glass in place. Some of the windows, particularly, on the saloon type Sydney tramcars, are held in place in a metal frame on the bottom side of the glass with a felt insert.

On some of the other system tramcars at the museum have the glass held in place with a rubber seal. When installing these seals an allowance in the size of the glass and the opening in which it is to be fitted for the wall thickness of the rubber. To install the glass, first put the rubber seal around the glass. Then use a thin cord and wrap that around the seal in the outer groove. After this, insert one edge of the glass/seal combination in the frame and gently push the glass towards the frame. Next slowly pull the cord through the opening from the entered edge. First work one edge then the other until the rubber and the glass is full in the opening.

### **22.4 Signs, Lettering and Lining**

At the present time the Museum has copies of most of the signs that were in use on the tramcars in Sydney. For the other systems the Museum is not so fortunate. So when working on a tramcar, no matter where it comes from, when you find a sign, photograph it and copy it by tracing its outlines. Also obtain colour samples if possible. The same goes for any lettering and lining. All of these ornamentations and notices add to the historical records of the years of service that the tramcars performed during their job.

As discussed in the *Paint Removing Section*, use paint stripper very carefully to remove layers of paint to obtain a clear view of the detail that is being revealed. Another important detail is to record exactly where the sign, the lettering or the lining was located on the tramcar. In measuring the location also measure the detail itself.

Body detailing was originally painted, and then some of the detail was applied by gold leaf method and picked out with paint. Finally decals or transfers were used as they saved time on the job as they were manufactured off site. There are even some body details that were cast, then painted and installed in the bodies. These types of signs are the most “long lasting” of all signs.

To reapply these types of details, you will need a copy of the original application method. If painting the detail, please read the *Painting Section*.

### **22.5 Doors**

We have in our collection many types of doors fitted to the tramcars. They are in the main canvas concertina, canvas blind type, sliding timber door and bi-folding timber door. To talk about how to repair a timber door all that needs to be said is that a copy of the original door in its construction following the type of joins must be used.

Canvas concertina and blind type doors are probably an easy but expensive item to repair as the Museum can go to a commercial supplier with samples and let them manufacture these components. When required the canvas doors can be refitted in the original style. That is using vertical steel bars on an upper runner to support and to attach the concertina canvas to form the door. The canvas blind is very similar to a Holland blind to install.

The main problem with doors is that different members have been well meaning in the past and started to repair a door. After they have fitted say a new canvas they leave out the rivets that stop the canvas sliding down the steel bars. Another problem is that the member doing the job does not check the condition of the door rollers and as these parts have already seen many years of use, they

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are worn. Being worn they do not roll properly or do not roll at all and they need to be renewed. If a little extra care was taken and the rollers were inspected, they can be replaced. As many rollers can be made from a piece of 100 mm brass bar. They have a slight reduction in the diameter in the middle of the rolling surface and a hole drilled through the longitudinal centre for the axle, usually a split pin. Possibly the member fitting the door does not have the knowledge to manufacture these items but if discussions were held with the maintenance staff the parts could be made by someone else.

### **22.6 Handrails**

As you are well aware that the first item on a tramcar you reach for is a handrail when either getting on or off. Therefore it is important to inspect the timber or metal work that the handrail is attached to make sure that it is in good condition. If the handrail is loose or does not feel firm, remove it and inspect the condition of the mounting screws and bolts. Hidden corrosion can be the cause of a handrail not feeling firm or slightly loose, therefore the screws and bolts will need to be replaced. Some damage may have been done to the mounting timber or metal work and will need to be repaired. Any corrosion from the screws or bolts must be removed and the mounting point thoroughly cleaned. Remaining corrosion particles can be neutralised (see *Preparation of Metal Surfaces section*) with rust converter, for if left behind they will soon cause the replacement to corrode.

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## 23 Replacement Woods For Body Repairs

The type of wood that were used in the manufacture of the tramcars are in the main still available today. They may not have the same length of seasoning as the woods of seventy years ago, as today's woods are now kiln dried. Woods of yesteryear were left to season for long periods until the saw miller was happy with the seasoning. Then the saw miller cuts the wood into useable sizes for the coach builder to finish to size and install. Kiln dried woods are better left, if possible, for two to three months before final finishing and use as they are still seasoning. The only wood that is very difficult to obtain is the "Red Cedar" that was almost completely cut out of Eastern Australia before the Second World War. It is only available today in small pieces that come from the re-use of second hand timber and it is very expensive, therefore another wood of similar colour and grain should be substituted.

Seasoned timber must be used whether it is by air/time or by kiln drying. Cried timber hopefully will not shrink, twist or warp after it has been cut and fitted to the tramcar body. Other selections points to consider are the straightness of the grain; the grain runs along the timber NOT across or diagonal, and the presences of knots as they weaken the timber.

In the archives of the Museum we have lists of what types of woods that were used in the building of the Sydney Tramcars and following is a short list of the type of woods and their uses.

Blackwood	- Motor Cut-out Switch base, Internal Bulkhead Rails (Top, Immediate and Bottom), Bulkhead Ceiling Moulding, Driver's Door.
Dregon	- Destination Rollers, Roof Bowrails, Roof Landing Rails, Cant rail, Floor Boards, Foot Boards.
Softwood	- Main Reservoir Packing Piece, Base for Governor, Fuse Block, Base for Compressor Terminal Block.
Hardwood	- Packing Blocks, Motor Lead Cleats, Trolley Bridge or Pantograph Board, Motor Cut-Out Switch Drum, Life Guard Gate Batterns, Life Guard Shield Batterns.
Maple	- Door Stiffeners (Canvas), Bulkhead Panels, Bulkhead Ceiling Mouldings, Driver's Windows, Axle Box Dust Guards.
Kaun	- Terminal Blades.
Queensland Maple	- Destination Box
Pine	- Destination Box, Roof Cable Trough, Roof Boards, Floor Batterns, Ceiling Boards.
Redwood	- Seat Slats.
Spotted Gum	- Roof Canopy, Guard Moulding.
Ash	- Driver's Window Sills.
Hoop Pine	- Floor Hatches, Floor Bearers.

When making new footboards, it is important to put stitch bolts across the board to hold it together strength wise and to help keep it straight, not warped.

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## 24 Hardware For Body Repairs

Following are some charts as to what screws, bolts and nails that are commonly used on tramcars. It is important to remember where brass screws are to be used for securing panels, etc. and where steel screws are to be used for strength.

Remember what type of screw head you need to use and stay away from Phillips and other modern headed fasteners as they are not to be used in the tramcar bodies as they are too modern a design. The main types used in the tramcar bodies are the Countersunk Head, Round Head, Raised – Countersunk Head and Cheese Head. There are both wood and machine screws used on tramcars; the machine screws are mainly used on the electrical and mechanical side.

### COMMONLY USED WOOD SCREWS

Available in Brass or Steel

Length	Diameter							
	51 mm (2")	102 mm (4")	152 mm (6")	203 mm (8")	254 mm (10")	305 mm (12")	356 mm (14")	406 mm (16")
13 mm (½ inch)	✓	✓						
19 mm (¾ inch)	✓	✓	✓	✓				
25 mm (1 inch)		✓	✓	✓	✓	✓		
32 mm (1-¼ inch)			✓	✓	✓	✓		
38 mm (1-½ inch)			✓	✓	✓	✓	✓	✓
44 mm (1-¾ inch)				✓	✓	✓	✓	
51 mm (2 inch)				✓	✓	✓	✓	✓
64 mm (2-½ inch)					✓	✓	✓	✓
76 mm (3 inch)						✓	✓	✓
89 mm (3-½ inch)							✓	✓

### TWIST DRILLS USED WITH WOOD SCREW

Gauge of Screw	Clearance Hole		Pilot Hole Hardwoods		Pilot Hole Softwoods		Countersink No.
	Inch	MM	Inch	MM	Inch	MM	
2	3/32	2.38	3/64	1.49	1/32	0.8	3
4	1/8	3.175	1/16	1.59	3/64	1.49	4
6	5/32	3.96	3/32	2.38	1/16	1.59	5
8	11/65	4.37	7/64	2.78	5/64	1.98	6
10	13/64	5.16	1/8	3.175	3/32	2.38	6
12	15/64	5.96	5/32	3.96	7/64	2.78	7
14	17.64	6.75	3/16	4.76	7/64	2.78	8
16	9/32	7.14	13/64	5.16	9/64	3.57	9

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The following table shows the commonly used sizes of machine screws, cheese head screws, cup head bolts, black (which can be galvanised) bolts and screws. In the table below the sizes shown are in both imperial and metric measurements.

Length	Diameter											
	3.2 mm ( $\frac{1}{8}$ " )	4.0 mm ( $\frac{5}{32}$ " )	4.8 mm ( $\frac{3}{16}$ " )	6.4 mm ( $\frac{1}{4}$ " )	7.9 mm ( $\frac{5}{16}$ " )	9.5 mm ( $\frac{3}{8}$ " )	11.1 mm ( $\frac{7}{16}$ " )	13 mm ( $\frac{1}{2}$ " )	15.9mm ( $\frac{5}{8}$ " )	19 mm ( $\frac{3}{4}$ " )	22.2 mm ( $\frac{7}{8}$ " )	25mm (1" )
13 mm ( $\frac{1}{2}$ " )	✓	✓	✓	✓	✓	✓						
16 mm ( $\frac{5}{8}$ " )	✓	✓	✓	✓	✓	✓						
19 mm ( $\frac{3}{4}$ " )	✓	✓	✓	✓	✓	✓						
25 mm (1 inch)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
32 mm (1- $\frac{1}{4}$ " )	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
38 mm (1- $\frac{1}{2}$ " )	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
44 mm (1- $\frac{3}{4}$ " )	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
51 mm (2 inch)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
64 mm (2- $\frac{1}{2}$ " )				✓	✓	✓	✓	✓	✓	✓	✓	✓
76 mm (3 inch)				✓	✓	✓	✓	✓	✓	✓	✓	✓
89 mm (3- $\frac{1}{2}$ " )				✓	✓	✓	✓	✓	✓	✓	✓	✓
102 mm (4 inch)				✓	✓	✓	✓	✓	✓	✓	✓	✓
114 mm (4- $\frac{1}{2}$ " )						✓	✓	✓	✓	✓	✓	✓
127 mm (5 inch)						✓	✓	✓	✓	✓	✓	✓
145 mm (5- $\frac{1}{2}$ " )						✓	✓	✓	✓	✓	✓	✓
152 mm (6 inch)						✓	✓	✓	✓	✓	✓	✓
178 mm (7 inch)								✓	✓	✓	✓	✓
203 mm (8 inch)								✓	✓	✓	✓	✓
229 mm (9 inch)								✓	✓	✓	✓	✓
254 mm (10" )								✓	✓	✓	✓	✓
305 mm (12" )									✓	✓	✓	✓

## **25 Appendix A – Tramcar Inspection Schedules**

The various scheduled documents are:

STM6088 – Body Maintenance Schedule

STM6089 – Controller Inspection Schedule

STM6090 – Mechanical Maintenance Schedule

STM6099 – Electrical Maintenance Schedule

STM6100 – PCC Car Inspection Schedule.

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## 27 Appendix B – DRTT NSW NOTES

The following is a copy of the instructions issued by the Tramways to their depots on maintenance and some safe working procedures. It is included as a historical interest reference.

### DEPARTMENT OF ROAD TRANSPORT AND TRAMWAYS N.S.W.

(21<sup>st</sup> July 1933)

#### Engineer for Workshops and Rolling Stock

#### ELECTRIC TRAM CAR MAINTENANCE AT CAR SHEDS

1933

#### PREFACE

##### Item A

1. THE SAFETY OF THE PUBLIC. The safety of the public shall be the first and most important duty of every employee.
2. VEHICLES CONCERNED. The vehicles concerned are all the Electric Motor Passenger, Service, and Trail, Tram Cars at all the Electric Tram Car Sheds of Sydney and Suburbs.
3. AVOIDANCE OF ELECTRIC SHOCKS< OR OTHER ACCIDENTS. Special care is to be exercised to avoid all forms of accidents.
4. DEFECTIVE APPLIANCES. Employees are to report at once to the Sub-Foreman, or employee in charge, any defective tools, or other working equipment, discovered while carrying out their duties.
5. INSTRUCTIONS FROM ONE EMPLOYEE TO ANOTHER. Employees, especially when working in conjunction, are to see that any instruction given from one to another is clearly heard and understood.
6. DEADENING OF ELECTRICAL CIRCUITS. In order to avoid possibility of electric shocks each employee before handling any electrical equipment must satisfy himself that the electrical circuit has been deadened by the opening of the switch, or switches, concerned. No employee is allowed to touch any portion of the electrical equipment of a tramcar until he has received instructions concerning the deadening of the electrical circuits from an authorised person. (Altered instructions may be necessary with each new type of tramcar or equipment.)
7. “KEEP POLE DOWN-DON’T MOVE CAR” TABLETS. These are to be attached to each trolley cord of single or coupled set of cars on which an employee may be working, at a point about midway between the lower edge of the car canopy and this sill/plate of the driver’s protection.

They are to be used in the case of all work of such a nature that unexpected livening of the electrical circuits, or movement of the tram, may be a source of danger to employees working on top of, in, or under, a car.

Four (4) tablets are to be included with the kit of tools and equipment signed for by each employee working or acting in the following grades, (The records indicating this are to be kept in the foolscap book provided): - Lead Fitter, Fitter, Car Builder, Standby Pitman, Pitman, Controller man, Leading Cleaner, Car Washer, Car Fittings Cleaner.

The tablets are to be lettered “LF”, “F”, “CB”, “SP”, “P”, “LC”, “CW”, “CF”, to indicate the grade of employee to whom they have been issued, and numbered for identification purposes.

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Four (4) tablets are to be kept in the Sub-Foreman's office labelled "O" for use of the Sub-Foreman, Sub-Inspectors and the Night Supervisor.

8. "DO NOT TOUCH SWITCH" TABLETS. These are to be attached to the handles of switches to avoid the possibility of their being operated unexpectedly. They may be used in the case of any switch on a car or in a car shed as occasion may arise.

There are NOT to be used in lieu of "Keep pole down-don't move car" tablets, but are to be used as an additional precaution in cases such as the testing of the operation of control circuit on multiple unit cars when the trolley pole **or pantograph** is required to be on the overhead wire with the main switch or switches of the single car or coupled set of cars in the "OFF" position.

Two (2) tablets are to be included in the kit of tools and equipment signed for by each employee working or acting in the following grades, (The records indicating this are to be kept in the foolscap book provided): - Lead Fitter, Fitter, Standby Pitman, Pitman, Controller man.

The tablets are to be lettered "LF", "F", "SP", "P", "CF", to indicate the grade of employee to whom they have been issued, and numbered for identification purposes.

Four (2) tablets are to be kept in the Sub-Foreman's office labelled "O" for use of the Sub-Foreman, Sub-Inspectors and the Night Supervisor.

9. "TRAM NOT TO BE MOVED" STAFFS. These staffs are to be hooked on an upright position by means of the attachment provided, on the buffer beam at the end of the tram concerned which is nearer to the front entrance of the depot. One staff only per tram is to be used.

The object of the staff is to obviate the necessity for employees working in the pit to climb out of such pit in all cases to attach the "Keep pole down-don't move car" tablets. Such tablets, however, are still to be used in all cases in which it is necessary for the poles to be kept down for any particular reason; including the possibility of electric shock should an employee be working on equipment which might be rendered alive unexpectedly.

It is important that great care is taken to use the staffs in all cases in which trams could be moved unexpectedly. They must thus be used in all cases of trams stabled at clear ends of roads or adjacent to vacant spaces of rails. There is, however, no compulsion to use the staffs on trams which are stabled in such a way that owing to the close presence of the other cars or stops there would be no likelihood of their movement.

One (1) tablet is to be included in the kit of tools and equipment signed for by each employee working or acting in the following grades, (The records indicating this are to be kept in the foolscap book provided): - Standby Pitman, Pitman.

The tablets are to be lettered "SP", "P", to indicate the grade of employee to whom they have been issued, and numbered for identification purposes.

One (1) staff is to be kept in the Sub-Foreman's office labelled "O" for use of the Sub-Foreman, Sub-Inspectors and the Night Supervisor.

10. REMOVAL OR "KEEP POLE DOWN-DON'T MOVE CAR" and "TRAM NOT TO BE MOVED" STAFFS. The removal of each of these tablets and staffs is to be performed only by the person, for whose protection the tablets or staffs have been placed in position, excepting in cases in which he specifically directs another person remove them on his behalf.

Should a case occur in which a tablet or staff has apparently been inadvertently left in position, it is to be respected and is to remain in position until the case has been referred to the officer, or employee, in charge of the shed, and he, after investigation, having proved that the tablet or staff is not required may authorise its removal.

11. PLACING OF TROLLEY WHEELS **OR PANTOGRAPH** IN CONTACT WITH AND WITHDRAWING THEM FROM THE OVERHEAD WIRE. Before placing any trolley

## SYDNEY TRAMWAY MUSEUM

wheel or pantograph in contact with the overhead wire, the employee concerned must satisfy himself that there are no “Keep pole down-don’t move car” tablet in position. He is then to call out in a loud “All clear Car No. .... Road No. ...”. In each case after calling, and before taking action, he is to listen for five (5) seconds for a reply, if any. In all cases the trolley pole or pantograph is to be operated by means of the cord, as otherwise should make personal contact with the trolley pole or pantograph directly, he may receive an electric shock.

12. **PREPARING TO MOVE A TRAM UNDER POWER.** Only employees whose names appear on the authorised list are allowed to drive cars at car sheds. Before preparing any tram for moving under power the employee concerned must satisfy himself that it is permissible to move such tram as indicated by the absence of “KEEP POLE DOWN-DON’T MOVE CAR” tablets, “DO NOT TOUCH SWITCH” tablets, and “TRAM NOT TO BE MOVED” staffs. In addition he is, by observation, to satisfy himself that no employee are working on top, in, or under the tram; that all parts of the equipment which may affect the driving or safe moving of the car are intact and properly secured; and that the tram is clear of pit jacks and not fouling any other car or object.  
  
Before placing the pole, or poles, on the overhead wire, and again before actually moving the tram the employee concerned is to call out in a loud voice “All clear Car No. ... Road No. “. In each case after calling, and before taking action, he is to listen for five (5) seconds for a reply, if any.
13. **AVOIDANCE OF CONTACT WITH OVERHEAD WIRE.** Employees who are called upon to work on the roofs of cars are to avoid the possibility of electric shock by seeing that they do not make personal contact with the overhead wire either directly or indirectly connected to it by another trolley pole or other means. Great care is to be exercised to avoid electric shock due to completing a circuit by indirect means, as in such cases the danger may not be immediately obvious. A case in point to be avoided would be the making of personal contact between trolley poles of adjacent cars, when another pole of one of the cars may be in electrical contact with the overhead wire either directly or indirectly.
14. **WANDERING ELECTRICAL LEADS.** Wandering electrical leads for operating lights must not be connected in tramcar circuits, in shed lighting circuits, or in any other than those specially provided for pit lighting purposes.
15. **RUBBER GLOVES.** Whilst rubber gloves are furnished as an additional protection against electric shock, employees should not in any case regard their use as a reason for not carrying out to the fullest extent the instructions issued regarding the precautions to be observed in the handling of electrical equipment. It must be recognised that, from their nature, the protection given by rubber gloves may be rendered more or less unreliable owing to damage as a consequence of misuse carelessness which the Department is powerless to prevent.
16. **GOGGLES.** In cases in which work is being performed by an employee which involves the risk of injury to his eyesight by flying fragments, application is to be made to the Sub-Foreman, or the Leading Fitter, for a pair of goggles to protect the eyes. (When the goggles are not in use they are to be kept in the Sub-Foreman’s office).
17. **LEATHER GLOVES FOR HANDLING GLASS.** Leather gloves are to be used by employees when they have occasion to handle sheets of glass either intact broken, or cracked. The gloves are to be part of each car builder’s kit.
18. **LEATHER GLOVES FOR HANDLING BRAKE SHOES.** Leather gloves are to be used by employees when loading, unloading, collecting and stacking brake shoes either new or worn.
19. **CARS IN THE CUSTODY OF THE TRAFFIC BRANCH.** Cars in the custody of the Traffic Branch and placed away from the pits due to their equipment having been called into question, or for any other reason, are on no account to be interfered with by Car Shed staff.

## SYDNEY TRAMWAY MUSEUM

Such cars are to be indicated by the Traffic Branch by the display “Keep Off. Don’t Interfere with Car” Boards.

20. EQUIPMENT TO BE KEPT STANDARD. There is to be no alteration of equipment, or fitting of experimental equipment, without special approval.
21. EQUIPMENT UNDER TEST. Failures of equipment under test are to be brought under the notice of the Sub-Foreman, or his authorised representative, without delay.
22. REMOVAL OF CARS FROM “STOPPED LIST”. The following staff only are authorised to remove cars from the “Stoped List”: -
  - Day Shift      The Sub-Foreman concerned, or during his absence from the depot, the Leading Fitter, or an Electrical Sub-Inspector.
  - Standby Shift      The Standby Pitman concerned as regarding Pitman’s, Controllerman’s and Cleaner work.
  - Night Shift      The Night Supervisor concerned.
23. ECONOMY IN LIGHTING AND POWER. In view of the necessity for economy, tramcar lights and compressors are not to be left “ON” unnecessarily.
24. TRAMCARS TO BE KEPT FREE OF MISPLACED MATTER. Employees who attend to trolley gear are to be held responsible for the removal, from the roofs of tramcars, of loose pieces of equipment, such as trolley wheels, washers, waste and other foreign objects. Employees who attend to other portions of the tramcar equipment are similarly held responsible for the removal of foreign objects.
25. JUMPING ACROSS PITS is prohibited.
26. ELECTRICAL SUB-INSPECTIONS. The Electrical Sub-Inspectors are officially authorised to take charge of any car shed and car shed staff, in the absence of the Sub-Foreman.
27. CO-OPERATION WITH MEMBERS OF THE POLICE FORCE. Employees must at all times extend full and immediate co-operation to members of the Police Force in the course of the carrying out of their duties and upon their request.
28. RESTRICTION ON THE MAKING OF STATEMENTS. Employees, except by special approval, must not furnish statements, either written or otherwise, regarding Tramway Breakdowns, Accidents, or other Departmental matters, to any person not connected with the Department. Any person not connected with the Department, other than members of the Police force, who may request information concerning accidents, is to be referred to the Claims Office, at the Head Office. Full information is to be given to members of the Police Force immediately upon their request.

# SYDNEY TRAMWAY MUSEUM

DEPARTMENT OF ROAD TRANSPORT AND TRAMWAYS N.S.W.

(24th July 1933)

## ELECTRIC TRAM CAR MAINTENANCE AT CAR SHEDS

### GENERAL PROVISIONS

#### Item B

1. Each individual part and each assembly of parts, of each car and the equipment, must fulfil the requirements: -
  - a. PROPER DIMENSIONS;
  - b. PROPER POSITION;
  - c. PROPER ATTACHMENT;
  - d. PROPER ADJUSTMENT;
  - e. PROPER CONDITION;
  - f. PROPER COMPLETENESS;
  - g. PROPER LUBRICATION (In case of working parts); and
  - h. PROPER OPERATION.
2. The standards are to be those as observed in the case of parts normally installed by Randwick Workshops, except where departure from the normal standards has been authorised by the Engineer for Workshops and Rolling Stock.
3. Compliance with the above requirements will ensure incidentally that: -
  - a. Each part is free of undue wear, bedding, distortion, fracture, tear or other damage;
  - b. Each part is free of foreign matter which might restrict proper operation, which might be unsightly to passengers or a source of possible damage to their clothing or that of employees in traffic;
  - c. Nuts are screwed home securely without undue straining of bolts or studs;
  - d. Spring washers are in all required positions and pressed flat;
  - e. Split pins are in all required positions with the neck of the pin close to the entering end of the hole occupied, and with each leg bent close to the leaving end of such at an angle of at least 45°, so that the angle between the legs is at least 90°;
  - f. The whole of the thread of each nut and lock nut, if any, is engaged by the male thread concerned; and
  - g. Electrical equipment is free of foreign matter which might prevent proper contact or reduce proper insulation.
4. THE GENERAL PROVISIONS ARE AMPLIFIED BY THE PARTICULAR PROVISIONS TO BE COVERED BY THE PERSONAL INSTRUCTION TO STAFF, AND IT IS TO BE UNDERSTOOD CLEARLY THAT COMPLIANCE WITH SUCH PARTICULAR PROVISIONS DOES NOT SECURE EXEMPTION FROM THE GENERAL PROVISIONS.

## SYDNEY TRAMWAY MUSEUM

### 28 Appendix C – Trolley Rope Lengths

The trolley ropes used on all the tramcars at the Museum is a standard cotton sashcord in **XXXX** in size. When renewing the rope the following steps should be followed:

- a) Renew the rope when worn or unduly dirty;
- b) Ensure that the upper knot or end fastener is in accordance with the following diagram;
- c) Ensure that the lower knot or end fastener is in accordance with the following diagram;
- d) The overall length of the rope is in accordance with the following table before the upper and lower terminators are made;
- e) Serviceable lengths (not less than 4.75 metres) of trolley rope broken in service are to be used to make fresh complete lengths by joining, provided that the joint is not outside the canopy of the tramcar when the cord is fully extended; and
- f) All Sydney tramcars are to be fitted with wax impregnated trolley ropes.

Tramcar Type	Length
Sydney 'C' Class	6.25 m (20' 6")
Sydney 'D' Class & Scrubber 134s	6.17 m (20' 3")
Sydney 'E' & 'K' Class & Scrubber 11W	5.64 m (18' 6")
Sydney 'F' & 'N' Class	6.17 m (20' 3")
Sydney 'J' Class	5.64 m (18' 6")
Sydney 'L/P' Class	6.17 m (20' 3")
Sydney 'O' & 'O/P' Class	6.17 m (20' 3")
Sydney 'P' & 'PR1' Class	6.17 m (20' 3")
Sydney 'R' 'R/R1' & 'R1' Class	6.40 m (21' 0")
Sydney Prison Tram Class	5.64 m (18' 6")
Sydney Ballast Motor 'U2' & 'U4' Class	8.53 m (28' 0")
Sydney Water Sprinkler 'W' Class	5.79 m (19' 0")
Sydney Freight Tramcar 24s	
Brisbane Tramcar 71	
Brisbane Centre Isle Tramcar 180	
Brisbane Drop Centre Tramcar 295	
Brisbane FM Tramcar 548	
Melbourne 'W2' Class	
Melbourne 'W7' Class	
Melbourne 'Z2' Class	
Adelaide 'H' Tramcars	
PCC 1014	
Nagasaki tram 1054	
Ballarat 12	5.49 m (18' 0")
Ballarat 37	5.49 m (18' 0")
Hobart Double Deck 20	
Peter Witt Tramcar	

## SYDNEY TRAMWAY MUSEUM

### 29 Appendix D – Tramcar Equipment Listing

	Equipment	Frequency of Attention	Points for Special Attention	Special Tools of Appurtenances to be used
1	Trolley Wheel – Oil & Grease lubrication type	Intermediate Inspection Intermediate Inspection  Intermediate Inspection Intermediate Inspection  Intermediate Inspection  As occasion demands	a) Renew wheels flatted in groove  b) Renew wheels worn in groove to condemning diameter. 100 mm (4") wheels gauge size 68mm (2-11/16"). 152 mm (6") wheels gauge size 98 mm (3-7/8").  c) Renew wheels unevenly worn in groove  d) Renew wheels unduly worn in bore. (Determined by wobbling the wheel).  e) Refill with standard trolley wheel lubricant until old lubricant is seen to just ooze from the bore of the wheel. (Spindle in position).  f) Insertion of fresh wheel. See that the axle of spindle is horizontal by test rod method.	Lubricant gun with special steel nozzle,  356 mm (14") length of 12 mm (1/2") round planished steel.
2	Trolley Wheel – Graphite lubrication type, no oil or grease.	Intermediate Inspection  Intermediate Inspection  Intermediate Inspection Intermediate Inspection  When renewing the trolley wheel. When renewing the trolley wheel  As occasion demands	a) Renew wheels flatted in groove.  b) Renew wheels worn in groove to condemning diameter. 100 mm (4") wheels gauge size 68mm (2-11/16"). 152 mm (6") wheels gauge size 98 mm (3-7/8").  c) Renew wheels unevenly worn in groove  d) Renew wheels unduly worn in bore. (Determined by wobbling the wheel).  e) See that the wheel is in the vertical plane by sighting method.  f) See that the springs are 27 mm (1-1/16") in length when free and graphic plugs not less than 19 mm (3/4") in length.  g) Remove the wheel from the harp to examine the plugs, spring, spindle and contact washers. Renew the plugs worn to 12 mm (1/2") in length. See that the springs are 27 mm (1-1/16") long when free. Clean contact washers and renew if revolving.	
3	Trolley wheel spindles (Oil & grease lubrication type).	When renewing the trolley wheel	a) Renew if unduly worn, pitted, or brass coated.	
4	Trolley wheel spindles (Graphite lubrication type. No oil or grease).	As occasion demands	a) Renew if unduly worn, pitted, or brass coated	

## SYDNEY TRAMWAY MUSEUM

5	Trolley Harps (Oil & grease lubrication type).	Intermediate Inspection	a) See that contact springs are bearing uniformly all round against contact washers and pressing these washers uniformly against the slides of trolley wheels.	
6	Trolley Harps and all special fittings. (Graphite lubrication type. No oil or grease).	Intermediate Inspection  When renewing wheels	a) See that bolts, nuts, and all other fittings are of the special type standard for this equipment. b) See that contact springs are firmly secured to the harps and that they are adjusted to ensure even tension. (Renewing of contact springs, except in the case of "E" type cars or other special cases, normally to be with pole in position on the tramcar.	Riveting anvil to sketch No. C.1.
7	Trolley Poles.	Intermediate Inspection  Intermediate Inspection  When renewing wheels	a) See that the poles are straight for a slight camber due to trolley base spring tension. In all cases it is necessary to adjust the poles so that the wheel will be exact alignment with the trolley base pedestal pin. b) Examine to see if painting is required. (Wollins black paint solution). c) See that tinning at end or ends is present and cleaned.	Jim Crowe
8	Trolley Bases. (Plain & roller bearing types)	Intermediate Inspection  Intermediate Inspection Intermediate Inspection Intermediate Inspection Intermediate Inspection  Intermediate Inspection  Intermediate Inspection Intermediate Inspection	a) Lubricate pedestal pin and pole socket axle pin with a few drops of oil. b) Rotate base on pedestal pin & eliminate stiffness if any. c) See that the trolley pole clamping bolts are tight. d) See that the trolley lead terminal clamp is tight. e) See that there are no fractures or loose or broken rivets in tension bands. f) Retrieving bases to be tested for retrieving action. Normally no need to measure exact height of retrieving and holding down, and normally adjustment should not be altered; however, measurements are to be made by means of marked batten with lower end on weather rail. The base should retrieve with the centre of the wheel at 6.26 metres (20'6") above the rail level and hold down at 508 mm 5.2 metres (17'). g) Clean all porcelain insulators. h) Check the spring tension. Pole to hold 11 kg (25 lb) weight suspended from wheel with centre of wheel between a height of 432mm (17") to 508 mm (20 ") from the rail level.	Oil as used for compressors.             Footboard batten suitable marked at the Car Sheds.
9	Trolley Hooks	Intermediate	a) Misshapen hooks to be removed	

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		Inspection Intermediate Inspection	from the car roofs for re-shaping. b) Clean all porcelain insulators.	
10	Trolley Cords.	Intermediate Inspection Intermediate Inspection  Intermediate Inspection  When renewing or joining cords.	a) Renew cords unduly dirty or worn.  b) See that upper knot and end fastener are in accordance with sketch C.2.  c) See that lower knot and end fastener are in accordance with sketch C.2.  c) The overall lengths before the typing of upper and lower knots to be in accordance with the following standards:  <b><u>With Windscreen Wipers</u></b> E & K .....5.64 metres (18' 6") N .....6.2 metres (20' 3") L/P .....6.2 metres (20' 3") O & O/P .....6.2 metres (20' 3") P .....6.2 metres (20' 3") R & R1 .....5.4 metres (21' 0") S (Breakdown Cars)...6.2ms (20' 3") S (Prison Tram) ..5.64 metres (18' 6")  <b><u>Without Windscreen Wipers</u></b>  U (Ballast truck with trolley base at end).....8.5 metres (28'0") W (Water Sprinkler) 5.8 ms (19' 0")  e) Serviceable lengths (not less than 4.72 metres (15'6")) of trolley cords broken in service are to be used to make fresh complete lengths by jointing, providing the joint is not outside the canopy of the tramcar when the cord is fully extended.	
		When renewing or joining cords		