MATA Training & Fixed Guideway Safety Training Workshop

Part A, Task 3 MATA Trolley Driving Guide

TranSystems

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1. INTRODUCTION

1.1 CONTROLLER FLASHOVER INVESTIGATION

In December of 2008, a report into the cause of controller flashovers on MATA trolleys had the following conclusion:

"The reason for controller flashovers is non-compliance to manufacturer's manuals and specifications and established industry practice and standards.

The solution is to comply."

The subsequent corrective actions detailed training for operations and maintenance personnel. This guide is the operations-training component.

1.2 SYSTEMS & COMPONENTS

Key components and system information of the control system is covered. The information is a guide and should only be actioned in the correct safe working environment with competent personnel. The information provided does not purport to cover all aspects of control systems as operated by MATA.

1.3 TRAINING CURRICULUM, SCHEDULE & MATERIALS

Training on controllers and trolley operation consists of a five-hour class, broken into two hours of theory in a classroom, two hours of practical on a car and a one-hour exam. Operational Management and other officers are participating as necessary and will have additional assistance to establish an ongoing train the trainer status.

Training materials are a printed Driving Guide, Power Point instruction and a multiple choice written exam.

1.4 CONSULTANT

Lead investigator of the controller flashovers and workshop class presenter is TranSystems Streetcar Specialist, Timothy R. Borchers who has a 31-year history in the heritage streetcar/trolley/tramway industry in both disciplines of maintenance and operations, inclusive of 12 years system management.

2. TROLLEY INFORMATION

2.1 ELECTRIC TROLLEY TYPES

2.1.1 MELBOURNE

All Melbourne cars have two trucks or are “double truck” cars and are powered by four motors (two motors per truck).

There are two exceptions - former Rio de Janeiro open car 1794 and Gomaco replica double truck “Birney” car 453. Although having different body styles, these car’s control systems and trucks are the same as the Melbourne cars.

2.1.2 OPORTO

All Oporto cars have one truck or are “single truck” cars and are powered by two motors.

There is one exception - Gomaco replica car 1979. It has a similar body style to an Oporto car, is single trucked with two motors, and its control system uses the same components as the Melbourne cars.

2.2 IMPORTANT ITEMS OF ELECTRIC TROLLEY EQUIPMENT

The important items of electric trolley equipment are:

A. Pantograph.
B. Lightning arrester and choke coil.
C. Line breaker with combined line breaker switch and fuse.
D. Controllers.
E. Resistances.
F. Motors.
G. Air compressor.
H. Combined air compressor switch and fuse.
I. Air compressor governor.
J. Air reservoir.
K. Air reservoir safety valve and drainage cocks.
L. Air brake relay valve and double check valve.
M. Air brake cylinder(s).
N. Driver's air brake valves: self-lapping valves or manual-lapping valves.
O. Air pressure gauges.
P. Brake systems: air, electric and hand.
Q. Sand gear: air operated.
R. Door operating equipment, driver's door valves.
S. Foot gongs.
T. Deadman system.
U. Life guard equipment.
V. Windshield wipers.
W. Door operating equipment, driver's door valves.

Note: Not all items fitted to a trolley are listed here.

3. CONTROL SYSTEM

3.1 PATH OF ELECTRIC CURRENT

The 600 VDC leaves the positive busbar of substation, flows through feeder cables to overhead trolley wire, is picked up by the trolleys pantograph, passes through the choke coil, line breaker, controller, resistances, motors, wheels, track feeder and cables to the negative busbar of the substation.

3.2 ELECTRICAL PROTECTION FEATURES

An automatic breaker (line breaker) is inserted between the trolley wire and controller. This opens automatically when too much current is applied to the motor circuit.

Circuit switches are used to switch the power on and off to electrical apparatus by hand. In circuits using lower power ratings, fuses take the place of automatic breakers. They will blow out and break the current if an overload is applied due to a fault and thus protect the apparatus from damage or fire.

The lightning arrester protects the trolley equipment from damage due to lightning. A spark gap is provided for the lightning surge to jump across and go direct to the rails (earth). The choke coil is used in conjunction with the lightning arrester, and acts as a block to lightning surges and allows the surge to discharge across the spark gap to the rails.

3.3 LINE BREAKER

This may be located under the floor or on the roof of a trolley and is an automatic switch that is operated by a relay circuit through switches in the controller. The line breakers closes when the controller is moved to the first point or notch position, but any movement of the controller handle (anticlockwise) towards the 'off' position from any notch automatically opens the line breaker. The controller handle must then be returned to the 'off' position before power can be applied again.

The line breaker will open automatically in case of overload; that is when there is an excess of current due to either incorrect operation of the controller or to some defect of the electrical equipment.

3.3.1 LINE BREAKER SWITCH AND FUSE

This is a small switch located on each driving platform used to open and close the line breaker circuit manually. It controls the power circuit to the line breaker activation switch in the controller, and also includes a fuse to protect the relay circuit in the line breaker.

3.4 CONTROLLER

3.4.1 RESISTANCES & SPEED CONTROL

Resistances are used in conjunction with the controller so that the current to the motors is applied gradually, thus giving a smooth and steady increase in speed from stop to full speed or full parallel. They heat up when a current passes through them and so the period that power is applied through the resistance notches must be limited.

A controller is used in conjunction with the resistances to regulate the power applied to the motors by notches or points. It also provides for the changing of the power circuits to the motors from 'series' to 'parallel' and to enable a defective motor or motors to be disconnected or 'cut out'. The controller can also be used to reverse the direction of the trolley and to operate electrical emergency brakes. The Oporto cars also have electrical service braking.

3.4.2 SERIES OPERATION

Series operation is the term used to describe the connection of motors in tandem. The current flows through one motor or set of motors and then goes on to the next motor or set of motors before returning to ground. The voltage applied is divided between each motor or set of motors. With two motors or two sets of motors connected in series with 600 VDC on the trolley wire, the voltage taken by each motor or set of motors would be 300 VDC, half of the 600 VDC supply voltage. This gives reduced speed, therefore trolleys start on series power.

3.4.3 PARALLEL OPERATION

Parallel operation is the term used to describe the connection of motors individually. The current flows through each motor or set of motors and then returns to ground. Full 600 VDC trolley wire voltage is applied to each motor or set of motors. This gives full speed; therefore trolleys do not start on parallel power.

3.4.4 CONTROLLER POINTS OR NOTCHES

3.4.4.1 CONTROLLER TYPE

Trolleys operated by MATA are fitted with two types of controllers:

- Oporto cars - GE B54: 4 series, 3 parallel (7) + 7 braking notches (total 14).
- Melbourne cars - GE K35: 5 series, 3 parallel (total 8).

3.4.4.2 POINT OR NOTCH SELECTION

Ensure that each notch is selected correctly. Use feel and the appropriate notch marking to position the control handle to be completely “in the notch”. Sitting between or not properly in a notch will result in controller arcing and poor operational performance of the trolley.

3.4.4.3 RESISTANCE POINTS OR NOTCHES

All notches or points except the last in each group are known as resistance notches. On the first notch, the full set of resistances are in circuit; on the second some resistances are switched out, and on subsequent notches still more resistances are switched out of circuit. As each resistance is switched out of circuit, the voltage across the motors is increased, also increasing motor power and trolley speed.

The controller may remain in resistance notches just long enough to maintain smooth acceleration. If a driver dwells too long on a resistance notch, power is wasted, the resistance becomes overheated and a fire may be caused in the resistance grids. Conversely, a Driver should not notch up too quickly, as this gives a rough ride and may cause the wheels to spin or the line breaker or circuit breaker to blow.

3.4.4.4 RUNNING POINTS OR NOTCHES

The last notch in each group is known as the running notch. This indicates full series or full parallel power, as the case may be. The resistances are not being used on these notches and the power may be kept applied as long as necessary without causing damage to the equipment.

Running notches should be used to maintain speed in order to keep to schedules. Power should not be kept applied unnecessarily, as this wastes electricity. Every advantage should be taken to coast the trolley, and power should be cut off well in advance of stops.

3.4.4.5 TRANSITION

The section of the controller movement between full series and first parallel notch is known as the transitional stage or “transition”. In this stage, the connections to motors are changing from series to parallel and the trolley may only be being driven by one motor or set of motors. Move the controller through the transition stage in one sweep without pausing. Do not attempt to cut off (move the controller anticlockwise) while in transition. It is also necessary to pause on the full series notch before cutting into parallel to prevent jolting and to protect the electrical equipment.

3.4.4.6 CUTTING ON AND OFF

The controller handle should be moved quickly and accurately to each successive notch when applying power, therefore providing smooth acceleration. Drivers should not pause between notches as severe arcing will occur in the controller and burn or blister the controller fingers and segments. This applies particularly to the movement across the transition stage from full series to first parallel. If the controller is notched up too quickly, excessive current flows to the motors. This may cause the line breaker or circuit breaker to 'blow' or the wheels to spin.

When cutting off, a clean and deliberate movement in one quick action is required to the 'off' position to prevent arcing between the contact segments and fingers. On trolleys fitted with line breakers, power will drop out as soon as the handle is moved backwards. Cutting off from first notch in series and parallel should be avoided wherever possible, as this has the potential to cause the greatest arcing.

3.4.5 REDUCING POWER CONSUMPTION

Power may be saved by utilizing the following techniques:

1. By cutting through resistance notches smoothly and quickly (as driving conditions allow).
2. By cutting off power as far as possible from the stopping place.
3. By coasting as far as practicable.
4. By releasing brakes as power is applied.
5. By cutting off power before applying the brakes.

3.4.6 REVERSING KEY

The reversing key changes the direction of the current applied to the motors, and therefore changes the direction of their rotation. It also acts as a key for locking the controller to prevent against illegal operation and is used in the operation of emergency electric brakes.

The reversing key must never be left in or on the controller at any time the Driver is not in the trolley.

3.4.7 LINE BREAKER SWITCH

Melbourne trolleys have controllers with a ratchet switch incorporated at the bottom of the controller or a LB–2A switch on top of the controller. Oporto trolleys have micro switches that perform the same function. When cutting on for first notch these switches pick up and complete a relay circuit which operates the line breaker. Any movement towards the 'off' position (counterclockwise) of the controller trips the switch and breaks the relay circuit. The line breaker therefore opens each time the controller is moved towards the 'off' position, and it closes each time the controller is moved from the 'off' position to the first series notch.

When reapplying power while still under momentum (e.g. cutting off while passing under an overhead fitting), cut first notch before moving the controller round to the required notch according to the speed of the trolley. If first notch is passed too quickly, the ratchet, LB–2A or micro switch may not engage.

3.4.8 CONTROLLER – DRIVING SUMMARY

3.4.8.1 MELBOURNE K35 CONTROLLERS

- Melbourne cars have K35 controllers.
- Total of eight points or notches.
- 1-5 called series notches.
- 6-8 called parallel notches.
- Align controller to notch position using feel and notch indicator mark.
- Never allow the controller to rest in between notches.
- Remain in notch 5 or 8 indefinitely (as safe to do so depending on track and traffic condition).
- Remain in notches 1-4 and 6-7 for only as long as it takes to accelerate to that notches speed, definitely no longer than 8 seconds.
- Avoid cutting off power (moving the controller anticlockwise towards zero) from notch 1, 6 and 7.

3.4.8.2 OPORTO B54 CONTROLLERS

- Oporto cars have B54 controllers.
- Seven points or notches (for powering the car forward).
- Seven points or notches (for braking).
- Total of fourteen points or notches.
- 1-4 called series notches.
- 5-7 called parallel notches.
- Align controller to notch position using feel and notch indicator mark as a guide.
- Never allow the controller to rest in between notches.
- Remain in notch 4 or 7 indefinitely (as safe to do so depending on track and traffic condition).
- Remain in notches 1-3 and 5-6 for only as long as it takes to accelerate to that notches speed, definitely no longer than 8 seconds.
- Avoid cutting off power (moving the controller anticlockwise towards zero) from notch 1, 5 and 6.

3.4.9 SHORT CIRCUITS

This defines a condition when electric current takes a short cut instead of through a normal circuit. In this condition a heavy flow of current occurs, and to prevent damage automatic breakers and fuses are activated. For example, a fallen trolley wire contacting the rail is a short circuit and would open the automatic circuit breakers at the traction substation.

3.4.10 CONTROLLER FLASHOVER

A short circuit in the controller that results in a muffled explosive noise, arcing, smoke and high temperature damage, under normal conditions it is contained within the controller case.

3.4.11 DRIVING WITH MOTORS CUT OUT

Controllers apply power on the first series notch and use series notches only. The controller handle should not be moved past the full series position when a motor or motors are cut out - most controllers have a mechanical interlock to prevent this.

In view of the load imposed on only one motor or set of motors, it will take longer to pick up the speed for each resistance notch. A longer period on each notch should then be allowed to avoid wheel spin or over-loading and consequent damage to the remaining motor or motors.

If it is necessary to change ends while driving with a motor or motors cut out, the corresponding motor(s) must be cut out at the other end. The motor(s) must always be cut out at the end from which you are driving.

Under no circumstances must Third or Fourth Emergency be used with motors cut out.

3.4.12 LINE OR CIRCUIT BREAKER OPENS

If the line breaker opens or 'blows' more than once, this indicates that the controller is being notched up too quickly or that there is a defective motor. If the former is the cause, driving technique should be modified to prevent notching up too quickly. If the latter is the cause, call the Dispatcher for assistance.

3.4.13 CONTROLLER LOCKED

If a controller becomes locked in an operating position:

1. Place the line or circuit breaker switch in the 'off' position, apply brakes and stop the trolley.
2. Call the Dispatcher for assistance.

4. BRAKING & COMPRESSED AIR SYSTEMS

4.1 MAIN PARTS OF THE AIR SYSTEM

The main parts of the air system are:

1. The combined air compressor switch and fuse. The switch controls the air compressor circuits and the fuse protects it.
2. The air compressor, driven by an electric motor, compresses the air used to operate the brakes, the sand valves, the windshield wipers (varies) and the sliding or folding doors (varies).
3. The air reservoir holds the compressed air. The air system has a safety valve fitted and there is a drain cock for allowing water to be drained from the reservoir.
4. A governor which automatically switches on the compressor motor when the air pressure in the reservoir falls below 60 pounds per square inch and switches the motor off when the air pressure reaches 70 pounds per square inch.
5. The Driver's valve for operating the air brakes. This enables the Driver to pass air from the reservoir to the brake cylinder(s) in order to apply the brakes, and also to discharge air from the brake cylinder(s) in order to release the brake. As the valve handle is moved to the right, air under pressure is applied to the brake cylinder(s) (through a double check-valve and relay valve). The movement of the valve handle regulates the pressure of the air in the brake cylinder that operates the brake levers connected to the brake shoes.
6. The air pressure gauge indicates the pressure of air in the reservoir. Trolleys fitted with self-lapping brakes have a duplex air pressure gauge, which also indicates how much brake pressure is applied.
7. The door operating valves by which opens and closes the doors (varies).
8. The sand valves. When operated, compressed air is applied to the valves at the bottom of the sand hoppers and sand is blown through the hoses to the rails.
9. The safety 'dead-man's' activation system.

4.1.1 SELF-LAPPING VALVE

Self Lapping or "self lap" brake valves are the standard type of valves used on MATA trolleys.

The movement of the brake handle to the right applies the brakes by the transfer of air pressure to the brake cylinder (through a double check valve and relay valve). The extreme right position is the emergency position for a quick and full transfer of air pressure to the brake cylinder. Also, in this position the brake handle may be removed.

Movement of the brake handle to the left permits air from the brake cylinder to be discharged through the exhaust and release brake pressure from the wheels. The extreme left position is the quick release position used when starting the trolley.

4.1.2 MANUAL-LAP BRAKE VALVES

Manual Lapping or “manual lap” brake valves are used on only two MATA trolleys Melbourne 539 and Oporto164.

The handle is removable in the extreme right position on 539 and in the center position on 164.

The center position of the handle is the lap position with all air ports closed.

The movement of the handle to the right on 539 or backwoods (towards the driver) on 164 applies the brakes by the transfer of air reservoir pressure to the brake cylinder. The extreme right or backwoods position is the emergency position for a quick and full transfer of air pressure to the brake cylinder.

Movement of the handle to the left or forward of the centre lap position permits air from the cylinder to be discharged through the exhaust and releases the brakes. The extreme left or forward position is the quick release position used when starting the trolley.

4.1.3 SAND VALVES

When the foot operated sand punch is pressed, compressed air is applied to the valves at the bottom of the sand hoppers and sand is blown through the hoses on to the rails.

4.2 AIR BRAKE FAULT DIAGNOSIS

The following procedures apply when diagnosing air brake faults:

4.2.1 AIR COMPRESSOR FAILS TO START

If the air compressor fails to start when pressure drops below 60 pounds per square inch, perform the following procedures:

1. If in motion, stop the trolley. If the air brake is not effective, use the hand brake. If the air brake has been used to stop the trolley, release the air brake and apply the hand brake.
2. See that the pantograph is on the overhead wire and check the lights. If they work (indicating that a power failure is not the cause), put the compressor switch to 'off' and then 'on' again to make sure that it is making good contact.
3. Call the Dispatcher for assistance.

4.2.2 AIR COMPRESSOR GOVERNOR FAILS TO CUT OUT

If the air compressor governor fails to cut out, perform the following procedures:

If the air pressure does not go over 90 pounds per square inch drive as carefully as possible using service braking only (avoid a possible emergency braking) and call the Dispatcher for assistance.

If the air compressor governor fails to cut out and the air pressure does go over 90 pounds per square inch stop the trolley as safe to do so, turn compressor off, apply hand brake and call the Dispatcher for assistance.

4.2.3 WHEELS OF TROLLEYCAR LOCKED

If the trolley cannot move due to the wheels of the trolley being locked:

1. Ensure that the hand brake is released at both ends of the trolley.
2. Try to unlock the wheels. Go to the rear cabin and, having made sure that the track ahead is clear for at least one trolley length, smartly cut several notches, two or three times if necessary, and try to drive the trolley a short distance back along the track.
3. If the wheels remain locked, call the Dispatcher for assistance.

4.3 HAND BRAKES

This is the manual means of applying the brake shoes to the wheels, using the same levers and rigging that are operated by the air brake. To operate the hand brake, the pawl must be forced into the ratchet with the side of the foot. The hand wheel is turned until the slack is taken up and the handle is brought to a position on the right side of the wheel from where it can be pushed down with repeated powerful strokes until the trolley has stopped. When releasing the hand brake, the wheel should never be allowed to spin freely as the handle may strike the Driver and cause an injury.

The hand brake must be used if the air pressure system is out of order and cannot be rectified by the Driver. It must also be applied when a trolley is to be left unattended on the road, or if the pantograph is removed from the overhead wire, other than when changing ends at a terminus (see section 6.9 'Parking Trolleys').

4.4 BRAKING PROCEDURES

There are three types of braking used on trolleys operated by MATA:

1. The AIR BRAKE, which is applied by operating a self-lapping or manual-lapping valve, or in the case of activation of the 'dead-man's' device.

2. The ELECTRIC BRAKE, which is applied by operating the reverse key on the controller, with the controller in the 'off' position (Melbourne cars), and, in conjunction with the controller handle (Oporto cars). On Oporto trolleys there are an additional seven notches, which when the controller is turned counter clockwise activate electric braking.

3. The HAND BRAKE, which is applied by turning the hand brake wheel or lever with the right hand, while the right foot holds the pawl into the ratchet.

There are two distinct forms of air brake application available: Service braking for all normal stops, and emergency braking known as 'First Emergency'.

There are also two different types of electrical brakes available: Service braking using the braking notches and 'Second' and 'Third' Emergency braking used on the Oporto two-motor trolleys, and 'Fourth Emergency' used on four-motor trolleys.

4.4.1 BRAKE EFFICIENCY

To obtain the most efficient braking, the greatest air pressure necessary should be applied as soon as possible. Reduction of the speed of the trolley is most effectively obtained by slowing down the wheels without skidding them. The wheels are less likely to skid when the speed is high, so the greatest pressure should be applied at the highest speed.

The air brake is only effective when the wheels are moving. If the wheels become locked in a skid, the brakes have no effect and the only force stopping the trolley is the friction between the wheels and the rails. This results in 'flats' on the wheels.

If the wheels do skid, release the air brake, apply sand to the rails to increase traction and assist the wheels to turn, and then reapply the air brake.

4.4.2 SERVICE BRAKING PROCEDURES

4.4.2.1 SELF LAP - AIR

For a normal service stop, move the brake handle smoothly, quickly and firmly as far to the right as necessary to obtain the maximum air pressure required in the brake cylinder to make the stop. The extent of the movement depends on the brake cylinder pressure required, which will vary according to the trolleys speed, load carried, downhill or uphill slope (grade), track conditions and the characteristics of the particular brake valve.

As the speed of the trolley reduces, gradually move the valve handle left back towards the release position, until the trolley comes to a stop.

When the trolley has stopped, move the handle full to the right to hold the trolley.

To change ends, move the handle to the extreme right position, then lift handle out.

4.4.2.2 MANUAL LAP - AIR

For a normal service stop, move the brake handle smoothly, quickly and firmly as far to the right as necessary to obtain the maximum air pressure required in the brake cylinder to make the stop. The extent of the movement depends on the brake cylinder pressure required, which will vary according to the trolleys speed, load carried, downhill or uphill slope (grade), track conditions and the characteristics of the particular brake valve.

When sufficient air has been admitted to the cylinder, return the handle to the lap position (center). The air brake will remain on and the valve will be closed to prevent air entering to or escaping from the cylinder. As the trolley is stopping, release a little air by moving the handle left to the release position and then back to the center lap position. Repeat this, as the trolley is about to stop.

When the trolley has stopped, move the handle full to the right to hold the trolley.

To change ends, move the handle to the extreme right position, then lift handle out.

NOTE: This type of brake system lends itself very easily to the poor practice of 'fanning', Drivers should avoid this practice.

4.4.2.3 ELECTRIC

Electric service braking is only available on the Oporto cars. It uses the energy of one motor as a source to retard the rotation of the other motor. As a result of this "dynamic" braking process, both motor's rotation speeds are reduced – resulting in a reduction in the speed of the trolley. The braking effect is dependent on the speed of rotation of the motors, if this slows; greater braking force is required by cutting more braking notches. This type of braking will not hold a trolley completely stationary on a grade.

To activate electric brake, move controller handle from the zero position counter clockwise selecting as many of the seven braking notches as required to brake the car. As the cars speed reduces, cut additional notches to maintain braking rate. Do not begin to move the controller handle back to the zero position until the car has stopped.

Once the car has stopped, use the air or hand brake to hold it stationary.

4.4.2.4 INCORRECT BRAKING PRACTICE

The wrong way to apply the service braking is to move the brake valve or controller handle too slowly, or little by little, as a result the trolley approaches too close to the stop mark before sufficient air pressure has been applied to check its speed. This then makes it necessary to increase air pressure to avoid over running the stop mark which in turn may cause the wheels to skid and the trolley to stop with a jolt.

Skidding of the wheel means reduced braking, in some cases greatly reduced braking which may feel to the driver like a brake failure, and often results in flat spots on the wheels or 'flats'. This incorrect method of braking can also give the driver the impression that the brakes are generally weak.

'Fanning' the brake valve handle (alternately applying and releasing air) is a poor practice. 'Fanning' is much less effective than the correct method, gives a rough ride and causes unnecessary wear and tear on the brake valve and the braking system.

Power must always be cut off before applying the brakes. Failure to do so could result in the trolley skidding immediately when power is cut off.

4.4.3 EMERGENCY BRAKES

Emergency braking procedures are importance as emergency braking is used to avoid an imminent accident; therefore it is essential that Drivers become proficient in their use. To save undue wear and tear on the trolleys, fluency in the procedures should be obtained by practicing with the trolley stationary.

4.4.3.1 1ST EMERGENCY BRAKE – AIR – MELBOURNE & OPORTO

The First Emergency Air Brake is affected by applying the full air reservoir pressure as quickly as possible to the brake cylinder, and applies both to manual-lap valves and self-lapping valves. These actions should be performed decisively and without delay.

1. *Hold controller in the 'off' position.*
2. *Apply sand.*
3. *Move air brake handle to the extreme right.*

4.4.3.2 1ST EMERGENCY BRAKE – ELECTRIC - OPORTO

In the event of an air brake failure, or if the air brake proves ineffective, the First Emergency Electric Brake may be used to stop a trolley. Note: the electric brake will have no effect if the wheels are already locked and skidding. These actions should be performed decisively and without delay.

1. *Apply sand.*
2. *Move controller anticlockwise to the 7th braking notch.*
3. *Once the car has stopped, use air or hand brake to hold stationary.*
4. *The controller must not be moved again until the trolley stops.*

4.4.3.3 2ND & 3RD EMERGENCY BRAKE – ELECTRIC - OPORTO

1. *Apply sand.*
2. *Second Emergency brake: with the controller handle in the 'off' position, pull the reverse key back to the reverse position. Cut one or two notches, no more. Should the retarding effect be insufficient causing the wheels to spin, cut the power off and repeat the process, if the line breaker opens the Third Emergency brake should be activated.*
3. *Third Emergency brake: after applying Second Emergency, move the controller handle quickly to the full parallel position.*
4. *The controller must not be moved again until the trolley stops.*

Third Emergency braking ceases to be effective at speeds less than 2 mph (1st notch speed); therefore the air brake or hand brake will be required to hold the trolley.

For operation of the electrical emergency brake, the reverse key must always point in the opposite direction to that of the movement of the trolley. Therefore, if the trolley were running backwards down a grade, the reverse key would remain in the normal forward driving position. With the line or circuit breaker out and the controller in the full parallel position the trolley would be stopped electrically.

When descending a grade in a trolley with brakes out of order, with the line or circuit breaker opened, the controller handle in the full parallel position and the key in the reverse position to the direction of travel, the trolley is retarded only by the self-generated current. Therefore, the motion would consist of a series of movements and retardation since the stopping or nearly stopping of the trolley also stops the self-generation of electrical energy by the trolley motors.

NOTE: The Second Emergency brake will NOT act if the pantograph is off the overhead wire or if there is a power failure. The Third Emergency brake WILL act when the pantograph is off the overhead wire or during a power failure. When a motor is cut out, the Third Emergency brake must not be used, as there is no longer a pair of motors that can generate against each other.

4.4.3.4 4TH EMERGENCY BRAKE - ELECTRIC BRAKE - MELBOURNE

The following procedure is used for emergency braking in trolleys equipped with four motors:

1. *Apply sand and First Emergency air brake.*
2. *Fourth Emergency brake (electric): The Fourth Emergency brake is applied while the First Emergency brake is left on. To apply Fourth Emergency brake, pull the reverse key back to the reverse position with the right hand. Continue to apply sand.*
3. *The reverse key must not be moved again until the trolley stops.*

Fourth Emergency braking ceases to be effective at speeds less than 2 mph (1st notch speed); therefore the air brake or hand brake will be required to hold the trolley. If travelling at a VERY slow speed (i.e. 2 mph or less) and the air brake and hand brake are inoperative or ineffective, pull the reverse key back to the reverse position and if there is no response cut a notch. A notch should NOT be cut if the electric brake responds normally (as it should at speeds greater than 2 mph).

When descending a grade in a trolley with brakes out of order, with the key in the reverse position to the direction of travel the trolley is retarded only by the self-generated current. Therefore, the motion would consist of a series of movements and retardation since the stopping or nearly stopping of the trolley also stops the self-generation of electrical energy by the trolley motors.

When a motor is cut out, the Fourth Emergency brake must not be relied upon.

4.4.3.5 ELECTRIC BRAKE - HOLDING TROLLEY STATIONARY

The electrical means of stopping a trolley will not hold it stationary on a grade. Therefore, in the event of failure of both the air brake and the hand brake, when having stopped the trolley it will be necessary to quickly place any large heavy item readily at hand in front of a wheel to prevent further motion. A trolley can be held on a grade by cutting on and off the controller.

4.4.4 SAND

Sand may be used to increase traction and reduce the risk of skidding. If the wheels lock when making a service stop, release the brakes, drop sand then re-apply the brakes.

Sand is applied to the rails by depressing the sand valve foot punch. Sand is then forced from the sand container by compressed air. It is the responsibility of the Driver to check that the sand hoppers have plenty of sand, and that the apparatus is in good working order. Under conditions that render slippery rails likely, the inspection should be frequent.

A trolley should have sand in the hoppers, and in sufficient quantity in case of emergency, and the sanding apparatus at both ends of the trolley is in good working order.

If a trolley runs out of sand while in service, notify the Dispatcher.

Sand should be used with service braking when the rails are greasy or slippery and it should not be wasted. Sand must be applied at the beginning of braking; otherwise the wheels may lock before the sand gets to them.

Sand must always be used first when applying emergency braking and kept on until the trolley stops.

Sand must be used if the wheels spin when starting on a slippery or greasy track. If the wheels spin, do not cut more notches - they will only spin faster. If the wheels spin to such an extent that the trolley cannot be driven to where the sand falls, the Driver should change ends; and having made sure that the track is clear, drive the trolley back for one trolley length while applying sand. Apply brakes again, change ends and then move off using sand until the slippery section has been passed. If necessary, sand must be taken by hand from the sand hoppers and spread on the rails in front of the wheels.

4.4.5 STOPPING DISTANCE

The distance required to stop a trolley becomes greater when the following conditions occur, and correspondingly greater when they occur simultaneously:

1. When the trolley is fully loaded.
2. When the trolley is travelling at faster speeds.
3. When the trolley is on a down grade.
4. When the rails are slippery.
5. When using the hand brake.

A trolley must be driven at a safe speed at all times and it is the Driver's responsibility to observe and make proper allowances for all conditions which may affect normal braking efficiency.

4.4.6 BRAKING AND RAIL CONDITION

Since the distance required in which to stop a trolley is dependent upon the grip of the wheels on the rails, it follows that the best results are obtained upon clean rails and adverse results when the rails are greasy. It is of interest that the total area of wheels actually in contact with the surface of the rails is less than one square inch on a double truck Melbourne trolley and even less on a single-truck Oporto trolley.

The best conditions occur when rails are thoroughly clean and wet, a dry rail not necessarily being a good clean rail. Adverse braking conditions can occur in the following conditions:

1. When rain commences.
2. Frost or ice.
3. Morning dew.
4. Track repairs or 'top dressing' using asphalt compounds.
5. Oil or fallen leaves.
6. Motor vehicles running over rails drying out after rain.
7. New rails, even when apparently clean, can cause conditions like greasy rails. Treat new rails as greasy rails.

Where such conditions exist, lighter air pressure is required to prevent skidding; therefore allow a longer distance to brake. The pressure applied should be just sufficient to bring the trolley to a standstill where desired without any need for an increase in air pressure. Sand should be used to increase traction.

Before the required air pressure is applied and also during the whole of the braking period, sand should be deposited on the rails as necessary. The air pressure should gradually be reduced as the trolley approaches the stopping point, thus completing the stop without any jolt or skidding.

Quick stops with high air pressure are not normally necessary. Such stops can result in wheel 'flats'.

4.4.7 BRAKE FAILURE

Since the air brake is dependent upon the supply of compressed air and requires a minimum of 60 pounds per square inch for adequate braking, failure of the air supply due to an electrical fault or break of a pipe line or fitting puts the air brakes out of action.

The same mechanical levers and bars are used for both the air brake and the hand brake and it therefore follows that the breakage or jamming of a lever or bar renders both the air brake and the hand brake inoperative.

4.4.8 BRAKES FAIL TO HOLD TROLLEY ON GRADE

The following procedures apply if the air brakes fail to hold a trolley when on a grade:

1. If the trolley rolls back, leave the reverse key in the forward position and quickly cut one notch of power, apply the hand brake and as soon as the hand brake is on, cut off the controller. Continue to drive the trolley using the hand brake for service braking.

2. If the trolley rolls forward downhill, pull the reverse key to reverse position and quickly cut one notch of power, apply hand brake and as soon as the hand brake is on, place controller handle to 'off' position. Put the reverse key to forward position and continue to drive the trolley using the hand brake for service braking.

5. GENERAL TROLLEY OPERATION

5.1 STARTING A TROLLEY

Cut a notch as the brakes are being released. This prevents rolling back on a grade, and provides a smooth start without jolting the passengers.

5.2 GONG SIGNALS

The gong should be sounded every time a trolley is about to be moved even if no passengers are on board. When passing a stationary trolley or other large vehicle that could impede visibility, reduce speed, sound the gong loudly to warn any pedestrians and be prepared to stop quickly. Use the gong to warn pedestrians or workers of the approach of a trolley. In particular, use the gong where pedestrians or vehicles may be likely to come suddenly onto the trolley line without visually checking for an approaching trolley.

5.3 SECTION ISOLATOR

These are fitted in the overhead trolley wire and divide the system into a number of separate circuits. It is necessary that the controller be in the 'off' position while the pantograph runs under the insulator in order to prevent an arc, which would occur due to the break in the current supply and would burn and damage the insulator, may cause a blinding flash and may lead to electrical arcing in controllers and motors.