LIGHT RAIL
Safety and Standards Board

OLE Maintenance and Reference Manual

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DESCRIPTION:

THIS DOCUMENT PROVIDES GUIDANCE ON THE MAINTENANCE OF OLE AND INCLUDES A REFERENCE MANUAL

EXPLANATORY NOTE:

LRSSB is not a regulatory body and compliance with this guidance document is not mandatory. This document reflects good practice and is advisory only. Users are recommended to evaluate this guidance against their own arrangements in a structured and systematic way, noting that parts of this guidance may not be appropriate to their operations. It is recommended that this process of evaluation and any subsequent decision to adopt (or not adopt) elements of this guidance should be documented. Compliance with any or all of the contents herein, is entirely at an organisation's own discretion.

SOURCE / RELATED DOCUMENTS:

LRG 1.0 Tramway Principles and Guidance (TPG) (LRSSB)
LRG 34.0 Guidance on Control of Contracted Works (LRSSB)
LRG 40.0 OLE Competency Training Guidance (LRSSB)
BS EN-50149 Railway applications. Fixed installations. Electric traction. Copper and copper alloy grooved contact wires
BS EN 50119:2020 Railway applications. Fixed installations. Electric traction overhead contact lines
BS EN 50121:2017 Railway applications. Fixed installations. Electrical safety, earthing and the return circuit Part 1: Protective
provisions against electric shock.

RELATED TRAINING COURSES:	**RELATED LEGISLATION:**
LRG 40.0 OLE Competency Training Guidance (LRSSB)	Health and Safety at Work Act etc. 1974 Railways and Other Guided Transport Systems (Safety) Regulations (ROGS) 2006 (as amended) Working at Height Regulations 2005 Lifting Operations and Lifting Equipment Regulations (1998) Electricity at Work Regulations 1989

CHANGE NOTES:

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19/07/2023	01	01	LRSSB	Amendments and additions to text / format

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OLE MAINTENANCE AND REFERENCE MANUAL

CONTENTS

Revisions from Previous Issue:

Changes to Page 1 including removal of the named preparer, reviewer and authorising person and insertion of an explanatory note in relation to the status of this guidance document. Additional references to LRG 34 and LRG 40 added following publication of additional LRSSB guidance along with BS EN references.

Additional terms and abbreviations added to Table A and Table B from existing and new text.

Amendments to text including insertion, replacement and / or removal to provide additional guidance and to aid clarification where required / appropriate.

Amendments to the tables in existing appendices including the insertion, replacement and / or removal of images and text.

Addition of new table at Appendix 4 to present assets for heritage systems.

Numerous minor presentational, minor factual and typographical changes.

TERMS AND ABBREVIATIONS

Table A – Terms

Term	Definition
Automatic Tensioning Device	Simple mechanical device used in tensioning equipment to automatically maintain tension in the conductors through design temperature limits of -20°C to +40°C (average UK parameters). Sprung devices or free moving weights are used to provide constant tension. (Gaseous or hydraulic tensioners are also used but not common.)
Breaking Load	The stress which, when steadily applied to a structural member, is just sufficient to break or rupture it (also known as ultimate load).
Building Fixing	Where the contact wire is suspended by span wire construction between opposite buildings.
Cantilever	Contact wire and or catenary support consisting of one or more transverse members projecting from a mast or pole.
Catenary Wire	Overhead wires used to support and provide electricity to a contact wire directly or indirectly.
Contact Wire	Electric conductor of an overhead contact line with which the pantograph makes contact providing an uninterrupted supply to a vehicle. The wire is characterised by having two linear clamping grooves. (As defined in BS EN-50149.)
Contact Wire Height	Distance from the top of the rail to the lower face of the contact wire, measured perpendicular to the track.
Contact Wire Sag	The deviation the contact is below its nominal height. This is usually found at mid span.
Duty Holder	Person in charge of operational activities at a particular time.
Flying Tail Pull Off	A single or series of span wires (bow wires) used to support the contact wire and hold it in registration on curves where structures cannot be used.
Foundation	Construction, usually of concrete or steel, completely or partly buried in the ground on which the support pole or mast is mounted. The foundation shall provide stability to all loads carried by the support.
Hazard Zone	An area extending and encompassing live apparatus in which work shall not be allowed unless isolated, proved dead and a Permit To Work is issued to that affect.
Heritage System (Tramway)	A tramway that operates to: (a) preserve, re-create or simulate tramways of the past; or (b) demonstrate or operate historical or special types of motive power or rolling stock; and is exclusively or primarily used for tourist, educational or recreational purposes. (As defined in the Health and Safety

	(Enforcing Authorities for Railways and Other Guided Transport Systems) Regulations 20061.)
Term	**Definition**
Hook-over	An action where the contact wire runs off the pantograph head and gets underneath with catastrophic results and dewirement.
Insulator	Components that separate the electrically live parts of the OLE from other structural elements and the earth.
Isolator	Mechanical switch used to isolate and earth electrical sections for emergencies or maintenance.
Maintainer	The organisation who has the responsibility for maintaining a Light Rail system.
Major Inspections	Preventive maintenance procedures including inspections, measuring and testing, exchange of some components and general checking.
Mast	A bolted or planted support structure usually in the form of an I or H section universal beam.
Operator	The organisation that has the responsibility (on behalf of the owner) to operate a particular Light Rail system.
Overlap	A location where two contact wires meet on a parallel plane without physical contact to allow uninterrupted change-over of electrical or tensioned sections.
Pantograph	A jointed framework to convey an electrical current to a tram from overhead wires.
Pole	A bolted or planted tubular support structure for the OLE system.
Rake	The setting of a pole or mast whereby when the load is applied it looks uniformly vertical. Positive rake is away from the load, negative rake is towards the load.
Registered / Registration	Where the contact wire is laterally restrained to a set distance and tolerance compared to the track centreline and pantograph contact zone.
Second Generation	UK Light Rail systems (tramways) that have been in operation from the 1990's.
Stagger	The system lateral offset of the contact wire compared to the projected track centreline. This allows for even wear of pantograph carbon strips.
Steady Arm	A component that locates the contact wire and allows dynamic upwards movement during pantograph passage.
Technician	The individual responsible for carry out the maintenance task.
Trolley Wire	The contact wire where it is self-supporting in terms of power supply and between span supports. The wire maybe subject to sag at its mid span despite being tensioned (FTTW or ATTW).

1 The Health and Safety (Enforcing Authorities for Railways and Other Guided Transport Systems) Regulations 2006: SI 2006/557 https://www.legislation.gov.uk/uksi/2006/557/pdfs/uksi_20060557_en.pdf

Table B – Abbreviations

Term	Definition
AC	Alternating Current
ATTW	Auto Tension Trolley Wire System
BWA	Balanced Weight Anchor
DC	Direct Current
FTTW	Fixed Tension Trolley Wire System
HSE	Health and Safety Executive
kA	Kiloampere
km/h	Kilometres per hour
kN	Kilonewton
kV	Kilovolt
LRSSB	Light Rail Safety and Standards Board
m	Metres
MEWP	Mobile Elevating Work Platform
mm	Millimetres
Ohms	Derived unit of electrical resistance (Ω)
OLE	Overhead Line Equipment
RRV	Road Rail Vehicle
TPG	Tramway Principles and Guidance
UK	United Kingdom
VDC	Volts Direct Current

1. Introduction

1.1. This guidance supports the high level principles set out in LRG 1.0 Tramway Principles and Guidance (TPG) published by the Light Rail Safety and Standards Board (LRSSB).

1.2. This document provides both high level guidance in relation to Overhead Line Equipment (OLE) Maintenance and also a Reference Manual for those delegated this responsibility in relation to UK Light Rail systems (tramways) based on 'line-of-sight' operations only. As with all guidance, this document is not prescriptive and is intended to give advice not to set a mandatory standard for the Light Rail sector, and it is based upon goal setting principles as good practice.

1.3. Much of this guidance is based on the experience and good practice gained from existing UK Light Rail systems and from published documents. It does not prescribe particular arrangements adopted by any existing UK Light Rail system and is intended to give guidance and advice.

1.4. This guidance is not intended to be applied retrospectively to existing Light Rail systems. However, owners and operators should consider and assess any implementation of this guidance and / or any subsequent revision, to ensure continual improvement in reducing risks, so far as is reasonably practicable.

2. Scope

2.1. The level of maintenance, frequency of inspections and routine maintenance methodology contained within this guidance has been collated using information provided from existing UK Light Rail systems employing a benchmarking approach. The guidance within this document is a general description of the assets and maintenance requirements (including frequency of maintenance) and a glossary of recommended terms for OLE equipment. It does not reference specifications for each individual system and therefore is not an exhaustive description of every associated task.

2.2. This guidance has also been informed by the following documents from existing UK Light Rail systems and manufacturers:

- Brecknell Willis: Overhead Line Equipment Operations And Maintenance Guidelines;
- Edinburgh Tram Network: Overhead Maintenance Manual;
- Manchester Metrolink: Overhead Line Equipment – Operation and Maintenance Guideline;
- SED/3/2001: Overhead Manual Instruction;
- Supertram Maintenance Limited: Overhead Maintenance Instruction; and
- Alstom / Taylor Woodrow JV Operation and Maintenance Manual: Overhead Line Equipment.

2.3. This document contains a glossary of recommended terminology to be used as a UK standard going forwards. Historically, terminology has developed within the various existing UK Light Rail systems and differences reflect the varying assets and their specific requirements. However, the Light Rail sector seeks to implement a standard approach to the use of terminology in order to maintain and increase guidance and clarity on asset identification.

2.4. Some of the items listed in Appendix 2, Appendix 3 and Appendix 4 have been taken from various sources available to LRSSB including existing Light Rail systems and supplier catalogues[2] and have been used here with their knowledge. However, this guidance should not be taken as an endorsement of any company or their supplies.

2.5. In relation to the interpretation of the information contained in this guidance, the appropriate person / organisation with the responsibility for OLE (including for maintenance and the Duty Holder etc.) or for the manufacturer of the equipment should be consulted due to the variances in the specifics of any particular Light Rail system.

2.6. This document does not give detailed technical particulars on the associated traction power element of the OLE.

2.7. The majority of guidance and information contained within this document has been based on Second Generation Light Rail systems. However, for overall guidance and reference purposes to component level, a limited section for heritage systems has been included.

2 Publication No, 337A British Insulated Calendar's Cables Limited (BICC) parts catalogue; BW14901 Brecknell Willis parts catalogue (obsolete) now Wabtec; Siemens, Malico, Alstom / Cariboni, Balfour Beatty, Rail Power Systems GmbH, Pfisterer, Electroline and Kruch have also been referenced.

3. Safety

General Considerations

3.1. The following is a brief overview of safety protocols. Its purpose is to provide a series of minimal considerations that the maintainer of OLE equipment should bear in mind for the safety of those working on the Light Rail system assets. It is not an exhaustive list of recommendations.

3.2. All those performing maintenance tasks on the OLE equipment shall be suitably and appropriately trained and duly authorised to undertake the tasks they are performing. Refer to LRG 34 Guidance on Control of Contracted Works for further information.

3.3. When carrying out maintenance work to assets in accordance with this guidance, to avoid hazards, there may be instances where tools and materials are recommended to assist safety precautions.

3.4. Before undertaking any maintenance work, it shall have been endorsed by a work order issued via the relevant organisational processes and procedures (refer to LRG 34 for further information). In addition, the following should be applied when undertaking work to OLE assets (not exclusively):

- Method statements and safety regulations shall be strictly followed;
- Where intrusive and physical works are involved at height, the system shall be isolated and proved safe for work to be undertaken on it;
- Staff involved shall have the appropriate required skills / competence in more than one discipline to work or operate equipment;
- The workplace shall be kept clean, orderly and safe;
- Appropriate personal protective equipment (PPE) shall be worn; and
- Appropriate tools shall be used (regularly checked and certified / calibrated as appropriate).

3.5. The above are applicable to every type of work including cleaning.

Potential Hazards

3.6. When working on the OLE, the technician has to be aware of a number of hazards. The following are some of the high level potential hazards and should not be considered as a difinitive list.

Electricity

3.7. The overhead line system, including conductors, supports, isolators and cables are usually energised at or above 750VDC at all times[3]. Therefore, whenever a technician is required to work close to or on the overhead line, electrical shock is always a hazard and the line shall be isolated before any work commences.

3.8. Before working on the overhead line or any associated equipment, the energy supply shall be isolated and the equipment proven dead with a suitably rated and functional live line test instrument.

3 750 VDC is a nominal voltage with some metros operating at 1500 VDC. Heritage systems can operate between 400 and 660 VDC.

3.9. The application of suitable earths whether automatic or manual should be undertaken.

3.10. Any technician should not be working on the OLE unless a safe system of work has been confirmed and is applied. This should be documented with a switching programme and permit to work issued in accordance with that operator's procedures.

3.11. Due to the large currents flowing through the contact wire and catenary, they can become very hot under fault conditions. Therefore, any technician should take care to ensure that the equipment is cool enough to work safely.

3.12. In addition, any technician should also be congisant of and take any appropriate measures in response to the heat of the day if required.

Working at Height and Access

3.13. As OLE poles in existing UK Light Rail systems can reach up to 11 metres, and usually accessed using a Mobile Elevating Work Platform (MEWP) or scissor lift, it is essential that all technicians are aware of the risks associated with working at height.

3.14. Only those who have the appropriate training and qualifications should be operating access equipment whilst working at height along with a safe system of work set in place prior to work commencing.

3.15. For further information, refer to LRG 40 OLE Competency Training Guidance.

3.16. Whilst working at height, all personnel shall wear any required and appropriate harnesses (in line with associated mandatory guidance) to prevent falling.

3.17. For further information, refer to the Working at Height Regulations 2005[4] and the Health and Safety Executive's (HSE) Work at Height guidance[5].

3.18. A suitable rescue plan shall also be in place and briefed to all OLE personnel prior to any works taking place.

Protective Clothing

3.19. All personnel should wear the appropriate protective clothing in accordance with the particular site regulations. Further information on PPE is noted in LRG 40 OLE Competency Training Guidance.

Risk Assessments

3.20. The technician performing the maintenance should refer to the appropriate risk assessments and take advice from appropriate competent individuals when preparing any risk assessment if there are areas outside of their own competence.

3.21. If there are no applicable risk assessments, then the technician should carry out their own risk assessment of the work to be undertaken.

4 https://www.legislation.gov.uk/uksi/2005/735/made/data.pdf
5 https://www.hse.gov.uk/work-at-height/index.htm

4. Introduction to Overhead Line Equipment (OLE)

4.1. The OLE is generally a collection of mechanical components which together form an electrical contact system (refer to Section 5 below). This system provides motive power to the tram vehicle. Many of the mechanical components within the OLE system are fixed and require no operational intervention after installation.

4.2. In electrical terms, the OLE system is electrically a double insulated system with at least two points of insulation between live and earthed components.

4.3. The contact and catenary wires (where employed) are supported by tubular poles or universal beam masts located between or to the side of the tracks. Cantilever assemblies are used to locate and register the wires. Where aesthetics, restricted space or heritage buildings exist the contact wire can be supported by span wire assemblies and building fixings.

4.4. The power circuit of any direct current (DC) supplied rail system has six key elements:

- Substations that supply DC at the line's designated nominal voltage (normally 750v but ranging anywhere between 550v and 900v);
- Overhead line;
- Positive distribution network;
- Load (the tram vehicle);
- Negative conductor (i.e. the rails, through which the current is returned to the substations); and
- Negative distribution network.

4.5. In most cases the rails are cross bonded together at regular intervals, and bonded or welded at joints to provide as low a resistance path as possible for the return current.

4.6. As individual OLE component failures often result in system failure which can lead to delays of the tram service, it is important that inspection and maintenance of the OLE is carried out as necessary in order to uphold system reliability.

4.7. The level of maintenance, frequency of inspections and routine maintenance methodology within this guidance is based upon the original manufacturer recommendations (where available) and information accumulated by the maintenance organisations in the UK during the commercial operation of Light Rail systems.

5. General Descriptions

Cantenary Wire, Reinforcement and Traction Return Cable

5.1. Where employed on segregated alignments, hemultistrand copper or copper alloy cantenary wire supports and maintains the linear path of the contact wire using conducting or non-conducting droppers. As well as supporting the contact wire, it will provide additional reinforcement for the traction supply using jumper cables.

5.2. An alternative system is where the catenary or reinforcement cables are run alongside the support poles and do not support the contact wire. This is known a parallel feeder cable.

5.3. The catenary is auto tensioned with the contact wire or seperately to allow for variations in thermal expansion or contraction.

5.4. For urban environments where cantenary is not desired, copper or aluminium reinforcement cables may be employed instead. These will run in a system of undeground ducts and take-off / drawpits, with feeder cables attaching to the contact wires at designated points along its length, as per the power design specification.

5.5. The rails are generally used as the return conductor for the OLE system. Traction return cables will be attached to the rails near substations and may have exposed connections on segregated alignments denoted by a red or brown sleeve. Traction continuity bonds may be found where joints occur in rails or to provide continuity paths between rails and / or tracks.

Contact Wire

5.6. The hard drawn copper or copper alloy contact wire transfers power to the carbon collector strips of the tram's pantograph. The wire section is generally circular with longitudinal groovesat the top to allow the wire to be gripped by supporting and registering clips without fouling a passing pantograph[6].

5.7. For Light Rail applications, contact wires will be type AC 107, AC 120 or AC 150 in single or twin formation depending on the design and power requirements. The system form can be trolley wire or catenary.

5.8. It is important that the contact wire presents a smooth even surface to a passing pantograph in order to prevent loss of contact, which can result in sparking and damage to both pantograph and contact wire. Therefore, successful current collection from the overhead contact wire by the pantograph requires a consistent predictable pressure between them. This is done by setting an uplift force in the pantograph mechanism which gives the required amount of contact pressure dictated by the dynamics of the catenary design.

5.9. The contact wire is restrained laterally (registered), approximately at right angles to the track by steady arms attached to cantilever or headspan supports at a maximum span of 60 m in open areas, or as 'pulling- off' devices in areas of span-wire construction, i.e. where track is not segregated, for example, in city centres and urban areas.
Contact Wire Height

6 BS EN 50149:2012 Railway applications. Fixed installations. Electric traction. Copper and copper alloy grooved contact wires

5.10. The height of the contact wire should be to the standard BS EN 50119:2020[7]. However, it shall be within the operating range of the pantograph[8], making due allowance for dynamic changes of the wire height.

5.11. Table 5.1 below lists the nominal contact wire height (at support) above rail level. However, there may be circumstances where systems heights differ from these figures.

Table 5.1: Contact Wire Heights

Track Type / Location	Height (m)
Segregated track Auto Tension Trolley Wire (ATTW) and Fixed Tension Trolley Wire (FTTW)	3.06 – 5.70 m[9]
Non-segregated track ATTW	5.99 – 6.02 m
Non-segregated track FTTW	5.70 – 6.30 m
Depot	6.20 – 6.30 m

5.12. At over-bridges or at grade crossings, the heights in Table 5.1 will be adjusted as necessary subject to the limits listed in Table 5.2 below. However, there may be circumstances where systems heights differ from these figures.

Table 5.2: Adjusted Contact Wire Heights

Location	Height (m)
At support absolute maximum height at support	7.00 m
At mid span, absolute minimum height at any point in span	
(i) Non-segregated track and depot	5.80 m (5.50 m)[10]
(ii) Segregated track	3.82 m
(iii) Heritage track	Approx 5.5 m

Contact Wire Gradient

5.13. As a general rule, the gradient of the contact wire(s) is defined as the difference between contact wire heights at adjacent supports divided by the span length. Therefore, based on this definition, the maximum contact wire gradient with respect to track will be as listed in Table 5.3 below.

5.14. The limitations of gradient shall not be exceeded.

Table 5.3: Maximum Contact Wire Gradients

Location	Gradient

7 BS EN 50119:2020 Railway applications. Fixed installations. Electric traction overhead contact lines
8 EN 50206-2:2010 Railway applications - Rolling stock - Pantographs: Characteristics and tests - Part 2: Pantographs for metros and Light Rail vehicles.
9 For heritage systems the height is usually in feet. 5.7 m is equivalent to 19 feet (with a max lowering to 17 feet at bridges)
10 BS EN 50121:2017 Railway applications. Fixed installations. Electrical safety, earthing and the return circuit Part 1: Protective provisions against electric shock.

Main lines >= 60 km/h	1:100 (10%)
Depot and slow speed areas >=10 km/h	1:33 (30%)

5.15. Excessive contact wire gradient with respect to track will produce an unacceptable vertical acceleration of the pantograph head, particularly by higher tram vehicle speeds. This would result in rapid contact wire wear and loss of contact at the gradient transition producing intermittant vehicle power loss, electrical arcing and unwarranted EMI emmissions.

Contact Wire Clearance

5.16. At all times the contact or catenary wire shall have sufficient clearance from earthed structures during static and dynamic actions experienced by the system.

Table 5.4: Static and Dynamic Clearances

System Voltage	Static Distance (mm)	Dynamic Distance (mm)
600-720 VDC (established heritage systems)	100	50
750-900VDC	100	50
1500-1800VDC	100	50

5.17. The above figures shall not be applied to safety distances for working on the OLE system.

5.18. For safety distances, systems shall employ designated hazard zones around any energised apparatus that requires isolation and sufficient safety controls to allow safe working with further guidance from BS EN 50122-1 and BS EN 50488.

Contact Wire Wear

5.19. An even rate of wear is desirable on all contact wires relative to the frequency of pantograph passes.

5.20. This can be achieved by proactive maintenance with regular checks and measurements of the contact wires for wear, which are then recorded across the section in relation to typical pantograph contact at predetermined positions (over the life of the system). As this is generally a manual process and to aid consistency in measurements, points or specific registrations are marked on the wire to identify future measurement locations. However, technological advancements may mean this can be undertaken digitally and automatically using on board equipment.

5.21. This check can be particularly important during the first year of operation to identify potential trouble spots requiring remedial action from the installer, and to provide a base line for data collection. Table 5.5 provides a guide of typical wear rates.

5.22. Wear exceeding either of the limits in Table 5.5 will increase the risk of potential failure and therefore will require contact wire replacement in part or whole.

Table 5.5: Contact Wire Wear Rates

Scenario	Wear Rate (%)
Recommended minimum functional cross-sectional area measured over a given length	20%
Recommended maximum reduction in cross sectional area at any position	33%[11]

Contact Wire Stagger

5.23. The purpose of contact wire stagger is to distribute wear of the pantograph carbons by causing the contact wire(s) to traverse across them regularly during movements of the vehicles, thus preventing the carbon being grooved in one location.

5.24. The lateral displacement of the contact wire is maintained by a steady arm. This is a light weight tubular arm clipped to the contact wire and connected to a cantilever, headspan or spanwire assembly at its heel.

5.25. Table 5.6 below lists the possible maximum contact wire stagger compared to track centreline and dependent on the system design.

Table 5.6: Indicative Contact Wire Stagger

Track Type / Location	Offset (mm)
Open route curved track	300 – 350 mm
Open route tangent track	200 – 280 mm

5.26. Although the stagger should not move significantly during thermal displacement, allowance shall be made for stagger change due to the temperature of the wire at the time of its measurement.

5.27. Readings are usually taken and compared to as-built readings which are undertaken at a set ambient temperature and time of year.

5.28. Depending on how the system was measured from the lines terminating point, stagger measurements determined using a height and stagger gauge maybe negative for pull-off registration or positive for push-off registrations. This is critical to achieve the correct and consistant measurents.

Insulated Flexible Feeders

5.29. Insulated, flexible feeder cables are used to carry the power from the isolator to the contact wires. Contact wire clamps used to connect feeders shall be checked for tightness (i.e. they should be tightened to a torque according to the manufacturers instructions).

5.30. Good, clean, electrical contact (tightness) is vital for componets, as looseness will produce arcing, overheating and oxidation of the surfaces, resulting in detachment and falling into the path of the pantograph. Therefore, the function of feeders is dependent on the efficiency of the joint.

11 BOStrab 1981 German Federal Regulations on the construction and operation of Light Rail systems allow 40% wear. However, the figures shown are nominal across the European Union.

Surge Arresters and Low Voltage Limiters

5.31. Surge arresters (lightning arresters) are provided for the protection of overhead electrification equipment. When connected into the equipment they provide protection from the effects of over-voltage caused by switching operations and atmospherically induced surges. They are positioned at feeder poles (injection points) or isolator at rectifier substations on the OLE side of the isolator.

5.32. Appropriate surge arresters are a gapless, metal oxide type device with a rated discharge current of 10 kA. The surge arresters are connected between the contact wire and earth electrodes to provide an earthing path of resistance of less than 5 ohms. The surge arresters and associated connections shall then be insulated from the poles on which they are mounted.

5.33. The earth should be tested annually. Any leakage determines that the surge arrester requires changing.

5.34. Similar to the surge arrester, a low voltage limiter[12] (LVL) will be employed to prevent the energisation of earthed metallic structures and impermissible high touch voltage, (for example, tramstop furniture,) in the event that a contact wire is brought down and makes contact before the breakers trip.

5.35. These should be tested periodically and after any fault.

Support and Registration

Cantilevers - Auto Tension Trolley Wire System (ATTW) and Fixed Tension Trolley Wire System (FTTW) Equipment

5.36. ATTW and FTTW equipment on both single and twin track are supported by cantilevers assembled from galvanised steel tubes or non-ferrous material, and they are hinged on to the poles to allow for thermal displacement of the contact wire during expansion / contraction, i.e. to allow free movement along the track in the direction of the of the tensioning device. Where space is available between the tracks, cantilevers for each track are usually mounted back to back on a common pole or mast.

5.37. At the foot of the cantilever, an insulator is usally employed to provide protection against traction voltage creepage.

5.38. The cantilever can be horizontal or set on a geometically equated angle and supported by additional tubes, steel or synthetic rope (Parafil or Minoroc[13]) tether wires. Steady arms connected directly or to a registration tube provides registation means of the contact wire.

Headspan / Cross-span Wire Construction

12 Also known as Voltage Limiting Device or Soule Device

13 These are common names for synthetic ropes and various types are available. Parafil A has been used to replace the more inferior Kevlar types.

5.39. Where the distance from the centre of the track to the Overhead Catenary Support (OCS) pole or other support is too great for cantilever construction, a crossspan may be erected between two poles, between building fixings or using one pole and one building fixing.

5.40. A headspan comprises of one or more steel or synthetic rope spans one above the other across the track between two supports under tensile load only. Registration points on the lower span are supported by vertical droppers between the upper and lower spans. The contact wire is supported by either a synthetic rope (Parafil or Minoroc) bridle (delta) or a line hanger assembly, clamped to the spanwire. A steady arm may be used to register the wire.

5.41. For synthetic span wire, no additional insulation is required at the supports[14]. However, for steel wires, inline insulators are required at both the supports and just outside an area occupied by the contact wire (approximately 1400 mm from contact line).

5.42. During assembly, the span is erected to a Light Rail system's nominal tension. When the contact wire has been finally registered by adjusting the steady arm connecting clamp positions on the span, the tensile loads introduced in the span may be all in one direction and produce a very low residual tension at one end of the span. This is a predictable condition, and turnbuckles are allocated for that side of the span assembly, so that adjustment can be made to produce a nominal tension.

5.43. Where support structures are not available or an amassed number of poles could result in a conjested area, for example, on a wide curve, the contact wire can be supported and registered by span wires located where possible between available supports and tethered off. These are known as flying tails or bow wires.

Overhead Catenary Equipment

Automatically Tensioned Equipment

5.44. The length of the contact wire varies with changes in temperature. The magnitude of length change is dependent on the distance between anchor positions. In order to keep this within manageable limits, the tension length is usually designed to be approximately 1500 m between the Balanced Weight Indicator (BWA) at each end of a tensioned section[15]. However, this can vary with specific installation requirements and / or local topography.

5.45. If the tension is not appropriate, excessive sagging of the contact wire between support positions could lead to hook over and dewirement.

5.46. To prevent conductor length changes due to temperature variations and therefore prevent significant contact wire sag, a constant tension is maintained by connecting each end of the overhead line tension length to an automatic tensioning device.

5.47. A BWA device generally has a 1 to 3 mechanical advantage tension wheel system by suspending a free moving balance weight stack from a stainless steel rope around the tension wheel system. The mass of the weight produces a tension in the rope suspending it equivalent to one third of the required contact wire tension. An example of a modern

14 Under BS EN50345:2004 1000 mm of rope will provide satisfactory insulation properties against voltage creep at 750 VDC.

15 Usually constricted by the available length of wire on the cable drum during construction.

equivelant is the Tensorex C+ spring tensioner employing encased, calibrated, spiral steel springs.

5.48. Generally, Light Rail systems are tensioned at 10 kN per half tension length.

5.49. Catenary and contact wires can be tensioned seperately or together, employing an equaling arm to apply equal tension.

5.50. Tension lengths of less than 750 m have one end terminated with an automatic tensioning device, the other terminated with a fixed anchor.

5.51. For urban areas, it is recomended that the weights are located inside the tubular pole thus allowing unobstrusive vertical movement and prevention of unauthorised interference or access of the weights.

5.52. FTTW equipment requires shorter spans than ATTW equipment to keep temperature changes within manageable levels; or a box spring tensioner can be used.

5.53. A further difference between the equipement equipment types is that FTTW equipment reflects temperature change in the wire's longitudinal profiledue due to its lower speed and shorter span lengths, and can easily accommodate climatically induced movements of the sag at mid-spans.

Mid-Point Anchor

5.54. A mid-point anchor is a method of restraining the contact wire at approximately the mid point between the automatic tensioned length of contact wire.

5.55. This restraint to movement is applied at the middle position of the tension length and effectively ensures that any changes in length due to expansion, contraction and / or creep of the conductor are equally distributed between the balance weighted pulley systems at each end of the tension length.

5.56. Where catenary is employed, Z droppers are used to tie in the catenary and contact wire and prevent unequal movement between the two.

Sectioning (Electrical and Mechanical)

5.57. Section insulators are designed to provide an electrical discontinuity of the contact wire whilst permitting a tram vehicle pantograph to maintain current draw during its passage across, by the use of continuity skids.

5.58. Section insulators can be high speed with contunity skids or low speed without. Electrical sectioning may also be achieved using non-continuity overlaps. However, care and safety during maintenance has to be the utmost priority, as one side of the overlap may reman live and therefore be a hazard to the maintainers.

5.59. Mechanical sectioning of the OLE with overlaps at the ends of tension or half tension lengths of equipment permits continuity of current collection by a pantograph, and limits mechanical damage in the event of a broken contact wire or a de-wirement.

5.60. Electrical sectioning of the OLE is achieved with section insulators cut into the contact wire at substations and sub-sectioning locations.

5.61. The section insulator design should be such that the electrical separation does not exceed the dimensions of a pantograph. Thus, should a tram vehicle be stopped at a point where its pantograph is directly under the section insulator, then the current is still capable of being fed to the pantograph. Similarly, as a tram vehicle passes underneath at speed, there is no momentary loss of current as its transverses the skids of the section insulator. In addition, the arc horns dissipate any current arcs that arise when the pantograph moves from one section to the next and are momentarily electrically connected.

5.62. It is important to remember that the working life of a section insulator can be detrimentally influenced by inaccuracies of setting during erection or maintenance adjustment, particularly in support dropper or skid setting.

5.63. Mechanical isolators, whether mechanically, manually or automatically operated are used to provide electrical sectioning and isolation during emergencies or when undertaking maintenance. Generally they are not load apparatus and should be only operated if the section feeding circuit breaker has been operated to open beforehand.

5.64. Isolators can be located in secure ground based cabinets or up on a pole and exposed to the elements. The assembly may incorporate a bypass switch allowing a OLE section to be fed from adjacent sections during fault or maintanace.

6. Maintenance Concepts

General

6.1. All equipment is designed with a particular function that which will degrade over time in line with a deterioration of their function. Therefore, there is a turnover of equipment required with optimum levels, usually obtained through operational experience by continuously monitoring the performance of the equipment and recording and analysing the frequency of faults over the lifecycle of a system. This enables remedial action to be planned and then carried out.

6.2. Generally, maintenance regimes are formulated based on manufacturers instructions and experience elsewhere, and then revised and scheduled following experience gained over the life of operating the particular Light Rail system.

6.3. Maintenance is performed regularly at dictated frequencies (generally between 4 weeks and 5 years) depending on the particular equipment, function and its environment and experience of the environment of that system. Work plans are produced in line with this for both routine inspections and planned maintenance.

6.4. The objective of any maintenance is to provide for the following:

- Optimise the reliability of the Light Rail system and its availability;
- Optimise the lifetime of the system and its components; and
- Preserve the highest level of the safety.

6.5. In line with the above, there is no typical scenario or condition for the maintenance of OLE equipment, therefore maintenance is based upon a set of guidelines. In some circumstances, Reliability Centred Maintenance (RCM) can be implemented.

6.6. OLE maintenance covers all the activities intended to maintain or restore an OLE asset in a state or in a given condition of dependability to accomplish a required function. Thus maintenance activities are a combination of technical, administrative and management activities.

6.7. Table 6.1 below provides an overview of the expected lifespan of standard OLE equipment in a typical environmental condition for that Light Rail system and in the system's standard operating conditions. Further information is listed in Appendix 1 in relation to some of the main OLE defects and their causes.

6.8. Maintenance usually consists of the followingtwo main activities:

- Surveillance of the system and;
- Intervention on the system.

6.9. The above two activities include both preventive maintenance and corrective maintenance. The intent of preventive maintenance is to prevent any failure of equipment occuring, whereas corrective maintenance is work required after a failure has already occured. Therefore, if preventive maintenance is correctly applied, corrective maintenance should be mainly linked to shelf life of the equipment or inproper use of the OLE.

6.10. The application of these two methods of maintenance is made within the framework of the maintenance policy.

Table 6.1: Expected Lifespan of Typical OLE Equipment

No.	Description	Expected Lifetime (duration)
1	Brackets of anti-fall balance weights equipment (tension wheel equipment)	≥ 30 years
2	Anti-fall balance weights arrangements (tension wheel equipment)	≥ 30 years
3	Cantilevers	≥ 30 years
4	Pantograph passages along contact wire	Approximately 2 x 10^6 pantograph passages
5	All other conductors	≥ 30 years
6	Insulators	≥ 30 years

Preventative Maintenance

6.11. Preventive maintenance is carried out in a regular organised manner in accordance with a planned schedule that is based on elapsed time since the planned date of the last intervention, or according to the state and the evolution of determined criteria, for example, wear limit.

6.12. A programme of preventive maintenance will define the frequency of maintenance activities. This programme is established according the requirements from the manufacturers, the experience of the maintainer and the specific conditions of the system to be maintained, for example, rail traffic, weather conditions, etc.

6.13. Preventive maintenance is carried out at predetermined intervals, or according to conditional criteria. It is based on three types of tasks: routine inspections, systematic mantenance and condition-based maintenance.

Routine Inspections

6.14. Inspections consist of frequent orderly assessments of the general aspect or state of the OLE. They can be visual or carried out with specific measurement tools (such as those in Appendix 2). Visual inspections and observation is the first step in anticipating equipment failure.

Systematic Maintenance

6.15. Systematic operations are scheduled according to the type of equipment, the environmental conditions and the equipment manufacturer recommendations (for example, time of use, number of sequences, mileage, etc.). They can consist of tasks such as greasing, small part replacement, cleaning, etc.

Condition-Based Maintenance

6.16. Condition-based operations are carried out according to recorded parameters (such as degree of wear, cleanliness, geometric parameter etc.), as required specific to each type

of equipment. These parameters can be recorded during routine inspections or according to drivers or other users obsevations / feedback.

Corrective Maintenance

6.17. Corrective maintenance includes activities performed after the failure of an item or the deterioration of its performance preventing its ability to achieve a required function and is neither planned nor anticipated.

6.18. Its purpose is to rapidly restore the best possible operating conditions for the Light Rail system.

6.19. Corrective maintenance includes permanent or temporary actions to restore the equipment to full or degraded operationing conditions[16], or to put into effect a temporary short-term alternative system (pallative) to allow restoration of the tram service whilst permanent alleviation (curative) is planned.

6.20. Palliative maintenance includes corrective maintenance activities intended to enable an item to temporarily achieve a part of the whole of a required function. These temporary repair activities shall be followed by curative maintenance activities.

6.21. Curative maintenance includes corrective maintenance activities intended to restore an item in a specified state or to enable an item to achieve a required function. These repairing, modification or improvement activities are inherently permanent.

6.22. Detailed information and assessment of all failures in service shall be recorded in the Maintenance Management System in order to analyse and determine root causes and prevent repeat failures.

Maintenance Levels Definition

6.23. All the maintenance levels that can apply to the maintenance of all OLE equipment are defined below.

Level 1 Maintenance – Cleaning, Inspections and Replacement of Consumables

6.24. Level 1 Maintenance includes activities that do not require any specialist tools or test equipment, and can be done by staff with a minimal level of technical training. Level 1 Maintenance tasks typically include the following (not exclusively):

- Cleaning of equipment;
- Replacement of lamps, fuses, filters and consumables;
- Exchange of removable components when necessary (for example Trams, Station seats, etc.); and
- Minor repairs and adjustments.

Level 2 Maintenance – Routine Preventive Maintenance

6.25. This relates to routine preventive maintenance and typically include the following (not exclusively):

16 Occurs when either a part or some parts of the tramway system continue to operate in a restricted manner over a period of time with additional controls in place.

- Actions that require simple procedures and / or simple to use test equipment, which include inspections, tests, checks, measurements, technical cleaning, lubrications, etc.;
- Maintenance safety checking handled by qualified technicians and exchange of simple components to ensure back into service without any safety risk to passengers or staff and damage to systems or equipment; and
- Minor repairs and replacement.

Level 3 Maintenance – Complex Preventive and Corrective Maintenance

6.26. Level 3 Maintenance relates to more complex preventive and corrective maintenance tasks and can only be performed by qualified technicians and / or engineers. These tasks typically include the following (not exclusively):

- Corrective maintenance procedures using complex-to-use test equipment, specialist tools and plant (refer to Appendix 2);
- Major preventive maintenance procedures including inspections, measuring and testing, exchange of some components and general checking;
- Parts exchange for small parts, for parts needing heavy lifting devices, removal of major assemblies such as poles, masts, or isolator assemblies; and
- Exchange of defective or worn parts.

Level 4 Maintenance – Overhauls

6.27. Level 4 Maintenance relates to all overhaul works activities and components exchange overhaul. This is led by highly skilled technical staff and may require the use of advanced technical instruments and equipment (refer to Appendix 2, Appendix 3 and Appendix 4).

Level 5 Maintenance – System Enhancements and Renewals

6.28. This concerns the design and implementation of modifications as may be required to enhance the performance of the system and includes renewals (whole or in part). It requires highly skilled, specialist staff and typically includes the following (not exclusively):

- Improvements required to improve system availability to overcome operation efficiency issues (including software modifications);
- Addition of new operational features to meet customer expectations;
- Improvements necessary to enhance maintainability and reliability; and
- Replacement of components due to obsolescence.

7. Maintenance Tasks and Schedules

Frequency of Maintenance

7.1. The required frequency of maintenance varies on a number of factors, including the age of the system and the actual components, and will vary over time.

7.2. Assessments for maintenance requirements shall be made based on experience of the Light Rail system. To assist, data capture is critical and as a good practice, it is recommended to start to capture this as early as possible within the lifecycle of a Light Rail system. However, a balance will always need to be made between the relevance of data and available resources based on economical decision making criteria.

7.3. Table 7.1 below provides guidance on the average recommended inspection frequencies of some of the critical OLE equipment, and is primarily based on a Light Rail system during a 10 year lifecycle. The figures may be adjusted or extended using risk assessment and condition-based monitoring, subject to no increase of pantograph passes for the installed system.

Table 7.1: Inspection Frequencies for Critical OLE Equipment

Task	Foot Patrol Visual Inspection (frequency)	High Level Inspection (frequency)
Contact wire inspection	2 months	12-36 months
Heights and staggers	2 months	12 months
Turnouts (and crossover)	2 months	12 months
Insulators	n/a	12 months
Surge arrestor	2 months	12-24 months
Balance weight anchors	2 months	12 months
Cantilevers	2 months	12 months
Pull-offs	2 months	12 months
Head-span	2 months	12 months
Isolators (trackside)	2 months	12 months
Isolators (pole)	2 months	12 months
Poles	2 months	12-48 months
Tension reducer	2 months	12 months
Section insulators	2 months	6-12 months
Underbridge arms	2 months	12 months
Overlaps	2 months	12 months
OLE major inspection	n / a	4 years

Ground Level Visual Inspections

7.4. An important factor in the maintenance of Light Rail systems is to have in place an early warning system that is developed from data captured during regular inspections. Generally, developing faults can often be detected and rectified as part of the planned routine maintenance (pallative) rather than as an emergency (curative), thus avoiding unplanned interruptions to services.

7.5. In relation to OLE equipment, the purpose of the visual inspection is to ensure maximum security and safety. A visual inspection can be carried out in two ways as described below:

- A visual examination only with a follow up report and separate site visits to carry out remedial work which may be required; or
- A visual examination carrying out remedial work and routine maintenance in the area inspected, within the one site visit.

7.6. It is anticipated that the maintainer of each Light Rail system will have their own method for fault capture data and related remedial plan system. Any work arising from visual inspections will need to be scheduled at a time when the OLE can be isolated and worked on directly. Appendix 5 makes a recommendation of the components to be included in visual inspections.

7.7. General observations and considerations when carrying out a ground level inspection of the OLE (i.e. items affecting wires, structures and switches etc.) include the following (not exclusively):

- All insulators, including section insulators and surge diverters (for signs of flashover), damage to insulators or to arcing horns and abnormal pollution. Damaged insulators are to be replaced at the first available opportunity;
- Contact wires for kinks or damage;
- Span wire (insulated ropes) assemblies for defects, loose attachments or excessive sag to avoid the possibility of loss of registration or hook-overs;
- Bare-stranded conductors for broken wires or other damage;
- Pole attachment misalignment. Registration assemblies and cantilevers to be correctly positioned relative to each other;
- A lack of or excessive movement of registration assemblies on ATTW equipment along the track relative to temperature;
- Insulated wires for damage to insulation or wires;
- Seasonal hazards such as birds nesting, trees or vegetation infringing electrical or pantograph clearance;
- Damage to locks on lineside switches, missing or loose components, including switch blades, faulty or damaged operating mechanism;
- Structure, assets or isolator identification or number plates;
- Bonding equipment, all connections to be checked for damage and security; and
- In areas where contact wires cross or meet, i.e. at overlaps, crossovers, mid points and tension reducers (to avoid the possibility of hook-overs between the contact wires and tram vehicle pantograph).

Intrusive Inspections

7.8. These tasks can be defined as routine maintenance or major works depending on the requirements and outcomes of previous inspections. Appendix 6 makes a recommendation of the inspection check components for intrusive inspections.

APPENDIX 1: MAIN OLE DEFECTS

Equipment / Asset	Defect
All installation	Diminution of the insulation level, checking of the anchoring
All types of isolators and insulators	Damage on the components due to pollution, environment, direct hits etc.
Cantilever	Deflexion and support
Cantilever parts	Mechanical and electrical wear
Contact wire	Average wear or abnormal wearing on a spot or support point, gradient of the wire, modification of the height or / and the stagger
Fix point	Corrosion
Inox cables / junction in between wire / Parafil (synthetic wire)	Wearing / damage on the wires, traces of heating, internal oxidation and parting
Interface steady arms and clamps	Wearing of the interface part
Interface terminal / Parafil	Default on the interface between the components
Section insulator	Electrical and mechanical wear and / or mechanical breaks of support system
Steady arm	Corrosion, wear, mountings, mechanical breaks
Steel wires	Cables for tensioning device, damage on the wires and / or oxidation / corrosion
Terminal	Damage on the piece and / or material separation

APPENDIX 2: TOOLS

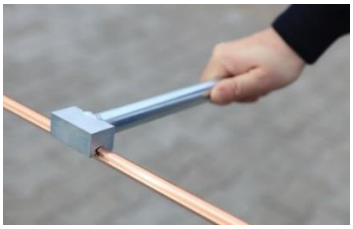
1) These terms and images show general tools used in OLE maintenance. They are listed alphabetically and have been obtained from various sources available to LRSSB including existing Light Rail systems and suppliers' catalogues (with their knowledge). As such, in some cases, the images contained within this appendix are of an average quality. In addition, their use in this guidance should not be taken as an endorsement of any company or their supplies.

2) The above tools will require skill and competency to undertake any maintenance of OLE systems. This can be referenced in guidance document LRG40 Competency for OLE Maintainers

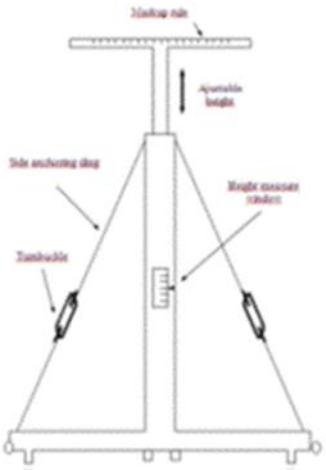
3) It shall remembered with the advancement of technology and innovation some of the above measuring and checking tools can be substituted with digital era tools providing the following:

- More freedom for maintainers allowing staff to do other corrective work;
- Obtain data without the need of isolation, out of service shifts or access vehicles etc.;
- Safer, quicker, more accurate and consistent readings;
- Automatic downloads to databases than manual counterparts; and
- Provides video evidence (streamed or stored) for visual aids for faulting and planning.

Name / Purpose of Tool	Illustration
2-5 kV Insulation Tester with Pole and Leads Used to test insulation properties of insulators and earthing system.	
Band-It Tool This device provides enough tension in the band to provide a secure fixing of fittings to poles where they are banded instead of bolted assemblies	
Cable Knife Used to pare back insulation on parafil wires	
Clamp for Parafil Wire Ø6-14 mm. smooth jaws to prevent damage to the insulation	

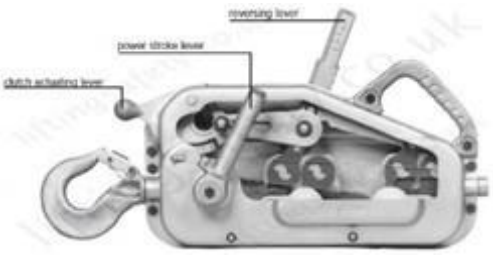
Come a Long Clamp for Steel Wires Various sizes are available	
Name / Purpose of Tool	**Illustration**
Conductor Wedge Clamp A device to provide a temporary tensioning anchor on a conductor whist removing, changing, or adjusting components.	
Contact Wire Roller (Screw Type) Used to remove kinks from contact wire or straighten a short length or wire for splicing.	
Contact Wire Twister (Quick Twist) A short handled "hook- on" lever for twisting the contact wire through a small arc about its longitudinal axis to provide a correct attitude for the wire to receive clamps or clips.	
Dynamometer An instrument used to record the tension being applied to a conductor from a tensioning rig. The tension is transmitted through the instrument.	
Grease Gun For injecting grease under pressure into the greasing point of jockey pulley, wheel or assembly used in the automatic tensioning assembly.	
Hand / Battery Operated Hydraulic Press For compressing lugs and sleeves Press and Dies onto bronze flexible to manufacture droppers.	

Height and Staggers Laser A calibrated instrument used to determine the vertical (Height) and lateral position of the contact wire relative to the running rails (Stagger). REFOS and Cant (Super Elevation) measurements may also be measured. This can be used with the OLE energised and should be tested before use on a specific test wire for accuracy of the calibration.	
Name / Purpose of Tool	**Illustration**
Hydraulic Cable Cutter Used to cut cable (not contact wire unless the jaws are specified for the job)	
Hydraulic Crimping with Dies Used to secure cable lugs to cables	
Kink Remover Hydraulically operated anvil to remove a kink from a contact wire	
Live Line Tester An instrument used to ascertain if the OLE is energised or de-energised prior to the application of earths. This should be tested before use to determine it is working correctly.	

MEWP or RRV (Road Rail Vehicle) or RMMM (Rail Mounted Maintenance Machine) Multicar Road / Rail access vehicle. Modular accessories system gives varied utility.	 
Name / Purpose of Tool	**Illustration**
Panning Device Used to check the setup of section insulators, crossovers and overlaps in terms of line and level and on curves to check the stagger is not beyond the working tolerance of a pantograph. A mark-up rule indicates offset. Nowadays fitted to RRV MEWPS	 

Portable Earthing contact wire clamp with bayonet pole fixing	
Portable Earthing Lead	
Portable Earthing Magnet Used for grooved rail on urban embedded applications where the rail foot is not accessible	
Name / Purpose of Tool	**Illustration**
Portable Earthing Rail Clamp Allows a secure connection to a rail foot	

Portable Earthing Pole The poles allow the application of a contact wire clamp attached to portable earth strap to be fitted safely. The poles can remain in place or be removed from the clamp	
Pull Lift Generally, 2 sizes 0.75T for registration rigging and 1.5T for rigging along track	
Pulling Hand or Come Along Clamp Device used to grip the wire and provide a temporary anchor	
Name / Purpose of Tool	**Illustration**
Riggers Podger Spanner (rachet) common sizes are 17 and 19 mm socket	

Section Insulator Installation Tool To allowing cutting in or replacement of section insulators into the contact wire.	
Section Insulator Setting Table A device to allow section insulator contact skids to be set level and provide the necessary air gap to prevent arcing and insulator contact	
Slings Various slings of varying lengths and tonnage to enable safe rigging of components on the overhead line.	
Tension Meter An instrument that can be applied to a tensioned conductor to record the tension in it, without cutting the conductor or removal.	
Three Roller Wire Straightener This special roller is used to remove the drum curve from contact wire.	
Name / Purpose of Tool	**Illustration**
Tirfor Lever operated tensioning device used in place of pulley blocks and ropes and to take off tension from a contact or catenary wire for removal or adjustment of balance weight wheel assemblies. Can be used to apply temporary tension to slipped support (back stay).	

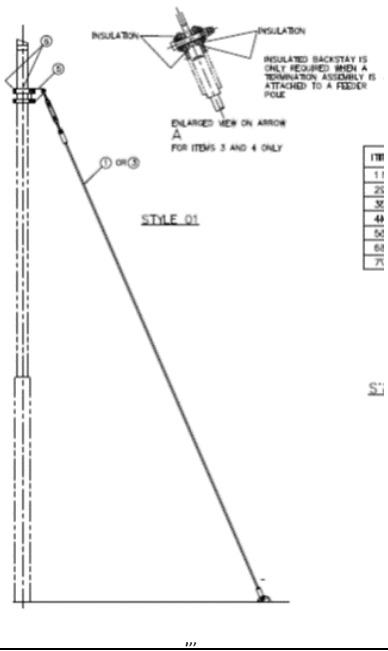
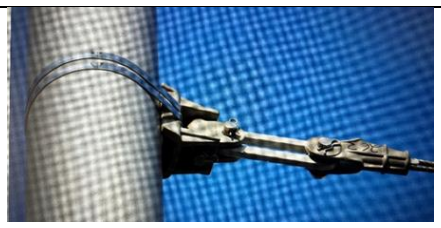
Torque Wrench Used to apply specific tightening torque to fixtures and fittings	
Vernier Calliper Used to take measurements of contact wire wear	

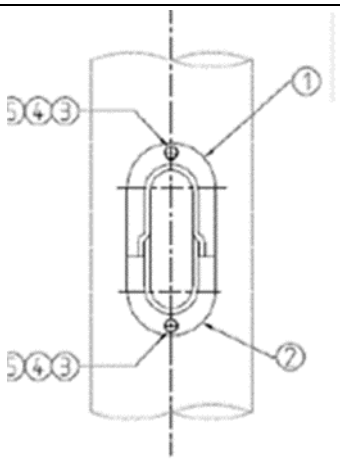
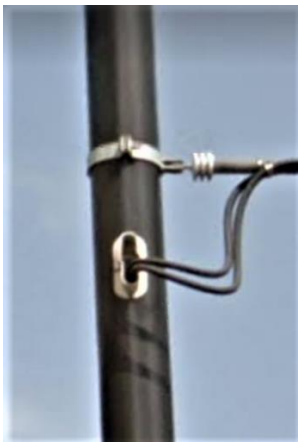
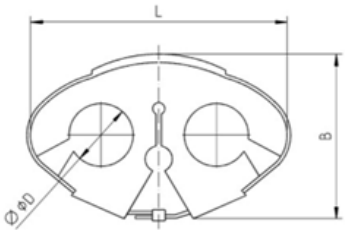
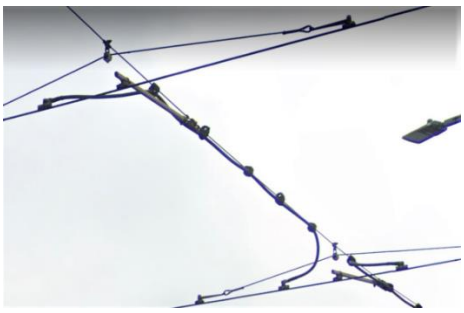
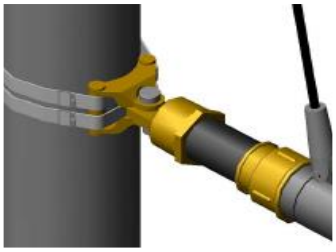
HERITAGE SYSTEMS

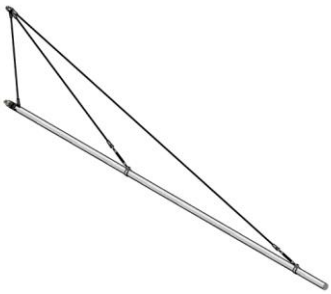
Name / Purpose of Tool	Illustration
Various Clamps and Tools Including mechanical screw driver for removing screws from ear clamps	

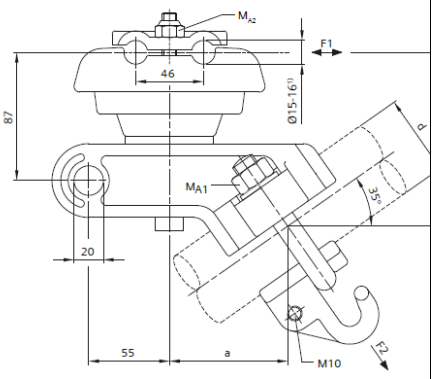
APPENDIX 3: OLE OVERHEAD LINE ASSET DESCRIPTIONS

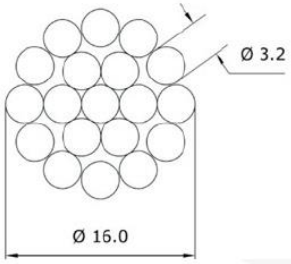
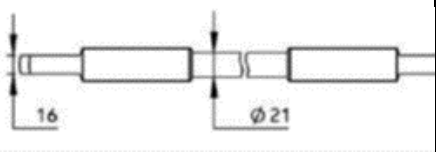
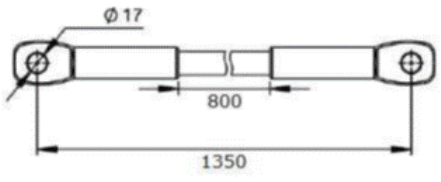
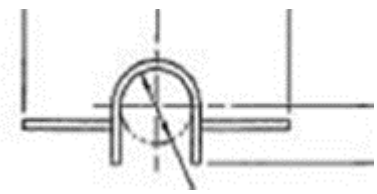
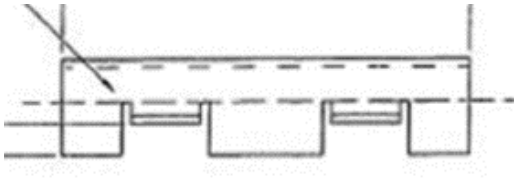
The following general and common OLE component terms and images are listed alphabetically and have been obtained from various sources available to LRSSB including existing Light Rail systems and suppliers' catalogues (with their knowledge). As such, in some cases, the images contained within this appendix are of an average quality. In addition, their use within this guidance should not be taken as an endorsement of any company or their supplies. Alternative sector names are in brackets.

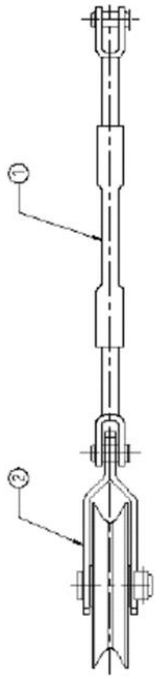
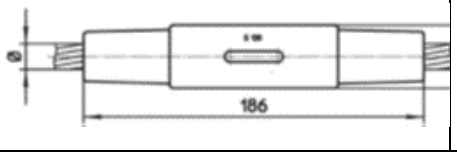
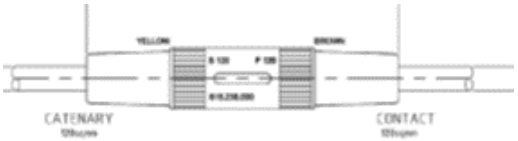
OLE Asset		
Anti-Climb Device Can be square or round profile		
Backstay Assembly		
Beta Pin (R pin)		

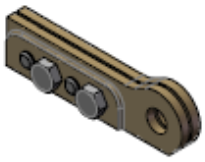
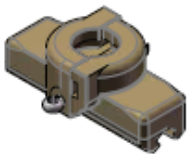
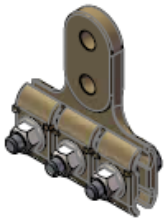
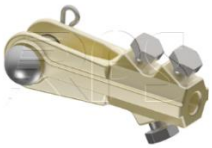
OLE Asset		
Binding Cylinder For cross spans (stainless steel and parafil)		
Bridle (Delta) Assembly with fixed pulley on cross span wire		
Cable Entrance Collar		
Cable Hanger (with Cable Tie) These can support between 1 and 5 cables on a cross span		
Cantilever 3 kV DC Polyamide Foot Insulator Machined insert, threaded and plain bush		

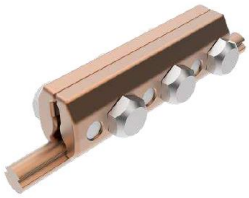
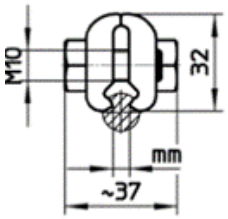
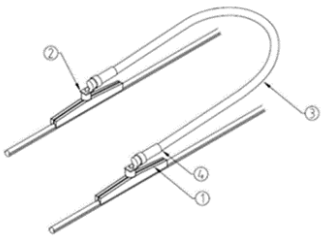
OLE Asset		
Cantilever 3 kV DC Polymeric Insulator End Fitting Socket and eye		
Cantilever Arm Double Track Single and Bi tube with parafil rope tether (tie) wires		
Cantilever Arm Single Track Single and Bi tube with parafil rope tether (tie) wires. Tubes are aluminum or galvanized steel		
Cantilever Bridle (Delta) Hanger		
Cantilever Catenary Wire (Messenger Wire) Non-Insulated		

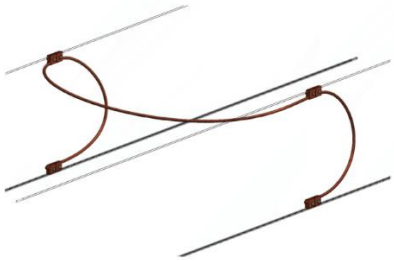
OLE Asset		
Cantilever Catenary Wire (Messenger Wire) Support (Insulated)		
Cantilever Clevis End Fitting		
Cantilever Drop Bracket For steady arm		
Cantilever End Cap		
Cantilever Eye Clamp		
Cantilever Foot Internally threaded and tongue		

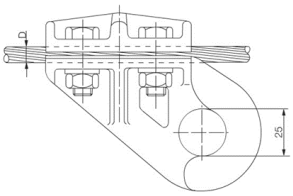
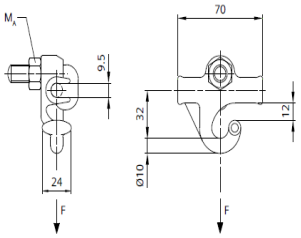
OLE Asset		
Cantilever Hook Clamp		
Cantilever Tongue / Spade End Fitting (Bolted)	Stranded 	
Catenary Wire Copper Stranded Conductor 150 mm²		
Catenary Wire (Messenger Wire) Dropper Clamp (Fixed)		
Catenary Wire Insulator Assembly Breaking load >80 kN (See fixed anchor for application)		
Catenary Wire Saddle Provides protection where a dropper is located		

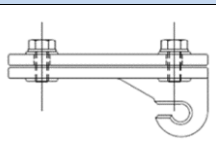
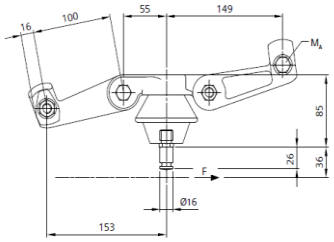
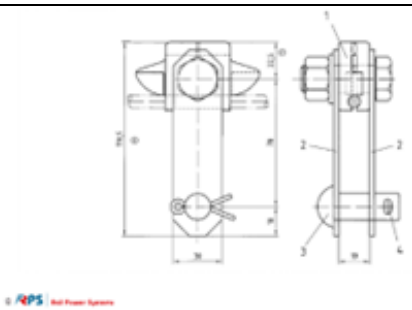
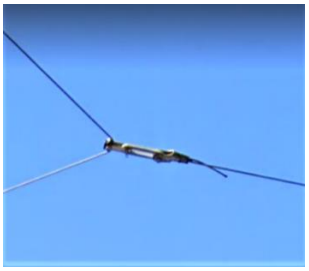
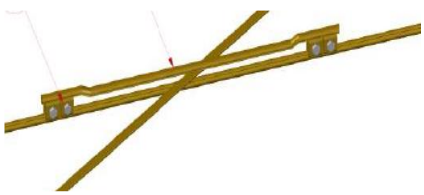
OLE Asset		
Catenary Wire Support Assembly with Inline Insulator		
Compression (Crimped) Lug For current carrying droppers		
Compression (Crimped) Sleeve For droppers		
Conical Coupling		

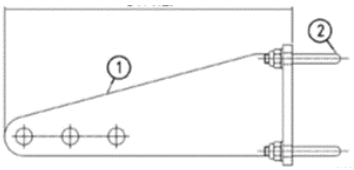
OLE Asset		
Contact Wire Anchor Clamp		
Contact Wire Clamp Bolted with steady arm bayonet fitting		
Contact Wire Clamp For dropper		
Contact Wire Clamp Friction with steady arm bayonet fitting		
Contact Wire Clamp Injection / Feed Cable		
Contact Wire End Clamp Bolted		
Contact Wire End Clamp Compression type		

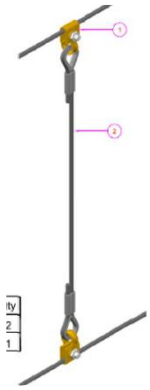
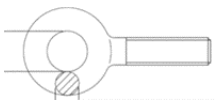
OLE Asset		
Contact Wire End Clamp (Fork)		
Contact Wire Spacer Clamp		
Contact Wire Splice Fitting Bolted (6-8 bolts, profiled and adjustable are available)		
Continuity Bond (Jumper Cable) Crossing		
Continuity Bond (Jumper Cable) Crossing		
Continuity Bond (Jumper Cable) Single track catenary to contact wire		

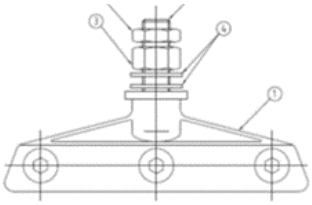
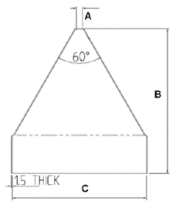
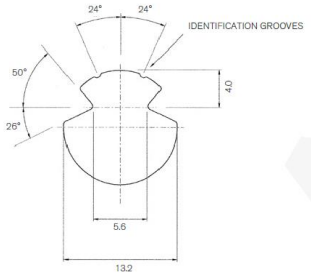
OLE Asset		
Continuity Bond (Jumper Cable) Twin track catenary to contact wire		
Cross Span Anchor Wedge Clamp With quick link for steady arm		
Cross Span (Parafil Wire) Cable Hanger for Bridle (Delta) Ø7-13 mm		
Cross Span (Parafil Wire) Dropper Assembly		
Cross Span (Parafil Wire) Dropper Assembly Alternative using wedge clamps		

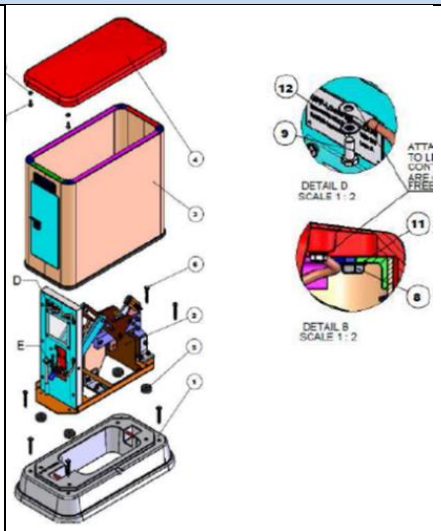
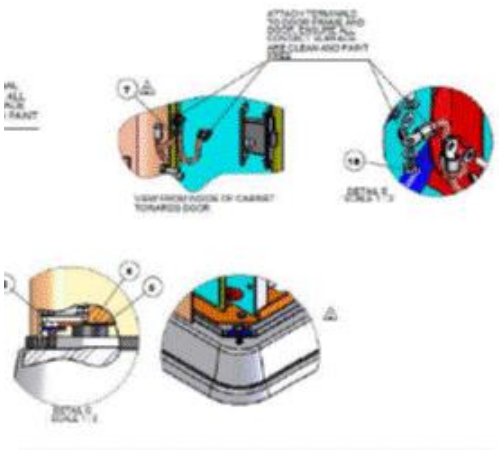
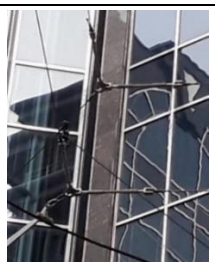
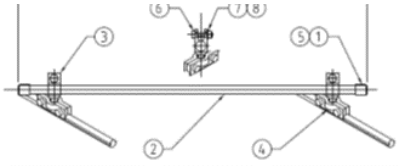
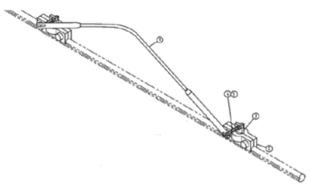
OLE Asset		
Cross Span Equalising Plate		
Cross Span Parafil Wire Ø11-13 mm (Elastic Support)		
Cross Span Stainless Steel Wire Ø 8mm		
Cross Span (Steel Wire) Double Eye Clamp (Snail Clamp)		
Cross Span (Steel Wire) Eye Clamp (Snail Clamp)		
Cross Span (Steel Wire) Hook Clamp For small pulley assembly		

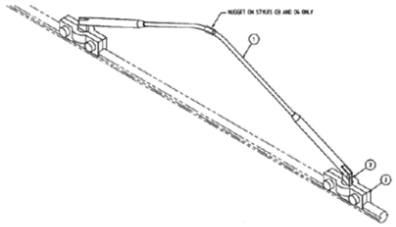
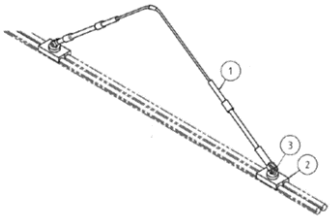
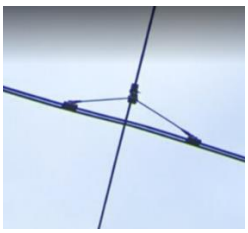
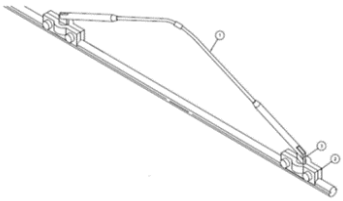
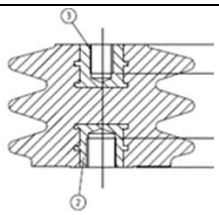
OLE Asset		
Cross Span (Steel Wire) Hook Snail Clamp		
Cross Span (Steel Wire) Insulated Pulley For Bridle		
Cross Span Porcelain Insulator Wire Clamp / Hanger / Ear As used in Blackpool		
Cross Span (Steel Wire) Line Hanger Single contact wire and insulated	 	
Cross Span (Steel Wire) Wire Clamp For bow wires and flying tails		
Crossing Bar		

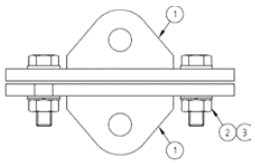
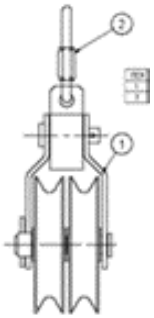
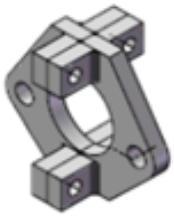
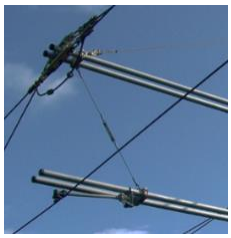
OLE Asset		
Dead End Wedge Clamp (Gun End) For Ø 6 mm or 8 mm Stainless steel wire		
Delta Link (Triangular Karabiner Link)		
Drop Plate Assembly		
Dropper Current carrying type		
Dropper Copper loop dropper		

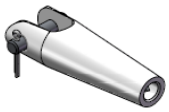
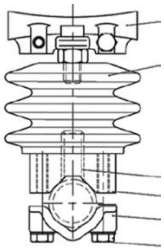
OLE Asset		
Dropper Non-current carrying type		
Dropper – Double Catenary Wire (Messenger Wire)		
Dropper Clamp (Saddle Clamp) Sliding		
Eye Bolt		
Feeder Clamp – Catenary Wire (Messenger Wire) To contact wire		
Feeder Clamp for Contact Wire (T-Clamp)		

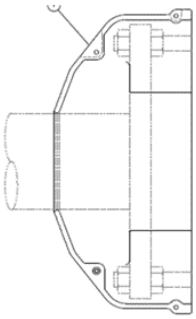
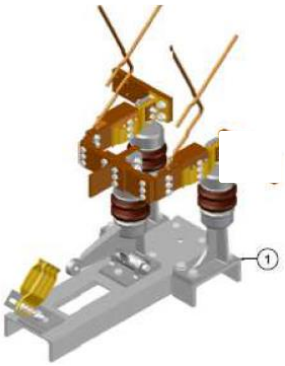
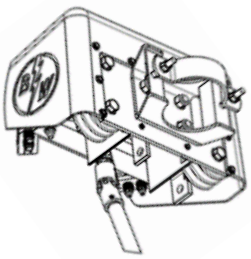
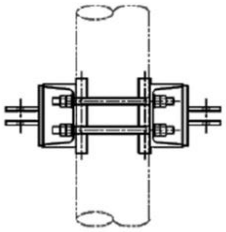
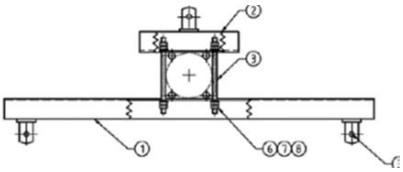
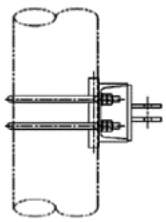
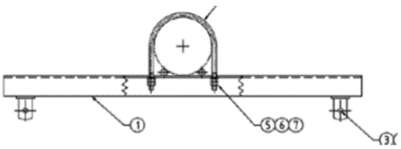
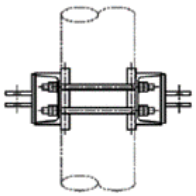
OLE Asset		
Feeder Ear Assembly		
Feeder Pole		
Finial		
Fixed Tension Anchor With insulators and turnbuckle		
Hard Drawn Grooved Copper / Copper Alloy Contact Wire AC 107, AC 120 and AC 150 / CuAg 0.1, Cu-EPT and CuMg		

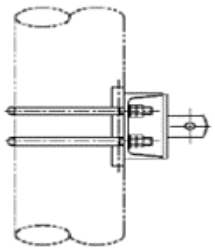
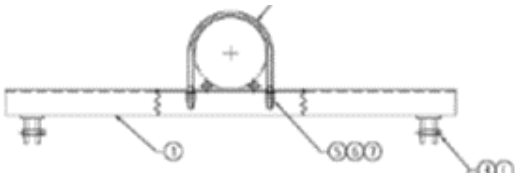
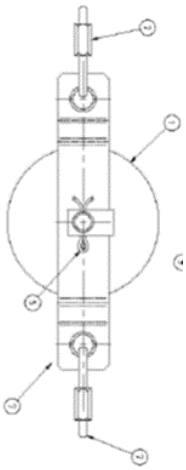
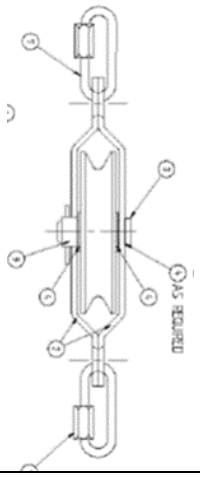
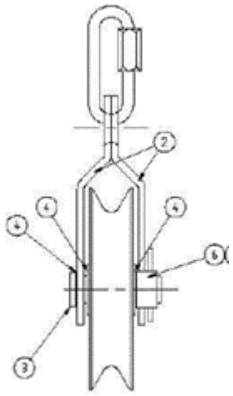
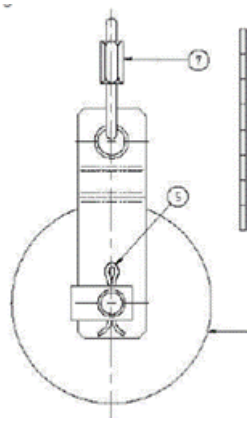
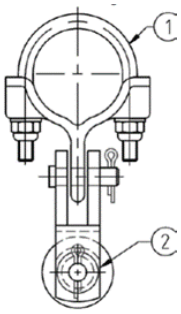
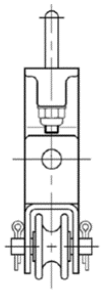
OLE Asset		
Ground Mounted Manual Isolator		
Headspan Assembly Ø8-10 mm stainless steel wire		
Inline Insulator 7t clevis-clevis		
Insulated Knuckle Assembly		
Insulated Stich (Bridle / Delta Stitch Lever Full Nut Type)		

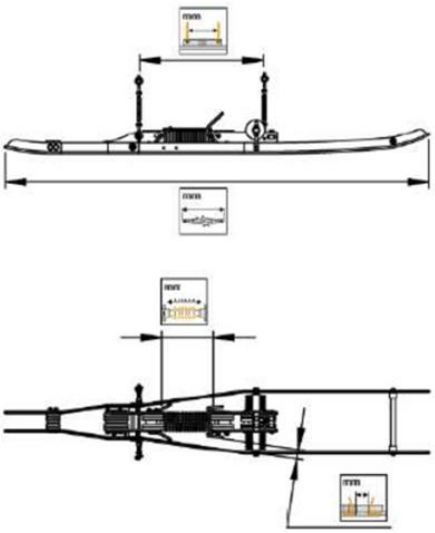
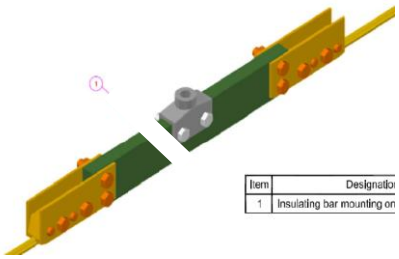
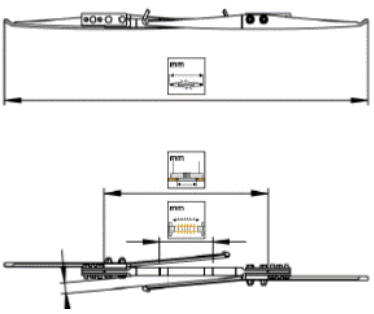
OLE Asset		
Insulated Stich (Bridle / Delta Stitch Nipple Type)		
Insulated Stich Assembly For twin contact wire (bridle / delta stitch)		
Insulated Stitch with Nuggets Single Contact Wire (Bridle / Delta Stitch)		
Insulator Body 1.5 kV DC Cast resin M16 treads		
Jumper Cable		
Link Plate Stainless Steel		
Loop Insulator 1.5 kV DC Cast resin (some may have an added coat of silicon)		

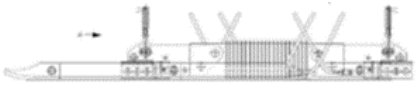
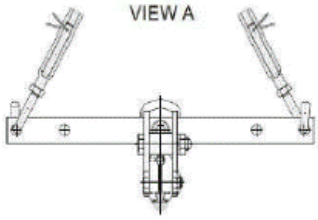
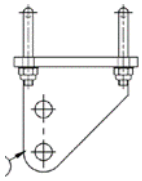
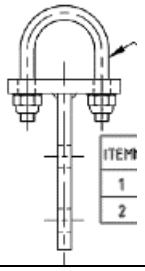
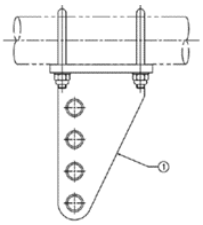
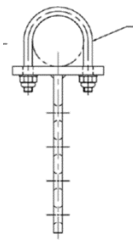
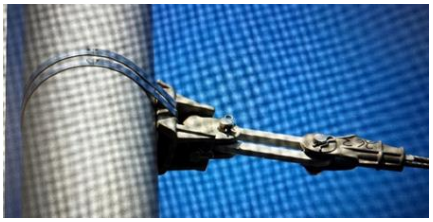
OLE Asset		
Mast – I / H Profile Universal Column With back-to-back cantilevers		
Messenger Wire (Catenary Wire) Head Span Clamp		
Messenger Wire (Catenary Wire) Twin Pullies Support Assembly		
Midpoint Anchor Clamp Assembly (On a cantilever)		
Nose Dropper Stainless steel with inline loop insulator Ø6 mm		
Parafil Type A Synthetic Rope Ø7-13.5 mm		

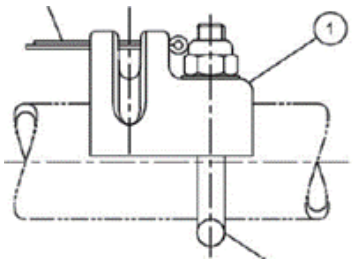
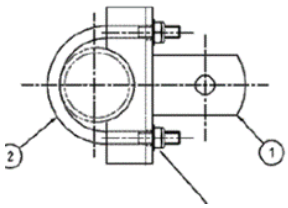
OLE Asset		
Parafil A Terminal (Wedge Fixing)		
Parallel Feeder Support Insulated on a cantilever		
Parallel Feeder Support Insulated on a Cross Span		
Pole Tubular various lengths and profiles		
Pole Clamp Swivel Bracket Banded For cantilever and span wires		
Pole (Mast) Clamp Swivel Bracket Bolted		

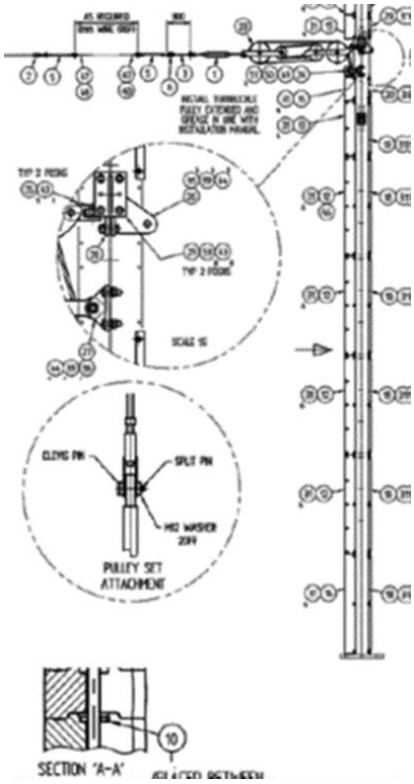
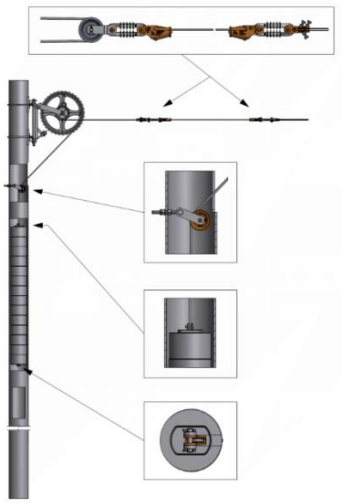
OLE Asset		
Pole Cowl		
Pole Mounted Isolator (Disconnector) no load operation with earthing contact		
Pole Overlap Bracket Assembly Twin		
Pole Overlap Cantilever Spreader Bracket Assembly		
Pole Overlap Cantilever Spreader Bracket Assembly Twin / Back-to-Back		

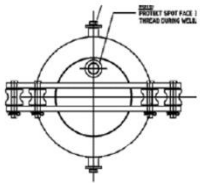
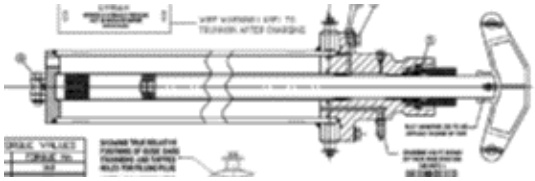
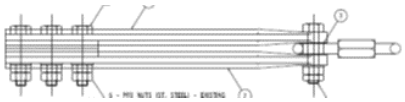
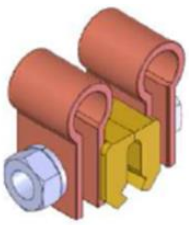
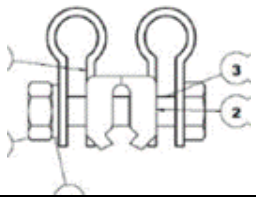
OLE Asset		
Pole Overlap Top Bracket Assembly		
Pulley Assembly Double Yoke		
Pulley Assembly Single Yoke		
Pulley Support Assembly On a cantilever		

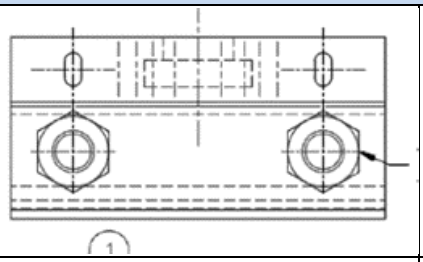
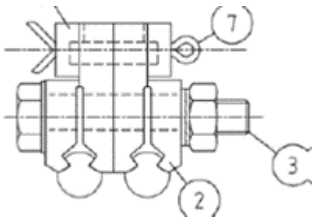
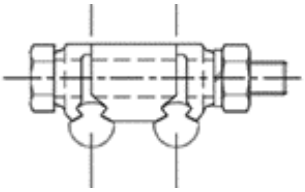
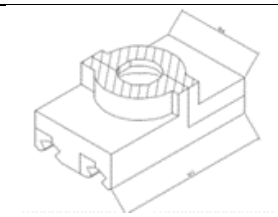
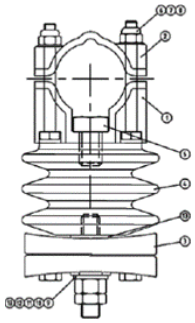
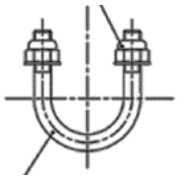
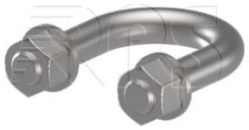
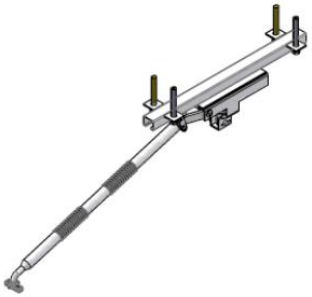
OLE Asset		
Quick Opening Link		
Section Insulator 3 kV DC high current systems speed up to 140 km/h Insulator breaking load of each beam 80 kN anti short circuit diodes fitted		
Section Insulator Skidless		
Section Insulator with Continuity Skids 1 kV DC speed up to 60 km/h Insulator breaking load of 60 kN		

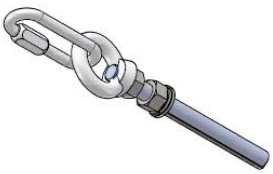
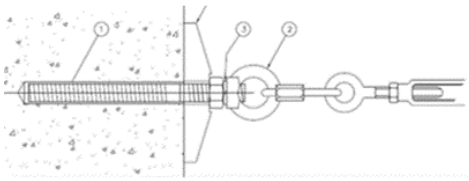
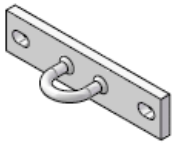
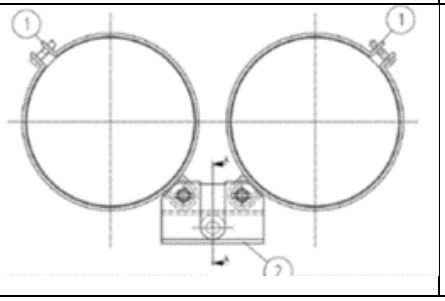
OLE Asset		
Section Insulator with Continuity Skids 1.5 kV DC speed up to 100 km/h. Insulator breaking load of 80 kN		
Short Drop Plate Assembly		
Short Dropper Assembly		
Snap Head Pin (Stainless Steel or Aluminum) For assemblies and used with Beta pin		
Spring Tensioner (Box Spring) Linear >12 kN for short tension lengths with fixed end		
Spring Tensioner Spiral Spring Tensorex C+		

OLE Asset		
Steady Arm Special profile with inline insulator		
Steady Arm Insulated (Registration Arm)		
Steady Arm Non-Insulated (Registration Arm)		
Stitch (Bridle / Delta) Support Assembly		
Stove Pipe Clamp On a drop tube		
Surge / Lightning Arrestor (Divertor)		

OLE Asset		
Tension Mast and Weight Assembly 1:4		
Tension Pole Tubular With internal weight stack 10-20 kN		
Tension Wheel 1:3 With equalising pulley		

OLE Asset		
Tensioner Cylinder Assembly Hydraulic or gas		
Tensioning Clamp Assembly		
Thimbles For dropper wires copper and stainless steel		
Turnbuckle Clevis / Clevis		
Turnbuckle Eye / Clevis		
Turnbuckle Eye / Eye		
Twin Catenary Wire Dropper Clip Contact Wire Clamp For Limited Clearance		

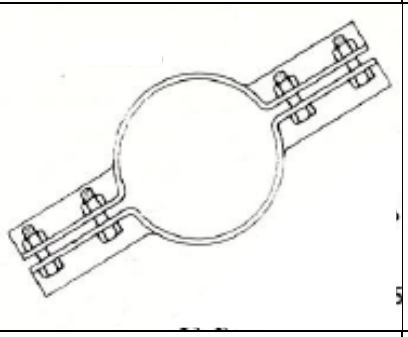
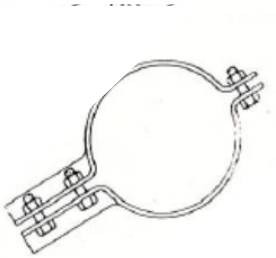
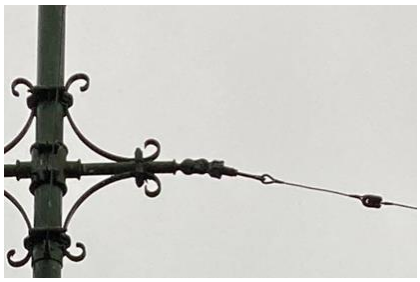
OLE Asset		
Twin Contact Wire Bolted Clamp		
Twin Contact Wire Clamp		
Twin Contact Wire Clamp With bayonet fitting		
Twin Messenger (Catenary Wire) Support Assembly		
U Bolt Assembly Stainless Steel		
Under-bridge (for Over-bridge) Contact Wire Support Arm Assembly Insulated arm anchor bolts (concrete)and or lindaptors (steel)		

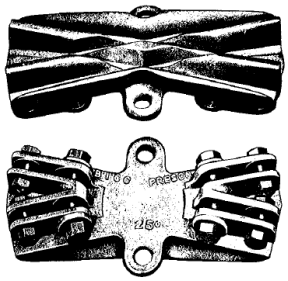
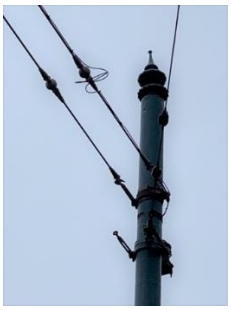
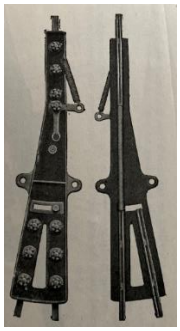
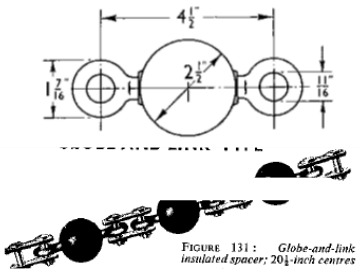
OLE Asset		
Voltage Limiting Device (Low Voltage Limiter)		
Wall Fixing Assembly M16> anchor bolt in epoxy resin cement compound		
Wall Plate Fixing		
Weight Stack Round and rectangular profiled weights – cast iron or steel		
Weight Stack Guide Bar Assembly (external weight stack)		

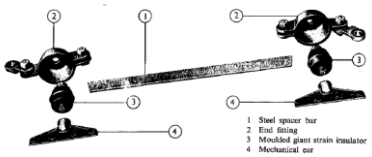
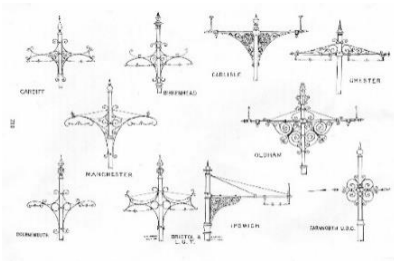
APPENDIX 4: OLE OVERHEAD LINE ASSET DESCRIPTIONS FOR HERITAGE SYSTEMS

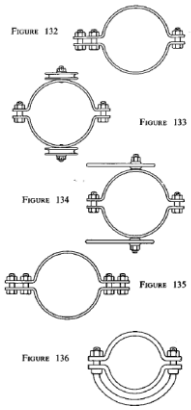
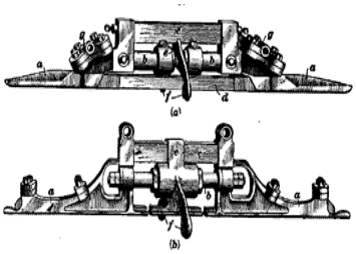
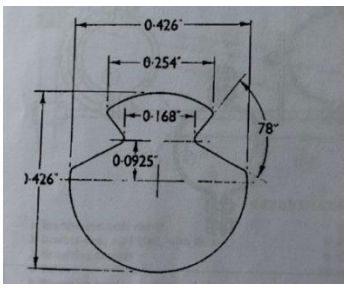
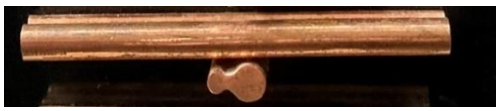
The following general and common OLE component terms and images are listed alphabetically and have been obtained from various sources available to LRSSB including existing Light Rail systems and suppliers' catalogues (with their knowledge). As such, in some cases, the images contained within this appendix are of an average quality. In addition, their use within this guidance should not be taken as an endorsement of any company or their supplies. Alternative sector names are in brackets.

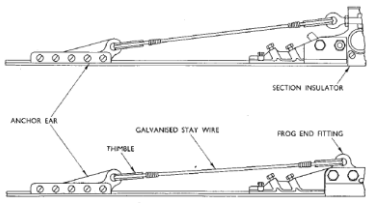
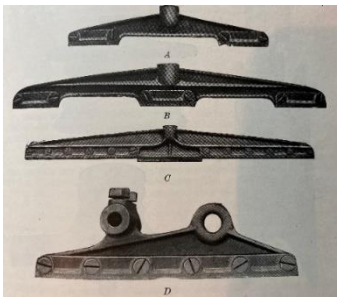
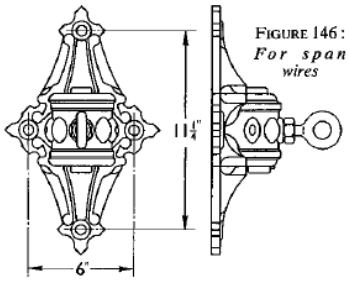
OLE Asset (Heritage Systems)		
Backstay Anchor		
Bonding Cable		
Bowstring Bracket With double globe insulators		
Bracket Arm (Long)		

OLE Asset (Heritage Systems)		
Bracket Arm (Short)		
Bracket Arm Collar (Double)		
Bracket Arm Collar (Single)		
Brooklyn Strain Insulator		
Finale		

OLE Asset (Heritage Systems)		
Fixed Crossing Solid casting with various angles		
Fixed Tension Anchor Assembly		
Frogs Fixed and switched, left and right hand orientation operated by the pole or insulated pull		
Glazed Vitrified Porcelain insulator (Suspension Insulator) Attached to span wires – eye splices used		
Globe Insulator (Suspension Insulator) Usually set in pairs with link bars between	 FIGURE 131: *Globe-and-link insulated spacer; 20¼-inch centres*	

OLE Asset (Heritage Systems)		
Hanger Cap and Cone with Short Ear on a Span Wire		
Hanger West End Single Pull Off and Straight (or Hockey Stick Assembly)		
Iron work		
Lightning Arrestor		
Pole		

OLE Asset (Heritage Systems)		
Pole Strap Various forms anchouring tie wire or span wire		
Section Insulator BICC (British Insulated Calendar's Cables Limited) Prescott in photo with surge coil in line feeder		
Surge Arrestor		
Trolly Wire Standard 0.125 Sq inch (4/0 SWG) CuCd bottom Top profile is early form trolley wire		 

OLE Asset (Heritage Systems)		
Trolly Wire Anchor Ear With globe insulator (alternative shown without insualtors in diagram)		
Trolly Wire Ears Various lengths and profiles 6-24 (inches) Item D is a feeder ear		
Trolley Wire Spice		
Turnbuckle and Hook Bolt		
Wall Rosette Cast iron with forged steel eyebolt		

APPENDIX 5: COMPONENTS FOR VISUAL INSPECTIONS

For consistency, the following items for visual inspections are listed in alphabetical order and thus are in the same sequence as those in Appendix 6 for intrusive inspections.

Visual Inspection Components	Extent of Work
Anti-Fall Balance Weight Equipment (Tension Wheel Equipment) (Position of weight set and wheel body relative to ambient temperature and tension length)	Position of weight stack and wheel assembly for ambient temperature (where visible) and movement
	Condition of weight stack and wheel assembly (where visible)
	Latching plate
	Steel wire condition and wraps on drums
	All contact or catenary wire connections
	Condition of inline insulators
	Condition of equalising pulleys and fittings
Catenary with Droppers and Contact Wires	Position of droppers
	Condition of dropper wire and connections between contact and catenary wires .
	Disconnections
	Foreign bodies
	Fastening of all clamps, pins etc.
Cantilevers	Horizontal position of cantilever arm (along track setting) compared to ambient temperature.
	Vertical position of steady arms (heel setting)
	Condition of cantilever and insulators
	All movable parts and catenary wire at support clamp
	Nuts, bolts, pins and fittings visibly in place
	Split pins and retaining clips (contact wire swivel clip,)
	Steady arm drop bracket
	Tether and dropper wires condition and security
	Bridle (delta) assembly
Crossover Arrangements (Turnouts)	Position of crossing conductors, crossing bars and jumpers
	Condition of cross bridges, droppers and crossover droppers
	Pantograph passage
	All connection (by means joints of fittings etc.)
Earthing and Bonding (Track Work Bonds)	Rail bonds condition (Traction and earthing)
	Return current cable and conductors' condition
	Security of all nuts, fittings and connections

Visual Inspection Components	Extent of Work
Feeder and Jumper Arrangements	Position of drop feed, jumpers
	Condition of jumpers
	Surge arrestor condition and connections
	Security and fastening of all connection / continuity clamps
Fixed Termination Anchors (Fixed Termination)	Condition of insulators
	Copper, bronze and steel wire terminations
	All connections (by means joints of fittings etc.)
	Dead end clamps and turnbuckle security
	Pins
Flying Tail Pull-Off (Pull-Offs)	Condition of insulators and wires (both steel and synthetic)
	Security of all nuts and fittings
	Pins
	Steady arm and contact / catenary connections and clearance
Foundations	Condition spalling , cracks or damage
	Anchor bolt connections and security / protection
Head-Span Arrangements	Position of conductor suspension clamps and steady arms
	Condition of insulators, all movable parts, wire and droppers
	Security of all nuts, fittings and pins
	Cross-span tensioning spring / turnbuckle security
	Catenary wire clearance at support clamps
	Steady arm and clamp clearance
Midpoint Anchors (Midpoints)	Condition of insulator, Z-droppers, support cables and all connections
	Security of clamps and pins
Overlaps with Electrical Jumpers	Position of wires, crossing conductors, insulators and jumpers
	Condition of the insulators and jumpers
	All connections and pins
Pole Mounted Isolators (Disconnectors) (Isolators with Manual Operating Mechanisms)	Condition of insulators, linkage and the disconnector device
	Foreign matter on mechanism
	Condition of earthing connection
	Security of all nuts and fittings
	Operating linkage
	Operating mechanism

Visual Inspection Components	Extent of Work
Poles	Condition of pole and protective coating (paint)
	Inclination (rake) or obvious ground heave
	Anti- climb devices / guarding in place
	Corrosion of parts
	Anchor arrangement and security
	Security of all nuts and orientation of fittings (spreader beams etc)
Section Insulator	Condition of the device
	Condition and security of support equipment
	Pantograph passing
	Damage to skids
	Checking of voltage passing / creep using circuit breaker meters
	Condition of insulated strips both contact and non-contact types
Tension Spring (Setting relative to ambient temperature for tension length)	Condition of tension spring assembly inc frame
	Condition of inline insulators
	All contact or catenary wire connections
Under Bridge Support Assemblies	Along track position of support and clearance
	Condition of insulators and assembly
	Bridle or pully assembly
	Insulation in place
	Security of fittings and visibly in place
	Pins and split pins and contact wire retaining clips.

APPENDIX 6: COMPONENTS FOR INTRUSTIVE INSPECTIONS

For consistency, the following items for intrusive inspections are listed in alphabetical order and thus are in the same sequence as those for visual inspections in Appendix 5.

Intrusive Inspection Components	Extent of Work
Anti-Fall Balance Weight Equipment	Weight stacks positioning and freedom of movement
	Rope wraps on pulleys and security
	Weight stacks and wheel assembly - greasing
	Wheel condition – cracks and wear by wire
	Latching plate position and security
	Steel wire condition, wear and oiling (periodically)
	All connections and fittings
	Termination insulators
	Snap head and clevis pins
	Equalising pulley and associated end fittings
Catenary and Flexible Droppers	Crossing conductors
	Debris (foreign bodies)
	Droppers
	Dropper rope loops and clamps
	Conductors
	All connections and fittings
Cantilevers and Mechanically Independent Supports and Registrations	Resetting of cantilever and steady arms positions
	Steady arm contact wire clamps (torqued to specification)
	Cleanliness and condition Insulator, replace as necessary
	Security of connections and fittings
	Check movable parts for wear
	Catenary wire at support clamp
	Snap head and clevis pins
	Bridle support wire
	Catenary support tube
Contact Wire	Condition of contact wire
	Contact wire measurement

Intrusive Inspection Components	Extent of Work
Crossover Arrangements	Security of all connections and fittings
	Crossing conductors and side wear
	Cross contact bridge freedom of movement
	Jumpers' security
	Crossover droppers (switch droppers)
Feeder / Jumper Arrangements (Drop Feed)	Feeder / jumper (drop feed) security on span or cantilever
	Check all connections on feeder clamp
Fixed Termination Anchors	Security of connections and fittings
	Fixture integrity
	Condition and positions of insulators – clean
	Termination wire security
	Snap head and clevis pins
Flying Tail Pull-Off	Flying tail pull-off
	Insulators
	All connections and fittings
	Condition of all movable parts
	Flying tail registration wires
	Snap head and clevis pins
	Steady arm
Head Span Arrangement	Conductor support and registration clamp
	Insulators
	All connections and fittings
	Cross-span tensioning spring
	Headspan / cross-span wires
	Snap head and clevis pins
	Safety / support droppers
Manual Disconnector	Check and clean post insulators
	Condition check of all parts and clamps
	Greasing of knife blades
	Conductors and termination feeders
	All connections and fittings
	Operating linkage
	Check of any fortress lock mechanism for correct operation
	Manual operating mechanism

Intrusive Inspection Components	Extent of Work
Midpoint Anchors	Security connections and fittings (torqued to specification)
	Insulators
	Midpoint cantilever security
	Midpoint anchor tie wire sag
	Midpoint Z-type droppers security
	Snap head and clevis pins
Overlaps with Electrical Jumpers	Position and parallelism of contact wires
	Position of crossing conductors
	Catenary and contact wires
	Security, condition and position of jumpers
	Snap head and clevis pins