ENGINEERING DESIGN STANDARD

EDS 02-0041

CABLE TUNNEL DESIGN MANUAL

Network(s): All

Summary: This standard sets out the use of the Cable Tunnel Design Manual to be used in the planning and design of all new cable tunnels and associated shafts.

Author: Jesse Garcia Date: 17/10/2018

Approver: Paul Williams Date: 29/11/2018

This document forms part of the Company's Integrated Business System and its requirements are mandatory throughout UK Power Networks. Departure from these requirements may only be taken with the written approval of the Director of Asset Management. If you have any queries about this document please contact the author or owner of the current version.

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## Revision Record

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**Reason for update:** Periodic review and update.

**What has changed:** References to internal and external standards updated. Details on flood levels for design added to Section 4.8.3; Section 17 on structural long-term monitoring added.

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1 Introduction

This document describes in outline the standard building and equipment requirements for cable tunnels, access shafts and ancillary equipment (ventilation, communications and fire suppression) for use in all three (SPN, LPN, EPN) UK Power Networks (UKPN) licence areas.

Whilst standardisation of tunnel design aspects is preferable, it is accepted that each project is specific. It is essential therefore that the tunnel design, whilst incorporating the requirements of this document, assesses each project design on its merits.

The designer must have due regard at all times to designing a tunnel that complies with all current UK Power Networks policy and European legislation and legal requirements.

Third party considerations, developers, local authorities etc., may influence the adopted design together with specific designers risk assessments, but it is essential that the requirements of this document are embedded within the final design.

UK Power Networks tunnel assets are strategically important to the continuity of supply. The risk of damaging more than one circuit must be kept very low, the consequences of damage to more than one circuit would be considerable.

All installations shall conform to the details within this document and those within UKPN engineering document EDS 02-0040 ‘Current Ratings Guide for Distribution Cables’.

2 Scope

This standard applies to all new cable tunnels and their associated infrastructure.

3 Glossary and Abbreviations

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tr>
<td>ASD</td>
<td>Aspirating Smoke Detection</td>
</tr>
<tr>
<td>BEWAG</td>
<td>Berlin Energy Supply Company</td>
</tr>
<tr>
<td>CCTV</td>
<td>Closed circuit television</td>
</tr>
<tr>
<td>CPC</td>
<td>Circuit protective conductor</td>
</tr>
<tr>
<td>DTS</td>
<td>Distributed Temperature Sensor</td>
</tr>
<tr>
<td>ENMAC/Power On</td>
<td>UK Power Networks network management system.</td>
</tr>
<tr>
<td>ID</td>
<td>Internal diameter</td>
</tr>
<tr>
<td>LSOH</td>
<td>Low smoke zero halogen</td>
</tr>
<tr>
<td>MCB</td>
<td>Miniature circuit breaker</td>
</tr>
<tr>
<td>M&amp;E</td>
<td>Mechanical and Electrical</td>
</tr>
<tr>
<td>NetMap</td>
<td>UK Power Networks graphical information system (GIS).</td>
</tr>
<tr>
<td>PIR</td>
<td>Passive infrared sensor</td>
</tr>
<tr>
<td>PLC</td>
<td>Programme logic controller</td>
</tr>
<tr>
<td>RCBO</td>
<td>Residual current circuit breaker with overcurrent protection</td>
</tr>
<tr>
<td>SAP</td>
<td>UK Power Networks asset register</td>
</tr>
<tr>
<td>SWA</td>
<td>Steel wire armoured</td>
</tr>
<tr>
<td>TBM</td>
<td>Tunnel boring machine</td>
</tr>
<tr>
<td>TVCMS</td>
<td>Tunnel ventilation control and management system</td>
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UK Power Networks (Operations) Ltd consists of three electricity distribution networks:
- Eastern Power Networks plc (EPN).
- London Power Network plc (LPN).
- South Eastern Power Networks plc (SPN).

<table>
<thead>
<tr>
<th><strong>UPS</strong></th>
<th>Uninterruptable power supply</th>
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<tr>
<td><strong>VESDA</strong></td>
<td>Very early smoke detection apparatus</td>
</tr>
<tr>
<td><strong>XLPE</strong></td>
<td>Cross linked polyethylene</td>
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4 Design Considerations

In addition to detailed site and ground investigations the following requirements must be considered in the final design:

4.1 Legislation

The tunnel must be designed to the current UK Power Networks Codes of Practice, Design Guides, Local Planning Authority legislation and British and European Standards.

Where appropriate and/or applicable, the design must comply with current Building Regulations and the Town and Country Planning Act 1990.

4.2 Environment

The design must have due consideration for the local environment and comply with the Environment Agency and Local Authority requirements.

4.3 Cable Spacing

Distances between cables and circuits are to be as set out in Section 5. Minimum cable spacing must be observed to reduce the risk of damage to other circuits in the event of fire or electrical fault and ensure efficient cooling.

4.4 Health & Safety

The shaft and tunnel structures are to be considered as confined spaces during construction and operation.

The design must comply with the Construction Design Management (CDM) and all Health, Safety & Environmental legislation; see Section 21.

4.5 Electrical Apparatus

The design must meet the technical and safety requirements for the plant and cables to be installed. Facilities must be provided for the delivery, offloading, handling and installation of plant and cables and for their possible future removal, additions or alterations.

Wherever practicable electrical connections are to be made where the risk from interruption or damage by flood water can be minimised.

All LV electrical installations shall comply with BS 7671 IEE Regulations and a compliance certificate must be obtained. The compliance certificate shall be retained on file, recorded on the Asset Register and where possible a copy displayed on site.
4.6 Cable Entries and Routes

The design must provide for the co-ordination of cable entries from outside circuits and for power and control cable routes within the tunnel.

Design guidance for typical cable bending radii for cables is given below:

Table 4-1 - Typical bending radii based on operating type and voltage

<table>
<thead>
<tr>
<th>Cable Voltage</th>
<th>Typical Bending Radius</th>
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<tr>
<td>132kV Cables</td>
<td>3m</td>
</tr>
<tr>
<td>33kV Cables</td>
<td>1.6m</td>
</tr>
<tr>
<td>11kV Cables</td>
<td>1.2m</td>
</tr>
<tr>
<td>Control cables</td>
<td>0.6m</td>
</tr>
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</table>

Actual cable bending radii are to be confirmed with the manufacturer by the Designer prior to the finalisation of the design.

The cable entries are to be sealed against water ingress into the shaft at the completion of construction. The sealing arrangement must be removable to enable the cables to be installed and the cables entries resealed.

Cable support steelworks and cleating systems are to be designed and specified to accommodate the weight of the cables and imposed short circuit loads of 20kN of which 10% (2kN) is transmitted into the support and structure.

4.7 Security

Security provision will be advised by UK Power Networks Company Security and following an Electricity Supply Quality and Continuity Regulations (ESQCR) based Security Risk Assessment. External doors to meet Loss Prevention Certification Board (LPCB) Level 4 (BS EN 179: Grade 4).

Infrastructure Planner and Project Managers must establish the security rating requirements for any installation before design commences, this must be reviewed on every occasion that new cables are installed.

For high risk areas where access to the tunnel and shafts is located the following measures may be required following a site specific security risk assessment:

- Dome cameras covering the approach to the substation;
- Motorised bollards or barrier access control with swipe in/out magnetic lock on main access door;
- Access to tunnel shafts with electronic Locken lock on main access door;
- Intruder alarm with PIR door contacts;
- Security lighting with infra-red lamps for night vision;
- Appropriate signage;
- A public address system to inform an intruder they have been detected;
- CCTV.
Specifications of the above equipment can be advised by UK Power Networks Company Security, reference shall also be made to EDS 07-0101 ‘Security Specification for Operational Sites’ (internal document).

4.8 Flooding/Water Ingress

When considering the location of a new tunnel and shaft head house it is essential, as well as considering the ecological impact and design suitability, that the risk from future flooding is assessed. In the case of tunnels and shafts the primary sources of water ingress are considered to be from ground water and water from a water main failure. Water ingress from pluvial or tidal flood event shall be considered at all tunnel shafts.

4.8.1 Ground Water

The ground investigation works essential to the design of the tunnel and tunnel route will highlight the presence of ground water. If ground water is considered likely to be present, the design must make allowance for the sealing of all joints in both the shaft and the tunnel itself. In extreme cases the possibility of uplift may need to be considered.

4.8.2 Water Main

As all tunnels by their nature are located below street level then the risk of flooding by burst water main or, to a lesser extent sewer, must be considered. In these cases the local water service provider shall be contacted in order to confirm the size, location and, where possible, age of any mains water feed along the proposed tunnel route and at shaft locations in order to establish the risk and likelihood of water main failure. The design is to incorporate protection against or early warning of these flood events where appropriate. As with protecting against ground water ingress all shaft and tunnel joints shall be designed to be water tight.

4.8.3 Fluvial and Tidal

If it is found that the proposed route is affected by flooding from any of these potential causes then it becomes essential that measures are put in place within the design in order to provide mitigation against the effects of flooding. As per previous section, cable tunnels shall be designed to be watertight structures. Access and ventilation shafts shall be designed to prevent the ingress of water during 1:1000 flood level event.

Information regarding flood risk and levels can be obtained from the local Environment Agency office, which can be contacted on 03708-506506 or https://flood-warning-information.service.gov.uk/long-term-flood-risk for all UK Power Networks licensed areas.

4.8.4 Mitigation

Possible mitigation solutions for the above flooding scenarios include specifying all above ground doors and access hatches as watertight or installing demountable flood protection barriers around shaft sites. Basic good construction and cable installation practices shall also be employed to ensure tunnel, shaft and cable entries are all watertight. Tunnel elevations shall be designed to fall towards the sump pump location (located at the lowest part of the tunnel section) and falls calculated to reduce puddling in the invert of the tunnel. Pump fail alarms will be taken back to UKPN Network Control with an indication of the position of the failed pump.
4.8.5 Removal

Any water collecting in the tunnel will have to be removed, any discharge to a water course or public sewer will require a Discharge Licence from the appropriate body; this will be sourced through the appropriate UKPN Property and Consents team. Any water likely to be considered contaminated will either have to be removed by tanker for treatment or passed through a Full Retention Oil Interceptor prior to discharge. The requirement and provision of this equipment must be considered at the design stage.

4.9 Fire Risk Assessment

It will be necessary for a fire risk assessment to be carried out by a competent person in compliance with the Regulatory Reform (Fire Safety) Order 2005.

It will also be necessary to carry out a Network risk assessment to establish the risk to the Network and need for mitigation/reconfiguration should circuits be affected by fire.

See also Section 18 Fire Prevention and Protection.

4.10 Functional Requirements

The principal function of the design is to provide structures to house and support the electrical cables and ancillary equipment and ensure a safe environment for operational and maintenance staff that work within the tunnel and general public safety.

4.11 Design Life

The life of the main fabric of the tunnel structure shall have a design life of not less than 120 years with internal and ancillary structures designed for a minimum 40 year life. In both cases careful consideration shall be given to minimum maintenance throughout.

4.12 Future Maintenance

The designer shall consider all future maintenance requirements together with possible addition and alterations to the installed cables and plant. The design shall provide for adequate access to and around cables and plant together with minimum future maintenance and risks to operational engineers.

In addition to maintenance, provision is to be made for the future removal and replacement of all cables and plant. This provision shall include consideration for maintaining wayleaves and access agreements throughout the life of the tunnel and shaft sites.

4.13 New Cables in Existing Tunnels

Before any plans to install cables in new or existing tunnels are finalised the Technical Sourcing and Standards Manager within UKPN Asset Management shall be informed and consent for the scheme pre gate B obtained. Consent will be conditional upon a review of the risk to the existing assets from the installation and will consider, among other things, ventilation, cable sizing and spacing, cable type, loading, security and fire risk.
5 Tunnel Layout and Requirements

5.1 Tunnel Dimensions

Based on the information contained in the BEWAG Report – Special Report on Fire Resistant Cable Installation in Tunnels and the dimensions quoted in clause 5.1 of this guide, the minimum internal dimensions of the tunnel are to be 2.325m while maintaining the minimum clearances between each circuit and between each circuit and the tunnel or shaft walls. Note that the BEWAG report does not consider 33kV and 11kV cables so for design purposes the minimum spacing for these circuits shall be considered the same as for 132kV cables.

While this minimum dimension is desirable it may be preferable to adopt larger internal diameters, typically 2.59-2.8m, in order to utilise standard tunnel lining segments, a particular TBM specification or specific ground conditions. If the tunnel is to accommodate multiple voltages then consideration of fire separation may inform the tunnel diameter.

Maximum emergency escape distance shall be no more than 1.2km. Consequently, the tunnel length between access/egress points shall not exceed 2.4km to ensure this safe emergency evacuation distance is maintained; these figures are based on a maximum escape time of 30 minutes using breathing sets.

5.2 Design Structural Loads

Materials to be considered at ultimate strength with appropriate load and material safety factors.

External tunnel walls are to be designed to withstand:

- Earth and ground water pressures;
- Uplift from ground water level fluctuations;
- Loads from any buildings or structures constructed or planned over the tunnel route or where it forms part of the foundations of any structure. Advice is to be sought from the competent and suitably qualified Structural Engineer regarding the loads associated with this type of neighbouring project.

The tunnel is to be designed to contain or dissipate internal overpressure caused by cable or joint failure.

Typically the tunnel is expected to be constructed from pre-cast concrete sections of a diameter suitable for both the tunnel requirements and the Tunnel Boring Machine (TBM) constructing the tunnel although ground conditions may determine an alternative method (e.g. thrust bore).

It is recommended that the British Tunnelling Society (BTS) / Institution of Civil Engineers (ICE) Tunnel Lining Design Guide is referred to during the design, construction and maintenance of the tunnel.
6 Emergency Egress

6.1 Signage and Lighting

Photo luminescent signs, sizing and layout in accordance with BS ISO 3864-1, are to be fixed to the walls of the tunnel at approximately 2 and 10 o’clock positions and to avoid being obscured by the cable installation. They are to be directional and show the distance to the nearest egress point where the exits are to be signposted.

Walkways and emergency escape routes shall be designed to be clear of trip hazards and obstructions.

7 Cable Layout and Configuration

7.1 General Arrangement Considerations

Based on the information contained in the BEWAG report ‘Special report on Fire Resistant Cable Installation in Tunnels’ 132kV XLPE LSOH cables are to be arranged in a trefoil. In order to limit damage should a cable failure occur and to provide clear access the minimum separation distances below shall be observed:

Table 7-1 - Minimum cable separation distances

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Vertical and Horizontal separation between circuits</td>
<td>200mm</td>
</tr>
<tr>
<td>Horizontal clearance for personnel access walkway</td>
<td>1000mm</td>
</tr>
<tr>
<td>Cable to tunnel wall</td>
<td>200mm</td>
</tr>
</tbody>
</table>

The provision of blast shielding between phases or circuits is not recommended as it is considered that it will increase the overall effects of a cable failure by not allowing the blast pressure to dissipate and creating a pressure cell and increasing the likelihood of the blast being reflected back onto the fault area compounding the damage.

The installation of other voltages must also conform with the details above and the diagram overleaf otherwise some other mitigation to prevent damage must be provided.

It has been assumed that the circuits for all voltages shall be laid in trefoil configuration.
Cable Tunnel Design Manual

7.1.1 Cables

Cables in the tunnel, coupled with a high standard of installation, shall be protected against mechanical damage, fire and water both during installation and in operation.

Pre gate B, the Asset Management Technical Sourcing and Standards Manager, in conjunction with the Planning team, shall provide a technical brief outlining the design parameters to include the following:

- Tunnel Diameter (mm);
- Tunnel Length (mm);
- Tunnel Depth to centre (mm);
- Air Velocity – current and future if forced ventilation is to be installed (m/s);
- Required ratings for cable circuits along the route (circuits to be installed and circuits that are existing);
- Voltage size and type of any existing cables.
- Cables to be installed in tunnels and basements shall have the following design parameters:
  - Cables shall be installed such that there is a clear walking space between the circuits on opposite sides of the tunnel. Taking into consideration the point raised above they shall be adequately supported for both installation and operation and secured in order to accommodate the dynamic operational forces and thermal expansion;
  - Cable entries and unused ducts are to be sealed against ingress of water, dust and other materials;
• Cables shall be specified and supplied in accordance with the following UK Power Networks Technical Specifications:
  - ETS 02-4040 - 132kV Cables with Extruded Insulation Suitable for use in Cable Tunnels, Galleries and Cable Basements (internal document);
  - ETS 02-0940 - 11kV Single Core XLPE Insulated Cables in Triplex Format (internal document);
  - ETS 02-0905 - 33kV Single Core XLPE insulated Cables (internal document);
  - ETS 02-0995 - 66kV Cables with Extruded Insulation Suitable for use in Cable Tunnels, Galleries and Cable Basements (internal document);
  - ETS 02-0950 - Auxiliary Multicore and Multipair Cables (internal document);
  - ETS 02-0956 - LSOH Waveform Cables (internal document).

No new fluid filled or cables which increase the risk of fire may be installed in any tunnel.

7.1.2 Joints

• Cable joint bay layouts are directly related to the size and type of joints used.
• The distance between joints should be as large as practicable based on available cable lengths;
• The joints used shall have similar fire resistance and low smoke and fume emission characteristics as the cables to which they are attached;
• Joints are generally staggered due to the spatial requirements of installing them; where possible joint bays are to be provided to avoid having joints encroaching into the tunnel access area;
• Joints are to be screened with a non-conductive shield to prevent unintentional contact.
• Attention is drawn to The Electricity at Work Regulations 1989, which require joints and terminations to be both electrically and mechanically suitable;
• Joints are to be kept clean and dry and constructed in accordance with UK Power Networks policy and procedure.
7.2 Cable Cleating and Support

The design of cable cleating and support steel work shall be designed in accordance with the following tables in this standard. Cable support distances cannot be determined until a cable installation design has been undertaken and approved.

7.2.1 Rigid Cable System Cleat and Steelwork Spacings

For the installation of a rigid cable system in a cable tunnel, all steelwork and cleats shall be designed so that it accommodates the largest cable which is likely to be installed. The following tables has been calculated, using the EA Technology “Thermo-mechanical Forces Design Tool for Cable Systems” to provide typical spacing values and the associated data required to design the required steelwork and cable cleats.

All spacings are based on the following design parameters:

- Cable installation temperature = 15°C;
- Low cycle temperature = 25°C;
- High cycle temperature = 44°C;
- Emergency temperature = 44°C;
- Short circuit current (RMS) = 19kA;
- Copper wire screen size if the cable type has one = 135mm².

7.2.1.1 132kV Single Core XLPE Cable – Copper Wire Screen and Aluminium Laminate

Table 7-2 - Rigid cable support and cleating – 132kV Copper Wire Screen Aluminium Laminate Cables

<table>
<thead>
<tr>
<th>Conductor Size(mm²) and material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum Cable Thrust (kN)</td>
<td>Cleat Spacing on Straight Sections (m)</td>
</tr>
<tr>
<td>300mm² Aluminium</td>
<td>4.02</td>
<td>2.06</td>
</tr>
<tr>
<td>630mm² Aluminium</td>
<td>7.52</td>
<td>1.74</td>
</tr>
<tr>
<td>1000mm² Aluminium</td>
<td>11.43</td>
<td>1.79</td>
</tr>
<tr>
<td>1200mm² Aluminium</td>
<td>13.55</td>
<td>1.76</td>
</tr>
<tr>
<td>1600mm² Aluminium</td>
<td>17.79</td>
<td>1.88</td>
</tr>
<tr>
<td>1200mm² Copper</td>
<td>18.56</td>
<td>1.59</td>
</tr>
<tr>
<td>1600mm² Copper</td>
<td>24.36</td>
<td>1.71</td>
</tr>
</tbody>
</table>
7.2.1.2 132kV Single Core XLPE Cable – Corrugated Aluminium Sheath

Table 7-3 - Rigid cable support and cleating – 132kV Corrugate Aluminium Sheath Cables

<table>
<thead>
<tr>
<th>Conductor Size(mm²) and material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum Cable Thrust (kN)</td>
<td>Cleat Spacing on Straight Sections (m)</td>
</tr>
<tr>
<td>300mm² Aluminium</td>
<td>4.02</td>
<td>4.75</td>
</tr>
<tr>
<td>630mm² Aluminium</td>
<td>7.52</td>
<td>3.88</td>
</tr>
<tr>
<td>1000mm² Aluminium</td>
<td>11.43</td>
<td>3.96</td>
</tr>
<tr>
<td>1200mm² Aluminium</td>
<td>13.55</td>
<td>3.95</td>
</tr>
<tr>
<td>1600mm² Aluminium</td>
<td>17.79</td>
<td>4.31</td>
</tr>
<tr>
<td>1200mm² Copper</td>
<td>18.56</td>
<td>3.45</td>
</tr>
<tr>
<td>1600mm² Copper</td>
<td>24.36</td>
<td>1.71</td>
</tr>
</tbody>
</table>

7.2.1.3 132kV Single Core XLPE Cable – Smooth Aluminium Sheath

Table 7-4 - Rigid cable support and cleating – 132kV Smooth Aluminium Sheath Cables

<table>
<thead>
<tr>
<th>Conductor Size(mm²) and material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum Cable Thrust (kN)</td>
<td>Cleat Spacing on Straight Sections (m)</td>
</tr>
<tr>
<td>300mm² Aluminium</td>
<td>4.02</td>
<td>4.75</td>
</tr>
<tr>
<td>630mm² Aluminium</td>
<td>7.52</td>
<td>3.88</td>
</tr>
<tr>
<td>1000mm² Aluminium</td>
<td>11.43</td>
<td>3.96</td>
</tr>
<tr>
<td>1200mm² Aluminium</td>
<td>13.55</td>
<td>3.95</td>
</tr>
<tr>
<td>1600mm² Aluminium</td>
<td>17.79</td>
<td>4.31</td>
</tr>
<tr>
<td>1200mm² Copper</td>
<td>18.56</td>
<td>3.45</td>
</tr>
<tr>
<td>1600mm² Copper</td>
<td>24.36</td>
<td>1.71</td>
</tr>
</tbody>
</table>
7.2.2 Flexible Vertical Movement Cable System Cleat and Steelwork Maximum Spacings

For the installation of a flexible vertical movement cable system in a cable tunnel, all steelwork and cleats shall be design so that it accommodates the largest cable which is likely to be installed. The following tables has been calculated, using the EA Technology “Thermo-mechanical Forces Design Tool for Cable Systems” to provide typical spacing values and the associated data required to design the required steelwork and cable cleats.

All spacings are based on the following design parameters:

- Cable installation temperature = 15°C;
- Low cycle temperature = 25°C;
- High cycle temperature = 44°C;
- Emergency temperature = 44°C;
- Short circuit current (RMS) = 19kA;
- Copper wire screen size if the cable type has one = 135mm².

7.2.2.1 132kV Single Core XLPE Cable – Copper Wire Screen and Aluminium Laminate

Table 7-5 - Flexible vertical movement cable support and cleating – 132kV Copper Wire Screen Aluminium Laminate Cables

<table>
<thead>
<tr>
<th>Conductor Size(mm²) &amp; material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. Cable Thrust (kN)</td>
<td>Cleat Spacing Straight Sections (m)</td>
</tr>
<tr>
<td>300mm² Aluminium</td>
<td>0.10</td>
<td>20.20</td>
</tr>
<tr>
<td>630mm² Aluminium</td>
<td>0.15</td>
<td>17.40</td>
</tr>
<tr>
<td>1000mm² Aluminium</td>
<td>0.24</td>
<td>16.99</td>
</tr>
<tr>
<td>1200mm² Aluminium</td>
<td>0.28</td>
<td>16.18</td>
</tr>
<tr>
<td>1600mm² Aluminium</td>
<td>0.38</td>
<td>15.88</td>
</tr>
<tr>
<td>1200mm² Copper</td>
<td>0.41</td>
<td>8.55</td>
</tr>
<tr>
<td>1600mm² Copper</td>
<td>0.53</td>
<td>8.17</td>
</tr>
</tbody>
</table>
### 7.2.2.2 132kV Single Core XLPE Cable – Corrugated Aluminium Sheath

Table 7-6 - Flexible vertical movement cable support and cleating – 132kV Corrugate Aluminium Sheath Cables

<table>
<thead>
<tr>
<th>Conductor Size(mm²) &amp; material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. Cable Thrust (kN)</td>
<td>Cleat Spacing Straight Sections (m)</td>
</tr>
<tr>
<td>300mm² Aluminium</td>
<td>0.26</td>
<td>18.96</td>
</tr>
<tr>
<td>630mm² Aluminium</td>
<td>0.33</td>
<td>18.20</td>
</tr>
<tr>
<td>1000mm² Aluminium</td>
<td>0.43</td>
<td>20.01</td>
</tr>
<tr>
<td>1200mm² Aluminium</td>
<td>0.52</td>
<td>19.21</td>
</tr>
<tr>
<td>1600mm² Aluminium</td>
<td>0.81</td>
<td>17.55</td>
</tr>
<tr>
<td>1200mm² Copper</td>
<td>0.74</td>
<td>10.17</td>
</tr>
<tr>
<td>1600mm² Copper</td>
<td>1.04</td>
<td>9.16</td>
</tr>
</tbody>
</table>
### 7.2.2.3 132kV Single Core XLPE Cable – Smooth Aluminium Sheath

Table 7-7: Flexible vertical movement cable support and cleating – 132kV Smooth Aluminium Sheath Cables

<table>
<thead>
<tr>
<th>Conductor Size (mm$^2$) &amp; material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. Cable Thrust (kN)</td>
<td>Cleat Spacing Straight Sections (m)</td>
</tr>
<tr>
<td>300mm$^2$ Aluminium</td>
<td>0.29</td>
<td>16.85</td>
</tr>
<tr>
<td>630mm$^2$ Aluminium</td>
<td>0.35</td>
<td>16.00</td>
</tr>
<tr>
<td>1000mm$^2$ Aluminium</td>
<td>0.45</td>
<td>17.41</td>
</tr>
<tr>
<td>1200mm$^2$ Aluminium</td>
<td>0.53</td>
<td>16.10</td>
</tr>
<tr>
<td>1600mm$^2$ Aluminium</td>
<td>0.59</td>
<td>15.69</td>
</tr>
<tr>
<td>1200mm$^2$ Copper</td>
<td>0.77</td>
<td>8.05</td>
</tr>
<tr>
<td>1600mm$^2$ Copper</td>
<td>0.84</td>
<td>7.13</td>
</tr>
</tbody>
</table>
7.2.3 Flexible Vertical Movement Cable System Cleat and Steelwork 3 Metre Spacing

For the installation of a flexible vertical movement cable system in a cable tunnel, all steelwork and cleats shall be designed so that it accommodates the largest cable which is likely to be installed. The following tables have been calculated, using the EA Technology “Thermo-mechanical Forces Design Tool for Cable Systems” to provide typical spacing values and the associated data required to design the required steelwork and cable cleats.

All spacings are based on the following design parameters:

- Cable installation temperature = 15°C;
- Low cycle temperature = 25°C;
- High cycle temperature = 44°C;
- Emergency temperature = 44°C;
- Short circuit current (RMS) = 19kA;
- Copper wire screen size if the cable type has one = 135mm²;
- Steelwork cleat spacing = 3 metres;
- Number of short circuits straps = 1.
7.2.3.1 132kV Single Core XLPE Cable – Copper Wire Screen and Aluminium Laminate – 3 Metre Spacing

Table 7-8 - Flexible vertical movement cables - 3 metre spacing support and cleating – 132kV Copper Wire Screen Aluminium Laminate Cables

<table>
<thead>
<tr>
<th>Conductor Size(mm$^2$) and material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. Cable Thrust (kN)</td>
<td>Sag under Cable weight (mm)</td>
</tr>
<tr>
<td>300mm$^2$ Aluminium</td>
<td>0.10</td>
<td>0.58</td>
</tr>
<tr>
<td>630mm$^2$ Aluminium</td>
<td>0.46</td>
<td>0.58</td>
</tr>
<tr>
<td>1000mm$^2$ Aluminium</td>
<td>0.59</td>
<td>0.46</td>
</tr>
<tr>
<td>1200mm$^2$ Aluminium</td>
<td>0.64</td>
<td>0.45</td>
</tr>
<tr>
<td>1600mm$^2$ Aluminium</td>
<td>0.78</td>
<td>0.38</td>
</tr>
<tr>
<td>1200mm$^2$ Copper</td>
<td>0.51</td>
<td>0.77</td>
</tr>
<tr>
<td>1600mm$^2$ Copper</td>
<td>0.63</td>
<td>0.62</td>
</tr>
</tbody>
</table>
7.2.3.2 132kV Single Core XLPE Cable – Corrugated Aluminium Sheath – 3 Metre Spacing

Table 7-9 - Flexible vertical movement cables - 3 metre spacing support and cleating – 132kV Corrugated Aluminium Sheath Cables

<table>
<thead>
<tr>
<th>Conductor Size(mm²) and material</th>
<th>Normal Operating</th>
<th></th>
<th>Short Circuit Operation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. Cable Thrust (kN)</td>
<td>Sag under Cable weight (mm)</td>
<td>Initial set sag (mm) f₀</td>
<td>Cyclic sheath strain (%)</td>
</tr>
<tr>
<td>300mm² Aluminium</td>
<td>0.81</td>
<td>0.30</td>
<td>172</td>
<td>0.05</td>
</tr>
<tr>
<td>630mm² Aluminium</td>
<td>0.91</td>
<td>0.28</td>
<td>182</td>
<td>0.05</td>
</tr>
<tr>
<td>1000mm² Aluminium</td>
<td>1.16</td>
<td>0.20</td>
<td>204</td>
<td>0.05</td>
</tr>
<tr>
<td>1200mm² Aluminium</td>
<td>1.27</td>
<td>0.19</td>
<td>212</td>
<td>0.05</td>
</tr>
<tr>
<td>1600mm² Aluminium</td>
<td>1.65</td>
<td>0.16</td>
<td>234</td>
<td>0.05</td>
</tr>
<tr>
<td>1200mm² Copper</td>
<td>0.95</td>
<td>0.35</td>
<td>212</td>
<td>0.04</td>
</tr>
<tr>
<td>1600mm² Copper</td>
<td>1.24</td>
<td>0.30</td>
<td>234</td>
<td>0.04</td>
</tr>
</tbody>
</table>
7.2.3.3 132kV Single Core XLPE Cable – Smooth Aluminium Sheath – 3 Metre Spacing

Table 7-10 - Flexible vertical movement cables - 3 metre spacing support and cleating – 132kV Smooth Aluminium Sheath Cables

<table>
<thead>
<tr>
<th>Conductor Size(mm²) &amp; material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. Cable Thrust (kN)</td>
<td>Sag under Cable weight (mm)</td>
</tr>
<tr>
<td>300mm² Aluminium</td>
<td>0.92</td>
<td>0.29</td>
</tr>
<tr>
<td>630mm² Aluminium</td>
<td>0.96</td>
<td>0.30</td>
</tr>
<tr>
<td>1000mm² Aluminium</td>
<td>1.18</td>
<td>0.23</td>
</tr>
<tr>
<td>1200mm² Aluminium</td>
<td>1.24</td>
<td>0.23</td>
</tr>
<tr>
<td>1600mm² Aluminium</td>
<td>1.23</td>
<td>0.24</td>
</tr>
<tr>
<td>1200mm² Copper</td>
<td>0.95</td>
<td>0.44</td>
</tr>
<tr>
<td>1600mm² Copper</td>
<td>0.96</td>
<td>0.49</td>
</tr>
</tbody>
</table>
7.2.4 Flexible Horizontal Movement Cable System Cleat and Steelwork Maximum Spacings

For the installation of a flexible horizontal movement cable system in a cable tunnel, all steelwork and cleats shall be design so that it accommodates the largest cable which is likely to be installed. The following tables has been calculated, using the EA Technology “Thermo-mechanical Forces Design Tool for Cable Systems” to provide typical spacing values and the associated data required to design the required steelwork and cable cleats.

All spacings are based on the following design parameters:

- Cable installation temperature = 15°C;
- Low cycle temperature = 25°C;
- High cycle temperature = 44°C;
- Emergency temperature = 44°C;
- Short circuit current (RMS) = 19kA;
- Copper wire screen size if the cable type has one = 135mm²;
- Number of short circuits straps = 1.
7.2.4.1 132kV Single Core XLPE Cable – Copper Wire Screen and Aluminium Laminate

Table 7-11 - Flexible horizontal movement cable spacing support and cleating – 132kV Copper Wire Screen Aluminium Laminate Cables

<table>
<thead>
<tr>
<th>Conductor Size(mm²) and material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. Cable Thrust (kN)</td>
<td>Cleft Spacing Straight Sections (m)</td>
</tr>
<tr>
<td>300mm² Aluminium</td>
<td>0.37</td>
<td>3.80</td>
</tr>
<tr>
<td>630mm² Aluminium</td>
<td>0.43</td>
<td>4.05</td>
</tr>
<tr>
<td>1000mm² Aluminium</td>
<td>0.56</td>
<td>4.55</td>
</tr>
<tr>
<td>1200mm² Aluminium</td>
<td>0.59</td>
<td>4.70</td>
</tr>
<tr>
<td>1600mm² Aluminium</td>
<td>0.72</td>
<td>5.21</td>
</tr>
<tr>
<td>1200mm² Copper</td>
<td>0.48</td>
<td>4.70</td>
</tr>
<tr>
<td>1600mm² Copper</td>
<td>0.60</td>
<td>5.21</td>
</tr>
</tbody>
</table>
7.2.4.2 132kV Single Core XLPE Cable – Corrugated Aluminium Sheath

Table 7-12 - Flexible horizontal movement cable spacing support and cleating – 132kV Corrugate Aluminium Sheath Cables

<table>
<thead>
<tr>
<th>Conductor Size (mm²) and material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. Cable Thrust (kN)</td>
<td>Cleat Spacing Straight Sections (m)</td>
</tr>
<tr>
<td>300mm² Aluminium</td>
<td>0.76</td>
<td>4.30</td>
</tr>
<tr>
<td>630mm² Aluminium</td>
<td>0.85</td>
<td>4.55</td>
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<tr>
<td>1000mm² Aluminium</td>
<td>1.08</td>
<td>5.10</td>
</tr>
<tr>
<td>1200mm² Aluminium</td>
<td>1.17</td>
<td>5.30</td>
</tr>
<tr>
<td>1600mm² Aluminium</td>
<td>1.51</td>
<td>5.85</td>
</tr>
<tr>
<td>1200mm² Copper</td>
<td>0.90</td>
<td>5.30</td>
</tr>
<tr>
<td>1600mm² Copper</td>
<td>1.16</td>
<td>5.85</td>
</tr>
</tbody>
</table>
## 7.2.4.3 132kV Single Core XLPE Cable – Smooth Aluminium Sheath

Table 7-13 - Flexible horizontal movement cable spacing support and cleating – 132kV Smooth Aluminium Sheath Cables

<table>
<thead>
<tr>
<th>Conductor Size (mm$^2$) and material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. Cable Thrust (kN)</td>
<td>Cleat Spacing Straight Sections (m)</td>
</tr>
<tr>
<td>300mm$^2$ Aluminium</td>
<td>0.88</td>
<td>3.70</td>
</tr>
<tr>
<td>630mm$^2$ Aluminium</td>
<td>0.91</td>
<td>3.95</td>
</tr>
<tr>
<td>1000mm$^2$ Aluminium</td>
<td>1.11</td>
<td>4.45</td>
</tr>
<tr>
<td>1200mm$^2$ Aluminium</td>
<td>1.16</td>
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<td>1.14</td>
<td>5.05</td>
</tr>
<tr>
<td>1200mm$^2$ Copper</td>
<td>0.90</td>
<td>4.58</td>
</tr>
<tr>
<td>1600mm$^2$ Copper</td>
<td>0.91</td>
<td>5.05</td>
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</tbody>
</table>
7.2.5 Flexible Horizontal Movement Cable System Cleat and Steelwork 3 Metre Spacing

For the installation of a flexible horizontal movement cable system in a cable tunnel, all steelwork and cleats shall be designed so that it accommodates the largest cable which is likely to be installed. The following table has been calculated to provide typical spacing values and the associated data required to design the required steelwork and cable cleats.

All spacings are based on the following design parameters:
- Cable installation temperature = 15°C;
- Low cycle temperature = 25°C;
- High cycle temperature = 44°C;
- Emergency temperature = 44°C;
- Short circuit current (RMS) = 19kA;
- Copper wire screen size if the cable type has one = 135mm²;
- Steelwork cleat spacing = 3 metres;
- Number of short circuits straps = 1.

7.2.5.1 132kV Single Core XLPE Cable – Copper Wire Screen and Aluminium Laminate – 3 Metre Spacing

Table 7-14 - Flexible horizontal movement cables - 3 metre spacing support and cleating – 132kV Copper Wire Screen Aluminium Laminate Cables

<table>
<thead>
<tr>
<th>Conductor Size (mm²) and material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. Cable Thrust (kN)</td>
<td>Initial set sag (mm) f₀</td>
</tr>
<tr>
<td>300mm² Aluminium</td>
<td>0.39</td>
<td>152</td>
</tr>
<tr>
<td>630mm² Aluminium</td>
<td>0.46</td>
<td>162</td>
</tr>
<tr>
<td>1000mm² Aluminium</td>
<td>0.59</td>
<td>182</td>
</tr>
<tr>
<td>1200mm² Aluminium</td>
<td>0.64</td>
<td>188</td>
</tr>
<tr>
<td>1600mm² Aluminium</td>
<td>0.78</td>
<td>208</td>
</tr>
<tr>
<td>1200mm² Copper</td>
<td>0.51</td>
<td>188</td>
</tr>
<tr>
<td>1600mm² Copper</td>
<td>0.63</td>
<td>208</td>
</tr>
</tbody>
</table>
7.2.5.2 132kV Single Core XLPE Cable – Corrugated Aluminium Sheath – 3 Metre Spacing

Table 7-15 - Flexible horizontal movement cables - 3 metre spacing support and cleating – 132kV Corrugated Aluminium Sheath Cables

<table>
<thead>
<tr>
<th>Conductor Size (mm²) and material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. Cable Thrust (kN)</td>
<td>Initial set sag (mm) fo</td>
</tr>
<tr>
<td>300mm² Aluminium</td>
<td>0.81</td>
<td>172</td>
</tr>
<tr>
<td>630mm² Aluminium</td>
<td>0.91</td>
<td>182</td>
</tr>
<tr>
<td>1000mm² Aluminium</td>
<td>1.16</td>
<td>204</td>
</tr>
<tr>
<td>1200mm² Aluminium</td>
<td>1.27</td>
<td>212</td>
</tr>
<tr>
<td>1600mm² Aluminium</td>
<td>1.65</td>
<td>234</td>
</tr>
<tr>
<td>1200mm² Copper</td>
<td>0.95</td>
<td>212</td>
</tr>
<tr>
<td>1600mm² Copper</td>
<td>1.24</td>
<td>234</td>
</tr>
</tbody>
</table>
7.2.5.3 132kV Single Core XLPE Cable – Smooth Aluminium Sheath – 3 Metre Spacing

Table 7-16 - Flexible horizontal movement cables - 3 metre spacing support and cleating – 132kV Smooth Aluminium Sheath Cables

<table>
<thead>
<tr>
<th>Conductor Size (mm²) and material</th>
<th>Normal Operating</th>
<th>Short Circuit Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. Cable Thrust (kN)</td>
<td>Initial set sag (mm) f₀</td>
</tr>
<tr>
<td>300mm² Aluminium</td>
<td>0.92</td>
<td>148</td>
</tr>
<tr>
<td>630mm² Aluminium</td>
<td>0.96</td>
<td>158</td>
</tr>
<tr>
<td>1000mm² Aluminium</td>
<td>1.18</td>
<td>178</td>
</tr>
<tr>
<td>1200mm² Aluminium</td>
<td>1.24</td>
<td>183</td>
</tr>
<tr>
<td>1600mm² Aluminium</td>
<td>1.23</td>
<td>202</td>
</tr>
<tr>
<td>1200mm² Copper</td>
<td>0.95</td>
<td>183</td>
</tr>
<tr>
<td>1600mm² Copper</td>
<td>0.96</td>
<td>202</td>
</tr>
</tbody>
</table>

7.3 Cable Support in Shaft

Cleats, fixings and frames are to be designed to support the vertical load of the cables as they rise up the shaft. Landing stages can be used as support points although the cables must be protected against mechanical damage where they pass through the flooring.

As a minimum the spacing between steelwork and cleats shall be half that for horizontal straight sections.

7.4 Design Fault Levels Assumptions

Unless accurate date is known the following will be used:

- 132kV 19.3 kA for 3 second;
- 66kV 17 kA for 1 second
- 33kV 7.5 kA for 1 second;
- 11kV 13 kA for 1 second.
8 Water Ingress Control and Removal

A risk assessment shall be carried out and a system designed to eliminate the flood risk as far as reasonably practicable. Reference to the STUVA Recommendations for Testing and Application of sealing Gaskets in Segmental Linings is recommended where appropriate.

The design process shall regard the prevention and exclusion of water ingress into the tunnel and shafts as a priority over its control and removal. It is possible for a large volume of water to build up within a tunnel and its removal to provide safe personnel access can be costly and take time. The mitigation methods mentioned in Section 4.8 or other available exclusion methods shall be considered as part of the design process.

Where water ingress cannot be controlled the provision of an adequate permanent pump and drainage system shall be considered at all low points along the tunnel network length. The pumps are to operate on an automatic float switch and be robust enough to deal with slurry and water. Consideration shall be given to duplicate pumps and pipe work, and to good accessibility to the pumps for regular servicing or changing over. Wherever possible pumps are to be located at the base of the shafts. The pumps installed are to be oil discriminating to a level of 5parts/million (5mg/l) and be able to cope with silt and sediment.

Where flood water is discharged into a watercourse or sewer a Discharge Licence shall be obtained from the Environment Agency or local sewer utility. In order to record flow rates to enable accurate billing, flow rate meters shall be installed at each pump location; remote readers are to be installed at the top of each shaft to enable recording of the total flow without inspectors having to enter the tunnel system. It is possible that the Environment Agency may consider the water to be polluted and that treatment in the form of oil or silt removal may be required prior to discharge.

Where the control of oil polluted water is considered a problem the pumped discharge from the tunnel should pass through a Full Retention Separator before discharging to a sewer or watercourse. The choice of oil separator shall be in line with Environment Agency Pollution Prevention Guidelines PPG 3 “choosing and using oil separators”( now withdrawn but widely used). Of the two Classes of Oil Interceptor, Class 1 Interceptors are required when discharging into surface or controlled waters, Class 2 Interceptors are required when discharging into foul sewers. Where treatment requirements cannot be met through the utilisation of the oil discriminating pump and interceptor, additional or alternative methods will have to be considered in the design and the overall costings.

The allowance for likely flow rates and the requirement for suitable oil and silt separation must be considered at the design stage.
9 General Access

Access to all shaft head houses is to be controlled by UK Power Networks standard electronic locks currently provided by Locken. Access hatches at other tunnel access points are to be secured with a dedicated physical locking system with the locks protected from corrosion by design and by an adequate maintenance regime.

Access to the tunnel is to be provided at the location of each shaft. Where possible the access door or hatch shall be located within a secure compound with parking provided for large vans (as largest Ford Transit) approximately 6.4m x 2.1m x 3m high with 3.7m wheel base. The delivery, offloading and handling of all plant and cable drums as normally packaged by the suppliers shall also be considered at the main tunnel access points.

Where intermediate shaft access points are located in trafficked areas then personnel access is to be provided from the footpath or other lower risk area where possible.

Prior to tunnel entry, UK Power Networks confined space entry procedures shall be adhered to. Access to UK Power Networks tunnels shall only be undertaken by trained and competent operatives.

Access is required 24 hours-a-day and is to be unrestricted.

See also Section 16 Doors and Access Hatches.

10 Shafts

10.1 General

In addition to providing personnel and plant access to the shaft and room for the ventilation inlet/extract plant, head houses are to provide space for a control room housing the LV distribution board, ventilation control/DTS interface system, and communications control systems.

If not located on a Grid or Primary substation site where facilities are already in place, toilet and hand washing facilities shall be provided within the main access shaft head-house where space permits.

The minimum shaft ID shall be specified to suit the construction methods, ground conditions, max no of cables, ventilation requirements and access equipment. For planning and initial design works this minimum ID is to be considered to be 7.5m. Where the physical environment (at and/or below ground level) calls for a limit to the shaft size to an ID less than 7.5m then the Designer must demonstrate that the reduction does not limit personnel or cable access and is not to the detriment of future cable installations within the shaft.

Main shaft head-houses are to provide room for occasional vehicle delivery of plant. Plant vehicle access into the head-house shall be via a secure sliding door, plant delivery to the shaft base shall be facilitated utilising a 5 tonne travelling crane located over the delivery point/area. Where space is of a premium it may be necessary to make provision for the temporary removal/dismantling of non-essential structures in order to fully utilise the access.

Copies of the as-built tunnel and shaft drawings and route details are to be kept at each head-house.
10.2 Access

So far as reasonably practicable the use of permanent stairs is the preferred method of accessing the tunnel via the shaft and shall be considered where shaft diameter and cable configuration permit.

Where stair access cannot be accommodated ladder access shall conform to the following:

- Every ladder shall be securely fixed at its base, the shaft walls at suitable spacings and at the upper landing. It shall extend at least 1.1m above the upper landing unless other adequate alternative handhold is provided;
- Vertical ladders fixed are to be made of steel and shall be suitably earthed;
- Vertical ladders shall be designed in accordance with BS EN ISO 14122-4:2004;
- The foothold at every rung on all ladders shall be unobstructed. Landings shall be at intervals not exceeding 6m and shall be solidly constructed with hand rails / guard rails and toe boards and be protected against swinging loads being handled in the shaft;
- Openings for ladders shall be as small as is practicable and sited clear of the foot of the ladder above; trap doors in the landings above the lower ladder shall be considered. Every landing shall be adequately lit (see Section 9);
- Ladders and landing stages shall be designed to be clear of trip hazards and obstructions.

As with ladders, landing stages and handrails are to be made of steel (rather than light alloy, timber or GRP) and shall be suitably earthed in accordance with UK Power Networks Earthing manual.

Working platforms and walkways are to be designed in accordance with BS EN ISO 14122-2:2001.

10.3 Emergency Egress

10.3.1 Injured persons

All shafts are to have provision for the emergency evacuation of personnel by either ambulance cages or by special emergency slings. To facilitate this clear access through the landing stages and clear of the ladder access is to be provided.

Installation of a permanent emergency egress system shall not be provided, rescue teams will provide their own tested equipment.

A Life Safety study shall be carried out to establish the best possible system for normal egress, emergency egress and removal of injured persons.

10.4 Cable Receptor Eye

Wherever ground conditions are suitable the cable receptor eye is to be constructed outside of the area of the shaft in order to prevent tunnel encroachment and allow room for utilising the maximum possible cable bending radii.

10.5 Shafts in Substation Sites

Where shaft heads are sited within a substation building they shall be segregated from the substation plant rooms and ventilated independently. This is to avoid the potentially high levels of moisture from the damp tunnel air entering the substation environment and affecting plant and equipment housed within the substation rooms.

Minimum 1 hour fire separation between the shaft head and substation is also required; this shall be extended to 4 hour fire separation where the shaft exits adjacent to oil filled plant.
11 Programmable Logic Controllers

A PLC is a digital system used for automation of typically electromechanical processes, in this case the control of the interface between the ventilation auxiliary LV and control systems.

The Control System shall be an open protocol PLC based system. The Control system shall be kept as simple as possible and include control panels located in the head house/equipment room.

The PLC shall be provided with a 72 hour battery backup system incorporated into the panel. This shall be designed to operate all software required to allow for complete restoration following a mains failure.

12 Ventilation

12.1 General

The tunnel ventilation system shall be designed to provide an adequate throughput of air in order to control the temperature of the tunnel.

Using the CRATER analysis tool derived from the Cigre 143, tunnel ventilation outlet temperatures should not exceed 44°C based on a maximum design inlet ambient temperature of 28°C. Temperature within the tunnel and consequently the ventilation flow rate necessary to control the tunnel and cable temperature is directly related to cable rating and diameter, load, current density, number of circuits and tunnel diameter.

The important physical aspects of air quality are temperature, humidity and velocity.

Recommended minimum air velocity in the tunnel is 2.0m/s to prevent layering of methane or other noxious gases. The air as supplied shall be as cool and dry as is reasonably practicable, as during its passage into the tunnel its temperature will tend to become that of the tunnel walls and it will take up moisture.

Ventilation plant and equipment shall be located in a head-house or a suitable housing outside of the shaft. Ventilation plant shall not be installed within or at the bottom of shafts. Where possible extraction/ventilation outlets should not discharge into public accessible areas. Where this is not possible vents are to be directed so as to cause minimum draft and noise nuisance. Fire stop dampers may be required and shall be designed to suit the ventilation scheme.

Ventilation plant and inlet and outlet vents shall be located so as not to cause unnecessary nuisance to local residents. A local baseline noise survey is required prior to the installation of ventilation plant at any location.

It is not considered necessary for ventilation fans and equipment to be gas IP rated.

12.2 Ventilation Ductwork

All ventilation ductwork systems shall be classified in accordance with the Building and Engineering Association specification DSP DW/144 for air system metal ductwork.

Ductwork for internal locations shall be fabricated from hot dipped galvanised sheet steel.

Ductwork for external locations shall be manufactured in galvanised sheet steel complying with DSP DW/144. All joints shall be sealed and completely weatherproofed including the sealing of all pop rivets, etc. weatherproof collars to be fitted where ductwork passes through roof or external wall.
12.3 Intake and Exhaust Louvres

All louvres shall be sized for an air velocity through the openings of no greater than 2.5 m/s and shall not be less than 50% free vent area. Additionally, they must have acceptable aerodynamic and acoustic performance to minimise any airflow generated noise.

All air intake and exhaust points shall be fitted with vermin mesh to the inner face to prevent entry to the shafts and tunnels by vermin, birds, rodents and wind-blown extraneous material such as leaves, rubbish, and papers.

Fixed blade external louvres shall be of the narrow blade type, constructed from high quality aluminium extrusions and incorporating a bird/insect wire screen formed from plated wire mesh.

12.4 Fire Dampers

Fire Dampers shall be manufactured with stainless steel folding curtain housed within a galvanised steel outer casing with continuously welded corners and spigot connections to comply with DW/144. The Fire Dampers are to include a release cassette with memory metal spring, which will release the damper at 72°C, the cassette shall also be self-latching reset. Fitted with an external visual indication of the damper curtain.

Fire dampers shall comply with EN 15650, fire tested to BS EN 1366-2 and classified to EN 13501-3. Dampers shall be approved by the Loss Prevention Certification Board (LPCB) certification scheme with a minimum rating of SR2.

12.5 Fans

Fans shall be provided to deliver the required air volume against the resistance of the designed system and within the stable region of the fan curve.

Fans shall be capable of continuous operation within an air stream temperature of 50°C.

Fans motors shall be suitable for use with variable speed drives.

The ventilation system fans shall include duty and standby fans either in series or parallel.

12.6 Sound Attenuation

Sound attenuators shall be designed for maximum attenuation for ductwork, and equipment where required to minimize noise breakout.

The attenuators shall be suitable for operation with air temperatures of 50°C and shall operate in octave bands in accordance with BS EN ISO 266.

12.7 Ventilation Monitoring and Control

12.7.1 General

In order to minimise future maintenance costs and resource requirements tunnel ventilation control systems shall be designed to operate as simply as possible and be located to allow ease of maintenance without specialist access requirements or processes and in a suitable enclosure to prevent moisture.

In order to maximise the efficiency of the tunnel operation and allow increased circuit loading it may be necessary to install more complicated automated systems using DTS and TVCMS to control air flow and temperature. The design of these systems will need to consider future operation and maintenance by UK Power Networks staff. Full operator manuals and training shall be provided at handover by the manufacturer.
12.7.2 Ventilation Plant Control

The control system shall be provided to maintain design temperature conditions throughout the parts of the tunnel network ventilated by the ventilation system.

The ventilation plant control panel shall be formed of two sections, comprising of a control section and a power section. It shall be constructed of a factory built and assembled cubicle type.

The power section shall have the necessary MCB’s and electrical supplies for the main plant power requirements. The control panels shall have hardwired interfaces via volt free contacts to the UK Power Networks’ SCADA system. Details of the SCADA M&E schedule can be found in Appendix A of this document.

12.7.3 DTS / TVCMS and SCADA

The tunnel and cable temperatures are to be remotely monitored by a proprietary DTS fibre optic system, utilising a single/multimode fibre, manufactured in accordance with IEC 60794-3-10.

The DTS shall be designed to monitor both cable and tunnel temperature, by means of fibre optic cable located in the gap within the trefoil cable arrangement and along the soffit of the tunnel.

Normally only 132kV circuits will be monitored, but consideration shall also be made for heavily loaded 33kV and 11kV circuits, selected by the Technical Sourcing and Standards Manager. This layout of fibre optics and sensors forms the basis of the TVCMS, with the DTS system linked to it to control the temperature in the tunnel by increasing or decreasing the ventilation rate and volume.

The cable DTS system will raise separate alarms should cable temperature exceed 65°C or if temperature rise exceeds 7°C/min; these alarms will be communicated via the SCADA system to UK Power Networks Control Centre, located at Fore Hamlet, Ipswich.

The tunnel DTS system in the soffit of the tunnel will raise an alarm should tunnel temperature exceed 45°C or if temperature rise exceeds 7°C/min, this rate of rise is to be used to indicate fire; these alarms will be communicated via the SCADA system to UK Power Networks Control Centre, located at Fore Hamlet, Ipswich. A local audible / visual alarm will also be triggered at each shaft.

The TVCMS is to be automated with a locally operated override. UK Power Networks Control will have no operational control. The TVCMS will alarm remotely to UK Power Networks control for failure only.

TVCMS maintenance information is to be available both locally and remotely.

UK Power Networks control requires ambient and cable hot spot readings for each tunnel section to be provided continuously.

The DTS/TVCMS system is to be developed and designed by a specialist consultant or designer in line with the information provided above.
12.8 Future Additional Cables

Where additional power cables are to be added to tunnel, a survey must be carried out in order to assess their impact on the temperature gradient and fire risk throughout the tunnel section. A ventilation assessment and design must take into account the additional heat load before any cable installation takes place. Approval for additional cables in an existing tunnel asset must be obtained from the UKPN Asset Management Technical Sourcing and Standards Manager.

13 Smoke Detection

Monitoring for the presence of smoke shall take place at the ventilation outlet points of the tunnel system and positioned where the detection device can be easily maintained and suitable for the environment. Access to this information shall also be available remotely with trigger alarms being sent to Control via the SCADA system.

Where appropriate an ASD system is to be used based on the (VESDA) system. The ASD system is to be designed and configured to be suitable for the ventilation outlet and to operate with minimal false alarms and be easy to maintain from floor access. Data on maintenance periods and procedures is to be provided by the manufacturer and/or Designer. User manuals and action to be taken upon an alarm must be clearly passed over at handover.

14 Lighting and LV Electrics

14.1 General LV Electrical

Distribution boards are to be sited at each shaft head house and building services circuits are to be taken from the board in plastic surface mounted conduit or trunking.

All electrical installations to comply with BS7671.

14.2 Incoming Supplies

The incoming supply shall be derived from 2 diverse LV network supplies.

14.3 Low Voltage Distribution

The LV switchboard (LVAC) shall be Form 4 Type 2 form of separation with degree as defined in BS EN 61439-1 with automatic change over and dust and water ingress protection of a minimum of IP54. The switchboard will be generally located in the head house equipped with all the necessary outgoing fuse circuit protective devices. The switchboard shall be provided with a 100 Amp standby generator connection, via a commando socket provided on the panel. The switchboard shall be sized for 20% spare capacity and shall have the facility to interface with the UK Power Network SCADA system through volt free contacts, see Appendix A for typical M&E SCADA Schedule.

14.3.1 Sub Main Distribution Wiring and Containment

LV sub-main distribution cables shall be XLPE/SWA/LSOH, suitably sized to meet the maximum demand, fault rating, volt drop and relevant de-rating factors. With the exception of the fire alarm, smoke damper and mechanical control panels, which shall be fire enhanced cables.

Where cables are vulnerable to impact by fire they shall be specified with a 60-minute fire resistance rated and tested in accordance with BS EN 50200.

The containment systems shall be appropriate for the environment in which they are installed and for a minimum design life of 30 years.
14.3.2 Distribution Boards

Distribution Boards shall include integral switch disconnectors and will utilise a combination of outgoing MCB and RCBO, as required throughout.

All distribution board will be furnished with approximately 20% spare way capacity.

Distribution boards are to be sited at each head house, outgoing circuits to be wired in surface mounted conduits and trunking.

14.4 Uninterruptable Power Supply (UPS)

UPS systems shall be provided where required to provide power to the following:

- PLC System:
- DTS System.

The UPS batteries shall be sized to maintain a continuous supply to the inverter for at least 2hrs during a normal input supply outage, with the UPS operating at rated load. The minimum design life at 20-25°C must be 15 years. The UPS shall have the facility to interface with the UKPN SCADA system through volt free contacts see Appendix A for details

14.5 Lighting

Lighting is to be provided in the shafts only. Inspections of the tunnel itself are to be carried out using portable or temporary lighting systems. Fixed lighting in the tunnel is not to be installed as it requires specific maintenance and frequent inspection that would generate increased numbers of visit requirements into the tunnel section.

- Lighting switches to have neon indicators so they can be located in the dark.
- Main door entrance to have LED external luminaires with PIR to operate as door is approached.
- Luminaires shall have a protective enclosure that conforms to a rating of IP 56 in accordance with BS EN 60529:1992 i.e. dust and water splash protected.
- Lighting shall be provided using LED luminaires for general access down the shaft and at work areas e.g. at the base of the shaft.
- Lighting control is be located within the head house of the shaft and is to be tested at 6 monthly intervals.
- Wherever possible pumps and all other plant are to be located at the base of the shafts. Where this is not possible (e.g. a low point of a tunnel occurs between shafts) lighting in accordance with BS 6164:2001 and BS EN 60529:1992 shall be installed at the location of the plant only.

14.5.1 Minimum Mean Lighting Levels

Table 14-1 - Minimum Mean Lighting Levels

<table>
<thead>
<tr>
<th>Area</th>
<th>Lighting Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walkways and landings</td>
<td>200 Lux at walkway / landing level</td>
</tr>
<tr>
<td>General working areas within the shaft (e.g. pump areas and joint bays)</td>
<td>200 Lux at working surfaces</td>
</tr>
</tbody>
</table>
Emergency lighting to be provided by 3hr self-contained maintained and non-maintained battery conversion kits housed within general purpose luminaries and emergency exit signs.

The system shall generally fulfil the following functions:

- Indicate clearly all escape routes and provide illumination along such routes for safe movement under an emergency condition;
- Ensure that the fire alarm call points and other safety equipment along the escape routes can be readily allocated.

Emergency lighting levels to be in accordance with BS 5266-1 / BS EN 1838:1999.

14.5.2 Siting of Luminaries

All luminaires shall be fixed to provide maximum uniformity of lighting and minimum vulnerability to damage. They shall be easily accessible for installation, maintenance and repair.

- They shall be arranged so that their fields overlap and shall be sited to minimize shadows cast on walkways or working areas;
- Where higher intensity light sources are required glare shall be minimized by proper siting and the use of diffusers and screening.

14.6 Small Power

Power within the tunnel is to be supplied via 13A single phase IP65 rated sockets located every 100m along the length of the tunnel. Sockets are to be mounted such that they do not interfere with HV/EHV cable installation, operation or maintenance and are protected from potential flood levels within the tunnel; each socket is to be labelled with the circuit reference.

The following socket outlets shall be provided within head house equipment rooms:

- Sockets within equipment rooms shall be wired in LSOH single core with full size CPC.
- Containment shall be surface mounted high impact plastic.

An RCBO shall be used to control the small power sockets within the head house and distribution boards.
15 Communications

The communications system is to be provided by a “leaky feeder” system, a partially shielded coaxial cable running the full length of the tunnel allowing radio communication with the surface or other areas of the tunnel without visual contact. The cable is to be fed from each end of the tunnel section and a marshalling communications base station is to be located at each shaft head house.

It may be necessary to install repeaters. These should be designed to be fitted above flood level in a shaft and a level suitable for floor level access for maintenance.

The communications cable is to be located at the soffit of the tunnel at a minimum of 50mm from tunnel wall.

Dedicated radios tuned to the correct operational communications frequency are to be installed complete with charger units at each shaft head house.

It is expected that the local Fire Brigade will request a dedicated channel within the communications system in order to allow them to interface with all other Emergency Services. The exact details and requirements are to be discussed and agreed with the local fire brigade representative as part of the development of the Fire Risk Assessment and Fire Plan (see Sections 18.1 and 18.2).

The Communications system is to be fully developed and designed by a specialist designer in line with the information provided above.

UK Power Networks Control will only receive a communications alarm should the communications fail.
16 Doors and Access Hatches

16.1 Fire and Security Rating of Doors

Fire rating: doors and frames generally are to be steel galvanised and powder coated with fire ratings and specification:

- Generally 1 hour fire rated unless installed within a structural area or fire break requiring a greater rating (i.e. 4 hours);
- Security rating for external doors is to meet LPCB Level 4; see Section 4.7.

16.2 Doors Generally

Doors to be complete with appropriate ironmongery to suit application and test certification.

Doors/openings are to have a clear opening suitable to accommodate the largest section of plant expected to pass along that route.

Double doors to have one passive leaf secured with tower bolts top and bottom and kept normally closed. Active leaf to be hinged and fitted with ironmongery as scheduled. Minimum size clear opening of 1500mm wide x 2700mm high.

Single doors to be a minimum of 800mm wide x 2100mm high.

Doors to open outwards for escape purposes, be fitted with emergency escape devices to BS EN 1125, i.e. full width panic bars and be self-closing preferably with rising hinges or fitted with a closing device.

If a door is used solely for escape purposes then it should have no means of being opened from the outside. Ironmongery must be such as to allow single action escape in an emergency. Doors to be provided with signage internally and externally denoting “Fire Escape Only”.

External doors to be self-locking; internal doors are not to be self-locking.

Doors from rooms containing operational plant (e.g. ventilation plant) are to be fitted with internal panic bars. Doors from non-operational rooms (e.g. office, mess room stores) are to be provided with lever handles both sides and internal thumb-turns for lock release.

Threshold strips to be let into the screed or floor to ensure a smooth floor finish.

Heavy duty handles to be fitted to doors.

Hinges to be stainless steel ball bearing type low maintenance heavy duty hinges. All doors to be fitted with self-closers.

All doors opening against a wall are to be fitted with doorstops.

Steel frames to be fixed in openings with chemical resin fixings.

The security level of the tunnels is to be at least that of the substations the tunnel head-houses are located at or those sites that the tunnel feeds.
16.3 External Doors

The preference for securing the main access doors to each shaft is to have an electronic Locken locking system and/or the UK Power Networks proximity card system. Where a fail secure solenoid locking and UK Power Networks access control system using the proximity card with PIN verification reader is used a Key operated mechanical override shall be installed to ensure access in the event of a power failure. Where doors are to provide emergency egress only, they shall be operated by internal panic bar systems only with no external door furniture.

All doors are to be fitted with internal panic bar systems and door open alarm systems linked back to Control through SCADA.

16.4 Internal Doors

Internal door furniture on rooms containing electrical plant and in corridors:

- **Internal single doors**: Escape panic bar hardware internal to room and locking to suit local locking system on outside;
- **Internal double doors**: Dead leaf with tower bolts top and bottom, escape panic bar hardware internal to room;
- **Live leaf**: As for single doors.

17 Access Hatches

Access points to the tunnel other than those through the shaft(s) are to be secured with suitable access hatches.

Access hatches are to be located in pedestrianised areas or UK Power Networks owned property and are to have the following minimum requirements:

- Minimum BS EN124 loading class of B125;
- Flushing fitting with the surrounding pavement surface;
- Fully lockable with local area key suite;
- Easy maintenance;
- Equipped with accelerant catchment tray to prevent fluids entering the shaft;
- Shall be able to be lifted by a maximum of two persons;
- Provided with hold open stay;
- Provided with ‘hatch open’ alarms linked back to Control through the SCADA system.
18 Fire - Prevention and Protection

The introduction of any fuel to a shaft or tunnel shall be avoided. A Network Design Fire Risk Assessment shall determine and reduce ALARP (As Low As Reasonably Practicable) the risk of cable failure affecting other circuits. The design must make sure that the tunnel will meet all of the requirements of the Fire Risk Assessment which is required to be undertaken and recorded upon completion of the construction of the tunnel.

It is considered unlikely that the Fire Brigade will enter a shaft or tunnel if smoke is present unless there is a risk to life. They will not enter at all without the presence of a competent and authorised UK Power Networks representative.

In accordance with Section 4.9, a Fire Risk Assessment is to be carried out on the tunnel, shafts and all other features of the tunnel design and construction. A competent and responsible person must make a suitable and sufficient assessment of the risks, to which relevant persons are exposed for the purpose of identifying, the general fire precautions needed to comply with the requirements and prohibitions, imposed by or under the Regulatory Reform (Fire Safety) Order 2005. It is essential that the Fire Risk Assessment and the Fire Plan mentioned below are developed in conjunction with the local Fire Brigade representative.

18.1 Fire Plan

This will be specific to the premises and will detail the pre-planned procedures in place for use in the event of a fire. A fire plan will be provided at each point of access and is to be held electronically against the tunnel asset in the Asset Database. Again this is to be developed in conjunction with the local fire brigade representative.

The emergency plan must be recorded where:

- A license under an enactment is in force;
- An Alterations Notice under the Fire Safety Order requires it;
- You are an employer and have five or more employees.

This shall (where appropriate) include the following features:

- Action on discovering a fire;
- Warning if there is a fire;
- Calling the fire brigade;
- Evacuation of the premises including those particularly at risk;
- Power/process isolation;
- Firefighting equipment (see paragraph 18.3 below);
- Places of assembly and roll call;
- Liaison with emergency services;
- Identification of key escape routes;
- Specific responsibilities in the event of a fire;
- Training required;
- Provision of information to relevant persons.
18.2 Fire Protection Equipment

It is recommended that the local fire service are consulted before the quantity, type and position of fire protection equipment is decided. Fire protection systems should be designed to save life and facilitate egress during a fire event.

18.3 General Structural Fire Resistance

Building elements are to be designed for the following fire resistance periods:

- Tunnel and shafts – 4 hours;
- Elsewhere 1 hour.

18.4 Fire Risks involving Cables and Joints

Circuit overloading or poor connection can cause heating with damage to insulation and subsequent breakdown which in turn can lead to arcing and ultimately the outbreak of fire.

In the event of a fire, cable insulation can ignite and spread the fire; itself producing fumes and smoke. All cables within the tunnel and shafts are to be LSOH XLPE cables supplied in accordance with UKPN Equipment Approval Standard EAS 02-0000.

The special vulnerability of grouped cables in a vertical shaft should be noted and essential circuits, such as fire alarms and emergency lighting shall be segregated where possible from other circuits to reduce the risk and consequences of the spread of fire. In vertical shafts the cables shall meet the requirements of BS EN 50266-1, BS EN 50266-2, BS EN 60332-3-25 and IET Guidance Note 4.

Where communication and LV cables are vulnerable to attack by fire they shall have a fire resistance of 60 minutes, when tested in accordance with BS EN 50200, which corresponds to a classification of PH 60 as detailed in BS EN 50200, Annex D.

Joint failure can be explosive which may in turn lead to an outbreak of fire. It is important that the tunnel is designed to contain the blast pressure or allow it to dissipate without damage to the tunnel structure.

18.5 Fires Involving Electrical Equipment

Electrical installations and equipment can cause fires by overheating and arcing.

Failure can result from overloading or as a result of accidental damage or penetration by water. Because of the restricted space in tunnels it is particularly important that arrangements for isolating defective cables or equipment be carefully planned so that persons are not exposed to the hazards of electric shock and electrocution.

The network of cables shall be planned so that essential fire-fighting resources, lighting and ventilation control are not cut off in the process of isolating overheated equipment, and so that signals and communications are maintained.

18.6 Fire Detection

Fire detection will be via the DTS system. An alarm will be raised if the ambient tunnel temperature exceeds 65°C or there is a temperature rise greater than 7°C/min.
18.7 Fire Suppression and Control

The general fire mitigation measure is to minimise fire fuel material – e.g. by installing steel doors, preventing use of wood or other flammable materials and by good housekeeping. Equipment shall be located strategically in accordance with the route of the tunnel and location of shafts, and shall be regularly tested and properly maintained. The installation of new oil filled cables and equipment in tunnels and tunnel shafts is not permitted.

- In the event of smoke or temperature rises being detected the main ventilation system is to be managed in accordance with the table below. UKPN Network Control will have agreed operating procedures to competently handle the next steps. It is unacceptable for the ventilation equipment to remain shut down for extended periods;
- Suitable portable fire extinguishers conforming to BS 7863 and to the appropriate part(s) of BS EN 3 shall be provided at each shaft head-house and are readily accessible by personnel. They shall be selected and installed in accordance with BS 5306-8 where guidance is given on the correct type of extinguisher to be used on specific fire types. For tunnels and shafts the two main types of fire are electrical and Class A (solid materials). CO₂, clean agent or powder extinguishers can be used on electrical fires whereas water or foam extinguishers are more suitable for Class A fires. Water and foam extinguishers that meet the requirements of the dielectric test requirements of BS EN 3-7 can be used to extinguisher fires in close proximity to live electrical equipment and may, in this case only, be preferable to CO₂ units. However these water or foam extinguishers shall not be used directly on live electrical equipment without specific consultation with the manufacturers and the local fire authority;
- All equipment shall be maintained in good working order and checked and maintained in accordance with the manufacturer’s instructions.

Table 18-1 - Fire suppression and control event and actions

<table>
<thead>
<tr>
<th>Event</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoke alarm activated and rapid increase in temperature detected</td>
<td>(Suggests fire in tunnel) Switch off fans</td>
</tr>
<tr>
<td>Rapid increase in temperature detected</td>
<td>Engineer to visit site and investigate in conjunction with UKPN Network Control</td>
</tr>
<tr>
<td>Smoke alarm activated</td>
<td>Engineer to visit site and investigate in conjunction with UKPN Network Control</td>
</tr>
<tr>
<td>Protection tripped</td>
<td>Engineer to visit site and investigate in conjunction with UKPN Network Control</td>
</tr>
</tbody>
</table>

A dry riser system is to be installed from the top of each shaft to the tunnel invert. The dry riser is to be accessible from outside of the shaft head-house but is to be made secure to prevent vandalism or misuse.
19  External Works

19.1  Vehicle and Pedestrian Access

With regards to the provision of access to shaft entrances the following shall be considered in the design:

- Access is to be provided for the delivery, offloading and handling of all plant and cable drums as normally packaged by the suppliers;
- Convenient access and parking for frequent visits by operational staff with van and equipment is required;
- Unrestricted 24 hour access is required for maintenance staff and vehicles.

19.2  Drainage

Parking, delivery and offloading areas, normally around shaft head houses, are to be drained into a dedicated soak-away or sewer. All surface water discharge is to pass through a Full Retention Oil Interceptor (in accordance with the Environment Agency Pollution Prevention Guidelines: PPG 2 Above ground oil storage tanks) prior to entering the soak-away or sewer and is subject to the same controls and limitations as water pumped from the tunnel itself.

Foul water discharge from toilets housed within the shaft head house is to be connected to the nearest foul sewer. If a connection cannot be arranged then foul water will have to be discharged to a septic tank complete with level indicator and alarm.

19.3  Water Supply

Where applicable, a fresh water supply to the main access shaft head house is to be installed to facilitate the operation of the toilet, hand washing and to provide a potable drinking water source.

20  Earthing

Refer to UK Power Networks’ Earthing Manual and ENA ER C55/5.

An earthing system in accordance with BS7671 and to the approval of UK Power Networks shall be provided.

20.1  Main Equipotential Bonding

All equipment shall be bonded as specified in BS 7671.

All exposed non-current carrying metallic parts of the installations within the shafts and intake/exhaust structures shall be bonded to the main earth terminal. This includes all pipes, supports, louvres, stairways/ladders and walkways.

20.2  Lightning Protection (Head-House)

A Lightning Protection System shall be designed and installed in accordance with BS EN 62305-1.
21 Health, Safety and Environment

21.1 Construction Design and Management (CDM) Regulations

The design shall meet the requirements of the CDM Regulations 2015 and include:

- Informing clients of their duties;
- Design to minimise Health & Safety risks;
- Providing adequate information about the Health & Safety risks of the design;
- Provide details of residual and operational risks.

21.2 Hazard Elimination and Management Lists (HEML):

Site specific HEML’s must be completed for all design elements by a person competent, with the foresight to identify all risks that may occur during the construction period, and by design, where possible minimise or remove all risks, encouraging a safe working environment. These documents shall be included in the CDM documentation for the tunnel system.

21.3 The Client

The client shall appoint a Principal Designer for all works at the commencement of the project.

21.4 Handover and As-built Records

Full as-built records are to be supplied by the Contractor to UK Power Networks upon completion and handover of the tunnel. Records are to include:

21.4.1 Tunnel Route

The tunnel route is to be clearly marked on a map or plan showing accurately any incoming branches and all directional and level changes with cross-sections where appropriate.

21.4.2 Auxiliary Assets

All auxiliary assets supporting the operation of the tunnel are to be recorded; these include the ventilation system (fans and controllers), communications and auxiliary LV and small power and lighting systems.

21.4.3 Cable Records

The cables and circuits within the tunnel are to be clearly recorded and marked on the Tunnel Route plan. Any feeds relevant but external to the tunnel are to be also recorded. All cable and joint information is to be forwarded to UK Power Networks Asset Records.

Labels identifying the circuits every 100m and at junctions shall be installed.

21.4.4 Location of Shaft Head Houses and Tunnel Access Points

All tunnel access points and shaft head houses are to be recorded and marked on the Tunnel Route plan. Access procedures, particularly where they may differ from standard UK Power Networks entry procedures, are to be recorded.
21.4.5 Operation and Maintenance Protocols

Maintenance periods and procedures and equipment supplier information for all LV, ventilation and monitoring systems.

21.4.6 As-built Shaft and Tunnel Drawings

Fully marked up as-built drawings detailing all structural and dimensional details of the shafts, the tunnel, electrical schematic drawings of all LV power and lighting, sump pump systems and structural steelwork.

21.4.7 DTS / TVCMS and SCADA Systems

Monitoring and operating details including passwords and protocols. Operation and maintenance manuals, instruction guides for out of hours emergencies and information to be provided to UKPN Network Control shall be provided as part of the hand-over of the tunnel system.

21.4.8 Storage of Records and Data

- Project and as-built drawings and structural details to be stored on Projectwise.
- Cable records to be stored with UKPN Network Records;
- Details of all plant, equipment and Civils assets to be stored on the Asset Register;
- Periodic downloading of DTS information to be stored on Projectwise.

21.4.9 Handover and Training

The operation, inspection and maintenance procedures of all control and operational systems is to be clearly communicated and trained out by the Contractor and/or Delivery team to the Operations team taking control of the tunnel system.

User manuals and action to be taken in the event of emergency are to be summarised and documented on site in order to provide guidance in future years.
22 References

22.1 UK Power Networks Standards

EAS 02-0000  Approved equipment list – Cables and Joints
EDS 02-0040  Current Ratings Guide for Distribution Cables
EDS 07-0101  Security Specification for Operational Sites
ETS 02-0905  Specification for 33kV Single Core XLPE Insulated Cables
ETS 02-0940  Specification for 11kV Single Core XLPE Insulated Cables
ETS 02-0950  Specification for Auxiliary Multi Core and Multi Pair Cables
ETS 02-0956  Specification for LV Mains Cables having Low Emission of Smoke and Corrosive Gases when Affected by Fire
ETS 02-0995  Specification for 66kV Cables with Extruded Insulation suitable for use in Cable Tunnels, Galleries and Cable Basements
ETS 02-4040  Specification for 132kV Cables with Extruded Insulation suitable for use in Cable Tunnels, Galleries and Cable Basements

22.2 National and International Standards

BEWAG Report  Special Report on Fire Resistant Cable Installation in Tunnels
BS 5266-1  Emergency lighting. Code of practice for the emergency lighting of premises
BS 5306-8  Fire extinguishing installations and equipment on premises. Selection and positioning of portable fire extinguishers. Code of practice
BS 6164  Code of practice for health and safety in tunnelling in the construction industry
BS 7430  Code of Practice for Earthing
BS 7671  Requirements for Electrical Installations. IET Wiring Regulations
BS 7863  Recommendations for colour coding to indicate the extinguishing media contained in portable fire extinguishers.
BS EN 3  Portable fire extinguishers. Provisions for evaluating the conformity of a portable fire extinguisher to EN 3-7
BS EN 3-7  Portable fire extinguishers. Characteristics, performance requirements and test methods
BS EN 1125  Building hardware. Panic exit devices operated by a horizontal bar, for use on escape routes. Requirements and test methods
BS EN 179  Building hardware. Emergency exit devices operated by a lever handle or push pad, for use on escape routes. Requirements and test methods
BS EN 1838  Lighting applications. Emergency lighting
BS EN 50200  Method of test for resistance to fire of unprotected small cables for use in emergency circuits
BS EN 50266-1  Common test methods for cables under fire conditions. Test for vertical flame spread of vertically mounted bunched wires or cables. Apparatus
BS EN 50266-2  Common test methods for cables under fire conditions. Test for vertical flame spread of vertically mounted bunched wires or cables. Procedures. Category A F/R
BS EN 61439-1 Low-voltage switchgear and controlgear assemblies. General rules
BS EN 62305-1 Protection against lightning. General principles
BS EN 60332-3-25 Tests on electric and optical fibre cables under fire conditions. Test for vertical flame spread of vertically mounted bunched wires or cables. Category D
BS EN ISO 266 Acoustics. Preferred frequencies
BS ISO 3864-1 Graphical symbols. Safety colours and safety signs. Design principles for safety signs and safety markings
BS EN ISO 14122-2 Safety of machinery. Permanent means of access to machinery. Working platforms and walkways
BS EN ISO 14122-4 Safety of machinery. Permanent means of access to machinery. Fixed ladders
BTS/ICE Tunnel Lining Design Guide
DSP DW/144 Specification for sheet metal ductwork low, medium and high pressure/velocity air systems.
ENA ER C55/5 Insulated sheath power cable systems
IEC 60794-3-10 Optical fibre cables - Part 3-10: Outdoor cables - Family specification for duct, directly buried and lashed aerial optical telecommunication cables
CIGRE 143 - Calculation of temperatures in ventilated cable tunnels - Part I.
IET Guidance Note 4 Protection against fire
PPG 2 Environment Agency Pollution Prevention Guidelines: Above ground storage tanks
PPG 3 Environment Agency Pollution Prevention Guidelines: Use and design of oil separators in surface water drainage systems
STUVA Recommendations for Testing and Application of sealing Gaskets in segmental Linings
Sustainable and Secure Buildings Act 2004
The Building Regulations 2010
The Construction (Design and Management) Regulations 2015
The Electricity at Work Regulations 1989
The Electricity Safety, Quality and Continuity Regulations (ESQC) 2002 as amended (2006)
The Regulatory Reform (Fire Safety) Order 2005
Town and Country Planning Act 1990
### Appendix A - Typical Cable Tunnel M&E SCADA Schedule

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>No. of Signals</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>Fire alarm panel</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Fire Alarm Operated</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fire Alarm Fault</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>b)</td>
<td>Alarm and fault - Tunnel / Shaft</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Ventilation Fan - Fault</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hi-limit temperature alarm -</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>c)</td>
<td>Alarm and fault - Head House</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Ventilation Fan - Fault</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ventilation Fan - Filter Dirty</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hi-limit temperature alarm -</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UPS - Fault</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>d)</td>
<td>Smoke damper control panel</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Smoke Damper Closed (Common Alarm</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Common Fault</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>e)</td>
<td>Sump pump control panel</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Pump Fail</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High Level Alarm</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>f)</td>
<td>LVAC Supplies</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Main supply selected</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Standby supply selected</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Main supply faulty</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Standby supply faulty</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
1. All alarms shall be provided to the M&E SCADA Marshalling Box