Design Manual for Roads and Bridges

Highway Structures & Bridges
Maintenance & Operation

CM 430
Maintenance of road tunnels

(formerly BA 72/03)

Revision 0

Summary
This document describes procedures for the safe and effective maintenance of tunnels on the motorway and all-purpose trunk road network.

Application by Overseeing Organisations
Any specific requirements for Overseeing Organisations alternative or supplementary to those given in this document are given in National Application Annexes to this document.

Feedback and Enquiries
Users of this document are encouraged to raise any enquiries and/or provide feedback on the content and usage of this document to the dedicated Highways England team. The email address for all enquiries and feedback is: Standards_Enquiries@highwaysengland.co.uk

This is a controlled document.

Contents

Release notes

Version	Date	Details of amendments
0	Mar 2020	CM 430 replaces BA 72/03. This full document has been rewritten to make it compliant with the new Highways England drafting rules. It has undergone an editorial revision with technical changes on the following themes: 1) account for different procurement and management arrangements; 2) reflect current good practice; 3) remove detailed references to inspections, transferred to appropriate standard; 4) reflect a focus on customer service; 5) provide a risk based approach to maintenance regimes

Foreword

Publishing information

This document is published by Highways England.

This document supersedes BA 72/03, which is withdrawn.

Contractual and legal considerations

This document forms part of the works specification. It does not purport to include all the necessary provisions of a contract. Users are responsible for applying all appropriate documents applicable to their contract.

Introduction

Background

Since the publication of BA72/03 in May 2003 a number of high profile incidents in heavily trafficked road tunnels across the world have involved significant loss of life and changes in provisions in tunnels for safe operation resulting from changes in legislation. Efficient, safe and sustainable operation of road tunnels relies on routine inspection and maintenance.

This document provides requirements and guidance relevant to the maintenance of all road tunnels on the motorway and all-purpose trunk road network in the United Kingdom. This document reflects changes in technology, the availability of new systems and incorporates experience from current practice. The following topics are included in the document:

1) Section 2 'Roles and responsibilities' describes the roles and responsibilities of the Tunnel Operating Authority (TOA) relating to maintenance activities;
2) Section 3 'Organisation and management' of maintenance outlines the organisation of the TOA, and the framework and tools necessary to manage tunnel maintenance effectively;
3) Section 4 'Tunnel structure cleaning' gives the requirements for cleaning of the tunnel structure;
4) Section 5 'Inspections' gives categories of inspections for the tunnels and the associated systems and structures;
5) Section 6 'Structure maintenance' describes routine maintenance, inspection, testing and repairs as applicable to road tunnel structures;
6) Section 7 'Ventilation systems' gives the requirements and general guidance on the maintenance of ventilation equipment;
7) Section 8 'Lighting systems' sets out the requirements and provides general guidance on the maintenance of lighting equipment;
8) Section 9 'Drainage plant' provides the requirements and advice on the maintenance of drainage equipment, such as pipes, pumps and valves;
9) Section 10 'Fire safety equipment' provides requirements and advice on maintenance of fire safety equipment including cross-passage doors, fire extinguishers, fire hydrants and hoses, fire mains, fire and gas detectors and automatic fire extinguishers or foam flooding systems;
10) Section 11 'Traffic control communications and information systems' describes the maintenance of communication cables, telephones, radio systems, closed circuit televisions, traffic detection systems, variable message signs and supervisory control and data acquisition systems;
11) Section 12 'Plant monitoring and control systems' outlines the maintenance of the plant monitoring and control system (PMCS);
12) Section 13 'Electrical power distribution' describes the maintenance of high-voltage (HV), and low- voltage (LV) power cables, earthing and lightning protection systems, high-voltage equipment, HV transformers and switchgear, LV switchgear, and distribution and control panels;
13) Section 14 'Emergency power equipment' provides requirements and advice on the maintenance of uninterruptible power supply (UPS) equipment and standby generators;
14) Section 15 'Service buildings and plant rooms' describes the maintenance of service building and plant room fabric and building services.

Assumptions made in the preparation of this document

The assumptions made in GG 101 [Ref 13.N] apply to this document.

Abbreviations

Abbreviations

Abbreviation	Definition
ACM	Asbestos containing materials
CDM	Construction Design and Management (Regulations)
CO	Carbon monoxide
CO_2	Carbon dioxide
DC	Direct current
FMEA	Failure modes and effects analysis
FPA	Fire Protection Association
HIPOT	High potential
HV	High-voltage (exceeding 1,000 volts AC or 1,500 volts DC between conductors, or 600 volts AC or 900 volts DC between conductors and earth)
HVAC	Heating, ventilating and air conditioning
IET	The Institution of Engineering and Technology (formerly the IEE)
ITCS	Integrated tunnel control system
ISO	International Standards Organisations
LED	Light emitting diode
LEL	Lower explosive limit
LHDS	Low-heat linear detection system
LPC	Loss Prevention Council
LV	Low-voltage
MTF	Mean time to failure
NDC	Normal distribution curve
NDD	Network delivery and development directorate
NFPA	National Fire Protection Association
NMC	National maintenance contractor
NO_2	Nitrogen dioxide
O&M	Operation and maintenance
OMM	Operation and maintenance manual
PA/VA	Public address /Voice alarm
PLC	Programmable logic controller
PMCS	Plant monitoring and control system
RMC	Regional maintenance contractor
RTSR	Road Tunnel Safety Regulations
SCADA	Supervisory control and data acquisition
SD	Standards deviation

Abbreviations (continued)

Abbreviation	Definition
SIS	Safety instrumented systems
TDSCG	Tunnel Design and Safety Consultation Group
TERN	Trans-European road network
TMMM	Technology management and maintenance manual
TOA	Tunnel operating authority
UPS	Uninterruptible power supply
VMS	Variable message signs

Terms and definitions

Terms and definitions

Term	Definition
Emergency services	All local services that can be called upon to intervene in the event of an accident or incident, including the police, fire and rescue services, ambulance services, traffic officers and tunnel operational staff.
Motorway and all-purpose trunk road network	Those parts of the UK highway and road network for which one of the Overseeing Organisations is, or acts on behalf of, the highway or road authority.
Overseeing Organisation	The authority responsible for the road tunnel. In the context of the Road Tunnels Safety Regulations (RTSR) SI 2007/1520 [Ref 11.N], can also be referred to as the Administrative Authority. This refers to the following organisations or their successors: 1) Highways England; 2) Transport Scotland; 3) Welsh Government (Llywodraeth Cymru); and 4) Northern Ireland the Department for Infrastructure (An Roinn Bonneagair - Transport NI)
Technical approval authority	The organisation responsible for agreeing the 'Approval in Principle' and acceptance of design and check certification.
Trans-European Road Network	The network of roads designated by the European Parliament as being strategically important for Europe-wide transport.
Tunnel design and safety consultation group	A consultation group made up of interested parties, convened for the purpose of reviewing and co-ordinating proposals for the design and operation of a road tunnel.
Tunnel manager	The individual or, in some cases, the organisation, responsible for management of the tunnel. Specific duties of the Tunnel Manager are defined in the RTSR.
Tunnel operating authority	The organisation responsible for day-to-day operation of the tunnel.
Tunnel Safety Officer	An independent individual responsible for monitoring and advising on issues relating to road tunnel safety. Specific duties of the Tunnel Safety Officer are defined in the RTSR.

1. Scope

Aspects covered

1.1 This document provides requirements and advice which shall be used for the maintenance of road tunnels.

NOTE 1 *This document covers general aspects of organisation and management of routine maintenance, detailed aspects of tunnel cleaning, inspection, servicing and testing of equipment, structure and other elements of road tunnels. It includes emergency maintenance works.*

NOTE 2 *This document provides guidance for the maintenance of motorway and other trunk road tunnels. It is intended as a tool for developing the most appropriate and sustainable maintenance approach to any road tunnel. It has been updated in the light of changes in technology including new systems introduced since the last version of the document.*

NOTE 3 *Information on general procedures, specific aspects of routine highway maintenance and management of health and safety are provided in this document.*

NOTE 4 *This document complements the requirements of CD 352 [Ref 2.I] 'Design of road tunnels', CS 452 [Ref 12.N] 'Inspection and records for road tunnels' , CG 302 [Ref 1.N] 'As Built, Operational and Maintenance Records for Highway Structures' and CS 450 [Ref 4.I] 'Inspection of Highway Structures' containing information on the general and specific design and operational requirements for road tunnels. CS 452 [Ref 12.N] provides requirements for the inspection and records for road tunnels and is to be read in conjunction with CS 450 [Ref 4.I] and CG 302 [Ref 1.N] which cover the structural elements.*

NOTE 5 *The frequency and nature of inspections and maintenance, is provided as an initial aid to the development of inspection and maintenance procedures. Each tunnel has unique conditions of traffic, general environment and equipment level and use.*

1.2 The TOA shall check with the Overseeing Organisation regarding any additional documentation and requirements that apply to the management and maintenance of technology assets in the tunnel.

1.3 Inspection and maintenance procedures shall be reviewed regularly and updated based on experience and feedback from tunnel operation.

1.3.1 This document may be used as the basis for reviewing and improving current maintenance arrangements.

Implementation

1.4 This document shall be implemented forthwith on all schemes involving maintenance of motorway and other trunk road tunnels on the Overseeing Organisations' motorway and all-purpose trunk roads according to the implementation requirements of GG 101 [Ref 13.N].

Use of GG 101

1.5 The requirements contained in GG 101 [Ref 13.N] 'Introduction to the Design Manual for Roads and Bridges' shall be followed in respect of activities covered by this document.

2. Roles and responsibilities

Tunnel operating authority

2.1 In respect of maintenance responsibilities, the Tunnel operating authority (TOA) shall:

1) prepare briefs and budgets for routine maintenance works;
2) prepare and prioritise as necessary, detailed recommendations for proposed remedial, refurbishment or contingency expenditure;
3) liaise with relevant stakeholders on future work programmes, preparing contracts, supervising works, etc. as required;
4) instruct, monitor and supervise the work of the maintainer, checking that competent and suitably trained personnel are used at all times;
5) undertake regular inspections and surveys, in accordance with all relevant standards, and take appropriate urgent action if anything which poses an immediate safety threat to road users or personnel involved in the maintenance and operation of the tunnel is discovered;
6) carry out regular comprehensive exercises and risk assessments to identify and manage all possible hazards of tunnel maintenance and operation. Thereafter develop and/or maintain appropriate contingency arrangements, through agreements with affected parties and emergency services;
7) liaise and maintain effective communications with the emergency services ensuring all parties have up to date information, relevant telephone contact numbers, etc. and regarding regular emergency drills and exercises, and ensure they are familiar with tunnel equipment and its operation. See CS 452 [Ref 12.N] for guidance on emergency exercises and drills;
8) keep records of all tunnel maintenance proposals, reports, activities, certificates, etc.;
9) undertake training of staff to ensure their safety and levels of competency. For appropriate staff, this should include maintaining currency with best international practice, new developments and thinking;
10) co-ordinate with contractors responsible for the maintenance of the motorway communications system provisions within the tunnel;
11) management of illegal access by pedestrians in vehicle only tunnels.

NOTE 1 *The TOA is appointed by the Overseeing Organisation. Under some contractual arrangements the TOA can be part of the Overseeing Organisation. Any tunnel-specific maintenance requirements will be set out by the TOA.*

NOTE 2 *The TOA can carry out the role of maintainer itself, or appoint one or more specialist sub-contractors to undertake maintenance works, as instructed by the TOA.*

2.2 In respect of maintenance responsibilities, the Tunnel operating authority (TOA) must:

1) ensure that a complete and up-to-date set of tunnel documentation, including the Health and Safety File under CDM Regulations (SI 2015/51 [Ref 25.N]), emergency procedures, operating manuals is maintained and available at all times;
2) notify the Health and Safety Executive of relevant safety delegations and appointments and correspond as necessary to comply with CDM Regulations (see Section 3).

2.3 The TOA shall manage safety risks and maintain the tunnel in accordance with requirements for safety risk assessments applicable for the Overseeing Organisation.

3. Organisation and management of maintenance

General

Maintenance organisation

3.1 The maintenance organisation shall be quality assured and accredited according to BS EN ISO 9001 [Ref 23.N], and be competent to undertake its duties.

NOTE 1 *Evidence of competence can be demonstrated by certification against NHSS Sector Scheme 22 'Particular Requirements for the Application of ISO9001:2015 for the Management, Operation, Installation and Maintenance of Road Tunnels NHSS 22 [Ref 7.I]] .*

NOTE 2 *This sector scheme document relates to the quality management system requirements for the management, operation, installation and maintenance of road tunnels. It sets out to identify common particular requirements of BS EN ISO 9001 [Ref 23.N] for Organisations and Certification Bodies engaged in the sector, and the minimum qualifications that an assessor/auditor requires. The document is complementary to and is to be read in conjunction with BS EN ISO 9001 [Ref 23.N].*

NOTE 3 *The organisation of maintenance of an individual tunnel can depend on whether it is manned or unmanned.*

NOTE 4 *Manned tunnels can have their own dedicated management structure and resources who take responsibility for traffic surveillance and the safe operation of the tunnel, including response to incidents and emergencies. This structure can include dedicated maintenance staff.*

NOTE 5 *Unmanned tunnels can be equipped with automatic detection facilities and does not have permanent operating and monitoring staff at the tunnel. They have arrangements for rapid response in the event of equipment failure or other emergencies. Responsibility for initiating action in connection with tunnel equipment in unmanned tunnels varies and can depend on specific agreements and arrangements with the emergency services.*

3.2 Whether a tunnel is manned or not, emergency cover shall be provided on a 24-hour basis, within a schedule of agreed operational response times, to carry out or oversee all maintenance work (including that contracted out).

NOTE 1 *Road tunnels can have varied management arrangements in relation to access, control, records and for management of specialist sub-contractors.*

NOTE 2 *The operation of a road tunnel is sometimes carried out on a shared responsibility basis. Typically, the local highway authority can have responsibility for all highway maintenance and the Overseeing Organisation can have responsibility for the tunnel structure and its equipment.*

Maintenance staff

3.3 The staff concerned with inspection, operation and maintenance of road tunnels shall be competent and have the necessary skills, qualifications, knowledge and experience to carry out their duties and responsibilities effectively.

3.4 Staff shall cover the spectrum of management, technical, maintenance and operational skills needed for effective maintenance of road tunnels and be capable of specific communication with tunnel stakeholders.

3.4.1 Senior tunnel operational and maintenance staff should be appointed at an early stage in the design of a new tunnel, to be available for consultation during the planning, design and construction processes.

3.4.2 Where tunnel maintenance staff carry out other functions such as routine traffic management and emergency response, their availability for maintenance tasks should not be compromised by their other duties.

3.5 Staff shall not be assigned to specific tunnel duties unless they have received the appropriate training and have been formally assessed for competence.

3.6 A continuous and specific tunnel training programme, including refresher courses, shall be developed to ensure that tunnel staff are knowledgeable and proficient in all aspects of the tunnel engineering and control systems.

3.7 Records shall be kept of the tunnel-specific training received by staff, and regular reviews undertaken to identify future training needs.

3.8 The tunnel maintenance team shall include those with qualifications and authorisation to comply with statutory safety procedures such as 'permit to work' systems relating to high voltage equipment, confined spaces and working at height.

Quality plan

3.9 A quality plan shall be developed and submitted in accordance with GG 102 [Ref 22.N].

3.9.1 The quality plan should contain a tunnel-specific management strategy that sets clear and sustainable performance objectives, delegates responsibility and establishes lines of communication with tunnel stakeholders.

3.9.2 The quality plan should explain how:

1) tunnel project briefs can be established/clarified and periodically reviewed and communicated;
2) appropriate tunnel-specific resources and tools are to be identified, allocated and managed and how suppliers are to be assessed and approved for use;
3) audit trails can be generated and made readily accessible through a controlled filing and archiving system;
4) the training and development needs of staff are to be identified and delivered.

3.9.3 Regular meetings should be held with the Overseeing Organisation, TOA and other parties, to review the tunnel specific quality plan and renew the key objectives.

Maintenance objectives

3.10 The following maintenance objectives shall apply to all tunnels:

1) tunnel is open and safe;
2) ensure safety of road users, tunnel operational staff and other roadworkers;
3) understand the needs of road users and neighbours;
4) maintain tunnel assets in a safe and serviceable condition;
5) obtain value for money through a whole-life cost approach;
6) continuity of tunnel system operation;
7) minimise time scale of an emergency from initial assessment to completion of repairs;
8) understand the potential effects of equipment failures on safety and traffic flow through the tunnel;
9) whether the tunnel can remain operational while the fault or failure is rectified;
10) knowledge of the location of equipment to be maintained;
11) understand and minimise environmental impact;
12) be sustainable;
13) ensure resilience in tunnel operation.

3.11 A risk management approach shall be adopted in planning maintenance (see 'Determining and reviewing maintenance recommendations subsection of this section.

3.11.1 The TOA should consult with the Overseeing Organisation regarding the appropriate safety risk assessment requirements to be adopted.

Constraints

3.12 The maintenance framework shall be developed within the constraints of relevant legislation, financial rules of the Overseeing Organisation and tunnel-specific requirements.

3.12.1 As part of the maintenance framework workplace hazards within the tunnel, associated service buildings, workshops and work compounds should be identified.

3.13 The TOA and the tunnel maintenance organisation and other suppliers must comply with the 'Construction (Design and Management) Regulations 2015' SI 2015/51 [Ref 25.N].

NOTE 1 *The Construction (Design and Management) Regulations 2015 SI 2015/51 [Ref 25.N] apply to the majority of tunnel maintenance activities, according to regulations 2(1)a and 2(1)e. Where not specified in the contract, advice can be sought from the Overseeing Organisation in designating the 'Client' under these regulations. CDM Regulations include the appointment of a Principal Designer and Principal Contractor, provision of information, preparation of a construction phase plan, assessment of competence, allocation of resources and the completion and maintenance of a health and safety file.*

NOTE 2 *Identification of workplace hazards within compounds. This is of direct relevance to tunnel operators' compounds and workshops, and its principles can be applied to hazards in control rooms, service buildings and in the tunnel.*

Maintenance funding

3.14 Funding of future maintenance for new or refurbished tunnels shall be planned and based on inspection information and the recommended service life of components and equipment.

3.14.1 Opportunities should be taken to implement efficiencies and to coordinate maintenance activities around planned tunnel closures, and where appropriate to bulk change equipment in order to ensure continued safe operation.

3.15 For an operational tunnel an evidence-based business plan for maintenance shall be developed and linked to the inspection cycle (see CS 452 [Ref 12.N]) to support the case for future funding over a rolling 3-year programme.

3.15.1 The business plan should identify what is to be achieved, the evidence, alternative options, risks addressed, method, timing and quality.

3.15.2 The plan should include funding provisions to deal with emergencies, contingencies and capital replacement items.

3.15.3 Costs in the business plan may be grouped under the following headings:

1) staffing;
2) planned maintenance;
3) emergency maintenance or contingency;
4) overheads such as vehicles and buildings; and,
5) capital replacement.

Planned closures

3.16 The primary constraints shall be the demand to keep the tunnel open to traffic as much as possible, and to be safe for road users and tunnel operational staff.

NOTE *Local conditions influence the nature, timing and frequency of planned tunnel maintenance activities.*

3.17 Closures shall be planned and activities prioritised to achieve the maximum amount of maintenance work per planned closure.

3.17.1 Set-up times, contingencies, and safety checks before re-opening should be assessed.

3.17.2 Planned closures should, wherever practical, avoid periods of peak day, holiday and local event traffic.

NOTE *Closures tend to be limited to periods of low traffic flows, for example late evening through to early morning and/or during weekends.*

3.18 Closures shall be agreed with the Overseeing Organisation in advance.

3.18.1 Other organisations affected by the closure should be consulted in the planning process.

3.18.2 Road users and neighbours affected by the planned closure should be provided with information about the closure and, where appropriate and necessary, alternative traffic routeing.

Management of maintenance

Maintenance standards

3.19 Maintenance requirements and associated activities shall be consistent with, and not compromise, the basic design assumptions of the tunnel as listed in CD 352 [Ref 2.I] and the tunnel OMM.

NOTE *Maintenance and performance levels and ongoing requirements are developed in consultation with the TDSCG and the prospective TOA during the tunnel design process.*

3.19.1 Tunnel-specific maintenance requirements or levels should typically be reviewed at intervals of not less than 3 years, after principal inspections, and with additional reviews when specific maintenance issues are identified.

Maintenance strategy

3.20 A tunnel specific maintenance strategy shall be developed by the TOA to ensure delivery of effective maintenance over the lifetime of the tunnel.

3.20.1 In developing a maintenance strategy, safety levels for users, fault levels, costs of contractor call-out, and disruption due to unplanned tunnel closures should be assessed.

NOTE 1 *Typically major tunnel refurbishment can be needed every 15 years, but the timing can depend on safety structure and equipment performance, and can require extensive planning.*

NOTE 2 *The following documents are relevant to the development of a maintenance strategy:*

1) *tunnel operation and maintenance manual (OMM) and tunnel inspection and maintenance records;*
2) *Overseeing Organisation's documents for the management and maintenance of technology assets;*
3) *Well-managed Highway Infrastructure – A Code of Practice (UK Roads Liaison Group) WmHI CoP [Ref 11.I].*

3.20.2 The tunnel maintenance strategy should aim to avoid unplanned tunnel closures through prudent preventative maintenance and optimisation of tunnel closures, as well as use of reliable equipment.

3.20.3 Tunnel service levels and the need for equipment replacement should be assessed when planning and costing a maintenance strategy, and determining the timing and intervals between closures.

3.20.4 The maintenance strategy should anticipate the extent of maintenance requirements, lane closure times available, noise and light pollution restraints, identification of any weak and vulnerable links in the system, the need for contingency planning, availability of funding, relationships with manufacturers and term contractors, and the emergency services.

3.20.5 The maintenance strategy should include the need for flexibility to deal with unplanned events and make changes in the light of experience.

NOTE 1 *There can be advantages into dividing work into:*

1) *tunnel zones;*
2) *specialist trades;*
3) *expected times to complete each task;*
4) *breaking down large tasks into smaller ones on a logical basis;*

5) *concentration on repeated or extensive faults and their elimination;*
6) *switching of items in-service to even out wear and tear.*

NOTE 2 *Other factors to be included in the maintenance strategy:*

1) *equipment and component service life expectancy;*
2) *obsolescence and spares availability;*
3) *ease of maintenance;*
4) *specialist tools and equipment;*
5) *specialist access equipment;*
6) *communications;*
7) *inspections;*
8) *feedback from incidents;*
9) *traffic management.*

3.21 A whole-life cost approach shall be adopted for developing the maintenance strategy.

NOTE 1 *Newer equipment can be cheaper to install and more reliable than existing provisions, even if the older equipment is still functioning. The older equipmentcan be difficult to maintain, if spares and product support are unavailable.*

NOTE 2 *It can prove cost effective to replace complex equipment with equipment that is simpler with fewer points of failure or is fail-safe.*

3.22 Once the maintenance strategy is established, maintenance planning objectives for the short, medium and long term shall be used to assist in the decisions as to which items of equipment can be maintained on a daily, weekly, monthly, yearly, urgent or routine basis.

NOTE *Road tunnel maintenance and inspection activities can generally fall into one of the following four categories:*

1) *inspection;*
2) *corrective maintenance;*
3) *planned and preventative maintenance;*
4) *major overhaul and refurbishment of the tunnel equipment and tunnel fabric.*

Monitoring and testing

3.23 In addition to the planned inspections of the tunnel structure and M&E equipment, a monitoring regime shall be undertaken which includes regular quantitative measurements of light outputs from tunnel luminaires, vibration of rotating machinery and performance measurements of other equipment.

NOTE *Details of inspection types and reporting records are given in CS 452 [Ref 12.N].*

3.23.1 The monitoring should be logged and failure rates against hours run established.

3.23.2 Periodically the monitoring logs should be reviewed, and assessed to assist decisions around future maintenance work to determine the need for increased frequency of monitoring, repair or replacement.

NOTE *Inspection, monitoring and testing plans are required to ensure that all M&E equipment and associated controls can be examined, taking account of:*

1) *focus on known faults;*
2) *where there are large numbers of identical equipment;*
3) *where equipment is not easily accessible such as behind secondary cladding panels;*
4) *equipment to be prioritised as it approaches its predicted end of serviceable life;*
5) *ensuring that all equipment is inspected.*

Lane closures

3.24 Lane, bore or full tunnel closures shall be implemented to protect the workforce from both highway and works traffic when maintenance and inspection works are within a tunnel.

3.25 Planned tunnel maintenance works shall assess, mitigate and allow for:

1) traffic within a tunnel, that can produce noise levels in excess of 95dB(A);
2) traffic that can produce turbulent air conditions, greater than in open air, with positive and negative (suction) pressures which could effect those on foot or working at height;
3) air quality;
4) projections from vehicles that can hit workers or unbalance working platforms etc.

3.25.1 Physical barriers, signage and other measures such as impact protection vehicles should be used to protect the workforce from errant vehicles in accordance with TSM Chapter 8 [Ref 9.I].

Equipment settings during maintenance

3.26 Planned tunnel maintenance shall include the status of safety systems and the appropriate mitigation measures.

3.27 Where safety systems are temporarily out of operation during maintenance works the risks shall be assessed and mitigation measures developed for replacement safe systems.

3.27.1 During maintenance activities the tunnel and approach lighting and tunnel ventilation may need to be enhanced so that staff can work in safety and efficiently.

3.28 Pollution levels can be higher during tunnel maintenance work and shall be continuously monitored.

3.29 Maintenance activities shall be planned so that pollution levels are restricted to levels to ensure that staff can work in safety and efficiently.

3.30 During tunnel maintenance operations the switching of luminaires shall be arranged to give continuity of lighting throughout the length of the tunnel.

Access and safety procedures

3.31 All tunnel staff, maintenance personnel and contractors involved with entering the tunnel shall:

1) be familiar with the tunnel site layout;
2) be issued with procedures of tunnel operations, including lane and tunnel closures, and signed for;
3) follow the designated working route for personnel in the tunnel;
4) notify tunnel operator and be recorded on entry and exit from the tunnel and associated buildings;
5) avoid lone working.

3.32 The tunnel operator shall be provided with details of any works that can adversely affect the traffic or tunnel services.

3.33 Before tunnel maintenance personnel and other roadworkers enter a tunnel, the environmental conditions shall be assessed for safe working conditions.

3.34 Tunnels with mechanical ventilation shall have their bores purged of vehicle pollution by manual operation of the fans prior to any work commencing.

3.35 Tunnels with only natural ventilation shall be allowed sufficient time for vehicle pollution to clear and readings of CO, NO_2 and other pollutants to be taken prior to entry to the tunnel.

NOTE *Service building entry doors are normally protected by intruder alarm systems. The alarm system can be switched off by maintenance staff on entering the building and reactivated on leaving.*

3.36 Some service building rooms are protected by fixed fire suppression systems and there are procedures that shall be followed such as switch-off before entry and engage after exit.

Tunnel documentation and maintenance records

3.37 Tunnel documentation and maintenance records shall be retained and kept up to date by the TOA.

NOTE *Tunnel documentation and maintenance records are essential for the safe operation and effective maintenance of the tunnel assets.*

3.38 The tunnel documentation shall include details of the requirements to maintain the asset base including the following:

1) corrective/emergency maintenance assessment and maintenance requirements;
2) routine/planned maintenance requirements;
3) knowledge of failure modes and effects analysis on an asset (FMEA);
4) appropriate holding of spares and consumables to support an asset throughout its expected life;
5) maintenance logistics to support each asset;
6) commissioning and testing records.

3.39 Tunnel operation and maintenance manuals shall be maintained in accordance with the requirements of the Manual of Contract Documents for Highway Works MCHW Series 7000 [Ref 20.N].

3.40 Records of tunnel inspections and maintenance shall be in accordance with CS 452 [Ref 12.N] for M&E systems and CG 302 [Ref 1.N] for structures.

3.41 The tunnel documentation shall include detailed procedures and methods for tunnel operation, maintenance, inspection and emergency response.

NOTE 1 *Tunnel maintenance records provide information on past performance upon which future decisions can be made, evidence that acceptable standards are achieved and information for future budgeting. Periodic statistical, logistical and financial analysis of the records can enable the performance of engineering assets to be assessed.*

NOTE 2 *On a scheme-specific basis, records can indicate significant trends in performance, which can be related to changes in operational and maintenance strategies, or they identify the potential for, and timing of, equipment failures.*

3.42 Tunnel records shall be collated and archived so that they remain secure, accessible and retrievable.

NOTE *Accurate records of inventory, condition and operation are essential for future management of the tunnel and to deal with customer enquiries and claims.*

3.43 Summary operational records for individual tunnels shall be submitted to Overseeing Organisations in accordance with CS 452 [Ref 12.N] for M&E installations and CG 302 [Ref 1.N] for structures, to assist future research needs, policy reviews, benchmarking and value for money assessments.

Determining and reviewing maintenance recommendations

3.44 Tunnel maintenance recommendations and performance shall be regularly reviewed in accordance with the Overseeing Organisation requirements in this document.

3.44.1 Proposed tunnel maintenance recommended actions should be reviewed at least annually.

3.44.2 The equipment manufacturers' recommendations should be taken as a starting point for scheduling equipment maintenance in tunnel documentation.

NOTE *Equipment manufacturers' recommendations are normally specified as time intervals based on maximum duty, but commonly actual use can be less. For example, fans in tunnels with uni-directional traffic can be used only occasionally. Conversely, the tunnel environment can be more aggressive and corrosive than is often assumed by manufacturers, which can act to shorten the life of equipment.*

3.45 The reasons for any variations to the maintenance schedules in tunnel documentation shall be evidence based on past recorded performance, and the effects of change monitored and reviewed.

3.46 Inspection or maintenance intervals shall not be extended beyond those recommended by equipment manufacturers.

3.46.1 Where this is unavoidable then risks should be assessed and warranty conditions discussed with the manufacturer.

3.46.2 Where compliance with manufacturer's recommendations cannot be achieved this should be reported to the Overseeing Organisation.

3.47 An audit trail shall be maintained to detail any deviations from the OMM manual or manufacturer's recommendations.

3.48 Wherever possible, the opportunity shall be taken to use feedback from plant monitoring equipment to inform future maintenance planning.

Asset management software

3.49 A software-based asset management system shall be implemented as agreed or instructed by the Overseeing Organisation.

3.50 All electronic data shall be in a format as required by the Overseeing Organisation.

NOTE *Where hand-held data capture devices are used, they can be configured to interface with the asset information system.*

Risk assessment

3.51 Tunnel operation and maintenance must comply with The Management of Health and Safety at Work Regulations SI 1999/3242 [Ref 9.N] which require regularly reviewed risk analyses to be undertaken.

3.52 The risk reviews in accordance shall include the safety of the public, highway neighbours, road workers and other parties.

3.52.1 The risk analysis process should identify all tunnel hazards, assessment of their likelihood of occurrence, their consequences and their management and mitigation.

NOTE 1 *The document 'Guidance on Risk Assessment at Work: Health and Safety' 89/391/EEC [Ref 3.I] provides useful general information.*

NOTE 2 *Other information on safety risk assessment is available from the Overseeing Organisation.*

NOTE 3 *For straightforward tunnel operations-based applications, risk assessment can involve a review of the task, followed by the setting up of a risk register based on a simple risk-rating matrix. More complex tunnel operations can involve setting up a workshop of all interested parties (police, emergency services etc) to identify and assess a full range of hazards affecting the operation.*

Maintenance planning and schedules

3.53 Maintenance schedules forming part of the tunnel maintenance strategy shall be developed from the requirements and recommendations contained in the tunnel OMM and in accordance with the MCHW [Ref 19.N].

3.53.1 When routine maintenance is being undertaken the opportunity should be taken to visually inspect adjacent equipment and components.

3.53.2 The planned maintenance workload should be evenly distributed throughout the year to minimise the number and duration of tunnel closures.

NOTE 1 *Evenly distributing the planned maintenance workload can reduce disruption to traffic and the costs associated with each tunnel closure.*

NOTE 2 *Planning of maintenance tasks can be constrained by factors such as the availability of access time, traffic management physical access limitations, and proximity working limitations .*

NOTE 3 *A rolling programme can be used to distribute work. For example, if luminaires are to be changed at intervals of one year, and four tunnel closures are scheduled each year, then one quarter of the lights could be replaced during each closure. A rolling programme has the additional benefit that peaks of equipment failure can be avoided.*

NOTE 4 *Planned maintenance carried out in tunnel service buildings can be scheduled outside the tunnel closure programme. It is to be included into the overall maintenance schedule.*

3.53.3 Before each tunnel closure, the planned maintenance tasks, any unplanned maintenance works and the availability of spares and consumables should be reviewed.

3.54 Programmed maintenance works and associated traffic management works shall be subject to a risk assessment.

3.55 On completion of the planned tunnel closure, the maintenance activities shall be reviewed, and improvements for future works noted.

3.56 Any faults or incipient problems not rectified shall be recorded and scheduled for future action.

3.57 Defects recorded and scheduled for future action shall be assigned priority for repair within planned programmes of work.

Works instructions manual

3.58 The procedures to be followed in the implementation of the tunnel OMM and maintenance strategy shall be clearly set out in a tunnels works instructions manual.

3.58.1 The procedures to be followed in the implementation of the tunnel OMM and maintenance strategy should implement current best practice for fulfilling all relevant legal and contractual obligations.

3.59 During tunnel maintenance activities the tunnel must be defined as a temporary site in accordance with European Directive - Temporary or mobile construction sites 92/57/EEC [Ref 3.N].

Value for money

3.60 The Overseeing Organisation's whole-life-based value management requirements shall be followed during the planning and design stages of major capital maintenance of existing tunnels.

Spares and stock control

3.61 A stock of spares and consumables shall be maintained to enable the tunnel maintainer to undertake planned and emergency maintenance works.

3.61.1 The stock control register of equipment spares and consumables should take into account:

1) the amount of stock held;
2) stock location;
3) availability of stock;
4) stock retrieval;
5) rate of use of stock;
6) reorder levels;
7) quantities required;
8) lead-time for supply.

NOTE *Agreements with suppliers for rapid delivery of parts at short notice, consistent with operational requirements, can reduce expenditure and storage space.*

3.61.2 For older equipment the possibility of spares no longer being available should be kept under review.

3.61.3 The review should assess whether the stock of spares is increased or obsolete equipment replaced.

NOTE *Where practical the store can be located within easy access to the tunnel and provide a suitable environment to avoid any equipment damage or deterioration. This particularly applies in the case of computer hardware and electronic components.*

3.62 The store shall be maintained safe and secure in use.

Corrective maintenance procedures

3.63 Effective tunnel procedures shall be developed for recording and correcting all known or suspected equipment failures or damage.

3.63.1 In developing procedures, risk assessment should be undertaken to assess the potential emergencies, including such factors as:

1) tunnel is open and safe;
2) the potential effects of equipment failures on safety and traffic flow through the tunnel;
3) whether the tunnel can remain operational while the fault or failure is rectified;
4) location of affected equipment, such as roof, traffic space, pavement, ducts.

3.64 The following general principles shall apply when developing tunnel emergency and corrective maintenance:

1) there are clear procedures for the call-out of maintenance staff;
2) defined actions to be taken in the event of faults, such as whether a lane closure or bore closure is required;
3) guidelines are in place for the response time for each category of defect, such as those that require immediate attention, and those that can be left until the next working shift or the next routine maintenance;
4) meeting the minimum operating requirements for the tunnel including the percentage of operational fans that are required to meet the design criteria for ventilation, and/or the numbers of luminaires that can fail before the lighting system requires emergency maintenance.

NOTE 1 *Faults normally require direct inspection and assessment by maintenance staff available on a 24-hour basis. Increasingly equipment can have remote control reset and diagnostic facilities, which enable the operational and maintenance staff to manage emergencies from the tunnel control centre or adjacent tunnel service buildings.*

NOTE 2 *The purpose of planned preventative maintenance is maintaining safety, preservation of investment and prevention of unscheduled closures and includes:*

1) specialist inspection of equipment;
2) performance testing of equipment;
3) calibration of equipment;
4) cleaning operations;
5) overhauls of equipment;
6) systems testing of safety critical items (including regular testing, auto diagnostics, continuous monitoring) such as for traffic management, programmable logic controllers (data processing), and communication systems.

NOTE 3 *The purpose of major overhaul and refurbishment of the tunnel equipment and tunnel fabric is:*

1) to ensure long-term preservation of investment by acting on the agreed recommendations of the principal inspection reports;
2) replacement of equipment;
3) repairs of tunnel fabric.

Tunnel users

3.65 When planning maintenance activities, the impact on tunnel users and neighbours shall be fully assessed, and measures put in place to mitigate the impact of those works and inform them in advance about traffic restrictions.

NOTE *Research Tunnel Vision [Ref 10.I] has found that users prefer that tunnels are well-maintained (including road surface, cleanliness and lighting) and that the environment meets high standards for ventilation and air quality for the safety, health and comfort of all users.*

4. Tunnel structure cleaning

General

4.1 The cleaning of the tunnel structure shall be in accordance with:

1) the tunnel OMM;
2) any additional requirements described within the contract for maintenance of the tunnel.

4.2 The exposed surfaces of the tunnel structure, including cladding, shall be cleaned to maintain the required level of light reflectance from the tunnel walls.

NOTE 1 *Maintaining the required reflectance can enhance safety and reduce the energy consumption of the lighting system.*

NOTE 2 *Cleaning of the structure can also reduce the risk of deterioration and fire damage through the removal of potentially corrosive, toxic and flammable deposits. Particular care is required with dust removal and checks undertaken on the nature of any contaminants in the dust.*

NOTE 3 *Cleaning can offer other operational benefits for inspection and maintenance.*

NOTE 4 *Maintaining the tunnel structure in a clean condition can also create a favourable and comforting impression for the road user.*

4.3 Contaminants in dust shall be checked prior to removal, so that safe methods of removal are adopted.

Frequency

4.4 Surfaces which are designed to have a high reflectance shall be cleaned at intervals to achieve the required luminance at all times.

NOTE *The high reflectance surfaces are normally the lower, lightly coloured, part of the tunnel walls, especially at the portals. Lighting can be managed to achieve the required luminance levels.*

4.4.1 The exact frequency of cleaning required is tunnel specific and may depend on a number of factors such as season of year, highway gradient, highway geometry, traffic speed and traffic composition.

NOTE 1 *Weather can also influence cleaning requirements, for example, a tunnel can become very dirty if approach roads are salted.*

NOTE 2 *The need for cleaning can also be influenced by other factors such as any leakage through and staining of the tunnel structure.*

NOTE 3 *Cleaning can be required before maintenance activities.*

4.4.2 The optimum cleaning frequency for a particular tunnel structure should be established by documented trials.

4.4.3 Different cleaning frequencies may be tested in different parts of a tunnel in order to determine the optimum frequency.

4.5 Parts of a tunnel where high reflectance is not required (notably the tunnel crown) shall be cleaned where the build-up of deposits poses a significant risk of detritus falling onto the carriageway, a fire hazard, or a significant soiling risk to personnel during maintenance work.

NOTE *The build-up of dust or presence of oil can present a fire hazard.*

4.6 Accumulation of silt and other material in the sumps and blockages in cross drains shall be removed at intervals established by operational experience.

NOTE *Factors such as the weather (winter salting on approach roads) and the effectiveness of gully traps to remove silt, influence the rate of accumulation.*

4.6.1 Additional cleaning may be required after a spillage.

4.7 Where daylight screens are provided at portal structures, cleaning shall be carried out to maintain their effectiveness.

NOTE *Louvres in screens usually have slender rib construction and can be vulnerable to corrosion and other forms of surface deterioration.*

Asbestos

4.8 Asbestos assessments shall be undertaken by the TOA in accordance with GG 105 [Ref 2.N] 'Asbestos Management in Trunk Road Assets' regarding the presence of asbestos in the tunnel and any mitigation measures required, and used to safely manage risks of asbestos exposure to staff during tunnel cleaning operations.

4.9 If the assessments have not been undertaken then the assumption shall be made that asbestos can be present in the tunnel, and cleaning operations planned accordingly.

NOTE *In some tunnels, particularly those with segmental linings constructed before 1970, asbestos can be found in the caulking rope between segments. Asbestos cement was sometimes used to form precast air ducting formers. In even older tunnels, asbestos has been found in fireproofing. Small concentrations of asbestos dust from vehicle brake linings etc. has been found in dust layers trapped in false ceiling and cladding areas. All these sources of asbestos can degrade with time, permitting fibres to become airborne. This is particularly serious if fibres are present in the ventilation airways and ducts, where higher air velocities can disturb fibres more readily.*

Scheduling

4.10 Individual tunnel cleaning operations shall be scheduled in coordination with other in-tunnel maintenance operations.

NOTE *Many tunnels schedule tunnel cleaning as the first major activity during a maintenance closure of the tunnel. Other tunnel managers prefer to schedule cleaning as the last operation.*

4.11 Cleaning shall not be carried out if freezing conditions are predicted to affect the tunnel.

4.11.1 Ventilation in damp conditions can cause temperatures to fall below ambient due to latent heat losses and allowances should be made for this phenomenon.

Traffic management and precautions

4.12 Tunnel cleaning shall be carried out during planned tunnel closures.

NOTE *The road layout in some tunnels can facilitate partial tunnel cleaning during lane closures rather than full closures. In these circumstances additional safety precautions are required including the effects of spray on passing vehicles, and can influence the selection of cleaning methods selected.*

4.13 Equipment such as: sensors for CO, visibility and other factors, lighting units, fans, emergency distribution panels shall be protected and isolated from potential water penetration and its effects.

NOTE *Cleaning operations can pose hazard by the noise and spray generated.*

4.13.1 It may be necessary to exclude and protect other tunnel maintenance personnel from the immediate area in which cleaning operations are taking place to avoid potential hazards, due to exposure to any detergents or other chemicals used in the cleaning process.

Cleaning processes

4.14 Cleaning methods and methodology selected shall be based on the deposits to be removed from the structure and the nature of the structure itself, including the lining / cladding / passive fire protection system and fixing materials, and any surface finishes which have been used.

4.14.1 Where possible, advice should be sought from manufacturers of paints and cladding on the appropriate cleaning techniques.

NOTE *Types of paint used in tunnels have been found to be vulnerable to damage by high pressure water jetting and cementitious based passive fire protection systems are susceptible to damage from water.*

4.14.2 Effects of washing on electrical equipment should be checked.

4.14.3 A typical washing cycle may include a first pass in which a vehicle mounted spray bar is used to apply a detergent solution under pressure to the lining. A second pass, using vehicle mounted rotating brushes can be used to scrub the lining and a third pass with water under pressure to rinse the lining

4.14.4 The optimum process may involve a combination of pressure washing with detergents and brushing using vehicle-mounted systems.

4.15 Washing water (whether or not detergents are used) shall be disposed of in agreement with the Environment Agency or the appropriate wastewater authority.

4.15.1 Wastewater should be tested for contamination before disposal.

NOTE *Wastewater is usually pumped away or taken away by tanker from site.*

Materials

4.16 A performance specification for tunnel cleaning shall be developed and implemented.

4.16.1 The performance specification should include the following:

1) nature of the deposits to be removed;
2) the substrate;
3) risk of corrosive or other long-term detrimental effects on linings, fittings and equipment;
4) environmental issues;
5) health and safety of the workforce;
6) disposal of wash water.

5. Inspections

General

5.1 Road tunnels and their associated structures, equipment and systems shall be subjected to periodic inspections at regular intervals to assess and record their condition and to identify any further actions required to maintain safety and operational availability.

NOTE *Categories of inspection are given in CS 452 [Ref 12.N] for road tunnels and M&E systems, supplemented by CS 450 [Ref 4.I] for structural elements.*

Safety inspections

5.2 Safety inspections shall be carried out in accordance with CS 452 [Ref 12.N] and CS 450 [Ref 4.I].

5.3 Safety inspections shall be undertaken in accordance with the requirements in the tunnel OMM.

Superficial inspections

5.4 Superficial inspections shall be carried out in accordance with CS 452 [Ref 12.N].

NOTE *The definition and frequency of superficial inspections are contained in CS 452 [Ref 12.N].*

General inspections

5.5 General inspections shall be carried out in accordance with CS 452 [Ref 12.N] and CS 450 [Ref 4.I].

NOTE *General inspections are defined in CS 452 [Ref 12.N] and comprise a thorough visual inspection of all reasonably accessible parts of the road tunnel and its M&E equipment.*

Principal inspections

5.6 Principal inspections shall be carried out in accordance with CS 452 [Ref 12.N] and CS 450 [Ref 4.I].

5.6.1 Principal inspections are defined in CS 452 [Ref 12.N] and comprise a close and detailed examination of all accessible parts of the tunnel and M&E systems and equipment, and may include removal of cladding, casings and other equipment.

Special inspections

5.7 Special inspections shall be carried out in accordance with CS 452 [Ref 12.N] and CS 450 [Ref 4.I].

NOTE *Special inspections are defined in CS 452 [Ref 12.N] and comprise a close examination of a specific area or defect of concern.*

6. Structure maintenance

General

6.1 The maintenance of the tunnel structure shall be in accordance with:

1) the tunnel OMM;
2) any additional requirements described within the contract for maintenance of the tunnel.

NOTE *Other sections of this document give requirements and advice for maintenance of other items within the tunnel.*

Asbestos assessment

6.2 An assessment must be carried out as to whether asbestos containing materials (ACM) are present in the structure in accordance with the Regulation 4 of the Control of Asbestos Regulations SI2012 No.632 [Ref 26.N] and GG 105 [Ref 2.N] 'Asbestos Management in Trunk Road Assets'.

6.2.1 Where there is no information on the presence of ACMs it should be presumed that materials do contain asbestos unless there is strong evidence that they do not.

NOTE *In some tunnels, particularly those with segmental linings constructed before 1970, asbestos can be found in the caulking rope between segments. Asbestos cement was sometimes used to form precast air ducting formers. In even older tunnels, asbestos has been found in fireproofing. Small concentrations of asbestos dust from vehicle brake linings etc. has been found in dust layers trapped in false ceiling and cladding areas. All these sources of asbestos can degrade with time, permitting fibres to become airborne. This is particularly serious if fibres are present in the ventilation airways and ducts, where higher air velocities can disturb fibres more readily.*

6.3 All works and tunnel staff operations shall be planned based on the results of the asbestos assessment reports, or presumptions that asbestos is present.

6.4 All contractors shall be provided with a copy of the asbestos assessment report, or presumptions that asbestos may be present, and works planned accordingly.

Routine maintenance

6.5 Routine maintenance shall be carried out in accordance with:

1) the tunnel OMM;
2) any other additional requirements described in the contract documentation for the tunnel maintenance contract.

NOTE *Routine maintenance does not include the repair or renewal of structural elements.*

Monitoring

6.6 Installed instrumentation on slopes at tunnel portals, such as rock anchors, and piezometers shall be monitored in accordance with the tunnel OMM.

Testing

6.7 Mechanical supporting systems and safety critical fixings shall be tested for support strength and fixation with the tunnel structure, particularly where failure represents a safety risk.

NOTE *Further guidance is available in 'Management of safety critical fixings' CIRIA C778 [Ref 6.I].*

6.8 The fixings shall be tested at intervals typically of one year.

6.8.1 The following typical tests should be carried out on one-fifth of all items, such that all items are tested every five years:

1) torque testing of all screws, bolts and other fastenings;
2) testing of anchors and their fixity to the structure. This should be done in accordance with manufacturer's recommendations, taking care not to exceed the elastic limit of the anchor or supporting structure;
3) isolation checks on points vulnerable to bimetallic corrosion;
4) testing of electrical earths.

Major maintenance

6.9 Major maintenance shall be planned and undertaken based on the information obtained from inspections, and any subsequent structural assessments, investigations and testing.

6.9.1 In planning major maintenance the root causes of defects, or the reasons for failure, should be identified so that works can address them and reduce the risk of recurrence.

7. Ventilation system

General

7.1 The maintenance of all tunnel ventilation systems and associated monitoring, control equipment shall be in accordance with:

1) the tunnel OMM;
2) any additional requirements described within the contract for maintenance of the tunnel;
3) manufacturer's recommendations.

7.2 A schedule of routine maintenance activities shall be prepared for all installed ventilation equipment and supporting monitoring and control equipment, including inspection and cleaning.

NOTE *Normally in-tunnel maintenance activities such as work on ventilation fans can be undertaken during full tunnel or bore closures..*

7.3 Spare fans kept in store shall be included within the maintenance regime and be inspected periodically for signs of damage or corrosion, and the impellers rotated to maintain lubrication and prevent deterioration of the motor bearings.

7.4 Individual fans shall be electrically isolated, isolators locked off and warning notices posted, before any work is commenced.

Ventilation fans

Equipment access arrangements

7.5 Method statements shall be in place covering all elements of safely accessing both tunnel-mounted ventilation plant and equipment, and plant and equipment installed in plant rooms.

7.6 Lifting platforms shall be available for operatives to access in-tunnel jet fans, jet fan mounting arrangements and associated control and monitoring equipment.

7.7 Manufacturer's recommended methods for jet fan removal or installation shall be followed.

NOTE 1 *Removal or installation of jet fans can require the use of specialist cradles.*

NOTE 2 *Fan maintenance procedures can require the application of a 'Permit to Work' system.*

7.8 Equipment and personnel shall be kept clear of the air stream generated by operating fans, at both the inlet and outlet ends.

Visual inspection

7.9 A visual inspection of all ventilation plant (both in-tunnel & plant room) shall be undertaken as part of routine tunnel maintenance activities as detailed in the tunnel OMM.

7.10 A visual inspection of jet fans shall be carried out at intervals typically of 3 to 4 months during planned tunnel closures and in accordance with manufacturer's recommendations.

7.10.1 The interior and exterior of the fan assembly, including the motor, impeller and sound attenuating sections, should be inspected for signs of wear, deterioration, overheating or build-up of foreign matter.

7.10.2 Particular attention is required to cowlings, covers, cones and other externally and internally accessible components and their fixings which should be examined to ensure they are safe and secure.

7.11 Plant room mounted fans, fire dampers and sound attenuators shall be inspected for damage or deterioration at intervals typically of 3 months and in accordance with manufacturer's recommendations.

7.11.1 Where expansion bellows are employed, these should be inspected for signs of deterioration and for loss of fixity.

7.12 Anti-vibration mountings, supports, bolts, fixings, linkages and connections shall be inspected for signs of corrosion, mechanical damage and build-up of foreign matter.

7.13 All fan fixings that secure a fan assembly in place shall be inspected for signs of loss of contact between the fan fixing plate and the tunnel fabric mounting surface.

NOTE *Advice about fixings is contained in 'Management of safety critical fixings in-service' CIRIA C778 [Ref 6.I].*

7.14 Electrical accessories (such as connectors, isolators, junction boxes, cabling and conduits) shall be inspected for signs of corrosion, damage, overheating or build-up of foreign matter.

7.15 Where plenum chambers are subject to condensation all exposed metalwork shall be monitored for signs of corrosion as part of the ventilation system routine maintenance activity.

NOTE *Under certain atmospheric conditions some plenum chambers can be subject to condensation.*

Cleaning

7.16 Cleaning of all in-tunnel and plant-room ventilation plant shall be undertaken as frequently as required to ensure ongoing safe and efficient system operation.

7.17 Impeller blades, and the inside and outside of the sound attenuators shall be cleaned at intervals of typically 3 months and in accordance with manufacturer's recommendations.

7.17.1 Cleaning intervals should be reviewed and adjusted as necessary to co-ordinate with opportunities for access, levels of system operation and the extent of fouling by dirt and dust.

Service

7.18 Routine plant servicing shall be undertaken in compliance with the manufacturers' requirements with additional servicing undertaken when a potential fault that requires attention is identified.

7.19 Where greasing and lubrication of motor bearings is required, this shall be included in the routine servicing.

NOTE 1 *Manufacturers typically recommend that jet fans can be removed to the factory for a complete overhaul including stripping and repainting, and the replacement of all anti-vibration mountings at intervals of approximately 5 years. However, where there is infrequent usage and low fan running hours, the intervals at which complete fan factory overhauls are to be undertaken can be reviewed in discussion with the manufacturer.*

NOTE 2 *Routine monitoring through the plant monitoring and control system can highlight equipment failures and can give an indication of the health of the fan, for example through changes in bearing or winding temperatures or load current readings.*

NOTE 3 *The maintenance requirements for motor control gear and starters are similar to those required for typical electrical distribution and control equipment, see Section 13 Electrical power distribution.*

Functional testing

7.20 System functionality testing shall be undertaken for all installed ventilation fans and associated equipment in compliance with the requirements of the OMM.

NOTE *The following system functionality testing is typically undertaken at intervals of 3 months:*

1) the fans run in both directions and checked for undue noise and vibration;

2) motor, impeller and blade mountings, casing and silencer joint fixings and electrical terminals checked to ensure they are in good order and tightened or replaced as necessary;

3) anti-vibration mounts, safety chain and movement proximity switches checked and the movement detection system checked for functionality.

7.21 The following system functionality testing shall be undertaken at intervals of 12 months unless otherwise detailed in the OMM:

1) all jet fan and plant room fan fixings that secure a fan assembly in place, and impeller bolts (where included), checked and torque-load tested;
2) measurements made of fan starting and running currents, vibration and insulation resistance;
3) blade clearances checked and adjusted if necessary.

NOTE *Measurement of insulation resistance can also be undertaken. It is not essential but is a useful diagnostic tool, which can reveal deterioration due to overheating or contamination.*

Fan handling equipment

7.22 All fan handling equipment is subject to periodic testing and certification. Inspection, maintenance and functional testing of handling equipment shall be carried out in accordance with the manufacturer's recommendations. SI 1998/2307 [Ref 15.N] 'Lifting Operations and Lifting Equipment Regulations 1998 (LOLER)' SI 1992/2793 [Ref 18.N] 'The Manual Handling Operations Regulations 1992, as amended in 2002'.

Ductwork and dampers

Equipment access arrangements

7.23 Method statements shall be prepared to outline ventilation duct access by maintenance operatives for inspection, cleaning and repair, covering safe access to all installed ductwork and associated flow balancing mechanisms and dampers/fire dampers.

NOTE *Ductwork (and associated equipment) inspection, cleaning and maintenance procedures can require the application of a 'Permit to Work' system.*

Visual inspection

7.24 A visual inspection of all installed ductwork and associated flow-balancing mechanisms, dampers/fire dampers and actuators shall be undertaken as part of a tunnel general inspection.

7.25 Dampers and actuators shall be inspected for signs of wear, deterioration or build-up of foreign matter.

7.26 Electrical accessories (such as connectors, isolators, junction boxes, cabling and conduits) shall be inspected for signs of corrosion, damage, overheating or build-up of foreign matter.

Cleaning

7.27 Cleaning of all installed duct-work and associated flow-balancing mechanisms and dampers/fire dampers shall be undertaken as frequently to ensure ongoing safe and efficient system operation.

7.28 The main ventilation ducts, dampers, filters and grilles shall be cleaned (particularly the registers in exhaust slots which can become severely restricted by dirt).

7.28.1 Cleaning intervals should be detailed in the OMM.

Service

7.29 Routine servicing of ductwork, dampers and actuators shall be undertaken in compliance with the manufacturers' requirements.

NOTE *Where dampers are installed, it is normal to lubricate them every 6 months.*

Functional testing

7.30 System functionality testing shall be undertaken for all installed ductwork, dampers and actuators in compliance with the requirements of the OMM.

NOTE 1 *Dampers are checked for correct operation (including remote operation if applicable and the fail-safe mode) at intervals of typically 6 months.*

NOTE 2 The following system functionality testing is typically undertaken as part of a tunnel principal inspection:

1) *supply/extract ductwork systems tested for even flow distribution to and from the traffic space;*
2) *flow rates into the respective distributed duct system tested;*
3) *the airflow through distributed ventilation slots and any air-balancing dampers adjusted as necessary to ensure the required air flow distribution is achieved.*

7.31 The air-tightness of the ductwork system shall be regularly tested and maintained, particularly where the extraction system passes through potentially occupied spaces.

8. Lighting system

General

8.1 Maintenance of the following lighting systems and equipment shall be undertaken in accordance with the manufacturers' recommendations and the tunnel OMM:

1) base lighting luminaires;
2) boost lighting luminaires;
3) tunnel lighting control and monitoring system;
4) emergency lighting;
5) dimming system (where applicable);
6) photometers.

8.1.1 Reference should be made to Section 6 - 'Structure maintenance' for the maintenance of mechanical supporting systems.

8.2 Intense light sources such as LEDs can constitute a photobiological hazard to personnel working in close proximity to them, and any such risks shall be assessed and managed.

Base lighting luminaires

Cleaning

8.3 Luminaires shall be cleaned by washing and brushing at intervals determined by the rate of dirt accumulation and the minimum performance criteria.

8.3.1 In most cases, cleaning may practically be achieved by the use of manual labour on a travelling access platform.

8.3.2 The cleaning intervals for a particular tunnel should be established by experience and trials; leaving short sections of lighting uncleaned and assessing the accumulation of dirt.

8.3.3 The optimum cleaning intervals can commonly be more than the intervals between wall washing, but should not normally exceed 12 months.

8.4 Dust from cleaning shall be treated as a health and safety hazard.

Inspection

8.5 Inspections from carriageway level or via plant control systems shall be carried out when all luminaires are on (normally during the day) at intervals of 14 days to detect lamp failures and mechanical damage, and an assessment made of the need for repairs, before the next scheduled tunnel closure or planned relamping.

8.5.1 Lamp failures may also be detected by analysis of lighting-circuit running currents, or by interrogating the lighting control system if it monitors lamp failures.

NOTE 1 *In tunnels it is normally acceptable for a small proportion of lamps to be inoperative.*

NOTE 2 *The use of manual labour on a travelling access platform can facilitate the immediate identification and repair of minor defects in the systems during cleaning.*

Relamping

8.6 For luminaires with replaceable lamps, the intervals for bulk lamp changes shall initially be as recommended by the manufacturer.

8.6.1 Subsequent trials may be carried out to optimise the intervals, by leaving short sections of lighting unchanged.

NOTE *In systems that do not use dimming to adjust lamp output, it is normally possible to predict incipient failure because the lights tend to dim gradually rather than suddenly fail.*

8.7 During relamping, gear-tray equipment shall be inspected and tested.

8.7.1 The sealing gaskets and clips should be replaced where damaged.

NOTE *Although manufacturers often recommend replacement of mercury fluorescent lamps at 12 monthly intervals, use of 'tri-phosphor' tubes for base lighting has been found to increase this period to 24 months.*

Testing

8.8 Where operational checks or maintenance records suggest that low or high voltage can be a cause of malfunctioning of one or more luminaires, then voltages shall be monitored over a period of time to check whether they are within the manufacturer's guidelines.

NOTE *Tunnel lighting systems are normally designed to accommodate deterioration in performance of lamps within their lifetime, together with an allowance for loss of reflectance off tunnel surfaces between cleaning. Measurement of illuminance is not normally necessary unless excessive deterioration in performance is suspected.*

Boost lighting luminaires

Cleaning

8.9 Boost lighting luminaires shall be cleaned at the same intervals as base lighting luminaires.

Inspection

8.10 Inspection procedures for boost lighting luminaires shall be as for base lighting.

Relamping

8.11 For luminaires with replaceable lamps, the criteria for lamp changes shall initially be in accordance with the tunnel OMM and in accordance with the manufacturer's recommendations.

8.11.1 It may be appropriate to generally replace on a breakdown-repair basis only. Thus, the relatively few failures can be replaced during planned maintenance closures.

NOTE 1 *Normal experience is that luminaires run for only around 1000 hours/ year and relatively few lamps fail in the intervals between planned maintenance, and at little detriment to the overall system performance.*

NOTE 2 *"Hours run" data alone from the lighting control system is not sufficient to indicate when lamp change is required. Lamp life is affected by both hours run and frequency of switching, which depends on the weather, tunnel orientation, and time of year. It is therefore difficult to predict, except by experience, when a lamp is approaching the end of its life.*

8.11.2 During relamping, gear-tray equipment should be inspected and tested and the sealing gaskets and clips replaced, if they have failed.

Testing

8.12 Testing of boost lighting luminaires shall be as for base lighting.

8.13 An operational check, to confirm the various stages of boost lighting switch on and off, shall be carried out at intervals of 12 months.

Tunnel lighting control and monitoring system

8.14 Lighting control and monitoring equipment shall be inspected, tested and maintained in accordance with the manufacturer's recommendations.

8.15 In the absence of any maintenance intervals recommended by the manufacturer, the following shall apply:

1) visual inspection, including cleaning of hardware, inspection for damage or signs of overheating and replacement of serviceable parts at typically 3 monthly intervals;
2) routine servicing of communication systems hardware/software at typically 6 monthly intervals;
3) functional testing of the lighting control and monitoring system at typically 12 monthly intervals.

Emergency lighting

8.16 Emergency lighting shall be inspected, tested and maintained in accordance with the manufacturer's recommendations.

Dimming equipment

8.17 Dimming equipment shall be inspected, tested and maintained in accordance with the manufacturer's recommendations.

8.18 In the absence of any maintenance intervals recommended by the manufacturer, the following shall apply:

1) visual inspection, including cleaning of hardware, inspection for damage or signs of overheating, checking of ventilation paths for obstructions and free circulation of air, and replacement of serviceable parts, at typically 3 monthly intervals;
2) functional testing of the dimming equipment at typically 12 monthly intervals.

Photometers

8.19 Photometers shall be inspected, tested and maintained in accordance with the manufacturer's recommendations.

8.19.1 Maintenance may be possible without a tunnel closure. If works are carried out during daylight hours, it needs to be borne in mind that automatic control levels for the tunnel lighting can be affected.

Cleaning and inspection

8.20 The photometer windows shall be cleaned to maintain functionality at intervals determined by the rate of soiling which can be determined by local weather and traffic conditions.

8.20.1 Visual inspection of all connections, electrical earths and the unit itself should be made whenever the units are cleaned.

Service

8.21 Washer bottles, where fitted, shall be refilled with water, cleanser and antifreeze as necessary.

8.21.1 When refilling washer bottles, typically during scheduled closures or every 3 months, the correct operation and calibration of the photometer and operation of the wiper and washer should be checked at the same time.

9. Drainage plant

9.1 The maintenance of all tunnel drainage including pumping systems and supporting monitoring, control equipment shall be undertaken in accordance with:

1) the tunnel OMM;
2) any additional requirements described within the contract for maintenance of the tunnel.

9.1.1 Reference should be made to Section 4, 'Tunnel structure cleaning', for maintenance of sumps and to Section 10, 'Fire safety equipment' for maintenance of fire protection systems in sumps.

NOTE 1 *Pumping systems include: cable chamber pumps, sump pumps, draw-pit pumps, interceptor chamber pumps and the valves and piping which links the system together, and associated level controls, valve actuators and electrical control gear.*

NOTE 2 *Some procedures can require the application of a 'Permit to Work' system.*

NOTE 3 *Since the sumps are normally confined spaces an access procedure that complies with The Confined Spaces Regulations SI 1997/1713 [Ref 10.N], is necessary.*

NOTE 4 *Removal of pumps commonly requires the use of a crane or similar lifting equipment.*

Inspection

9.2 Inspection of all drainage equipment shall be carried out to comply with the requirements of the categories of inspections described in CS 452 [Ref 12.N] 'Inspections and records for road tunnels'..

9.2.1 At intervals typically of 3 months, visual inspection for damage, corrosion, oil levels and condition, connections and earths should be carried out.

Service

9.3 Sump pumps shall be removed from the sump for internal inspection, service or rebuild in accordance with the manufacturer's recommendations.

NOTE *Depending on the type of pumps they require an inspection and service typically every year, and a rebuild every 5 years, in accordance with the manufacturer's recommendations.*

9.4 Sump level-monitoring equipment shall be cleaned and checked in accordance with manufacturer's recommendations.

9.5 Operation of all valves shall be tested at intervals of typically 3 months.

9.5.1 To avoid seizure, some manufacturers may recommend more frequent operation testing than every 3 months.

Testing

9.6 During every scheduled maintenance closure a test shall be carried out to check that sump alarms and gas detector beacons are visible and audible, to the required level.

10. Fire safety equipment

General

10.1 The maintenance of all tunnel fire safety systems and supporting monitoring and control equipment shall be undertaken in accordance with:

1) the tunnel OMMs;
2) any additional requirements described within the contract for maintenance of the tunnel.

10.2 A schedule of routine maintenance activities shall be prepared for all installed fire safety equipment and supporting monitoring and control equipment, including inspection and cleaning.

10.2.1 In-tunnel maintenance activities should be undertaken during full tunnel/bore closure conditions where possible.

Cross-bore doors

Maintenance

10.3 Maintenance procedures for the doors shall include door-opening mechanisms, emergency exit signs, alarms and beacons associated with cross-bore access.

10.4 Where cross-bore doors undergo maintenance during a single bore closure, procedures shall be in place to prevent maintenance personnel or materials entering the live carriageway.

10.5 Where opening of cross-bore doors is monitored by the plant monitoring and control system, procedures shall be in place for the safe cancelling of alarms during maintenance work and subsequent resetting.

Visual inspection

10.6 The doors shall be inspected to identify damage, corrosion or other defects during every scheduled tunnel maintenance bore closure.

General cleaning

10.7 All exposed (tunnel-facing) cross-bore door parts shall be cleaned as part of the routine tunnel wall washing processes.

10.8 The mating faces of magnetic locks shall be cleaned as part of the door cleaning to ensure that accumulated dirt does not impair operation or promote corrosion.

Routine service

10.9 Servicing shall include periodic cleaning and lubrication of hinges, handles, bolts and closing mechanisms including remedial painting of doors where it is identified as necessary.

Functional testing

10.10 During every scheduled maintenance closure, a test shall be carried out to check that alarms and beacons are visible and audible.

10.11 During every scheduled maintenance closure, the doors shall be opened to check that they move freely through their full range of opening.

10.11.1 The force required to open doors should be measured for compliance with the design opening forces as part of a principal inspection.

10.12 Remotely-controlled lock release systems shall be tested for correct functioning.

Emergency exit signage and evacuation lighting

General cleaning

10.13 All signs and evacuation luminaires shall be cleaned as part of the tunnel wall washing process.

Visual inspection

10.14 Emergency exit signs shall be inspected at every scheduled tunnel closure to identify signs of damage, corrosion or inadequate internal illumination.

Routine service

10.15 Emergency exit signs shall be checked for signs of water ingress at every scheduled tunnel closure and the seals replaced if defective.

10.16 Lamps for emergency exit signs shall be replaced when there is a failure and in accordance with the tunnel OMM.

Functional testing

10.17 All illuminated emergency exit signs and evacuation luminaires shall be tested for correct operation typically at 12-monthly intervals, both fed from the normal power supply and for the full required duration of the mains failure supply (typically two hours) with the normal power supply switched off.

Fire extinguishers

Maintenance

10.18 Where the lifting or removal of fire extinguishers is monitored by the plant monitoring and control system, procedures shall be in place for the safe cancelling of alarms during maintenance work and subsequent resetting.

Visual inspection

10.19 A check that all extinguishers are in place and of the correct type, noting if any have been used or need to be refilled or replaced, and shall be carried out in accordance with the tunnel OMM.

NOTE *This work is typically undertaken during scheduled maintenance closures or at typically at 3-monthly intervals.*

10.20 Used extinguishers shall be immediately replaced from spare stock.

General cleaning

10.21 The extinguishers shall be cleaned as part of the servicing to ensure dials and instructions remain readable.

Routine service

10.22 The fire extinguishers shall be serviced at intervals in accordance with the BS 5306-3 [Ref 5.N] 'Fire extinguishing installations and equipment on premises. Selection and positioning of portable fire extinguishers – Code of Practice'.

Fire hydrants and hoses

Maintenance

10.23 Where tunnel panel doors are monitored by the plant monitoring and control system, with alarms generated if a panel door is opened, procedures shall be in place for the safe cancelling of alarms during maintenance work and subsequent resetting.

Visual inspection

10.24 A check to see if any hoses are damaged or leaking shall be carried out during tunnel closures.

10.24.1 Evidence of damage or significant leakage from fire hydrants or hose points should be investigated and rectified at the earliest opportunity.

General cleaning

10.25 Where valves and connectors are exposed to the tunnel environment they shall be wet-cleaned as part of the tunnel wall washing routine.

Functional testing

10.26 Operation of the hydrants, hoses and couplers to verify functionality shall be carried out in accordance with the tunnel OMM.

NOTE *Typically operation of the hydrants, hoses and couplers is undertaken during scheduled closures or at 3-monthly intervals.*

10.27 Any alarms associated with the hydrants shall be tested at the same time as the hydrants, hoses and couplers.

10.28 Operation of the hydrants, hoses and couplers to verify the water delivery flow rate and pressure shall be carried out as part of a general inspection.

10.29 Operation of the hydrants shall be undertaken by the Fire and Rescue Service or by the tunnel maintenance staff as detailed in the tunnel OMM.

Fire mains

Visual inspection

10.30 Fire main valves shall be inspected for signs of damage and leakage at intervals in accordance with the tunnel OMM of three months.

NOTE *Typically inspection of the fire main valves is undertaken during scheduled closures or at 3-monthly intervals.*

10.31 The fire main shall be inspected for damage, leaks and cracks at 12-monthly intervals.

Service and functional testing

10.32 Valves shall be greased and fully operated (opened and closed at least twice) to check for seizure, correct seating of the valve body or any other problems at 12-monthly intervals.

10.33 The fire main system shall be overhauled at 5-yearly intervals.

10.34 The operation of pumps associated with the fire main shall be tested in accordance with the tunnel OMM.

NOTE *Typically testing the operation of pumps is undertaken during scheduled closures or at 3-monthly intervals.*

10.35 The operation of trace heating, pressure switches and other devices associated with the fire main shall be tested at 12-monthly intervals.

10.36 Fire main (including hose reel and hydrant connection pipes) insulation for frost protection shall be inspected and repaired at 12-monthly intervals, prior to the cold weather season.

10.37 The incoming water mains supply pressure shall be tested for adequacy every 12-months or at times of known low pressure supply.

10.37.1 Where the fire main also provides a supply to third parties, testing can cause fine sediment to become disturbed. Water supply companies should be consulted to determine if flushing would affect supplies to third parties.

10.37.2 Where sections of the fire main need to be replaced or repaired, then an invasive CCTV inspection should be undertaken to determine the extent of any remedial work.

10.38 The expansion chamber shall be pumped out at yearly intervals, and any leaks or cracks repaired.

In-tunnel fixed water-based fire fighting systems

Maintenance of fixed fire fighting systems

10.39 Cleaning and a visual inspection of pipework, spray nozzles and control valves shall be carried out annually, checking for signs of corrosion, physical damage and leakage.

10.40 Control valves shall be checked for correct operation annually.

10.41 A full system discharge test shall be carried out at intervals of no more than 3 years.

10.41.1 After each system activation, all filters and strainers should be cleaned or replaced as necessary.

10.42 Unless indicated otherwise in the manufacturer's recommendations, the operation of pumps, trace heating, pressure switches etc., associated with the fire fighting system shall be tested at 3-monthly intervals..

10.43 Insulation of fixed firefighting system pipes for frost protection shall be inspected and repaired if required at 12-monthly intervals, prior to the cold weather season.

NOTE *In the absence of detailed maintenance guidelines reference can be made to Standard for the Inspection, Testing and Maintenance of Water-based Fire Protection Systems (NFPA 25 [Ref 8.I]) .*

Fire water storage tanks

10.44 The bacterial concentrations in water storage tanks shall be tested at 12 monthly intervals.

NOTE *The risk of contracting Legionella from a fire-fighting system is normally low, however if bacteria are present then pressure leaks and mist systems can constitute a risk to health. Further information and guidance can be found in the FPA LPC Rules for Automatic Sprinkler Installations LPC Rules [Ref 5.I].*

Linear heat detection systems (LHDS)

Visual inspection

10.45 The sensor cable, any junction/splitter boxes and sensor control units shall be visually inspected at 12 monthly intervals.

General cleaning

10.46 Cleaning of the sensor cable, any junction/splitter boxes and sensor control units shall be completed at 12 monthly intervals.

Routine service

10.47 Servicing of the sensor cable, any junction/splitter boxes and sensor control units shall be carried at 12 monthly intervals.

Functional testing

10.48 Testing of the sensor cable, any junction/splitter boxes and sensor control units shall be carried out by at 12 monthly intervals.

10.48.1 The LHDS is typically monitored by the tunnel plant monitoring and control system, with automatic alarms generated under fault/alarm conditions. It may be necessary to have procedures in place for their safe cancelling during maintenance work.

Automatic fire protection systems – service buildings

10.49 Control panels shall be cleaned to ensure legibility and checked to ensure they are clear of alarms, at typically 3 monthly intervals.

10.50 Checks shall be made for signs of deterioration of flexible pipework, and signs of corrosion, damage or overheating of all connectors and earths.

10.51 Gas cylinder pressures shall be recorded and all cylinders checked for security.

10.51.1 Dampers should be checked for correct operation.

10.51.2 During discharge testing, extinguishant is normally released under pressure. Precautions should be taken to ensure that no one is within or adjacent to the protected area when this test is conducted.

10.51.3 Testing may require the control system to be manually overridden.

10.52 Room integrity testing shall be undertaken annually and tested after any material alterations to the room or entry points in compliance with:

1) BS 5306-3 [Ref 5.N];
2) ISO 14520 [Ref 8.N];
3) BS EN 15004-1 [Ref 6.N].

Maintenance of sump fire protection systems

10.53 The panels shall be cleaned to ensure legibility and checked to ensure they are clear of alarms in accordance with tunnel OMM.

NOTE *Typically cleaning of the panels is undertaken during scheduled closures or at 3 monthly intervals.*

10.54 Checks shall be made for signs of deterioration of flexible pipework, and signs of corrosion, damage or overheating of all electrical connections and protective bonding earths in accordance with tunnel OMM.

NOTE *Typically checks are undertaken during scheduled closures or at 3 monthly intervals.*

10.55 Gas cylinder pressures shall be recorded and all cylinders checked for security, in accordance with manufacturer's recommendations.

10.56 Sump ventilation dampers shall be checked for correct operation in accordance with tunnel OMM.

NOTE *Typically checks of the sump ventilation dampers are undertaken during scheduled closures or at 3 monthly intervals.*

10.57 A test discharge shall be carried out together with a purging of gas or foam at 12 monthly intervals.

10.57.1 As extinguishant is normally released under pressure, precautions should be taken to ensure that no one is within or adjacent to the protected area when this test is conducted.

Gas detection systems

10.58 The operation of the gas detection systems shall be tested, electrical connections checked and the sensors re-calibrated at 3-monthly intervals.

10.59 Sensors shall be replaced in accordance with manufacturer's recommendations.

11. Traffic control, communication and information systems

General

11.1 The maintenance of all tunnel traffic control, communications and information systems shall be in accordance with:

1) the tunnel OMM;
2) any additional requirements described within the contract for maintenance of the tunnel.

NOTE *The key systems are listed below:*

1) communication cable network;
2) telephone system;
3) radio relay system;
4) CCTV systems;
5) traffic signals and controllers;
6) variable message sign systems;
7) supervisory communication and data acquisition;
8) traffic detection systems;
9) integrated tunnel control system;
10) public address;
11) barriers.

11.2 A schedule of routine maintenance activities shall be prepared, including inspection and cleaning, for all installed tunnel traffic control, communications and information systems.

11.3 Spares kept in store shall be maintained in accordance with the manufacturer's requirements, including:

1) periodic battery replacement;
2) software upgrades;
3) inspection for signs of packaging damage.

11.4 Equipment shall be electrically isolated, isolators locked off, and warning notices posted before any work is commenced.

11.5 Electrical safety inspections in accordance with BS 7671 [Ref 24.N] shall be performed at least every five years.

Visual inspection

11.6 A visual inspection of all traffic control, communication and information systems shall be carried out at intervals not exceeding three months for computers, to ensure the integrity of computer connection and check cooling systems are uninhibited and 12 months for all other equipment.

11.7 A visual inspection of detector loops shall be carried out whenever the carriageway wearing course is inspected.

11.8 Inspection of traffic signal heads, poles and controllers shall be carried out in accordance with manufacturer's maintenance requirements and with 'Traffic signalling systems' TM 101 [Ref 27.N] .

Cleaning

11.9 Cleaning of traffic control, communication and information systems shall be undertaken to ensure ongoing safe and efficient system operation.

NOTE 1 *The default interval for cleaning CCTV camera lenses is one month on the National Network, but can also depend on the rate of soiling, which can be determined by local traffic and weather.*

NOTE 2 *The default interval for cleaning variable message signs (VMS), video analytic incident detection systems and RADAR systems is typically three months, but will depend on the rate of soiling, which can be determined by local traffic and weather conditions.*

NOTE 3 *The interval for cleaning audio filters on the audio power amplifiers to ensure cooling systems are uninhibited is typically three months, but can depend on the rate of soiling.*

NOTE 4 *The interval for cleaning traffic detection systems and overheight detection systems can depend on the rate of soiling, which can be determined by local traffic and weather, it is typically six months.*

NOTE 5 *An increase in the number of false alarms from a video analytics detection system can indicate a requirement to clean the associated camera lenses.*

Functional testing

11.10 The functionality testing of all traffic control, communication and information systems shall be undertaken at typical intervals as indicated, or based on manufacturer's recommendations:

1) all aspects of operation of the emergency telephones (one week);
2) an on-air test of radio relay systems on all channels for acceptable speech quality (one week);
3) operation of CCTV camera pan, tilt and zoom mechanisms (one week);
4) PA/VA systems (three months during planned closures), including:
   a) a check that there has not been any gradual degradation of the PAVA system;
   b) a check of emergency messages.
5) measurement of the impedance of detector loops (6 months);
6) checking for hidden damage to the detector loop cables (6 months);
7) individual battery supplies to telephones (12 months);
8) radio relay system (12 months), with checks of:
   a) frequency accuracy;
   b) transmitted power levels;
   c) receiver sensitivity and selectivity;
   d) transmitter output and audio levels to and from the control centre.
9) ITCS (12 months):
   a) all aspects of operation and response;
   b) computer hard discs for bad sector level, capacity and fragmentation.
10) all other traffic control, communications or information equipment (12 months).

Servicing

11.11 The routine servicing of traffic control, communications and information systems shall be undertaken at intervals as follows:

1) three months for back-up of software and data files, such as system logs;
2) five years for solid state radar array heads;
3) twelve months for all other equipment, unless the manufacturer requires a more frequent interval of service.

NOTE *Routine monitoring through the plant monitoring and control system (Section 12) can highlight equipment failures.*

12. Plant monitoring and control system

General

12.1 The maintenance of the following systems shall be in accordance with the manufacturer's and systems integrator recommendations and the tunnel OMM:

1) the plant supervisory control and data acquisition (SCADA) system;
2) the plant programmable logic controller (PLC) system;
3) the plant communications network(s);
4) field instrumentation.

Hardware maintenance

12.2 Visual inspection shall be carried out typically at 3-monthly intervals, and coordinated with planned closures.

12.2.1 Plant SCADA, PLC and communication systems hardware should be cleaned and inspected for damage or signs of overheating and serviceable parts replaced.

12.3 Routine servicing of plant monitoring and control system (PMCS) equipment and general cleaning of field sensors shall be carried out at 6-monthly intervals.

12.3.1 Periods where maintenance of critical equipment is being undertaken and is, as a consequence, unavailable may need to be scheduled into planned tunnel closures.

Software maintenance

12.4 Routine servicing of the PMCS software shall be carried out at 6-monthly intervals or in accordance with the manufacturer's (and/or systems integrator's) recommendations, whichever is the more frequent.

12.4.1 Routine servicing of PMCS software should include the following:

1) review of all system logs;
2) backup and secure storage of the alarm and event database;
3) backup and secure storage of all data point parameters, including user defined set points;
4) any required updates software packages.

12.5 Functional testing of the PMCS shall be carried out at 12-monthly intervals.

12.5.1 The following should be included in the functional testing of the PMCS:

1) software control sequences;
2) software interlocks and inhibits;
3) hardwired control sequences;
4) hardwired interlocks;
5) SCADA mimic representation and control;
6) alarm handling and management;
7) alarm and event log recording;
8) trending and data export;
9) remote status and alarm enunciation; and
10) time and data synchronisation.

Safety instrumented systems

12.6 Maintenance of safety instrumented systems (SIS) shall be in accordance with BS EN 61508-2 [Ref 7.N] 'Functional safety of electrical/electronic/programmable electronic safety-related systems'and with the relevant operation and maintenance manuals.

12.6.1 Proof testing should be performed on any plant and equipment where a verified SIS has been installed to protect people, plant or the environment.

12.6.2 Proof testing should be performed as part of schedule periodic testing and after any maintenance (including routine).

12.6.3 Maintenance and proof testing should be performed to ensure that the required safety integrity level (SIL) of each SIS is maintained during operation and maintenance.

12.6.4 Maintenance of the SIS should include:

1) maintenance of hardware and supporting systems;
2) visual inspection;
3) calibration of sensors;
4) service of the final element;
5) service of the logic solver.

12.6.5 Proof testing of the SIS should include:

1) complete system functional testing;
2) partial testing;
3) end-to-end testing;
4) calibration check of sensors.

13. Electrical power distribution

General

13.1 Maintenance of all parts of the following systems shall be in accordance with the manufacturer's recommendations and the tunnel OMM including:

1) high voltage (HV), and low voltage (LV) power cables;
2) earthing and lightning protection systems;
3) HV equipment, transformers and switchgear;
4) LV switchgear and distribution and control panels.

13.2 Only competent and authorised staff in accordance with BS 7671 [Ref 24.N] shall carry out maintenance of these items, and who have received specific training on how to safely operate and work on electrical systems.

13.2.1 Electrical systems maintenance works should be performed under a 'Permit to Work' system.

Power cables

Visual inspection and cleaning

13.3 A visual inspection of accessible cables in the tunnel bore, tunnel service buildings, sumps and draw-pits shall be carried out at 12-monthly intervals.

13.3.1 All accessible cables, cable glands and joints (where applicable) should be visually inspected for damage (such as mechanical or rodent), signs of overheating, signs of unauthorised interference and security of the support system and securing devices.

13.4 For cable pits designated as confined spaces an access procedure, which complies with the Confined Spaces Regulations , shall be in place.

NOTE *Bore closures are normally required to access power cables within the tunnel.*

13.4.1 Any deposits of foreign material on the surface of cables should be removed.

Testing

13.5 Testing of HV and LV cables, cable glands and joints (where applicable) shall be carried out as part of each principal inspection BS EN 62305 [Ref 21.N].

NOTE *Testing of HV and LV cables require the services of a specialist.*

13.6 HV cables, cable glands and joints (where applicable) shall be periodically insulation tested (DC ramp test or HIPOT) in accordance with the manufacturer's recommendations.

13.7 LV cables, cable glands and joints (where applicable) shall be tested in accordance with BS 7671 [Ref 24.N] 'Requirements for electrical installations, IET Wiring Regulations'.

Earthing and lightning protection systems

Visual inspection

13.8 At intervals of 12 months, accessible parts of the main earthing and equipotential bonding system shall be visually checked for any signs of loose connections or fixings, corrosion, damage (e.g. mechanical or rodent), signs of overheating, signs of unauthorized interference and security of the support system and securing devices.

13.9 Any defects likely to affect functionality of the earthing system shall be repaired immediately.

13.10 At intervals of typically of 12 months, the lightning protection systems shall be visually inspected in accordance with 'Protection against lightning' BS EN 62305 [Ref 21.N].

13.10.1 Additional visual inspections should be made following known lightning strikes.

13.11 Any defects likely to affect functionality of the lightning protection system shall be repaired immediately.

Testing

13.12 Testing of lightning protection systems shall be carried out as part of each principal inspection.

13.13 Earth continuity, together with resistance to the general mass of earth of all earth electrodes, shall be tested in accordance with BS 7671 [Ref 24.N] 'Requirements for electrical installations, IET Wiring Regulations' and BS 7430 [Ref 1.I] 'Code of practice for protective earthing of electrical installations'.

13.14 The lightning protection system (where applicable) shall be tested for compliance with the relevant parts of BS EN 62305 'Protection against lightning' BS EN 62305 [Ref 21.N].

13.15 All mechanical supports, fixtures, fittings and electrical connections shall be checked for tightness.

13.15.1 All surge protection devices should be checked in accordance with the manufacturer's recommendations.

High voltage system circuit breakers and transformers

13.16 At 3-monthly intervals the previous 3 months alarm list, for circuit breakers and transformer, shall be reviewed to identify instances of equipment failure.

13.17 Repeated failures shall initiate an immediate investigation of the failed equipment.

Visual inspection - switchgear

13.18 Visual inspections shall be performed at typically 12-monthly intervals or in accordance with the tunnel OMM, whichever is the more frequent.

13.18.1 Visual inspections of HV switchgear should be completed in accordance with BS 6626 [Ref 17.N] 'Maintenance of electrical switchgear and control gear for voltages above 1kV and up to and including 36 kV.

13.18.2 All accessible parts of the switchgear should be inspected for signs of wear, deterioration, overheating or build-up of foreign matter.

13.18.3 The mounting supports, bolts, anchors, linkages and connections should be inspected for failure, damage or build-up of foreign matter.

13.18.4 Ancillary equipment should be inspected for failure, damage, overheating or build-up of foreign matter.

Visual inspection - transformers

13.19 Visual inspections shall be performed at typically 12 monthly intervals or in accordance with the tunnel OMM, whichever is the more frequent.

13.19.1 The exterior of each transformer should be inspected for signs of wear, deterioration, overheating, leakage or build-up of foreign matter.

13.19.2 Visual inspections of the transformers should include checks on the following:

1) condition of silica gel breather, and renewed if discoloured;
2) oil level;
3) confirmation of normal operating temperature;
4) cable terminations and oil condition.

13.19.3 The mounting supports, bolts, linkages and connections should be inspected for failure, damage or build-up of foreign matter.

13.19.4 Ancillary equipment should be inspected for failure, damage, overheating or build-up of foreign matter.

General cleaning

13.20 General cleaning of HV switchgear and transformers shall be completed in accordance with BS 6626 [Ref 17.N].

Routine service

13.21 Servicing and calibration of HV switchgear and transformers (including protection relays and devices) shall be carried out in accordance with the manufacturer's recommendations.

13.22 Any corrosion and damage to HV switchgear and transformers shall be repaired.

Functional testing

13.23 Functional testing of HV switchgear and transformers (including protection relays and devices) shall be carried out as part of each principal inspection and in accordance with BS 6626 [Ref 17.N].

Low voltage system switchboards, switchgear and distribution panels

Visual inspection

13.24 Visual inspections shall be performed at typically 12 monthly intervals or in accordance with the tunnel OMM, whichever is the more frequent.

13.24.1 Visual inspection of LV switchgear, switchboards and distribution panels should be completed in accordance with BS EN 61439-1 [Ref 16.N] 'Low-voltage switchgear and control-gear assemblies. General rules' .

13.24.2 All accessible parts of the switchgear, switchboards and distribution panels should be inspected for signs of wear, deterioration, overheating or build-up of foreign matter.

13.24.3 The mounting supports, bolts, anchors, linkages and connections should be inspected for failure, damage or build-up of foreign matter.

13.24.4 Ancillary equipment should be inspected for failure, damage, overheating or build-up of foreign matter.

General cleaning

13.25 General cleaning of LV switchgear, switchboards and distribution panels shall be completed in accordance with BS EN 61439-1 [Ref 16.N] 'Low-voltage switchgear and controlgear assemblies. General rules'.

Routine service

13.26 At 3 monthly intervals the previous 3 months alarm list, for circuit breakers and transformer, shall be reviewed to identify instances of equipment failure.

13.27 Repeated failures during this period shall initiate an immediate investigation of the failed equipment.

13.28 Routine servicing of LV switchgear, switchboards and distribution panels shall be completed in accordance with BS EN 61439-1 [Ref 16.N] 'Low-voltage switchgear and controlgear assemblies. General rules'.

13.28.1 The mechanical operation (opening and securing closed) of panel doors and any alarms should be tested.

13.28.2 Panel door hinges should be lubricated, door latches and ingress protection seals cleaned and replaced if damaged or worn.

Functional testing

13.29 Functional testing of LV switchgear, switchboards and distribution panels (including protection relays and devices) shall be carried out as part of each principal inspection and in accordance with BS EN 61439-1 [Ref 16.N] 'Low-voltage switchgear and controlgear assemblies. General rules'.

13.29.1 Sufficient redundancy is normally built into the switchgear design to enable individual circuit breakers to be withdrawn one at a time, without detriment to the operation of the tunnel. It should be verified that the switchgear operates correctly, particularly under mains failure conditions.

NOTE *Simulating incoming supply failure does not necessarily mean switching off the incoming supply. It can, for instance, mean manually operating or disconnecting the relay that detects power failure. If the above cannot be carried out without disrupting power supplies to the tunnel, then suitable procedures can be developed to enable the testing to take place during planned closures.*

14. Emergency power equipment

General

14.1 Maintenance of all parts of the following systems shall be in accordance with the manufacturers' recommendations and the OMM:

1) uninterruptible power supplies (UPS) and batteries;
2) standby generators, including associated fuel and exhaust systems.

Uninterruptible power supplies

14.2 Measures shall be taken to maintain supplies to safety-related equipment when UPS are taken out of service for maintenance.

NOTE 1 *UPS units have an internal bypass arrangement that allows maintenance of the UPS to be carried out without affecting the supported load. External bypass arrangements can be provided to allow for the UPS module to be removed from operation or site without affecting the supported load.*

NOTE 2 *When in bypass (internal or external) the load is supported by the mains only and is therefore vulnerable to the possibility of a mains power failure whilst a UPS is shut down for maintenance, and which could leave supported systems without power.*

14.2.1 Where possible, UPS maintenance work should be carried out during tunnel closures.

14.2.2 UPS maintenance should not be carried out at the same time as work on other power supply or life safety systems.

14.3 Following any maintenance intervention, a check shall be made to confirm that all critical and life safety systems are correctly connected so as to be actively supported by UPS and not inadvertently supported by the normal power supply.

Visual inspection

14.4 Visual inspections of UPS shall be performed at 12-monthly intervals or to accord with the OMM, whichever is the more frequent.

14.4.1 The area around the UPS system should be clear of all obstructions, particularly those that affect cooling.

14.5 The battery system shall be inspected for swelling, leaks, loose foreign objects, overheated or corroded cables and connectors, loose connections on batteries and appropriate product labels related to safety and warning hazards.

Routine service

14.6 At 3-monthly intervals, the previous three months alarm list for the UPS system, shall be reviewed to identify any instances of equipment failure.

14.7 Repeated failures during this period shall initiate an immediate investigation of the failed equipment.

NOTE *Some UPS systems include automatic battery testing routines which simulate a mains power failure, without disruption to the supported load, whilst performing an on-load test of the battery. Where provided, this system can be used to periodically check the integrity of the UPS and battery between routine services.*

Functional testing

14.8 Functional testing of UPS systems (including a full battery discharge test) shall be carried out as part of each principal inspection.

Standby generators

14.9 Where a generator is taken out of service for maintenance, there is a risk of a tunnel power failure if the external mains supply is interrupted. For this reason, either:

1) generator maintenance work shall be carried out during tunnel closures; or,
2) contingency measures be put in place to mitigate the risks arising from loss of power.

14.9.1 Where a failure of any mains supply occurs during generator maintenance, the work should be aborted and the generator restored to service as quickly as possible.

Visual inspection

14.10 Visual inspections of standby generators shall be performed at 12 monthly intervals or in accordance with with the OMM, whichever is the more frequent.

14.10.1 The area around the standby generator should be clear of all obstructions, particularly those that affect cooling.

14.10.2 The engine and alternator should be visually inspected for damage (whether mechanical, rodent or corrosion), signs of overheating, signs of unauthorised interference and the security of all mountings, fixtures and fittings.

14.10.3 Fuel tanks and associated pipework should be inspected for signs of damage or leakage.

Routine service

14.11 At 3-monthly intervals the previous 3 months alarm list for the standby generator system shall be reviewed to identify any instances of equipment failure.

14.11.1 Repeated failures during the 3 month period should initiate an immediate routine service and further investigation of the failed equipment.

14.11.2 Additional servicing may be required after prolonged operation.

Functional testing

14.12 Functional testing of standby generators (including a full load test) shall be carried out as part of each principal inspection.

14.12.1 Functional testing should typically test run the standby generator for one hour, using the site load (provided it can contribute no less than 40% of the generator rating) or a resistive load-bank at 100% generator output rating, and include the following checks:

1) oil pressure and temperature;
2) engine speed;
3) exhaust temperature;
4) load (or load-bank) settings;
5) water temperature;
6) turbo air pressure;
7) alternator battery charging current and alternator output (i.e. voltage, current, power, frequency and power-factor);
8) battery charger current and voltage prior to starting;
9) operation of control panels, associated lamps and alarms;
10) fuel polishing.

14.12.2 Fuel tanks should be refilled immediately on completion of each test run.

15. Tunnel services building and plant rooms

General

15.1 The maintenance of tunnel service building and plant rooms shall be in accordance with:

1) the tunnel OMM;
2) any additional requirements described within the contract for maintenance of the tunnel.

Building fabric

Visual inspection

15.2 An inspection of the tunnel service building fabric shall be carried out at intervals of 12 months.

15.2.1 Where service buildings and associated equipment are subject to vandalism and damage, more frequent inspections than every 12 months may be required.

15.3 Working areas and floors shall be clean and free of obstructions and potential slip, trip and fall hazards.

15.4 The general condition and cleanliness of the following items shall be checked:

1) walls and roof;
2) doors and windows;
3) ventilation louvres/grills, fans;
4) accessible rainwater gutters and pipes;
5) accessible drainage pipes;
6) pedestrian foot paths;
7) vehicle parking areas;
8) stairs, steps, landings and hand-railing;
9) paintwork and sealants;
10) overgrown flora;
11) inspection covers;
12) security fencing and gates;
13) welfare facilities (where provided);
14) all internal areas of the building.

Maintenance

15.5 Touching up of paintwork and maintenance of the roof shall be carried out at intervals of 12 months.

15.6 Clearing of any debris from the gutters and weeding shall be carried out at intervals of 12 months.

15.7 Defective and/or damaged items shall be repaired/replaced immediately where safety is affected.

General cleaning

15.8 General cleaning of the tunnel service-building fabric shall be performed at intervals of 12 months.

Routine service and functional testing

15.9 Functional testing of the following systems shall be performed at intervals of 12 months:

1) all doors (including emergency) and windows checked for correct opening and closing and securing in the closed position;
2) all water taps be checked for correct operation, drips and leaks by opening and closing the valves at least twice;

3) all toilets checked for leaks and cistern overflows and the flushing mechanism and fill sequence for correct operation;
4) all sinks checked for leaks.

Building services

Visual inspection

15.10 A visual inspection of the tunnel service building heating, ventilating and air conditioning (HVAC), lighting and small power shall be performed at 3 monthly intervals.

General cleaning

15.11 General cleaning of the tunnel service-building HVAC, lighting and small power shall be performed at 12 monthly intervals.

Routine service

15.12 Routine service of the tunnel service-building HVAC, lighting and small power shall be performed at 12 monthly intervals.

NOTE 1 *Maintenance relating to electrical earthing and lightning protection is described in Section 13 'Electrical power distribution'.*

NOTE 2 *Maintenance relating to the fire alarm and fire extinguishing system is described in Section 10 'Fire safety equipment'.*

15.13 HVAC, lighting and small power shall be tested in accordance with the requirements of BS 7671 [Ref 24.N] 'Requirements for electrical installations, IET Wiring Regulations' and BS 5266 [Ref 4.N] (emergency lighting) as part of each principal inspection (see CS 452 [Ref 12.N].)

Security and access control systems

Maintenance

15.14 Maintenance of the security and access control systems shall be in accordance with BS 4737 [Ref 14.N].

NOTE *Security systems typically can incorporate proximity, vibration and passive infrared (PIR) sensors. They can also include access control to the service building.*

16. Normative references

The following documents, in whole or in part, are normative references for this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Ref 1.N	Highways England. CG 302, 'As-built, operational and maintenance records for highway structures'
Ref 2.N	Highways England. GG 105, 'Asbestos management'
Ref 3.N	European Agency for Safety and Health at Work (EU-OSHA). 92/57/EEC, 'Directive 92/57/EEC - Temporary or mobile construction sites'
Ref 4.N	BSI. BS 5266, 'Emergency escape lighting systems.'
Ref 5.N	BSI. BS 5306-3, 'Fire Extinguishing Installations and Equipment on Premises. Selection and Positioning of Portable Fire Extinguishers – Code of Practice'
Ref 6.N	BSI. BS EN 15004-1, 'Fixed firefighting systems. Gas extinguishing systems. Design, installation and maintenance'
Ref 7.N	BSI. BS EN 61508-2, 'Functional safety of electrical/electronic/programmable electronic safety-related systems.'
Ref 8.N	ISO/BSI. ISO 14520, 'Gaseous fire-extinguishing systems. Physical properties and system design.'
Ref 9.N	The National Archives. legislation.gov.uk. SI 1999/3242, 'HEALTH AND SAFETY - The Management of Health and Safety at Work Regulations 1999'
Ref 10.N	The National Archives. legislation.gov.uk. SI 1997/1713, 'Health and Safety. The Confined Spaces Regulations 1997'
Ref 11.N	The National Archives. legislation.gov.uk. SI 2007/1520, 'Highways - Tunnels - The Road Tunnel Safety Regulations 2007'
Ref 12.N	Highways England. CS 452, 'Inspection and records for road tunnel systems'
Ref 13.N	Highways England. GG 101, 'Introduction to the Design Manual for Roads and Bridges'
Ref 14.N	BSI. BS 4737, 'Intruder alarm systems'
Ref 15.N	The National Archives. legislation.gov.uk. SI 1998/2307, 'Lifting Operations and Lifting Equipment Regulations 1998 (LOLER) '
Ref 16.N	BSI. BS EN 61439-1, 'Low-voltage switch gear and control gear assemblies. General rules.'
Ref 17.N	BSI. BS 6626, 'Maintenance of electrical switchgear and control gear for voltages above 1 kV and up to and including 36 kV. Code of practice.'
Ref 18.N	The National Archives. legislation.gov.uk. SI 1992/2793, 'Manual Handling Operations Regulations 1992, as amended in 2002'
Ref 19.N	Highways England. MCHW, 'Manual of Contract Documents for Highway Works'
Ref 20.N	Highways England. MCHW Series 7000, 'Manual of Contract Documents for Highways Works, Volume 1 Specification for Highways Works, Series 7000 Mechanical and Electrical Installations in Road Tunnels, Movable Bridges and Bridge Access Gantries'
Ref 21.N	BSI. BS EN 62305, 'Protection against lightning'
Ref 22.N	Highways England. GG 102, 'Quality management systems for highway works'

Ref 23.N	BSI. BS EN ISO 9001, 'Quality management systems. Requirements'
Ref 24.N	BSI. BS 7671, 'Requirements for Electrical Installations, IET Regulations'
Ref 25.N	The National Archives. legislation.gov.uk. SI 2015/51, 'The Construction (Design and Management) Regulations 2015'
Ref 26.N	The National Archives. Legislation.gov.uk. SI2012 No.632, 'The Control of Asbestos Regulations'
Ref 27.N	Highways England. TM 101, 'Traffic signalling systems (maintenance and operation)'

17. Informative references

The following documents are informative references for this document and provide supporting information.

Ref 1.I	BSI. BS 7430, 'Code of practice for protective earthing of electrical installations'
Ref 2.I	Highways England. CD 352, 'Design of road tunnels'
Ref 3.I	EU-OSHA. 89/391/EEC, 'Guidance on Risk Assessment at Work: Health and Safety (Directive 89/391/EEC)'
Ref 4.I	Highways England. CS 450, 'Inspection of highway structures'
Ref 5.I	Fire Protection Association and RISC Authority. LPC Rules, 'LPC Rules for Automatic Sprinkler Installations incorporating BS EN 12845'
Ref 6.I	CIRIA. CIRIA C778, 'Management of safety critical fixings in-service. Guidance for the management and design of safety-critical fixings'
Ref 7.I	Sector Scheme Advisory Committee for the Management, Operation, Installation and Maintenance of Road Tunnels . NHSS 22, 'Particular Requirement for the Application of ISO 9001:2015 for the Management, Operation, Installation and Maintenance of Road Tunnels Issue 1'
Ref 8.I	National Fire Protection Association (NFPA). NFPA 25, 'Standard for the Inspection, Testing and Maintenance of Water-based Fire Protection Systems'
Ref 9.I	TSO. Department for Transport. TSM Chapter 8, 'Traffic Signs Manual Chapter 8 - Road works and temporary situations'
Ref 10.I	Transport Focus & Highways England. Tunnel Vision, 'Tunnel Vision: road users' experiences and expectations of tunnels'
Ref 11.I	UKRLG - The UK Roads Liaison Group. WmHI CoP, 'Well-managed Highway Infrastructure - A Code of Practice'