VOLUME 3 **HIGHWAY STRUCTURES: INSPECTION AND MAINTENANCE**

SECTION 2 **MAINTENANCE**

PART 3

BA 72/03

MAINTENANCE OF ROAD TUNNELS

SUMMARY

This Advice Note provides guidance on procedures suitable for the maintenance of road tunnels located within Motorways and Other Trunk Roads. It covers general aspects of organisation and detailed aspects of tunnel inspection, servicing and cleaning for the tunnel structure and its equipment. It complements the requirements of BD78 (DMRB 2.2.9): Design of Road Tunnels.

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Maintenance of Road Tunnels

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SECTION 2 MAINTENANCE

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MAINTENANCE OF ROAD TUNNELS

Contents

Chapter

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1. INTRODUCTION

General

1.1 This document provides essential 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.

1.2 It complements the requirements of BD78/99 (DMRB 2.2.9): Design of Road Tunnels. The advice regarding cleaning and maintenance frequencies in this document is based upon more up-to-date information. It supersedes advice given in Figure 14.1 of BD78/99. In practice, for a particular tunnel, such frequencies may need to be reviewed based on changes to traffic levels and seasonal variations actually experienced.

1.3 Aspects of the document will be of particular interest to the following parties during the various stages of a tunnel's life.

i. The Tunnel Design and Safety Consultation Group (TDSCG) and the Design Organisation (DO) during the planning and design of a new or refurbished road tunnel.

ii. The Managing Agent (MA) and Tunnel Operating Authority (TOA) responsible, or planning to take responsibility, for a road tunnel.

iii. Specialised contractors, equipment manufacturers and others involved in tunnel maintenance.

Scope of Document

1.4 The document covers general aspects of organisation and management of maintenance; detailed aspects of tunnel cleaning, washing, inspection, servicing and testing of equipment, structure and other elements of road tunnels. It includes for emergency maintenance works.

1.5 It has been written with particular reference to Highways Agency documentation and maintenance practices. Other Overseeing Organisations should be consulted about its application to the maintenance of road tunnels for which they have responsibility.

1.6 Guidance on typical maintenance arrangements for use by the TDSCG and DO during the planning and design of a new or refurbished tunnel is included. These arrangements will be expressed in maintenance standards and set down in the tunnel documentation, covering operation, maintenance, inspection and emergency procedures. The provision of appropriate levels of equipment, operating and maintenance arrangements and tunnel design are closely interdependent. Determining the optimum combination requires consideration of whole life costs and levels of risk.

1.7 Indicative advice, such as the frequency and nature of maintenance inspections etc, is provided. Such advice is intended as an initial aid to the development of the most appropriate maintenance procedures to suit the tunnel concerned. Advice contained in tunnel specific documentation should take precedence, but should be reviewed in operation (see Chapter 3).

1.8 The document may be used as the basis for reviewing and improving current maintenance arrangements.

Information Sources

1.9 An overview of tunnel maintenance and operation is given in "Operation and Maintenance of Road Tunnels" (Ford RJ 1998).

1.10 Information on the general and specific design and operational requirements for road tunnels, together with details of tunnel maintenance and operational documentation normally provided by the designer, may be found in BD78 (DMRB 2.2.9).

1.11 Much of the detailed technical specification requirements for road tunnel equipment may be found in the Standard Performance Specifications for Mechanical and Electrical Installations in Road Tunnels, Movable Bridges and Bridge Access Gantries (MCHW 5.7.2). A separate specification document to advise on the specific civil engineering requirements of road tunnel construction and maintenance is currently under preparation.

1.12 Meetings of the UK Road Tunnel Operators' Forum, organised by the Highways Agency, take place

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every six months. They provide a platform for the sharing of ideas and experiences and a valuable source of information and feedback on matters concerning design, operation and maintenance of UK road tunnels. In addition the forum enables attendees to participate in and benefit from international research and best practice work, particularly from the World Road Association (PIARC) Tunnel Working Groups.

1.13 Information on general procedures, specific aspects of routine highway maintenance and management of health and safety are provided in the Highways Agency Trunk Road Maintenance Manual - 1999 (TRMM). Volume 2 of TRMM is in the process of being revised to contain performance criteria for tunnel maintenance.

1.14 Standard procedures for inspection and records for road tunnels are set out in BD53 (DMRB 3.1.6).

1.15 Additional sources of information are referred to in the text and listed in Chapter 16.

Reference to British Standards and Legislation

1.16 Any reference to a British Standard can be taken to include any other International Standard or National Standard of another Member State of the European Communities, which is comparable in its scope and safety requirements to the given British Standard.

1.17 This document is not intended as a legal manual and any references made to legislation are intended only as an indication of the possible legal requirements. Reference should be made to the latest relevant UK and EEC legislation, ISO, BS or other EC Member States' Standards and relevant Department of the Environment, Transport and the Regions' documents. Tolled tunnels under estuaries may be controlled by special legislation such as the Dartford-Thurrock Crossing Act 1988.

Definitions

1.18 The Overseeing Organisation is defined in BD53 (DMRB 3.1.6).

1.19 The Design Organisation (DO) is defined in BD78 (DMRB 2.2.9).

1.20 The Tunnel Design and Safety Consultations Group (TDSCG) is defined in BD78 (DMRB 2.2.9).

1.21 The Managing Agent (MA) has replaced the role of the Maintaining Agent. The MA is defined in BD53 (DMRB 3.1.6).

1.22 The Tunnel Operating Authority (TOA) is defined in BD78 (DMRB 2.2.9) and is the body responsible for the operation, inspection and maintenance of the tunnel, together with the necessary maintenance plant and equipment.

1.23 The Term Maintenance Contractor (TMC) is the contractor appointed by the Overseeing Organisation to carry out all maintenance work under supervision by the MA.

1.24 The Managing Agent Contractor (MAC) is the contractor appointed by the Overseeing Organisation with the combined roles of the MA and TMC.

1.25 The Highways agency Value for Money Manual (VFMM) is a document providing guidance aimed at achieving better value for money in highway procurement and maintenance.

Implementation

1.26 This document should be used forthwith on all schemes for the maintenance of tunnels on trunk roads, including motorways currently being prepared, provided that, in the opinion of the Overseeing Organisation this would not result in significant additional expense or delay progress. MAs should confirm its application to particular schemes with the Overseeing Organisation.

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2. ROLES AND RESPONSIBILITIES

General

2.1 This Chapter summarises the main roles and responsibilities of the various stakeholders in the delivery of safe and effective tunnel maintenance. See also BD78 (DMRB 2.2.9)

Overseeing Organisation

2.2 The Overseeing Organisation is responsible for:

i. ensuring that a TDSCG is established during the planning and design of a new or refurbished tunnel, and agreeing its terms of reference;

ii. overseeing the maintenance of the tunnel through the appointment of competent experienced MAs and TMCS with adequate funding and other resources.

Tunnel Design and Safety Consultation Group (TDSCG)

2.3 The TDSCG should comprise appropriate levels of representation from the Overseeing Organisation, DO, Police or other control authority, emergency services and the MA. It is responsible for:

i. clarifying the design requirements;

ii. agreeing standards of safety, quality and economy;

iii. confirming basic operation, maintenance and emergency procedures.

Design Organisation (DO)

2.4 The DO is, in consultation with the TDSCG, responsible for:

i. the procedures for tunnel commissioning, acceptance inspection and handover;

ii. preparing all tunnel documentation needed for the effective handover of the tunnel to the TOA as described in BD53 (DMRB 3.1.6), BD78 (DMRB 2.2.9) and MCH 1349.

2.5 Note that in the case of mechanical and electrical (M&E) plant and systems, much of the detailed designs may be carried out by the manufacturer who may specify particular future maintenance and operational requirements. See BD78 (DMRB 2.2.9).

Managing Agent (MA), Tunnel Operating Authority (TOA)

2.6 The MA is responsible for:

i. establishing the TOA (or carrying out this function within its own organisation);

ii. implementing a maintenance agreement with the TMC;

iii. overseeing tunnel maintenance to standards normally established in service level agreements and tunnel documentation. Developing, implementing and periodically reviewing maintenance strategies to meet these standards. See BD78 (DMRB 2.2.9);

iv. all tunnel operations;

v. providing advice and assistance to the police and other emergency services. See BD78 (DMRB 2.2.9).

2.7 Senior operating staff of the prospective MA/TOA should be appointed early in the mobilisation process and should participate in the TDSCG and VFMM procedures. All aspects of future maintenance, including funding and organisation, should be addressed during the planning and design stages of a new or refurbished tunnel. Key decisions affecting maintenance should be approved by the Overseeing Organisation.

2.8 The MA/TOA is required to:

i. prepare briefs and agree budgets for routine maintenance works with Overseeing Organisation;

ii. prepare and prioritise as necessary, detailed recommendations for proposed remedial, refurbishment or contingency expenditure;

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iii. liaise with the Overseeing Organisation on future work programmes, preparing contracts, supervising works, etc as required;

iv. instruct, monitor and supervise the work of the TMC, checking that competent and suitably trained personnel are used at all times;

v. undertake regular inspections and surveys, in accordance with HA 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;

vi. carry out regular comprehensive exercises and risk assessment to identify and manage all possible hazards of tunnel maintenance and operation. Thereafter develop and/or maintain, through agreement with Overseeing Organisation, TMC and the emergency services, appropriate contingency arrangements;

vii. liaise with emergency services regarding regular drills and exercises, and ensure they are familiar with tunnel equipment and its operation. See Appendix F for guidance on emergency exercises;

viii. ensure a complete and up to date set of tunnel documentation, including the Health and Safety file, emergency procedures, operating manuals, etc is available at all times;

vix. keep records of all tunnel maintenance proposals, reports, activities, certificates, etc;

x. notify the Health and Safety Executive of relevant safety delegations and appointments and correspond as necessary to comply with Regulations (see Chapter 3);

xi. maintain effective and regular communications with emergency services, ensuring all parties have up to date information, relevant telephone contact numbers, etc;

xii. undertake training of staff to ensure their safety and levels of competency. For appropriate staff, this should include maintaining currency with best international practice, developments and thinking through attending UK Road Tunnel Operation Forums, etc;

xiii. co-ordinate with contractors responsible for the maintenance of the motorway communications system provisions within the tunnel.

In England

2.9 The National Motorway Communications System is maintained by the Regional Maintenance Contractor (RMC). The Contracts are managed by the Regional Maintenance Contracts – Management Consultants.

2.10 The National Transmission System is maintained by the National Maintenance Contractor and managed centrally by the Highways Agency.

In Scotland

2.11 The communication and transmission system is the National Driver Information Control System (NADICS), which is maintained by a term maintenance contractor under the management of the NADICS System Operator.

In Wales

2.12 The combined communication and transmission system is maintained by the Regional Maintenance Contractor. The contracts are managed by the Trunk Road Agent or the Regional Maintenance Contracts – Management Consultants.

In Northern Ireland

2.13 Presently there are no tunnels in Northern Ireland.

Term Maintenance Contractor (TMC)

2.14 The TMC is responsible for:

i. undertaking maintenance works, as instructed by the MA/TOA, using its resources or specialist subcontractors;

ii. holding and keeping up to date all documentation and records relevant to routine and minor maintenance;

iii. setting up and carrying out effective and safe procedures for the routine maintenance of all tunnel features and equipment in accordance with the HA standards (or as instructed otherwise by the MA/TOA to reflect current best practice);

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iv. reporting urgently any defects or circumstances that threaten the safety of tunnel users or personnel;

v. responding efficiently and effectively to reports for assistance in dealing with tunnel incidents, including fire and spillages;

vi. undertaking emergency exercises as required by the MA/TOA or emergency services;

vii. training of staff to ensure their safety and levels of competency. For appropriate staff, this should include maintaining currency with best international practice, developments and thinking through attending UK Road Tunnel Operation Forums, etc.

Managing Agent Contractor (MAC)

2.15 The roles and responsibilities of the MAC are those of the MA, TMC and TOA.

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3. ORGANISATION AND MANAGEMENT OF MAINTENANCE

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General

3.1 The objective of tunnel maintenance is to sustain the tunnel assets in a safe and usable condition, whilst obtaining best value for money. Such maintenance should also promote the safety of the travelling public and personnel, avoid traffic delays, and minimise any adverse environmental impacts.

3.2 This chapter explores the organisation of the TOA and the framework and tools necessary to manage tunnel maintenance effectively.

Organisation of TOA

3.3 Good organisation of the TOA, normally a part of the MA, is essential to achieving effective maintenance through a considered strategic approach. Senior operational and maintenance staff should ideally be appointed at an early stage in the design of a new tunnel, and definitely well in advance of taking over an existing tunnel. The appointments should be structured to cover the spectrum of management, technical and operational skills needed and to provide effective communications with the other stakeholders.

3.4 In planning the staff and resources necessary for maintenance, account should be taken of any other functions that may be carried out by the TOA, such as routine traffic management and emergency response. Tunnel staff employed by the TOA may carry dual responsibility for normal operations and emergency conditions. Appropriately trained and qualified staff should be designated specific responsibilities in the case of emergencies. See BD78 (DMRB 2.2.9).

3.5 All staff involved in tunnel maintenance should have the necessary qualifications, knowledge and experience to effectively carry out their duties and responsibilities. Staff should not be assigned to duties unless they have received the necessary training and have been formally assessed for competence to serve in the post. A continuous training programme, including refresher courses, should ensure staff are knowledgeable in all aspects of the engineering systems in use. Records should be kept of the training received by staff and the reviews undertaken to identify the need for such training and its suitability.

3.6 The TOA organisation will depend on the individual tunnel and whether it is manned or unmanned. Two broad categories of tunnel operation are defined in BD78 (DMRB 2.2.9):

i. manned tunnels have their own dedicated management structure and resources that take responsibility for traffic surveillance and the safe operation of the tunnel, including response to incidents and emergencies. The structure may include for dedicated maintenance staff;

ii. unmanned tunnels are designed to operate as fully automatic facilities and do not have permanent operating and monitoring staff at the tunnel. However, there needs to be a 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 will depend on any agreements and arrangements with the traffic police.

3.7 An example of a tunnel maintenance organisation for a non-tolled road tunnel, with planned maintenance undertaken through term contracts, is shown in Appendix A. This also provides guidance on the general background and training required for personnel. The main difference for a tolled tunnel will be the staff employed in collecting tolls on a shift basis and those dealing with accounting for the cash collected, toll prepayments, welfare and security.

3.8 Whether the tunnel is manned or not, TOA staff should ensure emergency cover is provided on a 24-hour basis, within a schedule of response times, to carry out or oversee all maintenance work (including that contracted out). See BD78 (DMRB 2.2.9).

3.9 Sometimes the operation of a road tunnel is carried out on a shared responsibility basis. Normally the Local Highway Authority will have responsibility for all work in connection with the roads and their maintenance and the Overseeing Organisation will have responsibility for the tunnel structure and its equipment. See BD78 (DMRB 2.2.9).

3.10 Where the TOA is part of a larger MA, staff may be available who are also assigned to other duties

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within the MA. Common services for administration, design, contract preparation, health and safety, legal advice, plant and testing facilities may also exist.

3.11 A single member of staff should be appointed as Safety Officer see BD78 (DMRB 2.2.9). Further requirements regarding aspects of safety are also covered in BD78 (DMRB 2.2.9). Staff should include, where necessary, those with qualifications and authorisation to comply with statutory safety procedures such as 'Permit to Work' systems relating to high voltage equipment and confined spaces.

Quality Plan

3.12 The MA/TOA will be Quality Assurance accredited (to BS EN ISO 9002) and have developed and submitted a Quality Plan for approval by the Overseeing Organisation as part of the tendering process for the term commission. It will contain a management strategy that sets clear and sustainable performance objectives, delegates responsibility and establishes lines of communication.

3.13 A Quality Plan will identify the key objectives under the commission and how these will be managed to best effect. It will, for example, explain how:

i. project briefs will be established/clarified and periodically reviewed and communicated;

ii. appropriate resources and tools will be identified, allocated and managed and suppliers will be assessed and approved for use;

iii. audit trails will be generated and made readily accessible through a controlled filing and archiving system;

iv. the training and development needs of staff will be identified and delivered.

3.14 Regular meetings between the Overseeing Organisation MA/TOA should be held to review the Quality Plan and renew the key objectives.

Main Maintenance Objective

3.15 The MA/TOA must establish the maintenance objectives to be managed. The following objectives are likely to apply to all tunnels:

i. sustaining tunnel assets in a safe and useable condition;

ii. obtaining value for money through a whole life cost approach;

iii. ensuring safety to road users and staff;

iv. minimising disruption to traffic through carefully planned maintenance operations;

v. minimising environmental impacts.

Constraints

3.16 The framework has to be developed within various constraints (see below). In the case of a new or refurbished tunnel, the Overseeing Organisation/DO will have developed maintenance standards within constraints of legislation, financial rules of the Overseeing Organisation and local circumstances of the individual tunnel. The maintenance standards become additional constraints within which the TOA will then further develop the maintenance strategy.

Legal Framework

3.17 The legal framework is derived from primary legislation (Acts), secondary legislation (eg Orders or Regulations), European legislation and common law.

3.18 TRMM Volume 3 contains the following guidance on Health and Safety that is relevant to tunnel maintenance:

i. a list of health and safety legislation, codes of practice and guidance notes, with brief explanatory notes;

ii. identification of workplace hazards within compounds. This is of direct relevance to tunnel operators' compounds and workshops, and its principles may be applied to hazards in control rooms, service buildings and in the tunnel;

iii. application of Construction (Design and Management) Regulations 1994 to highway maintenance. The regulations apply to the majority of tunnel maintenance activities, according to regulations 2(1)a and 2(1)e. However some activities may not be notifiable. Where not specified in the contract, advice should be sought from the Overseeing Organisation in designating the 'client' under these regulations. Its regulations include the appointment of a planning supervisor and principal contractor, provision of information, preparation of a health and safety plan,

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assessment of competence, allocation of resources and the completion and maintenance of a health and safety file.

3.19 The TOA should establish a set of procedures and working practices based on risk assessment techniques (eg Ford, 2000) and other methods used to ensure these regulatory provisions are enacted.

3.20 Further guidance on safety is contained in BD78 (DMRB 2.2.9) and summarised in Appendices B and C.

3.21 Atkinson (1997) lists a summary of other legislation commonly encountered in highway maintenance. The following Acts are of particular relevance to tunnel maintenance:

i. Local Government, Planning and Land Act (1980);

ii. Highways Act (1980);

iii. Road Traffic Regulations Act (1984);

iv. New Roads and Street Works Act (1991).

3.22 In Scotland, the equivalent legislation for (i.) and (ii.), namely The Town and Country Planning (Scotland) Act 1997 and The Roads (Scotland) Act 1984 respectively, apply.

Maintenance Funding

3.23 Maintenance costs are greatly influenced by decisions made during the design process, particularly the type and quality of equipment to be used and its expected life in service. Full involvement of the MA for such decisions at TDSCG meetings is important. An overview on the reduction of operational costs is given in (Ford, 1999).

3.24 Funding of future maintenance for new or refurbished tunnels should be addressed during the planning stages and be based on:

i. a 5-year programme for all tunnel assets;

ii. a 10-year replacement programme for assets with a design life of 10 years or less.

3.25 For an operational tunnel the TOA should develop a business plan for maintenance and make timely submissions of bids linked to the inspection cycle, BD53 (DMRB 3.1.6) to secure the necessary allocation of funds for all anticipated costs. The business plan should identify what is to be achieved, the reasons, alternative options and risks considered, method, timing and quality. Included in the plan should be suitable funding allocations for emergencies, contingencies and capital replacement. Guidance for MAs on obtaining funding and the bid cycle is contained in Area Management Memos 22, 23 and 24.

3.26 The TOA should work within agreed financial rules and follow agreed procedures for purchasing, tendering and auditing. When the TOA is part of a local government body these rules are drawn from the Local Government Act (1972), and interpreted into standing instructions and procedures by the Local Authority.

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

i. staffing;

ii. planned maintenance;

iii. emergency maintenance or contingency;

iv. overheads such as vehicles, buildings etc;

v. capital replacement.

3.28 Expenditure and future liabilities should be projected over a 3-year rolling bid cycle with management accounts that allow a continuous assessment of spend set against projected budgets.

Local Constraints

3.29 Local constraints influence the nature, timing and frequency of planned tunnel maintenance activities. The primary local constraint is the demand to keep the tunnel open to traffic as much as possible. Planned closure must avoid periods of peak day, holiday and local event traffic. Therefore closures tend to be limited to periods of low traffic flows, for example late evening through to early morning and/or during weekends.

3.30 Closures are normally required to be agreed with the Overseeing Organisation in advance. Other local bodies affected by the closure will need to be consulted and the public provided with adequate warning and alternative routeing, if necessary. The notice required will depend on the planned duration of the closure and suitability of alternative routes.

3.31 Considerable pre-planning and prioritising is required to achieve the maximum amount of maintenance work per closure. Allowance needs to be made for set-up times, contingencies, and safety checks before re-opening.

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Tools for Management of Maintenance

3.32 There are a number of tools to facilitate the management of maintenance against set objectives, including those discussed below:

Maintenance Standards

3.33 Maintenance standards will be expressed within service level agreements and tunnel documentation. They should be developed in consultation with the TDSCG and the prospective TOA (see also BD78 (DMRB 2.2.9)) and will specify standards of performance to be maintained.

3.34 Maintenance activities should be consistent with, and not compromise, the basic design assumptions of the tunnel as listed in BD78 (DMRB 2.2.9) and the tunnel documentation.

3.35 Maintenance standards and codes of practice should be reviewed at intervals of not less than 3 years to coincide with Principal Inspections, with additional reviews when specific circumstances require this.

Maintenance Strategy

3.36 The delivery of effective maintenance over the lifetime of the tunnel requires a maintenance strategy. This should reflect the requirements and/or recommendations of the following:

i. Tunnel O&M Manual and historic maintenance records;

ii. Highway Maintenance Handbook (Atkinson, 1997). This also includes a section on tunnel maintenance;

iii. TRMM Volumes 1, 2 and 3;

iv. Highway Maintenance. A Code of Good Practice (Association of County Councils, 1989).

3.37 Essentially there are three types of maintenance:

i. planned preventative maintenance;

ii. unplanned or reactive maintenance, such as breakdown and fault repair;

iii. pre-planned ad hoc major repairs, replacements and/or improvements.

3.38 The tunnel maintenance strategy should strive to avoid unplanned tunnel closures through prudent preventative maintenance and optimise on tunnel closures. For example, increasing intervals of service and part replacement would reduce the cost of planned maintenance and the numbers of planned tunnel closures. However, this would also normally result in increased frequency of faults and breakdowns, with a consequent decrease in safety levels for users, increase in costs of contractor call-out, and increase in disruption due to unplanned tunnel closures.

Tunnel Documentation and Maintenance Records

3.39 Tunnel documentation and maintenance records are of critical importance to safe operation and maintenance. Retaining test records, up-to-date manuals, record drawings etc are essential requirements for safe operation and effective maintenance.

3.40 Original tunnel documentation, covering operation, maintenance, inspection and emergency procedures, will normally have been developed by the DO in consultation with the TDSCG. Requirements for documentation and typical contents of such documentation are listed in BD 78 (DMRB 2.2.9). The Designer will, in accordance with the requirements of the standard performance specifications (MCHW 5.7.2), write specific manuals for the operation and maintenance of plant and equipment with details supplied by the manufacturers.

3.41 Records provide information on past performance upon which future decisions may be made, evidence that acceptable standards are achieved and information for future costing. In many cases, keeping adequate records is a statutory requirement and represents verification of compliance with legal obligations for testing and maintenance. As explained in the TRMM Volume 2, Part 1, records are necessary to deal with claims arising out of any alleged defect. Making a nil return is also important as it provides a positive record.

3.42 Records will be generated by different parts of the operations and maintenance organisation, as well as external contractors and consultants, and other associated organisations. Procedures should be developed to ensure that information is readily and easily accessible. This should include co-ordinating the output from computer-based fault reporting systems, hand-written logs, video logging, voice recording etc, as well as reports compiled by contractors at the end of maintenance activities and engineers investigating and monitoring the fixed assets of the tunnel.

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3.43 Management procedures should ensure that records are retained in an appropriate archive for an appropriate period and that they remain secure, accessible and retrievable. The records management systems should be part of the Quality Management System for the operation and maintenance of the tunnel.

3.44 The records management system should be capable of analysing the records collected and reporting summaries of the information at appropriate levels of detail. Statistical, logistical and financial analysis of the records should be undertaken to enable the performance of engineering assets to be assessed. On a scheme specific basis, they may indicate significant trends in performance, which may be related to changes in operational and maintenance strategies, or they may identify the potential for, and timing of, equipment failures.

3.45 Summary records for individual tunnels should be submitted in accordance with BD53 (DMRB 3.1.6) for national collation, as part of the information for further research needs, future policy reviews, benchmarking and value for money exercises.

Knowledge of Tunnel Asset Base Requirements

3.46 The TOA should have detailed knowledge of the requirements to maintain the asset base including the following:

i. corrective/emergency maintenance assessment and maintenance requirements;

ii. routine/planned maintenance requirements;

iii. knowledge of failure modes and effects on an asset (FMEA);

iv. appropriate holding of spares and consumables to support an asset throughout its expected life;

v. maintenance logistics to support each asset.

Determining and Reviewing Maintenance Recommendations

3.47 The equipment manufacturers' recommendations may be taken as a starting point for scheduling equipment maintenance in tunnel documentation. These are normally specified as time intervals based on maximum duty, but commonly actual use may be less. For example, fans in tunnels with uni-directional traffic may be used only occasionally. Conversely, the tunnel environment may be more aggressive and corrosive than is often assumed by manufacturers, which may act to shorten the life of equipment. Before varying the requirements in tunnel documentation, an appropriately qualified operator should gather operational information based on the past performance of each system and analyse this using engineering judgement. The reasons for any variations to the maintenance schedules should be recorded and the effects of change monitored and reviewed.

3.48 As an example, the application of alternative policies in respect of tunnel lamp changing is illustrated in Chapter 8. Zuman (1997) discusses policies for dealing with street lighting - these principles may be applied to other equipment. However, Zuman notes that choice may be governed by technical, financial and political factors, and therefore judgement is required on the part of the TOA.

Asset Management Software

3.49 Proprietary facility management computer programs are available that generate maintenance schedules, check lists, task sheets and automatic warnings of tasks required. The computer programs tend to be of a generic nature and will require some configuration to meet tunnel specific needs. Most are capable of dynamic trend analysis and reporting, as well a range of other functions that assist in fast and effective facility management.

3.50 Alternatively, adaptation of proprietary spreadsheet or database applications may prove sufficient, but they will be more user-driven. Spreadsheets are effectively two-dimensional (flat file) databases and are relatively easy to use. Relational databases are more demanding to set up but have a wider capability. Both may be configured to provide a level of functionality that greatly assists facility management.

3.51 Some modern applications may be configured to passively receive and analyse data direct from the tunnel's plant monitoring and control system.

3.52 Hand held data capture devices are used for highway maintenance. They may be adapted for generating lists that require checking off (including nil returns). They may also be used in conjunction with bar codes on tunnel walls and inside equipment boxes to identify equipment and confirm that the correct equipment has been examined. Data from these or other similar portable devices may be transferred to a centralised facilities management system.

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3.53 All electronic data should be in a conventional format that can be readily converted for future applications without data loss.

Risk Assessment

3.54 Risk analysis and management should be regarded as an integral part of tunnel operation and maintenance. The Management of Safety at Work Regulations of 1992: HSC Approved Code of Practice 1992 (revised 1999/2000) requires risk analyses to be regularly carried out and to include for the safety of the public and those nearby. The risk analysis process involves identifying hazards, assessment of their likelihood of occurrence and their consequences, and ultimately their management. This should involve identifying, evaluating and reviewing the options for reducing risk. Guidance on Risk Assessment at Work: Health and Safety: European Commission, 1996 provides useful general information.

3.55 For straightforward task based applications, risk assessment may involve a team review, followed by the setting up of a risk register based on a simple risk-rating matrix (eg Ford, 2000). For more complex tasks, risk assessment may involve setting up a workshop of all interested parties (police, emergency services etc) to identify and assess (eg Ford, 2000) a full range of hazards affecting the operation. Use of computer-based risk modelling techniques may be required for decisions on managing the more critical hazards. PIARC/OECD are to make available software for quantitative risk analysis and decision support for the passage primarily of dangerous goods transport through tunnels, (http://www.aipcr.lcpc.fr/index.html, and http://www.oecd.org). The software can be used equally well for non-dangerous goods transport.

Maintenance Planning and Schedules

3.56 Maintenance schedules should be developed from the information contained in tunnel documentation, notably manufacturers' recommendations. Taken together these requirements form the basis of the planned maintenance activities throughout each year.

3.57 It is essential that the planned maintenance workload is evenly distributed throughout the year to make the best use of, and minimise, tunnel closures. This should reduce disruption to traffic and the costs associated with each tunnel closure.

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

3.59 Planning of maintenance tasks may be constrained by factors such as the availability of access time, physical access limitations, proximity working limitations etc. Planned maintenance carried out in tunnel service buildings may be scheduled outside the tunnel closure programme but should still be included into the overall maintenance schedule. Examples of maintenance schedules and a typical tunnel closure programme are shown in Appendices D and E.

3.60 Before each tunnel closure, the maintenance schedules, any necessary but unplanned maintenance works and the availability of spares and consumables should be reviewed at a meeting of all parties involved. Any necessary deviations from traffic management plans should be identified. The safety implications of the programmed maintenance and traffic management works should be reviewed and any new hazards identified and subjected to a risk assessment. Such meetings should be recorded and the minutes should form part of the activity record.

3.61 On completion of the tunnel closure, the maintenance activities should be reviewed in a similar manner. Any faults or incipient problems not rectified should be recorded and scheduled for future action. Relevant historical data should be collated (see BD53 (DMRB 3.1.6)) and analysed for planned maintenance improvements.

Forms of Contract

3.62 Planned maintenance of assets often 'peaks' at regular intervals. The TOA should consider whether to cope with these 'peaks' of activity by using contractors. This will be influenced by the availability of specialised maintenance personnel and organisations.

3.63 "First line" maintenance or breakdown maintenance may best be provided by a dedicated resource employed by the TOA. This would be available on a 24-hour basis to provide assistance for emergencies and other incidents and may help to maintain engineering standards.

3.64 For new equipment, the manufacturer or installer may provide effective "second line" maintenance cover. This cover may only be available under the terms of the 12 month defect liability period or a separate contract.

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3.65 The choice of contractor may be restricted for technical reasons. For example, maintenance of proprietary software may only be possible by the code supplier, or only limited numbers of contractors may have the necessary expertise or equipment for maintenance.

Service Level Agreements

3.66 Service level agreements are an effective tool for managing the delivery of service to achieve specific standards of performance. Such agreements seek to guarantee the availability of appropriate resources and timely delivery of a quality service.

3.67 The TOA will operate under a service level agreement with the MA/Overseeing Organisation. In addition the TOA will implement, usually through the TMC, service level agreements with maintenance suppliers to, for example, categorise call-out response times in the event of equipment failures and to put in place tools, equipment and spares to facilitate immediate rectification. Service level agreements will also apply to routine maintenance activities such as tunnel washing, equipment calibration, etc.

Works Instructions Manual

3.68 A works instruction manual is used to clearly define the procedures to be followed in the implementation of the maintenance strategy and other works within the tunnel confines. These procedures are prepared by the MA/TOA for the implementation of current best practice and for fulfilling their legal and contractual obligations.

3.69 Such procedures should, for example, provide the robust and effective approach to the management of safety as required by CDM Regulations. During typical tunnel maintenance activities the tunnel would be defined as a temporary site, in accordance with the Temporary Sites Directive.

Condition Assessment and Prioritisation

3.70 The programme of inspections and servicing should identify the routine maintenance, repair and renewal required, to enable efficient programming of the work and to make timely application for funds.

3.71 It is good practice in preventative maintenance to carry out visual inspection and simple testing where convenient during routine maintenance. For example testing of insulation resistance may reveal deterioration due to overheating or contamination and enable remedial action to be taken on a planned basis before complete failure occurs.

3.72 Defects that are identified as a result of inspections or servicing should be categorised for priority. Prompt attention should be given to defects that present an immediate or imminent risk. If there is a risk of short-term deterioration, procedures for emergency maintenance should be followed. Other defects should be assigned priority for repair within planned programmes of work.

3.73 Prioritisation is strongly linked to risk analysis, safety considerations and value engineering, as well as funding constraints. Some guidance is given in Atkinson (1997).

Value for Money

3.74 In order to achieve quality and value for money, the procedures in the VFMM should be followed during the planning and design stages of new tunnels and major capital maintenance. The implications and provision for operation and maintenance should be fully considered in relation to capital works at each Benchmarking, Value Management, Estimating, Risk Analysis and Value Engineering review stage. Consideration of whole life cost is an important part of this process.

3.75 The TOA of an existing tunnel should also follow the procedures in the VFMM. Further information on the application of Value Management and Value Engineering principles, respectively, in the context of road tunnels is given in Bird et al (2000) and Evans et al (2000).

Spares and Stock Control

3.76 An adequate, but not excessive, stock of spares and consumables should be retained to enable the TOA to undertake planned and emergency maintenance works. Consideration should be given to rate of stock use, re-order levels, quantities and lead-time. In order to reduce expenditure and storage space, consistent with operational requirements, consideration should be given to storage off site, eg parts to be supplied by contractors or agreements with manufacturers for rapid delivery. However, for older equipment the possibility of spares no longer being available should be kept under review, and consideration given to increasing the stock of spares.

3.77 The store should be located close to the tunnel and provide a suitable environment to avoid any

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equipment damage or deterioration. This particularly applies in the case of computer hardware and electronic components. The store premises should be maintained safe and secure in use.

3.78 The store should have a stock control system, preferably computerised, for assessing availability, locating and retrieving stock. Procedures should be developed for inspection, testing and handling of equipment.

Corrective Maintenance Procedures

3.79 Effective procedures should be developed for correcting and recording all potential equipment failure or damage. Procedures should be in place at all times in an operational tunnel, in order that the necessary corrective or emergency maintenance may be implemented immediately. Reference should also be made to TRMM Volume 2, Part 1 regarding general highway emergency procedures.

3.80 In developing procedures, risk assessment should be undertaken to assess the potential emergencies taking into account such factors as:

i. time scale of an emergency from initial assessment to completion of repairs;

ii. the potential effects of equipment failures on safety and traffic flow though the tunnel;

iii. whether the tunnel can remain operational while the fault or failure is rectified;

iv. location of affected equipment, eg roof, traffic space, pavement, ducts, etc.

3.81 Procedures may vary depending on whether the tunnel is manned or unmanned and the proportion of maintenance undertaken by contractors. Indeed, decisions about such arrangements depend on their suitability for corrective maintenance. The following general principles apply.

3.82 Operating staff should have clear guidelines for call-out of maintenance staff and the action to be taken in the event of faults, eg whether a lane closure or bore closure is required.

3.83 Faults normally require direct inspection and assessment by maintenance staff available on a 24-hour basis. Increasingly equipment may 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.

3.84 Guidelines should be in place about necessary response time for each category of defect, eg those that require immediate attention, those that can be left until the next working shift or the next routine maintenance. In providing guidelines, the implications of non-availability of equipment and other tunnel assets should be taken into account. For example, the percentage of operational fans that is required to meet the design criteria for ventilation, and numbers of luminaires that can fail before the lighting system requires emergency maintenance. This should minimise the number of emergency interventions between planned maintenance activities.

3.85 Maintenance staff who inspect faults should have a good understanding of all equipment, control systems and safe working practices so that they might either effect simple repairs themselves or rapidly make an accurate assessment of the need for more extensive repairs. Access arrangements to equipment should be established and tested.

3.86 Spares should be available to suit the required repair response times. They should be certified as fit for use, particularly after being away for repair.

3.87 Procedures should include recording of faults and repairs carried out, as well as any fault not repaired immediately.

Obsolescence

3.88 Equipment may become obsolete when spares are no longer available or improved equipment is available that may offer savings in running or maintenance costs. Decisions to replace equipment should be taken after considering future discounted costs of capital replacement, running, maintenance and spares.

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4. INSPECTION AND SERVICING CATEGORIES

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General

4.1 Categories of inspection and servicing standards are given in TRMM Volume 2, Part 1 for highways in general and BD53 (DMRB 3.1.6) specifically for road tunnels. The requirements are discussed below in the context of their application to road tunnels. For most effective results, each type of inspection should be conducted separately.

Safety Inspections

4.2 Safety Inspections are defined in TRMM Volume 2. In road tunnels, they are regular visual inspections designed to identify defects that are likely to create a danger to the public or staff or lead to unnecessarily high maintenance costs or disruption to traffic. Such defects may include:

i. collision damage and debris;

ii. water seepage;

iii. ice formation;

iv. spalling concrete;

v. loose, missing or defective equipment, panels, signals and controls;

vi. oil spill or accumulation of dripped oil and/or debris posing a fire risk.

4.3 The scope of Safety Inspections will depend on whether the tunnel is manned or unmanned and what tunnel informational systems exist and how they are monitored. For all cases, a Safety Inspection from a slow moving vehicle or on foot, as appropriate, should be carried out at intervals determined following risk assessments, but not less often than monthly. Where monitoring equipment does not provide complete coverage, it may be necessary to carry out Safety Inspections on a daily basis.

Ad-hoc, Superficial Inspections

4.4 Superficial ("on the surface only") Inspections are defined in BD53 (DMRB 3.1.6) and are ad-hoc, informal inspections for obvious defects. These inspections should be carried out as an "ongoing responsibility" by TOA staff whenever they are at the tunnel. Although informal, keeping basic records of such inspections is recommended (see Chapters 2 and 3).

Detailed Inspections

4.5 Detailed Inspections are defined in TRMM Volume 2. They are designed to establish programmes of routine maintenance tasks not requiring urgent execution and are of particular relevance to highway items. Guidance on Detailed Inspections is set out in Chapter 6. Specific requirements for inspection may also be contained in the tunnel documentation catering for tunnel specific needs.

Cleaning, Inspection, Servicing and Testing

4.6 In the case of many items of mechanical and electrical (M&E) equipment, Detailed Inspections are not specifically suggested because that objective should be accomplished during routine servicing.

4.7 General guidance on equipment maintenance for the purpose of planning and review is set out in Chapters 5 to 15; but that contained in tunnel documentation should normally take priority. Each tunnel has unique conditions of traffic, general environment and equipment level and use. Therefore, the necessary maintenance should be determined in the first instance by the designer, taking account of manufacturers' recommendations and the requirements of the IEE wiring regulations (BS 7671), set out in tunnel documentation, and subsequently reviewed in operation by the TOA (see Chapter 3).

General Inspection

4.8 General Inspections are defined in BD53 (DMRB 3.1.6) and comprise a thorough visual inspection of representative parts of the road tunnel. General Inspections of tunnel structures should be carried out at intervals of 2 years. General Inspections of M&E equipment and a functional check of all emergency and essential systems should be carried out at intervals of one year. No General Inspection is necessary when a Principal Inspection is being carried out.

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Principal Inspection

4.9 Principal Inspections are defined in BD53 (DMRB 3.1.6) and comprise a close and detailed examination of all accessible parts of the tunnel. Principal Inspections of tunnel structures should be carried out at intervals not exceeding 6 years. Principal Inspections of M&E equipment and an emergency drill of functions should be carried out at intervals not exceeding 3 years. With the agreement of the Overseeing Organisation these intervals may, in exceptional cases, be extended upwards to a limit of 10 years and 5 years respectively. It should be noted that periodic inspection and testing of electrical installations should also be in accordance with BS 7671, normally at intervals not exceeding five years, and less for certain items. The TOA should consider the co-ordination of BS 7671 inspection and testing with Principal Inspections.

Special Inspections

4.10 Special Inspections are defined in BD53 (DMRB 3.1.6) and comprise a close examination of a particular area or defect of special concern.

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5. TUNNEL STRUCTURE CLEANING

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General

5.1 This Chapter provides an overview of the cleaning requirements for the tunnel structure. Other Chapters give cleaning advice for specific items that should also be considered when planning tunnel-cleaning operations.

Purpose

5.2 Cleaning of the tunnel structure (including any cladding systems) is principally necessary to maintain the required level of light reflectance from the tunnel walls. Maintaining the required reflectance enhances safety and reduces the energy consumption of the lighting system. Cleaning of the structure may also reduce the risk of surface structure and fire damage through the removal of corrosive, toxic and flammable deposits and may offer other operational benefits, for example to ease inspection and maintenance operations. Additionally maintaining the tunnel structure in a clean condition creates a favourable and comforting impression for the road user.

Frequency

5.3 Surfaces which are required to have a high reflectance (normally the lower, lightly coloured, part of the tunnel walls, especially at the portals) should be cleaned sufficiently frequently to ensure that the required luminance is achieved at all times without the need for excessive lighting provision. 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. Weather also influences cleaning requirements, for example, a tunnel can become very dirty within 24 hours if approach roads are salted. It may also be influenced by other factors such as any leakage through and staining of the tunnel structure.

5.4 The optimum cleaning frequency for a particular tunnel structure should be established by recorded trials (note that different cleaning frequencies may be tested in different parts of a tunnel in order to determine the optimum frequency). As an indication, it may be helpful to note that cleaning four times per year is typical for some tunnels on UK trunk roads.

5.5 Other parts of the tunnel where high reflectance is not required (notably the tunnel crown) may be cleaned if excessive build up of deposits is observed during routine inspections. Such deposits may be considered excessive if there is a significant risk of detritus falling onto the carriageway or if there is considered to be a fire hazard, for example if dust builds up or if oil is present. Additionally, cleaning of these areas may be appropriate if their condition is such that personnel or equipment are at risk of significant soiling during other maintenance works - leading to inefficient maintenance.

5.6 Cleaning requirements for specific items of equipment may be scheduled separately to general structure cleaning and should be described within the specific maintenance requirements for those items.

Scheduling

5.7 Individual tunnel cleaning operations should normally be scheduled immediately before any other in-tunnel maintenance operations. As such, tunnel cleaning should usually form the first major activity during a maintenance closure of the tunnel.

5.8 Cleaning should not be carried out if freezing conditions are likely to occur in the tunnel. It should be noted ventilation in damp conditions could cause temperatures to fall below ambient due to latent heat losses and allowances should be made for this phenomenon.

Traffic Management and Precautions

5.9 Because of the processes involved, tunnel cleaning will normally take place during a tunnel closure. Additionally it may be judged prudent to exclude other maintenance personnel from the area in which cleaning operations are taking place. This is because of the possible hazards arising from low visibility and high noise around a jet washing operation and also to avoid unnecessary exposure to any detergents or other chemicals used in the cleaning process.

5.10 Consideration may need to be given to protecting CO, visibility and other sensors, emergency distribution panels etc from the effects of spray and run-off and to the isolation of fans.

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Processes

5.11 The optimum cleaning process for a tunnel structure may vary to some extent between tunnels according to the nature of the deposits which should be removed from the structure. It may also depend on the nature of the structure itself, the lining and fixing materials, and in particular, any surface finishes which have been used. For example, some types of paint used in tunnels have been found to be vulnerable to damage by high pressure water jetting. Advice should be sought from the manufacturers of paints and claddings on appropriate cleaning techniques.

5.12 In general, the optimum process will normally involve a combination of pressure washing with detergents and brushing using vehicle mounted systems. A typical 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 may be used to scrub the lining and a third pass with water under pressure to rinse the lining.

Materials

5.13 Optimum choice of detergent may be site specific due to the differing nature of the deposits to be removed. COSHH and other relevant regulations should be considered during the selection of materials. Consideration should also be given to any corrosive or other long-term detrimental effect that the cleaning process and materials may have on tunnel linings, fittings and equipment. Additionally, detergent choices are commonly contractor specific and confidential for commercial reasons.

5.14 It is therefore likely that optimum results may be achieved with a performance specification for tunnel cleaning rather than precise specification of the detergents and methods to be used.

5.15 Consideration should be given to environmental issues during selection of detergents or other materials to be used in tunnel cleaning. Appropriate consents should be obtained before any discharges to sewers.

5.16 Consideration should also be given to the health and safety of the workforce and wherever possible materials which present a risk to the workforce should be avoided.

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6. STRUCTURE MAINTENANCE

General

6.1 This Chapter describes routine maintenance, inspection, testing and repairs as applicable to road tunnel structures.

Tunnel Lining

Description of Typical Structure and Access Arrangements

6.2 The purpose of the tunnel lining is to support the surrounding ground, exclude ground water and provide support for any cladding and equipment. The structural lining typically is composed of concrete, that may be reinforced or unreinforced, in situ, sprayed, segmental, or cut and cover tunnels constructed with diaphragm or piled walls. Items such as steel arches and ground anchors may be built in. Other forms of construction include cast iron or composite steel and concrete segments.

6.3 Access by platform is necessary to the upper parts of tunnel walls and the roof.

Asbestos

6.4 In some tunnels, particularly those with segmental linings constructed before about 1970, asbestos may have been used in the caulking rope between segments. Asbestos cement was sometimes used to form precast air ducting formers. In even older tunnels, asbestos may have been used for 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 may 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 may disturb fibres more readily.

6.5 Both specialist removal and encapsulation have been used to treat asbestos found in older tunnels. Where the presence of asbestos is thought to be a possibility, the advice of the Overseeing Organisation should be sought without delay. Health and Safety Executive, Guidance Note EH40: Occupational Exposure Limits (updated annually) gives guidance.

Cleaning

6.6 Cleaning of the structural lining should be in accordance with the guidance given in Chapter 5.

Inspection

6.7 Except at Principal Inspections, inspection will normally only be possible for exposed parts of the lining. Such areas should be visually inspected as part of the normal structural inspection regime described in Chapter 4 and BD53 (DMRB 3.1.6).

6.8 A surface inspection, by an Engineer, should be made during every scheduled tunnel closure, to identify any obvious defects with the structural lining. Such defects might include collision damage, staining, water seepage, ice or stalactite formation, joint sealant failure, spalling or cracking. Particular attention should be paid to any defects which have become apparent since the previous inspection and which do not have an obvious cause.

Routine Maintenance

6.9 Routine maintenance does not include the repair or renewal of structural elements. Such work should be identified during the regular inspection process, and should be included in a planned structural maintenance programme.

6.10 Typical routine maintenance requirements, for which the maintenance interval should be 12 months, are given below. Additional requirements for complex components should be specified in the tunnel documentation.

i. remove any remaining graffiti (for best results graffiti should be removed as soon as possible);

ii. clean and rod through any ground water drainage system. However, if there is a risk of an unplanned build up of water pressure against the structural lining, drainage cleaning should be more frequent;

iii. remove debris from movement joint seals;

iv. repair gap sealant to movement joints;

v. clear any debris from bearing shelves.

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Testing

6.11 Testing is not normally required except when instrumentation for long-term structural monitoring has been installed. Such instrumentation should be monitored in accordance with the requirements of the tunnel documentation. Other testing work, such as ultrasonic or ground radar inspection may occasionally be required but is beyond the scope of this Advice Note.

Tunnel Cladding

Description of Typical Structure and Access Arrangements

6.12 Cladding will normally consist of a panelling system and supporting framework of ribs or rails that is attached to the structural lining.

6.13 The purpose of cladding is to provide a smooth surface for light reflectivity, reduced ventilation flow friction, and easy cleaning where this is not achieved by the structural lining. Cladding is also used to improve the appearance of the tunnel to the user and prevent water leakage appearing on the intrados or damaging operational equipment and supply cables.

6.14 Access by platform is necessary to the upper parts of tunnel walls and the roof.

Cleaning

6.15 Cladding should be regularly washed to maintain the required level of luminance within the tunnel during operation. The required frequency of washing will be site specific and dependent on operational conditions and should be determined during the early operational life of the tunnel as described in Chapter 5.

Inspection

6.16 A surface inspection by an Engineer should be made during every scheduled tunnel closure to identify areas of impact damage or other deterioration.

6.17 During every scheduled tunnel closure, the visible parts of the cladding drainage system should be inspected to identify any blockages, leakages or excessive accumulation of debris.

6.18 At least once per year, a representative sample of any exposed fixings should be checked to ensure their integrity.

6.19 At the time of every Principal Inspection, a fully representative sample of panel mounting system elements should be inspected.

Routine Maintenance

6.20 Any requirements for routine maintenance and repair should be specified in the tunnel documentation.

Portal Structures

Description of Typical Structure and Access Arrangements

6.21 Most immersed tube and bored tunnels have some form of portal structure, usually of a cut-and-cover nature, which is distinct from the internal tunnel structure.

6.22 Other elements associated with the portal may be wing-walls, retaining walls, fascias and parapets. Access by platform may be necessary to the upper parts of portal walls and the roof, however additional access may be available to carry out inspection to the outside of the structure whilst the tunnel is operational.

6.23 The portal structures may include darker surrounds, extended fascias and vegetation to assist adaptation of drivers' eyes to the tunnel interior. The portal structures may also include daylight screens.

Cleaning

6.24 Cleaning will normally only be necessary on the inside of the portal structure and will normally be similar to the cleaning applied to the internal tunnel section.

6.25 Where the effectiveness of daylight screens depends on cleaning, this should be carried out at intervals determined by experience.

Inspection

6.26 Inspection procedures should follow those for structural linings as described above.

6.27 Louvres in screens usually have slender rib construction and are vulnerable to corrosion and other forms of surface deterioration.

Routine Maintenance

6.28 Routine maintenance does not cover the repair or renewal of structural elements.

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6.29 Reference should be made to the routine maintenance requirements for Retaining Walls and Bridge Substructures in the TRMM Volume 2. Additional requirements for complex components should be specified in the tunnel documentation.

Testing

6.30 Testing is not normally required.

Structural Concrete

6.31 Concrete structures including tunnel linings, portal structures, suspended road deck slabs and their sub structures should be inspected and maintained as described in the Design Manual for Roads and Bridges.

6.32 Particular reference should be made to BA35 (DMRB 3.3.2) and BD27 (DMRB 2.3.2). However, both documents are under review and in particular the specification for repairs and related materials has been superseded by updated documents used on a scheme specific basis. Improved specifications are available. They will be published as separate documents.

6.33 The inspection of tunnel structures should generally be carried out in accordance with the Bridge Inspection Guide (HMSO 1983). This is currently being updated and expanded and will be reissued in the form of a Bridge Inspection Manual, split into six separate volumes. Volume 1 covering 'General Procedures' and Volume 2 dealing with 'Concrete Bridges and Concrete Elements' are likely to be most relevant to tunnels.

6.34 These documents describe typical defects to be found in concrete structures and deterioration mechanisms. They also provide information on the scope and nature of appropriate inspection regimes and testing requirements.

6.35 Impregnation of concrete by a hydrophobic material inhibits the ingress of water and chloride ions. Advice on the criteria and specification for impregnation of concrete using a hydrophobic material such as silane is given in BD43 (DMRB 2.4.2) and BA33 (DMRB 2.4.2).

6.36 Advice on painting of concrete is given in BE8/75 (DMRB 2.4.2). This advises that painting is generally not recommended, as it presents maintenance liabilities, may become poor in appearance and causes difficulties in inspecting any underlying defects in the concrete substrate. However, where there are special considerations such as on the approach walls and within tunnels, there may be overriding engineering reasons to utilise coatings. Specialist advice will be required when specifying and selecting coatings, particularly in terms of reflectance properties and as regards avoiding dirt retention.

6.37 Consideration should be given to developing a management strategy for all tunnel structures, embracing inspection, testing, structural assessment based on whole life principles, identification of defects and the determination of the cause of the deterioration and remedial measures where required.

Waterproofing and Surfacing Deck Slabs

6.38 The need to minimise disruption to traffic may have a significant effect on the maintenance of deck slabs in tunnels. Major concrete repairs and the re-waterproofing of existing structures may require overnight lane closures. If time constraints are severe, it may be necessary to install preformed replacement deck slabs which have been waterproofed and overlaid with a layer of surfacing (eg Dartford East and West Tunnels). The removal of the existing deck, the positioning of new slabs, overlaid with the wearing course and the expansion joints and bearings may be carried out during overnight lane closures.

6.39 Deck slabs should normally be waterproofed and surfaced in accordance with BD47 (DMRB 2.3.4) and BA47 (DMRB 2.3.5).

6.40 When replacement slabs are waterproofed, the deck waterproofing system or an alternative registered waterproofing system should be applied to the end faces to prevent damage, should the expansion joints leak.

6.41 When existing slabs are to be re-waterproofed, sufficient time should be made available to prepare the slabs and complete the installation satisfactorily.

6.42 As much as possible of the old surfacing and waterproofing system should be removed carefully to prevent damage to the slab. Any material, which remains on the deck, should be checked to ensure that it is compatible with the new system.

6.43 Testing for chloride damage should be carried out where the old waterproofing system has leaked and near leaking expansion or any other joints to identify the risk of reinforcement corrosion.

6.44 Existing deck slabs may not have an MCHW, U4 finish. In such cases, either a surface finish, which is suitable for the waterproofing system, or a

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waterproofing system, which is suitable for the surface finish, should be provided.

6.45 Spray or liquid applied systems may be applied to any sound, void free surface. However, the thickness of the membrane should be monitored and the effect of irregularities in the surface on sub-surface drainage should be assessed. If the thickness of the membrane at high points is much greater than 2 mm, its flexure under wheel loading may impair the performance of the surfacing. If water infiltrates the surfacing and accumulates on the membrane at low points, hydrostatic pressures generated by wheel loading may weaken the surfacing and its bond to the membrane.

6.46 Spray or liquid applied systems are the most suitable for phased construction as there are no restrictions on the width of the installation. Also, spray applied systems may be installed more rapidly over large areas. However, time must be allowed for curing.

6.47 Noxious fumes may build up in tunnels when spray or liquid applied systems are being applied and are curing. Therefore, health and safety measures will be required to prevent asphyxiation and fire hazards. Particular attention should be paid to confined spaces, such as under-deck slabs. Whereas, the build-up of fumes may be controlled by ventilation in short tunnels, unnecessary access by site staff and road users should be prevented during application and curing in long tunnels. Any ventilation used during application should minimise the local dispersal of the sprayed materials.

6.48 The lowest areas of deck slabs should be waterproofed first. The installation of the waterproofing system should be completed as quickly as possible to prevent contamination of the different layers, but sufficient time should be allowed for materials to cure. Particular care is needed to prevent defects when making overlaps during phased construction. Leak detection equipment may be used to locate pinholes and defects at joints or overlaps. Care in detailing joints is required and advice from manufacturers of the materials should be sought.

6.49 The bituminous mixture directly overlaying the waterproofing system should be laid and rolled at a temperature which is high enough to achieve a good bond (eg by activating the tack coat) and to achieve satisfactory compaction, but not so high as to damage the waterproofing system. The minimum and maximum temperatures should be obtained from the supplier of the waterproofing system and the tack coat supplier. Allowance should be made for the enhanced cooling effect of any mechanical or natural ventilation.

6.50 The surfacing in tunnels may be less than the 120 mm minimum specified in BD47 (DMRB 2.3.4). See also BD78 (DMRB 2.2.9). As the surfacing thickness is reduced, the forces generated by trafficking at the interface between the surfacing and the waterproofing systems increase. In such cases proven alternatives should be considered subject to approval by the Overseeing Organisation.

6.51 The contact area between the mixture directly overlaying the waterproofing system and the waterproofing system itself should be high in order to maximise the initial bond strength and minimise its deterioration in service. Problems are most likely to occur if the red sand asphalt protection layer that is specified for bridge decks in BD47 (DMRB 2.3.4) is either poorly compacted, or omitted so that the mixture overlaying the waterproofing system contains large aggregates and reduces the contact area. In extreme cases, mastic asphalt should directly overlay the waterproofing system, but note that mastic asphalt complying with BS 1447: 1988 is unacceptable as the waterproofing system.

6.52 Generally, the amount of water entering the surfacing in tunnels will be low if surface water is prevented from flowing along the deck slabs. If this is not the case, cracks and defects in the wearing course should be sealed and adequate falls should be provided to prevent water accumulating on the surfacing. Sub-surface drainage should be provided at low points where water may accumulate within the surfacing at the interface with the waterproofing system.

6.53 The wearing course should be designed according to Clauses 942 or 943 of the Specification for Highways Works (MCHW1). Although surfacing in tunnels is not exposed to solar radiation, increased rutting may occur in tunnels with narrow lanes.

Expansion joints

6.54 Expansion joints with Departmental Registration should be installed in accordance with BD33 (DMRB 2.3.6) and BA26 (DMRB 2.3.7) to accommodate movements and rotations at deck ends and provide an acceptable running surface. The number of expansion joints should be kept to a minimum, to reduce problems of leakage.

6.55 Measures should be taken to prevent any leakage from expansion joints from reaching vulnerable parts of the structure by applying protective coatings, and installing drainage channels below joints. The need for

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this will depend on the provision of surface and sub-surface water drainage systems within the tunnel.

6.56 The service lives of expansion joints vary according to their type. Further details on the various types available and their advantages and disadvantages are given in TRL Application Guide 29 (Barnard and Cuninghame, 1997). To determine the type most suitable for each application, the whole-life cost of different types should be estimated taking into account traffic delay costs.

6.57 Health and safety measures should be taken to prevent the build up of noxious fumes when joints are installed.

Expansion Joints and Covers in Immersed Tube Tunnels

Description of Typical Structure and Access Arrangements

6.58 Immersed tube tunnels comprise opposing portal structures linked by immersed preformed tunnel elements. A short closure joint is used to make the final connection between the last element to be positioned and the corresponding portal structure or between the two last tunnel elements placed.

6.59 Reinforced concrete tunnel elements are often made up of two or more segments, but can be of a single monolithic unit. Segment jointing systems vary, but usually a continuous loop, grout-injected, water-bar is cast into the segments across the match cast joint. This joint is inaccessible and is protected by a dust and/or fire resistant seal (eg fire rope) formed at the internal joint surface.

6.60 Typically, continuous loop Gina and Omega rubber seals are used at the element joint. The Gina seal forms the initial watertight joint between successive elements and at the connection to the portal structure. The Omega seal provides a second inner watertight seal, which is mounted once the immersion joint has been dewatered. Both the Gina and Omega seals are designed to operate under hydrostatic pressure and to accommodate thermal movement. A fire resistant steel plate or reinforced concrete infill panel is used to provide fire protection to the element joint. Concrete panels are provided with fireproof/dust seals and joint filler material. Some tunnels are fitted with drainage channels or pipework at the joints to enable inspection for leakage and to allow leakage water to be drained.

6.61 All of the jointing systems are essentially non-replaceable and maintenance free. However, the fire resistant joint covers, fire ropes and/or other forms of joint protection may require routine inspection and maintenance, where they are accessible, ie where not covered over by ballast concrete, road surfacing etc.

6.62 Access by platform may be necessary to joints in the upper parts of tunnel walls and roof.

Maintenance

6.63 As the jointing systems are designed to be non-replaceable the dust and fire protection systems are vital to their preservation. There should be no routine need to remove joint covers, fire ropes etc. Nor do the covers require specific cleaning or inspections. However, for example, annual service of the joint covers may include testing of 25% of the screws for tightness and replacement of damaged fixings. If drainage or leakage facilities are provided, inspection should be carried out on an annual basis which will require removal of the joint cover plates.

Brickwork

Inspection and Testing

6.64 Periodic inspection is necessary to provide an early indication of problems that may arise. The interval of the inspection should be based on the current state, condition and the severity of the defect and the probability and consequences of the defect leading to failure.

6.65 Much of the data required can be obtained by means of visual inspection at touching distance. Other methods may require a specialist and may include: acoustic emission; radar; hammer tapping; ultrasonic pulse; sonic pulse; thermography; borescope and endoscope; vibration monitoring. It may also be necessary to remove and test sections to determine the strength. Further information is given in TRL Report 204 (Page J, 1996).

6.66 General inspection and loading tests used for arch bridges which may also apply to brickwork in tunnels, are given in BD21 (DMRB 3.4.3) and BA16 (DMRB 3.4.4).

Repairs

6.67 There are a number of techniques that can be used to repair deteriorating brickwork structures. Further information can be obtained from TRL Report

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204 (Page, 1996) although not all techniques will be appropriate for use in tunnels.

6.68 Repair techniques involving the use of retrofitted or near-surface reinforcement are available for consideration (Sumon, 1998). Although further research is required to investigate fully their merits and limitations, the results seem generally promising and their use may be appropriate.

6.69 Local mesh repairs can be carried out to prevent small areas of loose bricks falling out. This should be considered only as a temporary measure until permanent work can be undertaken.

6.70 Other short-term improvement measures include the improvement of drainage to the surrounding fill. This involves the drilling of weep holes through the brickwork. However, the excess water should be routed to a controlled drainage area and not to another part of the tunnel. Special measures may be required if solids are brought into the tunnel with the drainage water.

Drainage Sump Structures

6.71 One or more sumps will be provided for a pumped drainage system where tunnel construction does not facilitate gravity drainage.

6.72 Sumps are normally constructed from reinforced concrete and may be located beneath or preferably beside the carriageway, both within the tunnel and at the tunnel portals.

6.73 Traffic management may be required for access depending on the location of the sump. Since the sumps are often confined spaces, an access procedure, which complies with the Confined Spaces Regulations, 1997, is necessary.

6.74 Maintenance of pumps, associated equipment and pipework is described in Chapter 9.

Cleaning

6.75 Accumulation of silt and other material in the sumps should be removed at intervals established by experience. Factors such as the weather (winter salting on approach roads) and the effectiveness of gully traps influence the rate of accumulation. Special arrangements may be required after a spillage.

Inspection

6.76 Inspection will normally only be possible for exposed parts of the structure. Such areas should be visually inspected as part of the normal structural inspection regime described in Chapter 4 and BD53 (DMRB 3.1.6).

6.77 A surface inspection should be made, during every scheduled pumping equipment maintenance operation, to identify any accumulation of silt and obvious defects to the sump lining. Such defects might include joint sealant failure, spalling or cracking.

6.78 During Principal Inspections, the sump should be emptied to enable close examination of submerged elements.

Pavement Maintenance

6.79 Reference should be made to the TRMM Volume 1 for requirements for pavement maintenance. Assessment includes, as appropriate:

i. High Speed Road Monitor (HRM) surveys;

ii. CHART Surveys on flexible and bituminous pavements;

iii. Visual Condition Surveys (VCS) on concrete surfaced pavements;

iv. Deflectograph Surveys on flexible carriageways, including those with lean concrete roadbases;

v. SCRIM Surveys.

6.80 Inspections, surveys and any maintenance work should be co-ordinated as fully as possible with other maintenance activities in the tunnel and adjacent road network.

Routine Highway Maintenance (Tunnel and Approaches)

General

6.81 Routine highway maintenance of the tunnel carriageway and its approaches covers such items as: minor carriageway repairs, footways and cycle tracks, covers and gratings, kerbs, highway drainage, gullies, safety fences and barriers, road studs, road markings, and road traffic signs and signals.

6.82 Reference should be made to TRMM Volume 2 for guidance on routine maintenance of highway items. The requirements should be followed where applicable except as described in the following sections.

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Cleaning

6.83 Gullies should be emptied at intervals established by experience. The frequency should be sufficient to ensure that solids do not enter the drainage system. It should be realised that some tunnels have very shallow gullies. Where the drainage is by pumping, the regular cleaning of the traps is essential to protect the pumping equipment.

6.84 Portal cross drains require checking and cleaning at intervals determined by experience and the availability of access.

6.85 General sweeping, cleansing and litter clearing should be co-ordinated as fully as possible with wall washing.

6.86 Silt and other solids arising from emptying and cleansing operations pose a potential threat of pollution and should be disposed of in an appropriate manner, preferably to licensed tips.

Inspection

6.87 Intervals for detailed inspection should be in accordance with those in the TRMM Volume 2, Table 1.1.2 and the Routine Maintenance Management System (RMMS) User Manual, Tables 3.2.1, 3.2.2 and 3.2.3 (Highways Agency, 1996) except where shown in Table 6.1.

6.88 The need for shorter (or longer) intervals should be established by experience, but should not exceed the intervals shown in the TRMM and the Routine Maintenance Management System (RMMS) User Manual. Shorter inspection intervals than on the general highway are considered necessary for some items because of the particular safety and operational requirements of tunnels, including the need to co-ordinate maintenance work with tunnel closures.

6.89 The RMMS User Manual gives guidance on items to be inspected and defects to be noted, however some may not be applicable within a tunnel.

6.90 Inspections should be co-ordinated as fully as possible with other maintenance activities in the tunnel and adjacent road network. For example, consideration should be given to carrying out inspections before tunnel closures so that any necessary repairs can be carried out effectively during the closures.

6.91 The running surfaces in tunnels should receive particular attention during inspections to check for:

i. rutting, which on gradients can prevent fuel spills entering the gullies and create a fire risk;

ii. lane centre oil drop accumulation, particularly on tunnels with lane control. This creates a skidding hazard but can be removed by pressure washing;

iii. areas where leakage drips or runs onto the carriageway. This may give rise to deposits of leachates, or ice formation in cold weather, which may locally reduce skidding resistance.

6.92 Separate drains may be provided to collect ground water from behind the tunnel lining or any cladding.

Slope and Ground Stability Adjacent to Portals

Description of Typical Structure and Access Arrangements

6.93 Some tunnels have natural or cutting slopes in the area adjacent to or above the tunnel portal. Any instability of these slopes may pose a threat to the road user and to the integrity of the portal zone of the tunnel.

6.94 Stabilisation measures that might be incorporated in the slopes and ground adjacent to the portals include surface or sub-surface drainage, ground anchors, soil-nailing or other forms of reinforced soil, crib walling and planting of vegetation.

Inspection

6.95 A visual or walkover survey of any slopes, which have the potential to threaten the tunnel, should be conducted by a competent person at intervals, typically of one year, to check for any indications of instability. Normally, the inspection should be conducted in the Spring and, where possible, the inspection should be undertaken by the same individual in successive years, as this will increase the likelihood of changes being recognised. Guidance given in HA48 (DMRB 4.1.3) should be followed as appropriate. The collection of photographic records of slope condition may also aid identification of changes at future surveys.

6.96 Where evidence of instability or potential instability is noted, it may be appropriate to increase the monitoring frequency, or if the risk of slope failure affecting the tunnel is significant, remedial slope protection works should be initiated.

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Routine Maintenance

6.97 Any remedial actions identified as necessary in the inspection should be undertaken at the earliest opportunity. Typical routine maintenance requirements, for which the maintenance interval should be 12 months, are clearing debris from rock traps, drainage ditches and filter drains, and repairing rock fences.

Testing

6.98 Periodic monitoring of any instrumentation in the slope (for example piezometers or instrumented rock anchors) should be undertaken as appropriate.

Anchors and Mechanical Supporting Systems

Description of Typical Structure and Access Arrangements

6.99 Anchors, plus fail-safe chains, are used to fix items, such as jet fans, monitoring equipment and signs to the structure. Mechanical supporting systems are used to support cladding, lighting and cabling systems and also require fixing to the structure. Failures may be from corrosion, local structural deterioration, vehicle strike or vibration. Access, via a platform, will be necessary to inspect and maintain many of these fixing and supporting systems.

Cleaning

6.100 No specific cleaning is required beyond the general cleaning of the structure.

Inspection

6.101 Visual inspection from an elevated level should be carried out at intervals typically of 3 months or during each tunnel closure, whichever is sooner. For example, luminaires are often formed of dissimilar metal to their supporting system and should be checked for galvanic corrosion and other structural deficiencies.

6.102 A detailed inspection of all fixings and supporting systems should be carried out, from an elevated level where necessary, at intervals typically of one year, or whenever access is available, whichever is sooner.

Testing

6.103 Fixings into the structure should be selected to survive their design life without requiring routine structural integrity testing. Mechanical supporting systems and fixings should be periodically tested for support strength and fixation with the structure, particularly where failure represents a safety risk. For example, at intervals typically of one year the following tests should be carried out on one-fifth of all items, such that all items are tested every 5 years:

i. torque testing of all screws and fastenings;

ii. 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;

iii. isolation checks on points vulnerable to bimetallic corrosion;

iv. testing of electrical earths.

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Table 6.1 Intervals for Detailed Inspection

Item	Suggested intervals (may be varied, but not to exceed the intervals in RMMS)
Minor Carriageway Repairs	3 months
Footways and Cycle Tracks	3 months
Covers, Gratings, Frames and Boxes	3 months
Kerbs, Edgings and Pre-formed Channels	3 months
Highway Drainage – General	Varies
Piped Drainage System	At Principal Inspections
Gullies, Catchpits and Interceptors	3 months, co-ordinate with wall cleansing
Motorway Communication Installations	Co-ordinate with other communication installations
Embankments and Cuttings	See Chapter 6 for slope and ground stability adjacent to portals
Safety Fences and Barriers	1 year
Road Studs	6 months
Road Markings	6 months
Road Traffic Signs	Signs lamp failure – as lighting see Chapter 8
Road Traffic Signals – applies to lane control signals	Variable message signs – see Chapter 11
Road Lighting	See Chapter 8
Cross passage doors	6 months
Outbuildings	12 months

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7. VENTILATION SYSTEM

General

7.1 This Chapter provides general guidance on maintenance of ventilation equipment.

Fans for Longitudinal Ventilation

Description of Typical Equipment and Access Arrangements

7.2 BD78 (DMRB 2.2.9) provides descriptions of various forms of ventilation. Forced ventilation, in its basic and most common form, is achieved by the use of jet fans mounted in the tunnel outside of the traffic space (see Figure 7.1).

7.3 Impeller diameters for jet fans vary notionally from 600 to 1500mm. Fan motor speeds and power ratings vary notionally from 3000 to 750rpm and 5 to 60kW respectively, with the larger slow speed fans being more efficient and less noisy. Acoustic silencers are fitted to either end of the fans. Most fans are designed to ventilate (thrust) in either direction according to the selected rotational direction of the motor. Fans are usually fixed in groups (or pods) to the tunnel lining with anti-vibration mountings.

7.4 Jet fans are usually accessed for maintenance using hydraulic plant. A full-bore closure is normally required. Specialist, possibly bespoke, handling equipment and tools are normally needed to install and remove fans. Most procedures will require the application of a 'Permit to Work' system. Individual fans should be electrically isolated and isolators locked-off using safety padlocks, and warning notices should be posted, where appropriate, before any work is commenced.

Cleaning

7.5 Typically, the impeller blades and the inside and outside of the silencers should be cleaned at intervals of 3 months.

Inspection

7.6 A visual inspection should be carried out at intervals typically of 3 months.

7.7 Routine observation through the Plant Monitoring and Control System will highlight equipment failures and may give an indication of the health of the fan, for example through changes in winding temperature and load current readings.

7.8 The bearing life of jet fans tends to be unrelated to hours run and is, therefore, difficult to predict. This may be the result of fans freewheeling with traffic induced air movement and/or out of tolerance vibration loads from dirty or unevenly corroded impellers. Vibration monitoring provides an indication of the mechanical condition of the fan, including bearings.

Service

7.9 Typically, a service at intervals of 6 months should include the greasing and lubrication of parts.

7.10 At intervals of approximately 5 years, fans should be removed to the factory for a complete overhaul including stripping and repainting, and the replacement of all anti-vibration mountings.

7.11 The maintenance requirements for DOL (direct on line) and Star Delta starters are similar to those required for typical electrical distribution and control equipment, see Chapter 13.

Testing

7.12 At intervals typically of 3 months, the fans should be run in both directions and checked for undue noise and vibration. Motor, impeller and blade mountings, casing and silencer joint fixings and electrical terminals should be checked to ensure they are in good order and tightened or replaced as necessary. Anti-vibration mounts, safety chain and movement proximity switches should be similarly checked and the movement detection system checked for functionality.

7.13 At intervals, typically of 12 months, the main mounting arrangements should be checked and measurements made of run and starting current, vibration and insulation resistance. Blade clearance should be checked and adjusted if necessary. Measurement of insulation resistance is not essential but is a useful diagnostic tool, which may reveal deterioration due to overheating or contamination.

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Fans for Transverse, Semi-transverse and Hybrid Systems

Description of Typical Equipment and Access Arrangements

7.14 BD78 (DMRB 2.2.9) provides descriptions for the various forms of ventilation.

7.15 Semi-transverse and fully-transverse ventilation systems require the use of axial, or centrifugal, fans mounted outside the traffic space. The same may be true for longitudinally ventilated, but the use of jet fans is more common.

7.16 In most case, these fans will be mounted in connection with supply or extract shafts and accommodated in a ventilation building accessible by a service road. Duty and standby arrangements enable fans to be maintained without tunnel closures. Most maintenance procedures will require the application of a 'Permit to Work' system.

7.17 In some cases, the airflow direction may be changed by either reversing the direction of impeller rotation or by reversing the blade pitch angle. The rotational speed of the fans may be varied through frequency inversion or a multiple pole motor with step control. Alternatively, changing the blade pitch angle may vary the airflow rate.

Cleaning

7.18 Axial etc flow fans should be cleaned at intervals typically of 3 months.

Inspection

7.19 A visual inspection for damage or deterioration of axial etc fans and fire dampers should be carried out at intervals typically of 3 months. Where expansion bellows are employed, these should be inspected for signs of deterioration and for loss of fixity.

Service

7.20 At intervals of approximately 5 years, fans should be removed to the factory for a complete overhaul including stripping and repainting. Intervals will be determined by operational history.

Testing

7.21 At intervals typically of 3 months, the fans should be run and checked for undue noise and vibration.

7.22 At intervals typically of 12 months, the bolts in mountings and impellers should be checked and tightened if necessary, the terminals should be checked and measurements made of run and starting current, vibration, electrical continuity and insulation resistance (also see earlier comment on insulation resistance). Blade clearance should be checked and adjusted if necessary.

Fan Handling Equipment

7.23 Jet fans are supported in a cradle system mounted on a trolley. An integral hydraulics scissor lift mechanism provides manoeuvrability when mounting/demounting the fan. A platform lift or other mechanism is required to raise and lower the fan in its cradle as necessary.

7.24 For some tunnels, duty and standby axial etc fans are permanently fixed, with the nominated standby fan isolated from the air stream by motorised dampers. Such fans may be orientated either horizontally or vertically. In some cases the fans are connected to the ductwork using flexible bellows. Lifting equipment is needed to remove the fans in accordance with installation specific safe working procedures.

7.25 Other tunnels have a duty and standby axial fans pair mounted on guided trolley arrangement such that the standby fan is displaced from the shaft and thereby exposed for maintenance if needed. Such equipment is of a bespoke design and motorised to enable automatic or manual swapping over of fans as needed.

7.26 Handling equipment is subject to certification under statutory law.

7.27 Inspection, maintenance and functional testing of handling equipment should be carried out in accordance with the manufacturer's recommendations. Maintenance of such equipment introduces safety issues requiring system isolation and, in some cases, tunnel closures. Most procedures will require the application of a 'Permit to Work' system.

Ductwork and Dampers

7.28 Point extraction of air with a ducted and distributed supply is common for semi-transverse systems. Fully transverse ventilation requires both distributed supply and extraction. Mostly, the ductwork is formed by the tunnel structure, such as the use of an invert void beneath the road deck in a bored tunnel, for which reference should be made to Chapter 6.

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7.29 Fabricated ductwork is often used to connect the fans with the structure, for example the top of a ventilation shaft (see Figure 7.2). Although uncommon, ductwork may also be used for forming a distributed extraction system suspended above the traffic space. In any event, most procedures will require the application of a 'Permit to Work' system.

7.30 The airflow through the distributed ventilation slots should have been adjusted to achieve an evenly distributed and balanced flow as part of the commissioning process. Mechanisms for this are often rudimentary, such as baffle plates that partially choke the air supply slot. Alternatively, adjustable dampers may have been installed providing for ease and fineness of adjustment. Once set, the flow balance is unlikely to change significantly.

7.31 Fire dampers may be used to assist in the control of the fire smoke removal under different modes of emergency operation and to isolate fans not in service enabling maintenance operations to take place.

Cleaning

7.32 The main ventilation ducts, dampers, filters and grilles require cleaning, particularly the registers in exhaust slots which can become severely restricted by dirt. Intervals should be determined by operational experience.

Inspection

7.33 Where dampers are installed, it is normal to check their operation (including the fail-safe mode) and lubricate them every 6 months.

Testing

7.34 Supply/extract ductwork systems should be tested every 3 years for even flow distribution to/from the traffic space. At the same time, flow rates into the respective distributed duct system should be tested.

7.35 The air-tightness of the ductwork system should be regularly tested and maintained as necessary, particularly where the extraction system passes through potentially occupied spaces.

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Figure 7.1: Jet Fans providing Longitudinal Ventilation

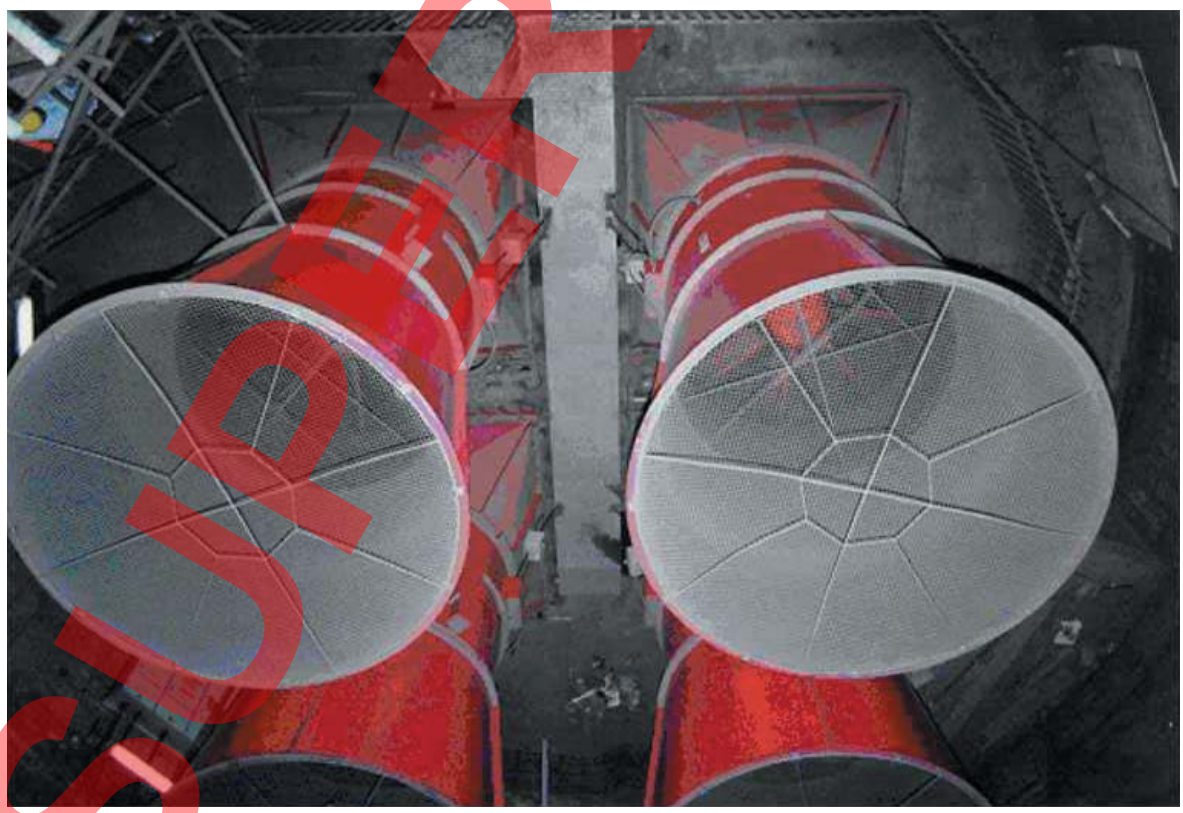

Figure 7.2: Fixed Axial Fans over Supply/Extract Shaft

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Figure 7.3: Axial Fans on Motorised Duty/Standby Trolley over Supply Shaft

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8. LIGHTING SYSTEMS

General

8.1 This Chapter provides general guidance on the maintenance of lighting equipment.

8.2 BD78 (DMRB 2.2.9) includes a section on the design of tunnel lighting. “Base lighting” distributed throughout the tunnel. Brighter “boost lighting” is afforded to the threshold and transitions zones to facilitate driver eye adjustment on entering and leaving the tunnel during hours of daylight. Lighting levels are automatically controlled according to exterior light levels.

Base Lighting Luminaires

Description of Typical Equipment and Access Arrangements

8.3 Tunnel luminaires are typically fixed to the soffit or to the upper regions of the walls. Maintenance of the luminaires requires an access platform and often a closure of the bore, as illustrated in Figure 8.1.

8.4 The base lighting luminaires are most commonly equipped with fluorescent lamps. Switching is normally provided to achieve the required changes in illumination levels. Dimming technology is advancing as a viable and improved alternative to traditional switching.

8.5 The maintenance of the base lighting luminaires should be taken to include the luminaires themselves, any dimming system and the immediate supports to the luminaires.

8.6 End-access luminaires have removable end caps that provide access for maintenance and relamping. The luminaire must first be lowered, by approximately 200 mm, by means of an integral bracket arrangement. It is not normally necessary to lower the luminaires for routine cleaning, which can be limited to the outside surfaces only.

8.7 Entry to front-access luminaires for maintenance and re-lamping is by a hinged glass front cover and is generally much easier than for the end-access luminaires.

Cleaning

8.8 Typically, the luminaires should be cleaned by washing and brushing at intervals that depend on the rate of dirt accumulation. In most cases, cleaning may most practically be achieved by the use of manual labour on a travelling access platform. The cleaning interval for a particular tunnel should be established by experience and trials – leaving short sections of lighting uncleaned and assessing the accumulation of dirt.

8.9 The optimum cleaning interval may commonly be more than the interval between wall washing, but should not normally exceed the interval required for the high pollution category in the TRMM Volume 2, Table 1.19.1, namely 12 months for an IP Rating of less than 54, and at bulk lamp change for IP 54 or greater.

8.10 Dust from cleaning should be treated as a health and safety hazard.

Inspection

8.11 Inspections from carriageway level should be carried out when all luminaires are on (normally during the day) at intervals of 14 days to detect lamp failures, and an assessment made of the need for repairs, before the next scheduled tunnel closure or relamping. Recording of lighting circuit running currents gives an early indication of lamp failure. In tunnels, it is normally acceptable for a small proportion of lamps to be inoperative.

8.12 The use of manual labour on a travelling access platform facilitates the immediate identification and repair of minor defects in the systems, during cleaning.

Relamping

8.13 The intervals for bulk lamp changes provided in the TRMM Volume 2, Table 1.19.2 should be used for initial guidance. Information on hours run should be available from modern SCADA systems. Trials may be carried out to optimise the intervals, by leaving short sections of lighting unchanged. It is normally possible to predict incipient failure because the lights tend to slowly dim rather than suddenly fail.

8.14 During re-lamping, gear-tray equipment should be inspected and tested. The sealing gaskets and clips should be replaced, if necessary.

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8.15 Although manufacturers may recommend replacement at 12 monthly intervals, use of 'tri-phosphor' tubes for base lighting has been found to increase this period to 24 months.

Service

8.16 The maintenance requirements for lighting control equipment are similar to those required for typical electrical distribution and control equipment, see Chapter 13.

Testing

8.17 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. Therefore, measurement of illuminance would not normally be recommended unless excessive deterioration in performance is suspected. If operational checks or maintenance records suggest that low or high voltage may be a cause of malfunctioning of one or more luminaires, then voltages should be monitored over a period of time to check whether they are within the manufacturer's guidelines.

Boost Lighting Luminaires

Description of Typical Equipment and Access Arrangements

8.18 The boost lighting luminaires provide additional lighting in the entrance and exit zones during daylight and are generally installed in the approximate ratio of one booster for every two base lighting luminaires.

8.19 Some tunnels may still use low-pressure sodium (SOX) lamps for boost lighting. Newer installations tend to use the higher intensity high-pressure sodium (SON) lamps that are more compact and give a longer lamp life. Typically, switching of groups of luminaires varies boost lighting levels. Dimming technology for SON lamps is advancing and is expected to improve energy usage and prolong lamp life.

8.20 Maintenance of the luminaires requires an access platform and closure of the bore.

Cleaning

8.21 Boost lighting luminaires should be cleaned at the same intervals as base lighting luminaires.

Inspection

8.22 See base lighting luminaires for inspection procedures.

Relamping

8.23 The intervals for bulk lamp changes provided in the TRMM Volume 2, Table 1.19.2 should be used for initial guidance.

8.24 In the case of the boost lighting, normal experience is that they run for only around 1000 hours/year and relatively few lamps fail in the intervals between planned maintenance. Also, leaving a few lamps that fail until the next scheduled maintenance would not normally impair the overall lighting requirement. It may, therefore, be appropriate to generally replace on a breakdown-repair basis only. Thus, the relatively few failures would be replaced during planned maintenance closures.

8.25 There may be tunnels where "hours run" meters from a SCADA system would indicate when lamp change is required. However, 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 luminaire is approaching the end of its life.

Service

8.26 At intervals typically of 12 months any failed components should be repaired or replaced in accordance with the manufacturer's instructions.

Testing

8.27 An operational check, to confirm the various stages of boost lighting switch on and off, is recommended typically at intervals of 12 months.

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Figure 8. 1: Cleaning the Luminaires

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9. DRAINAGE EQUIPMENT

General

9.1 This Chapter provides general guidance on the maintenance of drainage equipment, such as pipes, pumps and valves. Reference should also be made to Chapter 6 for maintenance of sumps and to Chapter 10 for maintenance of fire protection systems in sumps.

Pumps, Valves and Pipes

Description of Typical Equipment and Access Arrangements

9.2 Pumping systems include: cable chamber pumps, sump pumps, draw-pit pumps, interceptor chamber pumps and the valves and piping which links the system together. Some maintenance operations may require traffic management arrangements, depending on the locations in which access is required.

9.3 Most procedures will require the application of a 'Permit to Work' system. Since the sumps are normally confined spaces then an access procedure, which complies with the Confined Spaces Regulations 1997, is necessary. Removal of pumps commonly requires the use of a crane or similar lifting equipment.

9.4 Pump duty cycling is usually provided by an electro-mechanical relay. Sump level monitoring equipment may comprise float switches, or, capacitance, ultrasonic or radio frequency probes.

Inspection

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

Service

9.6 At intervals typically of 12 months, sump pumps should be removed from the sump for limited internal inspection and overhaul. In tunnels where conditions are particularly onerous, more frequent servicing may be necessary.

9.7 At intervals typically of 5 years, in accordance with the manufacturer's recommendations, sump pumps should be removed to the manufacturer's workshop for a full service and rebuild.

9.8 Sump level monitoring equipment should be cleaned, checked and lubricated in accordance with manufacturer's recommendations.

9.9 The maintenance requirements for control equipment and DOL and Star Delta starters are similar to those required for typical electrical distribution and control equipment, see Chapter 13.

Testing

9.10 All aspects of pump operation, including level control, should be tested typically at intervals of 3 months.

9.11 Valve operation should be tested at intervals typically of 3 months, although, to avoid seizure, some manufacturers recommend more frequent operation.

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10. FIRE SAFETY EQUIPMENT

General

10.1 This Chapter provides general guidance on maintenance of fire safety equipment including cross-bore doors, fire extinguishers, fire hydrants and hoses, fire mains, fire and gas detectors and automatic fire extinguishers or foam flooding systems.

Cross-Bore Doors

Description of Typical Equipment and Access Arrangements

10.2 These include doors, door opening mechanisms, emergency exit signs, alarms and beacons associated with cross-bore access. A bore closure is required for most operations associated with such equipment. Additionally, if cross-bore doors are operated during a single bore closure, particular care must be taken to prevent maintenance personnel or materials entering the live carriageway. Door opening may be detected by automatic alarms and signalling equipment, therefore procedures should be in place for their safe cancelling during maintenance work.

Cleaning

10.3 All exposed parts should be subjected to the normal tunnel wall washing processes.

Inspection

10.4 The doors should be inspected and operated during every scheduled closure, to identify damage, corrosion or other defects.

Service

10.5 Servicing should include periodic cleaning and lubrication of hinges, handles, bolts and closing mechanisms and remedial painting of doors. If door mechanisms are found to be stiff, due to corrosion and dirt ingress, then replacement with stainless steel parts may provide a possible solution. The seals of emergency exit signs should be checked and replaced if defective. Lamps, providing illumination for signs, should be replaced at intervals typically of 12 months.

Testing

10.6 During every scheduled maintenance closure a test should be carried out to check that alarms and beacons are visible and audible, to the required level. The doors themselves should open under a reasonable pressure and swing freely through their intended angle.

Fire Extinguishers

Description of Typical Equipment and Access Arrangements

10.7 Fire extinguishers are normally housed both within the tunnel service building and in the tunnel emergency panels (See Figure 10.1). The distribution and number of fire extinguishers throughout the tunnel is a function of the tunnel length and geometry. To safely remove and replace extinguishers in the tunnel a single bore closure is normally required.

Cleaning

10.8 The extinguisher should be cleaned as part of the servicing to ensure dials and instructions remain readable.

Inspection

10.9 The services of a specialised contractor are normally required. Typically, the distribution, number and type of extinguishers should be checked at intervals of 3 months, noting if any have been used or need to be refilled or replaced. If the TOA is aware that any extinguishers have been used, then they should be replaced without delay.

Service

10.10 The services of a specialised contractor are normally required. The typical requirement is servicing at intervals of 12 months, in accordance with the relevant British Standards.

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Fire Hydrants and Hoses

Description of Typical Equipment and Access Arrangements

10.11 Figure 10.2 illustrates a fire hydrant and hose reel housed in a tunnel panel. The distribution and number of hoses and hydrants throughout the tunnel is a function of the tunnel length and geometry. A single bore closure is normally required to safely access fire hydrants and hoses in the tunnel.

Cleaning

10.12 Typically, cleaning of the hydrants and hoses is not required.

Inspection

10.13 A periodic check to see if any hoses are leaking should be carried out during tunnel closures. Evidence of significant leakage from fire hydrants or hose points should be investigated at the earliest opportunity.

Service

10.14 Typically no servicing operations are required which are distinct from routine testing. Periodic replacement of hoses may be required.

Testing

10.15 Operation of the hydrants, hoses and couplers to verify the delivered pressure should be carried out at intervals typically of 3 months. This may be undertaken by the fire service or by tunnel maintenance staff depending on local circumstances. The systematic use of fire hoses and hydrants in tunnel cleaning may be an appropriate means of testing the equipment.

10.16 Testing should include: the flushing of hydrants and operation of the valve to ensure the required pressure is achieved with a blanking cap in place; and the required flow is achieved with the blanking cap removed. This testing, together with any testing of alarms associated with the hydrants, should be carried out at intervals typically of 3 months.

Fire Mains

Description of Typical Equipment and Access Arrangements

10.17 At least one fire main will be carried within the tunnel. The fire main may be a dedicated service for the tunnel or may be a mains water supply also serving third parties. Various hydrants and isolators may also be distributed at points along the tunnel. A single bore closure is normally required to safely access valves in the tunnel.

10.18 Major maintenance of the fire main, valves and hydrants which require draining of all or significant parts of the system should only be carried out during a tunnel closure.

Cleaning

10.19 No cleaning is required other than that needed to permit servicing operations.

Inspection

10.20 Typically at intervals of 3 months, valves should be inspected for signs of leakage. At intervals, typically of one year, the main should be inspected for leaks and cracks.

Service and Testing

10.21 Valves should be greased and fully operated to check for seizure, or any other problems, at intervals typically of 3 months. The whole unit should be overhauled at intervals typically of 5 years: this work is normally carried out by a contractor and not by the fire service.

10.22 The operation of pumps, trace heating, pressure switches etc associated with the fire main should be tested at intervals typically of 3 months. Insulation for frost protection should be inspected and made good as necessary at intervals typically of 12 months, prior to the cold weather season.

10.23 Where the fire main also supplies to third parties, testing may cause fine sediment to become disturbed. Water supply companies should be consulted to determine if flushing would affect supplies to third parties. Water mains supply pressure should be tested for adequacy every 12 months or at times of known low pressure supply.

10.24 The expansion chamber should be pumped out at intervals typically of one year, when any leaks or cracks should be repaired, as necessary.

10.25 If it is considered that sections of the fire main may need to be replaced or repaired, then a CCTV inspection should be undertaken to determine the extent of any remedial work.

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Fire Protection (and Gas Detection) Systems

Description of Typical Equipment and Access Arrangements

10.26 Selected rooms in tunnel service buildings, enclosed sumps and other hazardous areas are afforded fire protection (see BS 5839: Part 1: 1988) and, where appropriate, gas detection. Plant room automatic fire extinguishing systems and enclosed-sump foam flooding systems are controlled and monitored through their respective fire control panels. Condition-status and alarms are relayed to the tunnel SCADA system, as appropriate.

10.27 Figure 10.1 shows a typical tunnel panel containing nitrogen foam and sump gas-detection equipment.

10.28 Automatic gas-discharge fire-extinguisher and extraction systems are normally installed in rooms within the tunnel service buildings that contain operational safety-related equipment, typically the high and low-voltage electrical switchgear, battery, computer and communications equipment rooms. Older systems may still use Halon gas, now prohibited from new installations. Installations that are more recent may use carbon dioxide (CO_2). The most recent systems use synthetic gases mixed with nitrogen/argon that, unlike CO_2, are breathable in the concentrations concerned.

10.29 Gas detection systems are sited in locations where measurements of gas may be required: eg cable chambers, sumps and draw-pits, tunnel service buildings and control and switch rooms. Different gases may be measured, typically oxygen and hydrocarbons. The systems trigger events to contain the situation once a set percentage of the lower explosive limit (LEL) has been passed. Typically pumps are inhibited when concentrations reach 30% LEL and then a nitrogen foam flooding system is initiated. In service buildings, when 20% LEL is reached, alarms and automatic fire extinguishers are triggered and at 30% LEL the gas extraction fan is inhibited.

10.30 A nitrogen-foam flooding system comprises a number of nitrogen gas cylinders, a foam generating set, a control system and a number of foam-generator nozzles. The foam-generator nozzles are installed within the sump and are connected by pipework to the foam-generating set, normally located in a tunnel panel. A bore closure may be required to safely access the foam generating set.

10.31 Care should be taken to ensure that whole systems are tested periodically, where for example servicing and testing of parts of the system are scheduled at different times or undertaken by different contractors.

Maintenance of foam flooding systems

10.32 Maintenance should be in accordance with the manufacturer's recommendations. Typically at intervals of 3 months, the panels should be cleaned to ensure readability and checked to ensure they are clear of alarms. Checks should also be made for signs of deterioration of flexible pipework, and signs of corrosion, damage or overheating of all connectors and earths. Nitrogen cylinder pressure should be determined and all cylinders checked for security.

10.33 A test fire should be carried out together with a purging of foam, in accordance with the manufacturer's recommendations, at intervals typically of 12 months. Care must be taken to ensure that no one is within or adjacent to the sump when this test is conducted.

Maintenance of gas detectors

10.34 This should be in accordance with the manufacturer's recommendations. The services of a specialised contractor are normally required. Typically, the operation of the systems should be tested, electrical connections checked and the sensors re-calibrated at intervals of 3 months: sensors should be replaced at intervals, typically of 12 months.

Maintenance of automatic fire extinguishers

10.35 Inspection of the automatic gas discharge and extraction system should be carried out at intervals typically of 3 months. Specialised servicing of the system, in accordance with the manufacturer's recommendations, should be carried out at the same time, together with testing which may require the control system to be manually overridden.

Maintenance of fire detection systems

10.36 This should be in accordance with the manufacturer's recommendations.

10.37 Testing and maintenance of the fire alarm and detection system should be carried out in accordance with BS 5839: Part 1. This requires daily checks of panels and log books and selective system and equipment testing at weekly, 3-monthly, yearly and 5-yearly intervals.

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Figure 10.1: Tunnel Emergency Panel

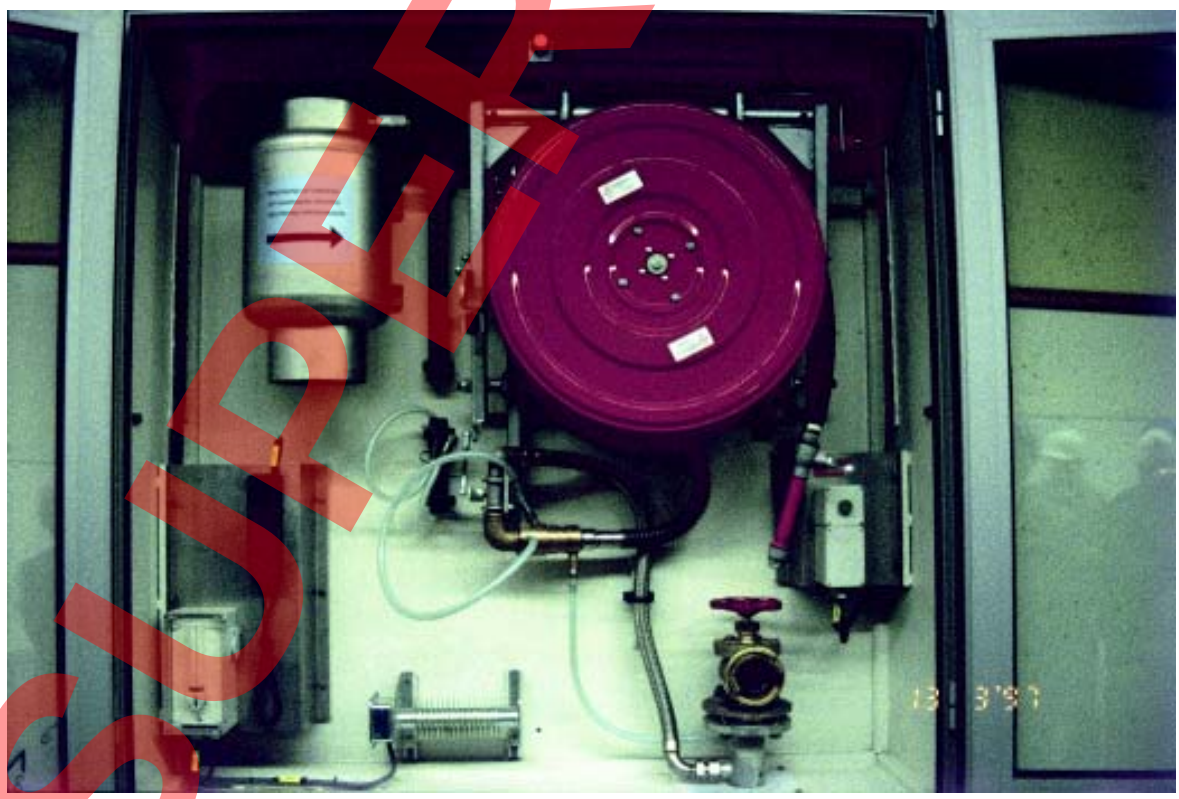

Figure 10.2: Tunnel Fire Fighting Equipment

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Figure 10.3: Sump Gas Detection and Nitrogen Foam Flooding System

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11. COMMUNICATION AND TRAFFIC CONTROLS EQUIPMENT

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General

11.1 This Chapter provides general guidance on maintenance of any communication cables, telephones, radio systems, closed circuit televisions and variable message signs that are not included in the RMC or NMC contracts, see Chapter 2. Reference should also be made to Chapter 7 for maintenance of mechanical supporting systems.

11.2 In England, maintenance of the NMCS is detailed in the Highways Agency's Motorway Communications (MC) series of document which take precedence over tunnel documentation. Key documents are listed in the Reference Chapter.

Communication Cables

Description of Typical Equipment and Access Arrangements

11.3 Communications cables in the tunnel bore, tunnel service buildings, sumps and drawpits are covered within this Chapter.

Cleaning

11.4 Typically, no cleaning of the cabling is required. Inspections should be carried out on all accessible cables at intervals typically of 3 months noting any signs of damage, corrosion or similar defects. Typically no routine servicing is required

Telephone Systems

Description of Typical Equipment and Access Arrangements

11.5 The provision of telephone systems varies from one tunnel to another, and historically has been determined largely by the requirements of the tunnel operator and the local police and fire service.

11.6 Up to three separate systems may be provided, fulfilling the following functions:

i. an emergency telephone system, to enable the public to summon assistance in the event of an incident;

ii. a smoke control telephone system, to enable the fire service to communicate between one end of the tunnel and the other;

iii. an internal telephone system, for use by maintenance staff.

Cleaning

11.7 The telephone set should be cleaned at the same interval as testing, but is currently carried out monthly for the National Network (ref MCH 1743).

Inspection

11.8 Visual inspection for defects and correct number labelling should be carried out at the same interval as testing.

Service

11.9 Generally, the telephone systems require no servicing.

Testing

11.10 Typically testing of all aspects of operation of the emergency telephones should be carried out at intervals of one week, and of other telephones at intervals of 3 months. Battery supplies to the telephones should be tested at intervals of one year.

Radio-Relay Systems

Description of Typical Equipment and Access Arrangements

11.11 A typical tunnel radio-relay system comprises a leaky feeder antenna through each bore of the tunnel, linked to a number of transceivers in a tunnel service building. For optimum signal quality, the transceivers are normally linked to the appropriate users' remote base stations by landlines, so that the tunnel system behaves as an additional transmitter/receiver on the local area communications network.

11.12 In cases where a landline connection from the tunnel service building is not feasible, an external antenna may be located near the tunnel to receive

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transmissions 'off-air' and rebroadcast them inside the tunnel.

Service

11.13 Generally, radio relay systems require no servicing.

Testing

11.14 An on-air test of all channels for acceptable speech quality should be carried out typically at intervals of one week.

11.15 At typically yearly intervals, the system frequency accuracy, transmitted power levels, receiver sensitivity and selectivity, and transmitter output and audio levels to and from the control centre should be tested.

Closed Circuit Television Cameras

11.16 Traffic surveillance CCTV cameras are normally located on the approaches to and within the tunnel. Cameras may also be used for security surveillance of other areas such as service building and maintenance access roads. Video images from these cameras are usually accessible in at least one location through a multiplexing system serving an array of monitors with video recording provisions.

Cleaning

11.17 Cleaning of the lenses is important to maintain visibility. The interval will depend on the rate of soiling, which will be determined by local traffic and weather conditions.

Inspection and testing

11.18 The equipment is used daily and so any problems or malfunctions of cameras will be immediately apparent. Operation of the pan, tilt and zoom mechanisms should be tested at intervals, typically of one week.

Service

11.19 Servicing of camera and pan, tilt and zoom mechanisms and motors depends on the type of equipment, but typically should be carried out at intervals of 6 months. This may involve removal of the camera assembly to a workshop. Security of supports should be checked, and testing of the CCTV camera functions should form part of the servicing programme.

VMS System

Description of Typical Equipment and Access Arrangements

11.20 A typical Variable Message Sign (VMS) system will include internally illuminated tunnel signs, internally illuminated post mounted and gantry signs, and a number of different types of rotating prism signs. Each of these different signs has different maintenance requirements.

11.21 Depending on its location, maintenance or inspection of the VMS may require traffic management.

11.22 There may be a distinction in requirements for maintenance of signs for information and those that have legal status. The advice in this Chapter is based on the assumption that all VMSs have legal status.

Cleaning

11.23 Cleaning should be carried out typically at intervals of 3 months depending on the rate of soiling, but should not exceed the one year interval required in the TRMM Volume 2. Internal cleaning should be carried out at intervals, typically of one year.

Inspection

11.24 A visual inspection of operation and for defects should be carried out at an interval that does not exceed the one month interval required in the TRMM Volume 2, Table 1.18.1.

11.25 An internal inspection of the VMSs should be carried out at intervals typically of 3 months.

Service

11.26 The VMS lamps should be replaced within the 6-monthly intervals stipulated in TRMM Volume 2 or on reaching 2000 hours of accumulated service life, whichever is shorter.

11.27 Electrical and mechanical components should be serviced at the intervals required in the TRMM Volume 2 or in accordance with the manufacturer's recommendations, whichever is shorter.

Testing

11.28 Testing of all aspects of sign operation should be carried out at intervals not exceeding those required in the TRMM Volume 2, Table 1.18.1.

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Traffic Induction Loops

Description of Typical Equipment and Access Arrangements

11.29 Traffic Induction Loops comprise a number of turns of loop cable installed in slots cut into the wearing course of the carriageway to form inductive coils which detect the presence of a vehicle by its metallic content.

11.30 They are usually fitted on a per lane basis across all lanes at a number of sites along a tunnel. Depending on the loop type they can detect either vehicle presence or presence and speed. They are linked by loop feeder cable to loop detectors mounted in the tunnel maintenance cabinets.

Cleaning

11.31 The loops require no cleaning.

11.32 The feeder cables should be treated as communications cables (see above).

11.33 The loop detectors should be cleaned at the same frequency as the other equipment within the maintenance cabinets, typically every 12 months.

Inspection

11.34 The loops should be visually inspected whenever the carriageway wearing course is inspected, typically every 3 months.

11.35 The feeder cables should be treated as communication cables.

11.36 The loop detectors should be inspected when cleaned.

Service

11.37 The loops, associated cables and detectors typically contain no serviceable components. Service is by replacement on failure.

Testing

11.38 The impedance of the loops should be measured at least every six months in order to check for hidden damage to the loop cable.

Traffic Computer

Description of Typical Equipment and Access Arrangements

11.39 The traffic computer control function typically:

i. looks at vehicle flow, taken from loop detectors, CCTV image analysis etc;

ii. considers environmental factors, such as pollution levels;

iii. sets signs to control vehicle movements accordingly.

11.40 The traffic computer may also control tidal flow traffic signals and maintenance signing for closures.

11.41 A traffic computer does not normally exist as a separate entity. The traffic control function is usually undertaken by the environmental control computer (see section 12 - Plant Monitoring).

Cleaning and Inspection

11.42 A visual inspection of computers to ensure cooling systems are uninhibited, cleaning filters etc, as necessary, is required at intervals, typically of 3 months.

11.43 A visual inspection of computer connections should be made at intervals, typically of 3 months. Where appropriate, connection integrity should be checked.

Service

11.44 Backup copies of software should be stored off-site. Data files, such as system logs, should be copied on a regular basis. At intervals, typically of 3 months, back up copies of software should be taken.

Testing

11.45 At intervals, typically of 12 months, the following should be tested:

i. power supplies and earthing connections to PLCs should be tested in accordance with the requirements of BS 7671;

ii. all aspects of computer system operation and response;

iii. computer hard discs for bad sector level, capacity and fragmentation.

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Peripheral Units

Description of Typical Equipment and Access Arrangements

11.46 Various peripheral units may be interfaced to the traffic control system, typically these will be additional input devices, such as overheight detectors, interfaces to fire systems etc or output devices, such as lane control signals or traffic signals.

Cleaning

11.47 Input devices exposed to the tunnel environment should be cleaned at intervals, typically of 3 months.

11.48 Input devices from other systems should be cleaned when their host system is cleaned.

11.49 Output devices, ie those presenting visual infromation to the driver should be cleaned typically every 3 months.

Inspection

11.50 A visual inspection of operation should be carried out at an interval that does not exceed one month.

Service

11.51 All peripheral equipment should be serviced in accordance with the manufacture's requirements and at intervals typically of every 6 months.

Testing

11.52 All peripheral equipment should be tested for correct operation typically at intervals of every 3 months.

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12. PLANT MONITORING AND CONTROL OR ENVIRONMENTAL CONTROL SYSTEM

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General

12.1 This Chapter provides guidance for maintenance of the plant monitoring system and maintenance of control provisions for tunnel lighting and ventilation such as carbon monoxide sensors, visibility sensors, air speed monitors and photometers. Reference should also be made to Chapter 6 for maintenance of mechanical supporting systems.

Plant Monitoring

Description of Typical Equipment and Access Arrangements

12.2 The Environmental Control System (ECS) provides signals to control the tunnel lighting and tunnel ventilation systems. The ECS may also provide a means of communicating measurements of gas and pollution levels, luminance levels and the status of tunnel systems to a remote location. It is also usual for the ECS to handle alarms, status information and remote control signals for other tunnel plant, particularly electrical switchgear and emergency and fire protection systems.

12.3 A variety of designs of ECSs may be encountered in tunnels. Newer designs use a Supervisory Control and Data Acquisition (SCADA) system based on a central computer with distributed Programmable Logic Controllers (PLCs) at each out-station serving equipment. All control and other information is passed along a common data transmission network. PLCs filter out and direct relevant commands to connected equipment and relay status information back to the SCADA system. Maintenance procedures depend on the particular type of system installed.

12.4 The SCADA system itself is often self-diagnostic and does not require planned maintenance.

Cleaning and Inspection

12.5 A visual inspection of computers to ensure cooling systems are uninhibited, cleaning filters etc, as necessary, is required at intervals, typically of 3 months.

12.6 A visual inspection of computer and PLC connections should be made at intervals, typically of 3 months. Where appropriate, connection integrity should be checked.

Service

12.7 Backup copies of software should be stored off-site. Data files, such as system logs, should be copied on a regular basis. At intervals, typically of 3 months, back up copies of software should be taken.

Testing

12.8 At intervals, typically of 12 months, the following should be tested:

i. power supplies and earthing connections to PLCs should be tested in accordance with the requirements of BS 7671;

ii. all aspects of computer system operation and response;

iii. computer hard disks for bad sector level, capacity and fragmentation;

iv. local PLC memory batteries.

Carbon Monoxide and Visibility Monitors

Description of Typical Equipment and Access Arrangements

12.9 The carbon monoxide and visibility sensors are normally located at a high level in the tunnel. A platform and a bore closure will normally be required to access the sensors. Maintenance requirements are specific to each manufacturer and product.

Cleaning

12.10 Typically, cleaning of the sensors should be carried out at intervals of 3 months.

Inspection

12.11 The equipment is used constantly and so any malfunctions should become apparent through the ECS. Modern equipment is often fail-safe.

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Service

12.12 The services of a specialist contractor are required. Typically servicing and calibration of the sensors are required at intervals of 3 months. It may be found that intervals for calibration may be increased to 12 months but the manufacturer's guidance should be sought.

Testing

12.13 Typically at intervals of 3 months, testing of alarms, alignment and the displays at the ECS terminal, etc should be carried out.

Air Speed Monitor

Description of Typical Equipment and Access Arrangements

12.14 Air speed monitoring equipment is normally located at a high level in the tunnel. A platform and bore closure will normally be required to access the sensor. Maintenance requirements are specific to each manufacturer and product.

Inspection

12.15 The equipment is used constantly so any malfunctions should become apparent through the ECS.

Service

12.16 The services of a specialist contractor are required. Typically servicing is required at intervals of 6 months and calibration of the airflow sensor is required at intervals of one year. Cleaning and testing normally forms part of the servicing.

Photometers

Description of Typical Equipment and Access Arrangements

12.17 External photometers are generally mounted on poles (see Figure 12.1) in the verge and central reserve to monitor external light levels. Maintenance may be possible without a tunnel closure. If works are carried out during daylight hours, it should be borne in mind that automatic control levels for the tunnel lighting may be affected. Photometers may also be mounted inside the tunnel to compare internal and external lighting levels.

Cleaning

12.18 The photometer windows require cleaning, typically at intervals of 3 months, but the interval will depend on the rate of soiling which will be determined by local weather and traffic conditions.

Inspection

12.19 The equipment is used constantly and so any malfunctions should become apparent through the ECS.

12.20 Typically, visual inspection of all connections, electrical earths and the unit itself should be made whenever the unit is cleaned.

Service

12.21 Washer bottles require refilling with water, cleanser and antifreeze, typically at intervals of 3 months. The correct operation and calibration of the photometer and operation of the wiper and washer should be checked at the same time.

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Figure 12.1: Pole Mounted Photometers

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13. ELECTRICAL POWER

General

13.1 This Chapter provides general guidance on maintenance of power cables, earth and lightning protection systems, high voltage equipment, transformers, low voltage equipment and distribution and control panels. Reference should also be made to Chapter 6 for maintenance of mechanical supporting systems.

Power Cables

Description of Typical Equipment and Access Arrangements

13.2 Power cables in the tunnel bore, tunnel service buildings, sumps and draw-pits are covered within this Chapter. Some cable pits may be confined spaces and an access procedure, which complies with the Confined Spaces Regulations 1997, should be in place. Bore closures are normally required to access power cables within the tunnel.

13.3 Authorised Persons must carry out maintenance of these items. Such persons must have received specific training on how to operate and work on electrical systems. Additional training is required for those working on high voltage systems. Most procedures will require the application of a 'Permit to Work' system.

Cleaning

13.4 Individual cleaning of the cables is not required.

Inspection editing

13.5 A visual inspection of accessible cables should be carried out at intervals, typically of 3 months.

Service

13.6 Typically, no routine servicing is required.

Testing

13.7 The complete electrical system must be tested periodically, typically at 5-year intervals, in accordance with the requirements of BS 7671.

Earthing and Lightning Protection Systems

Description of Typical Equipment and Access Arrangements

13.8 Earthing points are present in various parts of the tunnel system, including within the tunnel bore, sumps, tunnel service buildings and lightning protection system. Bore closures are normally required to access earthing points within the tunnel.

13.9 Authorised persons who have received specific training appropriate to work on tunnel electrical systems must carry out maintenance procedures on these items.

Cleaning

13.10 Specific cleaning processes are not normally required, unless substances likely to cause corrosion are present.

Inspection

13.11 At intervals, typically of 3 months, accessible parts of the main earthing system should be visually checked for any signs of loose connections or fixings, damage or corrosion.

13.12 Visual inspection of the lightning protection system should be carried out in accordance with BS 6651, normally at intervals of one year. Additional visual inspections should be made following known lightning strikes.

Service

13.13 Any faults, corrosion or damage should be repaired immediately.

Testing

13.14 The services of a specialised contractor are required. Resistance to earth of the main earthing system should be tested in accordance with BS 7671, typically every 5 years, and of the lightning protection system in accordance with BS 6651, typically every year.

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High Voltage System Circuit Breakers and Transformers

Description of Typical Equipment and Access Arrangements

13.15 A typical tunnel will receive two separate 11 kV electrical feeds. Transformers, usually located in the service building convert this to the low voltage supply normally distributed within the tunnel. For older tunnels, this supply is likely to be at a nominal 415 volts; more recent tunnels may use the harmonised level of 400 volts. High voltage circuit breakers are usually provided with power solenoid operating mechanisms. The closing and tripping supply to each switchboard is derived from dedicated tripping and closing battery units, located within the respective HV switch rooms. Mechanical interlocks formed through safety key mechanisms are usually provided within each circuit breaker to prevent incorrect operation.

13.16 Authorised Persons who have received specific training to operate and work on high voltage electrical systems must carry out maintenance procedures on these items. Such procedures will require the application of a 'Permit to Work' system.

Cleaning

13.17 Specific cleaning processes are not normally required.

Inspection

13.18 Inspections of the transformers, typically at intervals of 3 months, should include checks on the following:

i. condition of silica gel breather, which should be renewed if discoloured;

ii. oil level;

iii. confirmation of normal operating temperature.

13.19 In addition, typically at 12-month intervals, cable terminations and oil condition should be checked.

13.20 Corrosion and damage to the transformer should be repaired as necessary.

13.21 Typically, the switchgear should be checked for overheating or any other readily apparent problems at intervals of 3 months, and a full inspection and operational check should be conducted at intervals of 12 months.

Service

13.22 Typically, the transformer does not need servicing. The switchgear requires servicing and lubrication at intervals, typically of one year.

Testing

13.23 Operation of the switchgear and indicating lamps should be tested, typically at intervals of 3 months. The transformer oil condition should be analysed, typically at intervals of one year. Operation of over-temperature and over-pressure trippings should be checked every 5 years.

Low Voltage System Switchboards and Circuit Breakers

Description of Typical Equipment and Access Arrangements

13.24 The switchboards and circuit breakers are generally housed in the tunnel service buildings.

13.25 Authorised persons who have received specific training appropriate to work on tunnel electrical systems must carry out maintenance procedures on these items. Most procedures will require 'Permit to Work' procedures

Cleaning

13.26 The circuit breakers and switchgear are usually housed in relatively dust free environments and do not normally require cleaning. Any such cleaning would require the application of a "Permit to Work".

Inspection

13.27 At intervals, typically of 3 months, switchboards should be cleaned externally and inspected visually for any obvious damage or signs of malfunctioning. Anti-condensation heaters should be checked. Faulty indicator lamps should be replaced and settings and correct installation of protective devices checked. Accessible external wiring connections should be checked visually for signs of loose connections and overheating, or other deterioration.

13.28 A visual inspection of cable connections for tightness, cable entries, glands and sleeves for fit and deterioration and for any other visible damage should be carried out at intervals, typically of 6 months.

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13.29 Low voltage circuit breakers and relays should be inspected at intervals, typically of 6 months, including the condition of the contacts and electrical and mechanical interlocks.

13.30 Main circuit breaker tripping mechanisms, arc shields and contacts should be inspected at intervals, typically of one year.

13.31 It should be noted that cubicles are typically interlocked such that power isolation is required before they can be opened. Access to the interior of cubicles will require the application of a "Permit to Work".

Service

13.32 Typically, the switchboards and circuit breakers do not require servicing. Any servicing that becomes required should be in accordance with the operation and maintenance manual.

Testing

13.33 A test of all operations of the switchboards should be carried out at intervals, typically of one year. In addition, routine testing and servicing of the unit's batteries and cabinets should be undertaken.

13.34 In a modern tunnel, sufficient redundancy is normally built into the switchgear design to enable individual circuit breakers to be withdrawn one at a time, for maintenance without detriment to the operation of the tunnel. It is essential to verify that the switchgear operates correctly, particularly under mains failure conditions, although it should be noted that simulating incoming supply failure does not necessarily mean switching off the incoming supply. It could, 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 will need to be developed to enable the testing to take place during planned closures.

Distribution and Control Panels

Description of Typical Equipment and Access Arrangements

13.35 There is considerable variation in the design of tunnel panels and their contents. Typically tunnels contain electrical distribution, emergency distribution, emergency equipment, smoke control, sump control, lighting control, and ventilation control panels. Depending on their location, a lane or bore closure is normally required for access.

13.36 Maintenance procedures on these items may need to be carried out by authorised persons who have received specific training appropriate to work on tunnel electrical systems. Most procedures will require 'Permit to Work' procedures.

Cleaning and testing of panels

13.37 The operation of panel doors and alarms should be tested at intervals, typically of 3 months or during routine tunnel closures, whichever is sooner.

13.38 Panel door hinges should be lubricated, door latches and ingress protection seals inspected and panels vacuum-cleaned internally at intervals, typically of one year. External faces of the panel doors should be cleaned regularly, usually as part of the tunnel cleaning operations (see Chapter 5).

Cleaning, Inspection, Service and Testing of Equipment

13.39 Typical operations that should be carried out on electrical distribution and control equipment within the panels include:

i. at intervals, typically of 3 months, switchboards should be cleaned externally and inspected visually for any obvious damage or signs of deterioration or malfunctioning. Anti-condensation heaters should be checked. Faulty indicator lamps should be replaced and configuration settings and correct installation of protective devices checked. Accessible wiring connections should be checked visually for tightness, chafing and signs of overheating or deterioration;

ii. at intervals, typically of 6 months, a more detailed check of all wiring, connections and terminations should be made for signs of overheating or damage, and cable entries, glands and sleeves for fit and deterioration;

iii. at intervals, typically of one year, all control, switching and protective devices should be checked for correct operation and any deterioration of contacting surfaces.

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13.40 Visual inspection of electrical connections could expose live conductive parts that cannot be readily isolated without isolating tunnel primary/essential power circuits. Therefore the need, extent and frequency of such inspections should be determined through risk assessment that considers the potential risks to the inspector against the probability and nature of the risks that would be realistically avoided through a regime of visual inspections.

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14. EMERGENCY POWER EQUIPMENT

General

14.1 This Chapter provides general guidance on maintenance of uninterruptible power supply equipment and standby generators.

Uninterruptible Power Supply (UPS)

Description of Typical Equipment and Access Arrangements

14.2 UPS equipment may be used to provide protection against power supply failure to a limited number of systems within a highway tunnel. UPS units may be sufficient to supply systems for a short period (typically thirty minutes) while any standby generators (where provided) are started, or they may be sufficient to provide several hours' supply on their own. The protected systems may include part of the tunnel lighting, pumps, environmental monitoring systems, traffic management equipment and computer control systems. UPS units are commonly located in tunnel service buildings and control room buildings. A number of UPS units of differing capacity may be used to provide supplies to different systems within a tunnel.

14.3 Traffic management is not required to access most UPS units. Consideration should be given to the risk of a tunnel power failure whilst the UPS is shut down for maintenance. If possible, UPS maintenance work should be carried out during tunnel closures. Additionally, UPS maintenance should not be carried out at the same time as work on other power supply systems.

Maintenance

14.4 This should be in accordance with the operation and maintenance manual. Typically, cleaning and inspection should be carried out at intervals of 3 months. Servicing is not normally required. Operation should typically be tested at intervals of 3 months, and a battery discharge test carried out once a year. Nickel Cadmium (NiCad) batteries require a shorter discharge testing interval.

Standby Generators

Description of Typical Equipment and Access Arrangements

14.5 Standby generator sets are typically diesel engines equipped with battery-fed electric starting systems, an alternator and diesel tanks containing sufficient fuel for several hours of continuous running. The generator sets supply electrical power to critical systems during periods of total mains power supply failure.

14.6 Traffic management is not normally required to access standby generators. However, it should be noted that when the generator is disabled for maintenance activities there is a risk of a tunnel power failure if the main supply is interrupted. Therefore, it is beneficial if generator maintenance work is carried out during tunnel closures.

14.7 It is very important that maintenance is not carried out on this item whilst work is being carried out on the main supply, as this would increase the risk of a supply failure to the tunnel. If a failure of any mains supply occurs during generator maintenance, this work should be aborted and the generator restored to service condition as quickly as possible.

Cleaning

14.8 Cleaning is required typically at intervals of three months and should form part of the servicing.

Inspection

14.9 An inspection of the generator should be carried out at intervals, typically of 3 months.

Service

14.10 Typically at intervals of 3 months, servicing should include the checking of fluid levels, belts, starter batteries, vents, leaks and lubrication where necessary. At intervals, typically of one year, servicing should include a full lubrication and adjustment service. During servicing, checks for any excessive vibration, alarm operations, lights, building and door damage should be carried out. Repairs to the building housing the generator should be made as necessary.

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Testing

14.11 Typically, a test run of one hour duration, using a resistive load-bank at 100% generator output rating, should be carried out at intervals of 3 months and include the following checks:

i. oil pressure and temperature;

ii. engine speed;

iii. exhaust temperature;

iv. load-bank settings;

v. water temperature;

vi. turbo air pressure;

vii. alternator battery charge current and alternator output (ie voltage, current, power, frequency and power-factor);

viii. battery charger current and voltage prior to starting;

ix. operation of control panels, associated lamps and alarms.

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

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15. SERVICE BUILDING AND PLANT ROOM MAINTENANCE

15.1 This Chapter provides general guidance on maintenance of service building and plant room fabric and building services. Reference should also be made to the relevant Chapters for equipment housed in these buildings, and to Chapter 10 for maintenance of fire protection systems. Maintenance procedures and intervals contained in tunnel documentation should normally take priority, but should be reviewed in operation, see Chapter 3.

Building Fabric

Description of Typical Equipment and Access Arrangements

15.2 Tunnel service building structures vary between tunnels. Full access is normally possible without any traffic management.

Maintenance

15.3 An inspection of the tunnel-service-building fabric should be carried out at intervals, typically of one year. Depending on its location, more frequent inspection of the service building roof, perimeter and aerials may be necessary, because of vandalism etc Touching up of paintwork and maintenance of the roof should be carried out at intervals, typically of one year, if need is identified during the inspection. Cleaning of the gutters and weeding should also be carried out at intervals, typically of one year.

Heating, Lighting and Ventilation (HVAC)

Description of Typical Equipment and Access Arrangements

15.4 Tunnel-service-building systems vary between tunnels. Access is possible without traffic management. Systems include air conditioning, automatic heating and lighting.

Maintenance

15.5 All aspects of maintenance should be conducted in accordance with the operation and maintenance manual.

Security Systems

Description of Typical Equipment and Access Arrangements

15.6 The security system typically may incorporate proximity, vibration and PIR sensors. Traffic management is not normally required for access to carry out maintenance.

Maintenance

15.7 Maintenance should be in accordance with BS 4737, where typically a maintenance inspection is required at intervals of one year on buildings with a bell warning system, and at intervals of six months where remote signals connect to a central control system.

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16. REFERENCES AND GLOSSARY OF TERMS

16.1 Legislation

The Confined Spaces Regulations

The Construction (Design & Management) Regulations

The Control of Substances Hazardous to Health Regulations

The Electricity at Work Regulations

The Framework Directive, EC Directive 89/665/EEC

The Health & Safety at Work etc Act

The Highways Act

The Local Government, Planning and Land Act

The Town and Country Planning (Scotland) Act

The New Roads and Street Works Act

The Roads (Scotland) Act

The Road Traffic Regulations Act

16.2 Safety

Health and Safety Executive, Guidance Note EH40: Occupational Exposure Limits (updated annually)

16.3 Emergency Exercises

BD 53 Inspection And Records For Road Tunnels

The Exercise Planners Guide – Home Office (available on Home Office web site www.homeoffice.gov.uk)

Technical Bulletin 1/1993 Operational Incidents In Tunnels And Underground Structures – Home Office

Fire Services Act 1947

16.4 British Standards – British Standards Institution, London

BS 1447: Mastic asphalt (limestone fine aggregate) for roads, footways and pavings in building

BS 2853: Specification for the design and testing of steel overhead runway beams

BS 4737: Section 4.2: Intruder alarm systems in buildings Part 4: Codes of practice Section 4.2: Code of practice for maintenance and records

BS 5628: Part 2: Structural use of reinforced and pre-stressed masonry

BS 5839: Part 1: Fire detection and alarm systems in buildings

BS 6651: Code of practice for protection of structures against lightning

BS 7671: – Requirements for Electrical Installations, IEE Wiring Regulations, Sixteenth Edition

BS EN ISO 9002: Quality systems model for quality assurance in production, installation and servicing

16.5 Design Manual for Roads and Bridges – The Stationery Office, London

BD 21 The assessment of highway bridges and structures. DMRB 3.4.3

BD 27 Materials for the repair of concrete highway structures. DMRB 2.3.2

BD 33 Expansion joints for using in highway bridge decks. DMRB 2.3.6

BD 43 Criteria and material for the impregnation of concrete highway structures. DMRB 2.4.2

BD 47 Waterproofing and surfacing of concrete bridge decks. DMRB 2.3.4

BD 53 Inspection and records for road tunnels. DMRB 3.1.6

BD 62 As built, operational and maintenance records for highway structures. DMRB 3.2.1

BD 63 Inspection of highway structures. DMRB 3.1.4

BD 78 Design of road tunnels. DMRB 2.2.9

BA 16 The assessment of highway bridges and structures. DMRB 3.4.4

BA 26 Expansion joints for using in highway bridge decks. DMRB 2.3.7

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BA 33 Impregnation of concrete highway structures. DMRB 2.4.2

BA 35 Inspection and repair of concrete highway structures. DMRB 3.3.2

BA 47 Waterproofing and surfacing of concrete bridge decks. DMRB 2.3.5

BA 63 Inspection of highway structures. DMRB 3.1.5

BE 8 Painting of concrete highway structures. DMRB 2.4.2

HA 48 Maintenance of highway earthworks and drainage. DMRB 4.1.3

16.6 **Manual of Contract Documents for Highway Works – The Stationery Office, London**

Volume 1, Specification for Highway Works. MCHW1, including but not limited to:

Volume 5, Section 7, Part 2. Standard Performance Specifications for Mechanical and Electrical Installations in Road Tunnels, Movable Bridges and Bridge Access Gantries. MCHW 5.7.2

16.7 **Trunk Roads Maintenance Manual – The Stationery Office, London)**

TRMM Volume 1: Highways Maintenance Code

TRMM Volume 2: Routine and Winter Maintenance Code

TRMM Volume 3: Management of Health and Safety

RMMS: User Manual for the Highways Agency's Routine Maintenance Management System

16.8 **Network Communications Documents Motorway Communications (MC) – Highways Agency TSS Plans Registry, Temple Quay House, 2 The Square, Temple Quay, Bristol, BS1 6HA.**

MCH 1277 Maintenance Instruction – Responders

MCH 1279 Maintenance Instruction – Communication Equipment

MCH 1280 Maintenance Instruction – Indicators

MCH 1332 Maintenance Instruction – Cleaning of Optical Equipment

MCH 1349 Maintenance and Operational Requirements for New Systems and Equipment

MCH 1350 Liaison with Third Parties

MCH 1381 Reporting NMCS Operational Problems

MCH 1386 NMCS1 and NMCS2 Transmission Equipment and Circuits

MCH 1399 Notification of a Change in Equipment Quantities for Maintenance

MCH 1419 Maintenance Instruction – Standby Battery Unit for 2305A for 617 Transmission Station

MCH 1425 Maintenance Instruction – Motorway Communications Cable and Equipment

MCH 1433 Standard Cable Repair Procedures using Jointing Kit Type 1000

MCH 1453 Mini Carrier Systems – RMC Responsibilities

MCH 1454 National Motorway Communication Systems – Transmission Standards

MCH 1461 Contractor Reports and Availability/ Performance Calculations

MCH 1470 Procedures for the Production of Site Records for Maintenance

MCH 1499 Mini Carrier Maintenance Handbook

MCH 1523 Approval of Dedicated Maintenance Team and Changes

MCH 1526 Maintenance Instruction – NMCS2 Transponders

MCH 1527 Maintenance Instruction – NMCS2 Responders

MCH 1528 Maintenance Instruction – NMCS2 LCC/ DBP Maintenance

MCH 1582 Routine Maintenance of Camera Masts, Poles and Mounting Equipment

MCH 1587 Routine Maintenance of Fog Detector Equipment

MCH 1590 Maintenance Boundaries Relating to Transmission Station Equipment

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MCH 1598 Requirements for Repair and Reinstatement of Damaged Motorway Communications Equipment Including Cable

MCH 1626 Routine Maintenance of the Enhanced Message Signs Stand Alone Controller

MCH 1640 Routine Maintenance – Variable Message Signs Maidstone Control Office Area

MCH 1644 Maintenance Handover Certificate

MCH 1645 Maintenance Instruction for Contractors Submitting Invoices to the Department

MCH 1647 Notification of Cable Damage and Repairs

MCH 1649 Procedure for Contractors using the RCC Network for Testing NMCS2 Hardware and Software

MCH 1654 Routine Maintenance of Telemetry T100 Units

MCH 1675 Contract Termination Requirements and Procedures

MCH 1685 Enhanced Message Signs: Modem Equipment Maintenance Procedures

MCH 1710 NMCS Operational Problem Report Form

MCH 1740 NMCS1 and NMCS2 Transmission Equipment and Circuits Procedure

MCH 1743 Testing and Cleaning of Roadside Emergency Telephones

MCH 1760 National Routine Maintenance Procedures

MCH 1784 M25 Controlled Motorway Pilot Scheme. Enforcement and CMI Equipment Special Maintenance Procedures

MCH 1793 Controlled Motorway Indicators. Routine Maintenance Instructions

MCH 1825 M25 Controlled Motorway Pilot Scheme. MIDAS Special Maintenance Procedures

MCH 1844 Routine Maintenance of CCTV Equipment

MCH 1852 NOMAD – Definition of Categories, Types and Variants.

MCF 2331 Service Specification

MCG 1022 Testing for Newly Installed Motorway Communications and Power Cables

MCG 1099 NMCS Non-Armoured Cables, Installed Cable Testing Procedures

TR 1173 Multi-pair Communications Cable Polyethylene Insulated, Polyethylene Sheathed Armoured

TR 1238 Power Cable for Motorway Communication System (Split Concentric, Armoured)

TR 2017 NMCS Armoured Composite Optical Fibre Communications Cable

TR 2067 NMCS RS485 Standard – Electrical and Protocol

Road Traffic Advisor Project. Maintenance Requirements Specification

Ducted Cable Infrastructure – Routine Maintenance Requirements

TRH 1239 National Motorways Communications System. Installation Drawings

16.9 **World Road Association (formerly Permanent International Association of Road Congresses (PIARC)) – British National Committee, World Road Association, Room 4/52, St Christopher House, Southwark Street, London, SE1 0TE**

Classification of tunnels, Existing Guidelines and Experiences, Recommendations – 1995

Road Safety in Tunnels – 1995

Road Tunnels: Reduction of Operational Cost – 1999

16.10 **Other References**

Association of County Councils (1989) Highway maintenance: a code of good practice. Published by the Association of County Councils, London on behalf of the Association of County Councils, Association of District Councils, Association of Metropolitan Authorities and the Convention of Scottish Local Authorities.

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Bird S, J E Potter, D M Hiller and K H Bowers (2000). Value management for tunnel procedures. TRL Report 448. Transport Research Laboratory, Crowthorne.

Department of Transport, Bridge Inspection Guide (1983), HMSO, London.

Evans, A, S Bird, K H Bowers, G I Crabb and R H Harse (2000). Value engineering for tunnel equipment. TRL Report 449. Transport Research Laboratory, Crowthorne.

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Ford R J (2000). Operational Risk Management Of Road Bridges And Tunnels.

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Highways Agency (1999). Trunk Road Maintenance Manual. The Stationery Office, London.

Management of Safety at Work Regulations of 1992: HSC Approved Code of Practice 1992 (Revised 1999/ 2000).

Page J (1996). A guide to repair and strengthening of masonry arch highway bridges. TRL Report 204. Transport Research Laboratory, Crowthorne.

Risk Priority Number (RPN) Method: Trunk Road Management Conference: University of Nottingham: September 2000, "Surveyor".

Sumon S K (1998). Repair and strengthening of three-ring-brick masonry arch bridges. Proc Fifth International Masonry Conference, London, 1998.

Zuman N (1997). Street lighting and illuminated traffic signs, in: Highway maintenance handbook, edited by Atkinson K. Thomas Telford Publications, London.

16.11 Glossary of Terms

CCTV	Closed Circuit Television
CDM Regulations	Construction (Design and Management) Regulations
CHART	Computerised Highways Assessment of Ratings and Treatments
COSHH	Control of Substances Hazardous to Health
DMRB	Design Manual for Roads and Bridges (Highways Agency)
DO	Design Organisation
DOL	Direct-on-Line
ECS	Environmental Control System
FMEA	Failure Modes and Effects on an Asset
HRM	High Speed Road Monitor
HV	High Voltage
IEE	Institution of Electrical Engineers
LEL	Lower Explosion Level
MA/NMMA	Maintaining Agent/New Managing and Maintenance Agent
MCF	Mercury Low Pressure Fluorescent (lamp)
NiCad	Nickel Cadmium
NMC	National Maintenance Contractor
NMCS	National Motorway Communications System
NTS	National Transmission System
QA	Quality Assurance
PLC	Programmable Logic Controller
RMC	Regional Maintenance Contractor

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RMC–MC	Regional Maintenance Contracts – Management Consultants
RMMS	Routine Maintenance Management System (Highways Agency)
SCADA	Supervisory Control and Data Acquisition
SON-T	Tubular High Pressure Sodium (lamp)
SOX	Low Pressure Sodium (lamp)
TDSCG	Tunnel Design and Safety Consultation Group
TMC	Term Maintenance Contractor
TOA	Tunnel Operating Authority
TRMM	Trunk Road Maintenance Manual (Highways Agency, 1999)
UPS	Uninterruptible Power Supply
VCS	Visual Condition Surveys
VFMM	Value for Money Manual
VMS	Variable Message Sign

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17. ENQUIRIES

All technical enquiries or comments on this Advice Note should be sent in writing as appropriate to:

Divisional Director
Room 913
Sunley Tower
Piccadilly Plaza
Manchester
M1 4BE

Andrew Jones
Divisional Director

Chief Road Engineer
Scottish Executive Development Department
Victoria Quay
Edinburgh
EH6 6QQ

J HOWISON
Chief Road Engineer

Chief Highway Engineer
Transport Directorate
Welsh Assembly Government
Llywodraeth Cynulliad Cymru
Crown Buildings
Cardiff
CF10 3NQ

J R REES
Chief Highway Engineer
Transport Directorate

Assistant Director of Engineering
Department for Regional Development
Roads Service
Clarence Court
10-18 Adelaide Street
Belfast BT2 8GB

D O'HAGAN
Assistant Director of Engineering

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APPENDIX A TYPICAL STAFF STRUCTURE AND PROFILE

A.1 The Tunnel Manager should be a Chartered Engineer with suitable experience in a senior management position. He has overall responsibility for matters relating to the administration, operation and maintenance of tunnels and, possibly, parts of the adjacent road network.

A.2 The Deputy Tunnel Manager should be an experienced Chartered Engineer or Incorporated Engineer who would take responsibility for all delegated matters in the absence of the Tunnel Manager.

A.3 The Chief Electronics, Electrical, Mechanical and Civil Engineers should be experienced Chartered (or near Chartered) Engineers or Incorporated Engineers and would undertake such duties that enable continuing safe and efficient operation and maintenance of the tunnel. Some of the engineering functions may be combined, depending upon the complexity of the operation and the experience of the personnel involved.

A.4 Support Engineers/Technicians provide a 'first line' maintenance and operational support function. They will also provide an out of normal working hours emergency facility. They should normally be qualified to HNC level. Additional duties may include supervision of contractors, the management of 'Permit to Work' systems, assisting and directing maintenance type improvement works. Civil Engineers for example would manage the civil assets in respect of maintenance inspections, control of any specialist Consulting Engineers and programming capital infrastructure schemes. Other engineers would carry out corresponding functions.

A.5 Operations Managers would be available, on a shift basis, to the Control Room on a 24 hour, continuous basis. They perform all relevant duties relating to the operation of the tunnels and, possibly, the adjacent road network. They should have a background of operational experience together with an understanding of control and monitoring systems.

A.6 The Administration Manager is responsible for all office functions, including financial control of income and expenditure, preparation of documentation relating to maintenance contracts and other general duties.

A.7 The Quality Assurance Manager is responsible for all aspects of quality, including the preparation of plans and procedures. These should be maintained within the Quality Assurance Manual for the TOA.

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NOTIONAL ORGANISATION OF A TUNNEL OPERATING AUTHORITY (TOA)

Some of the engineering functions may be combined, depending upon the extent of the tunnel, the complexity of the operation and the experience of the personnel involved.

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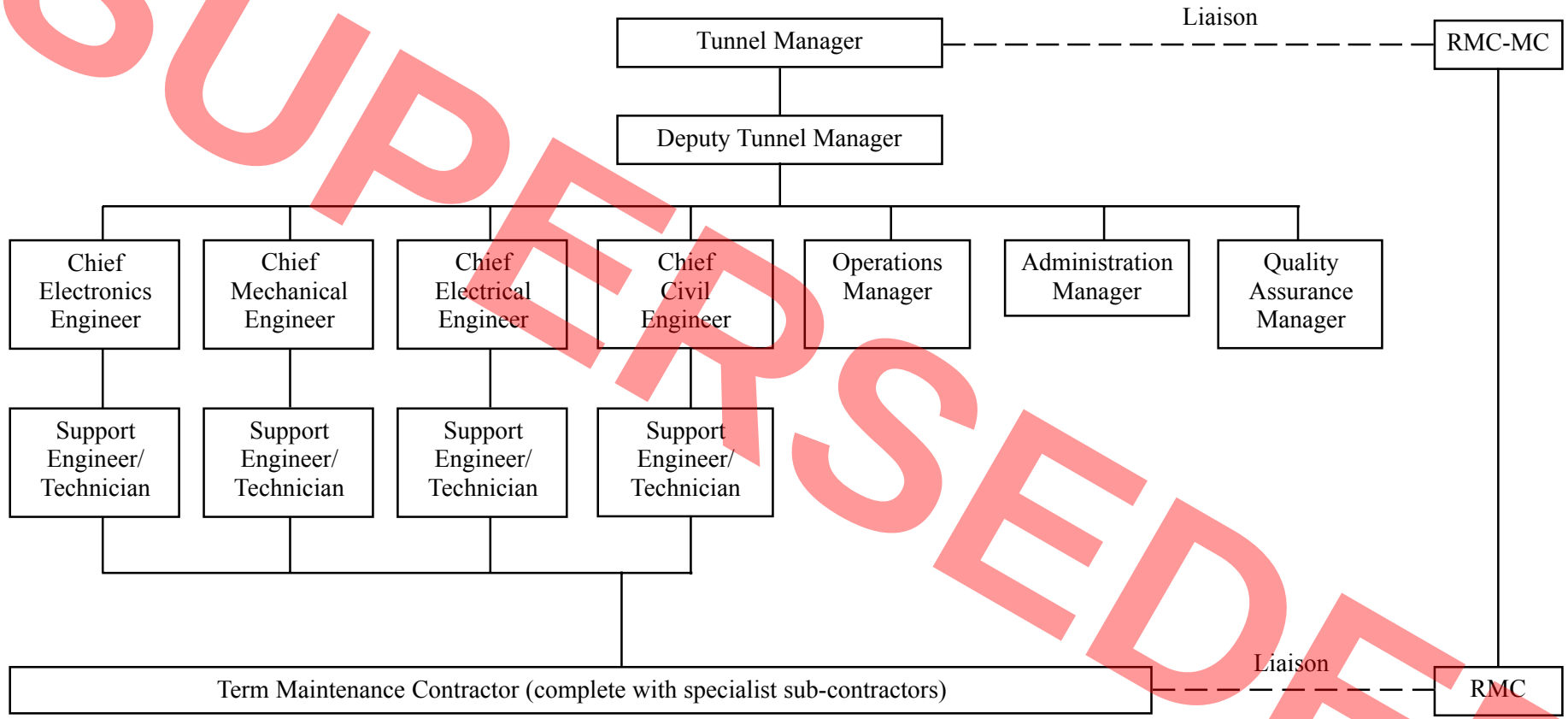

Volume 3 home page

APPENDIX B GUIDANCE ON SAFETY DURING MAINTENANCE WORKS AND INSPECTIONS

See BD 78 for more details.

Traffic Control

B.1 Special traffic conditions involving lane restrictions, contra-flows or closures, may be created depending upon the scale of the work and the layout of the tunnel. Equipment already provided for traffic control should be supplemented with additional signing, cones etc PIARC C5 Report (Brussels 1987): - Signing in the Case of Works Inside Tunnels provides further guidance.

B.2 Temporary signing is an onerous and dangerous process. Police assistance should be sought at lane closing/opening stages and in enforcing speed limits.

B.3 Protection of the workforce in a closed lane of a bore may require vehicle speeds to be physically restricted in the running lanes to say 15 mph. This will help limit air velocities and allow maintenance to be carried out safely whilst letting traffic flow through the bore.

B.4 Protection should also be provided from vehicles which may try to enter a closed tunnel bore or lane.

B.5 Traffic can produce excessive noise levels. It can also produce turbulent air conditions which with positive and negative (suction) pressures and other air speed hazards can unbalance those on foot or working at height.

B.6 Projections from vehicles can hit workers or unbalance working platforms etc.

Equipment Settings

B.7 Effect of safety items being temporarily out of operation during the maintenance works should be considered. Where possible work on equipment should be carried out in workshops away from the tunnel.

B.8 Lighting and ventilation may have to be enhanced to cope with possible higher pollution levels arising from changed traffic conditions.

Access Procedures

B.9 Those entering the tunnel should be aware of the rules and procedures for lane and tunnel closures. Instructions should be simple and clear. Entry and exit should be controlled and details of work which may affect the traffic or tunnel services obtained and acted upon.

B.10 Tunnels with mechanical ventilation should be purged of vehicle pollution prior to entry. Those with natural ventilation may need time to clear and prior to entry, readings of CO, NO_2 etc should be taken using personal gas monitors.

B.11 Intruder Alarm Systems should be switched off on entry and re-activated on exit.

B.12 Fire extinguishing systems in Halon or CO_2 protected rooms should be “locked off” prior to entry and re-activated on exit.

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APPENDIX C GUIDANCE ON HEALTH AND SAFETY LEGISLATION

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General

C.1 Major health and safety legislation affects those who operate and maintain tunnels. The primary one for compliance by employers and employees is The Health and Safety at Work etc Act 1974 (HSWA). In Northern Ireland, Health and Safety at Work (NI) Order 1978 applies.

C.2 The HSWA is supported by Regulations, Codes of Practice and Guidance Notes issued from time to time which lay down more specific requirements. These can be applicable across all industries eg. the Control of Substances Hazardous to Health Regulations or be targeted at particular sectors eg. the Construction (Design and Management) Regulations.

C.3 A breach of a provision of a Regulation is a criminal offence and can lead to prosecution.

C.4 Approved Codes of Practice (ACoPs) approved by the Health and Safety Commission or Health and Safety Executive Northern Ireland give guidance on the general requirements of Acts and Regulations. An ACoP can be changed to keep it up to date with current practice without changing the law. Failure to comply with an ACoP is not an offence in itself but the onus is on the defendant to prove that he complied in some other acceptable way.

C.5 Guidance Notes are produced by the Health and Safety Commission and the Health and Safety Executive and Health and Safety Executive Northern Ireland as opinions on good practice. Whilst they have no legal force they will be used in determining good practice and what is 'reasonably practicable' in a particular industry.

Criminal/Civil Law

C.6 The Acts and Regulations mentioned above are statute law. Failure of a corporate body or an individual to comply with the provisions of these documents is a criminal offence. Those who transgress these laws run the risk of prosecution by the HSE or, in the case of manslaughter, by the Crown Prosecution Service (Procurator Fiscal in Scotland, Director of Public Prosecutions in Northern Ireland).

C.7 Employers also have obligations under common law, which has been established over time, and owe a duty of care to their employees to provide a safe place of work. Those found guilty of an offence when prosecuted under common law have also committed a criminal offence.

C.8 By their very nature proceedings under health and safety legislation often result from accidents when people have been injured or killed. The injured party or his/her dependants may choose to pursue an action under civil law for compensation due to the negligence of the defendant. Thus a single incident can lead to both criminal and civil proceedings in different courts of law. The standard of proof required under criminal law (beyond all reasonable doubt) is usually much higher than under civil law (balance of probabilities).

Other relevant legislation

C.9 These include:

a) Management of Health and Safety at Work Regulations;

b) Workplace (Health, Safety and Welfare) Regulations;

c) Construction (Design and Management) Regulations;

d) Confined Spaces Regulations;

e) Control of Substances Hazardous to Health Regulations;

f) Electricity at Work Regulations;

g) Noise at Work Regulations;

h) Personal Protective Equipment at Work Regulations;

i) Provision and Use of Work Equipment Regulations.

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APPENDIX D EXAMPLES OF DETAILED MAINTENANCE SCHEDULES FOR LIGHTING AND VENTILATION

SUPERSEDED

System: Tunnel Lighting		Unit Identifier: Base lighting luminaires (rows 1&6)
Unit Description: The tunnel base lighting comprises two rows of 1 x 58 W dimmable fluorescent luminaires which extends for the full length of the tunnel. Base lighting comprises Stages 1,2 & 3 which correspond to 30%, 60% and 100% luminaire output, controlled via the ECS. Luminaires are constructed from extruded aluminium alloy housing, with end caps of cast aluminium. The exterior finish is a paint powder epoxy in black. The unit incorporates removable gear tray and reflector/lamp assembly. Approx weight 22 kg. One in every 12 luminaires is fed from UPS Supply.		
Number of Units: 1221	Maintenance Freq: 12 Months	Manual Ref: Volume 4
Drawing Ref: C3/1-33		Location of Equipment: Westbound bore

Maintenance Tasks:

a) Externally clean all the luminaires.
b) Relamp/replace or repair any failed luminaires - refer to manufacturer's maintenance instructions.
c) Check luminaire flexible connections from junction box. Ensure that IP65 sealing standard is maintained. Repair/replace components as necessary.

Items Completed (Tick for Yes): a b c

Special Requirements:

Permits Required	YES	NO	Traffic Management Required	YES	NO

Type of Permit:
1] Permit to Access
2] LV Permit to Work
3] HV Permit to Work
4] LV Permit to Test
5] HV Permit to Test
6] HV/LV Permit to Work or, Test (Hazardous Areas)

Any Special Handling/Lifting Requirements to Carry out Task:
Cranes *Fork Lifts*
Scissors Lifts *Fan Cradles*

Signature:
Date:

Volume 3 home page

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System: Tunnel Lighting		Unit Identifier: Base lighting luminaires (rows 1&6)
Unit Description: The tunnel base lighting comprises two rows of 1 x 58 W dimmable fluorescent luminaires which extends for the full length of the tunnel. Base lighting comprises Stages 1,2 & 3 which correspond to 30%, 60% and 100% luminaire output, controlled via the ECS. Luminaires are constructed from extruded aluminium alloy housing, with end caps of cast aluminium. The exterior finish is a paint powder epoxy in black. The unit incorporates removable gear tray and reflector/lamp assembly. Approx weight 22 kg. One in every 12 luminaires is fed from UPS Supply.		
Number of Units: 1221	Maintenance Freq: 24 Months	Manual Ref: Volume 4
Drawing Ref: C3/1-33		Location of Equipment: Westbound bore

Maintenance Tasks:

a) Externally clean all the luminaires.
b) Relamp/replace or repair any failed luminaires - refer to manufacturer's maintenance instructions.
c) Check luminaire flexible connections from junction box. Ensure that IP65 sealing standard is maintained. Repair/replace components as necessary.
d) Relamp all row 1 and 6 luminaires.

Items Completed (Tick for Yes):	a	b	c	d
Special Requirements:				

Permits Required	YES	NO	Traffic Management Required	YES	NO

Type of Permit:
1] Permit to Access
2] LV Permit to Work
3] HV Permit to Work
4] LV Permit to Test
5] HV Permit to Test
6] HV/LV Permit to Work or, Test (Hazardous Areas)

Any Special Handling/Lifting Requirements to Carry out Task:
Cranes *Fork Lifts*
Scissors Lifts *Fan Cradles*

Signature:
Date:

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System: Tunnel Lighting			Unit Identifier: Boost lighting luminaires (rows 2, 3, 4 & 5)		
Unit Description: The tunnel boost lighting comprises rows 2, 3, 4 and 5 which is made up of both fluorescent and SON-T luminaires. They make up stages 4, 5, 6, 7 and 8 which are controlled via the portal photometers, the luminaires being switched on at preset lighting thresholds via the ECS. The SON-T lamps are made up of: 150 W, 250 W and 400 W units (all double) and the fluorescent 2 x 50 W units. Luminaires are constructed from extruded aluminium alloy housing, with end caps of cast aluminium. The exterior finish is a paint powder epoxy in black. The unit incorporates removable gear tray and reflector/lamp assembly. Each unit weighs approx 25 kg.					
Number of Units: 574 in total		Maintenance Freq: 12 Months			Manual Ref: Volume 4
Drawing Ref: C3/1-33			Location of Equipment: Westbound bore		
Maintenance Tasks: a) Externally clean all the luminaires. b) Relamp/replace or repair any failed luminaires - refer to manufacturer's maintenance instructions. c) Check luminaire flexible connections from junction box. Ensure that IP65 sealing standard is maintained. Repair/replace components as necessary. Items Completed (Tick for Yes): a b c					
Special Requirements:					
Permits Required	YES	NO	Traffic Management Required	YES	NO
Type of Permit: *1] Permit to Access* *2] LV Permit to Work* *3] HV Permit to Work* *4] LV Permit to Test* *5] HV Permit to Test* *6] HV/LV Permit to Work or, Test (Hazardous Areas)*			Any Special Handling/Lifting Requirements to Carry out Task: *Cranes* *Fork Lifts* *Scissors Lifts* *Fan Cradles* Signature: Date:		

SUPERSEDED

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System: Tunnel Lighting	Unit Identifier: Boost lighting luminaires (rows 2, 3, 4 & 5)

Unit Description: The tunnel base lighting comprises two rows of 1 x 58 W dimmable fluorescent luminaires which extends for the full length of the tunnel. Base lighting comprises Stages 1,2 & 3 which correspond to 30%, 60% and 100% luminaire output, controlled via the ECS. Luminaires are constructed from extruded aluminium alloy housing, with end caps of cast aluminium. The exterior finish is a paint powder epoxy in black. The unit incorporates removable gear tray and reflector/lamp assembly. Approx weight 22 kg. One in every 12 luminaires is fed from UPS Supply.

Number of Units: 1221	Maintenance Freq: 12 Months	Manual Ref: Volume 4
Drawing Ref: C3/1-33	Location of Equipment: Westbound bore	

Maintenance Tasks:

a) Relamp/replace or repair any failed luminaires - refer to manufacturer's maintenance instructions.
b) Check luminaire flexible connections from junction box. Ensure that IP65 sealing standard is maintained. Repair/replace components as necessary.
c) Change SON-T lamps as per the site instructions of TNG staff.

Items Completed (Tick for Yes): a b c

Special Requirements:

Permits Required	YES	NO	Traffic Management Required	YES	NO

Type of Permit:
1] Permit to Access
2] LV Permit to Work
3] HV Permit to Work
4] LV Permit to Test
5] HV Permit to Test
6] HV/LV Permit to Work or, Test (Hazardous Areas)

Any Special Handling/Lifting Requirements to Carry out Task:
Cranes *Fork Lifts*
Scissors Lifts *Fan Cradles*

Signature:
Date:

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System: Tunnel Ventilation		Unit Identifier: Ventilation Fans
Unit Description: 600 mm diameter reversible jet fan unit manufactured by Company A and comprises a central fan unit with acoustic silencers mounted at each end. The fan is driven by a 12 kW motor at 2900 rpm. The units are suspended from the tunnel ceiling on mounting frames with anti-vibration mountings to isolate any fan vibrations. The fan impeller consists of a central hub onto which is mounted six cast aluminium blades. Fans are mounted in 9 rows of 4 longitudinally along the tunnel.		
Number of Units: 36	Maintenance Freq: 3 Months	Manual Ref: Volume 6
Drawing Ref: C4/1-9		Location of Equipment: Westbound bore

Maintenance Tasks:

a) Visually check each fan for any obvious damage/defect.
b) Clean dirt build up from impeller blades.
c) Clean interiors of silencers and dust the exteriors.
d) Run fans in both directions and check for signs of any undue vibration/noise.
e) Ensure the fan mountings are in good order and correctly tightened.
f) Check fan terminal-box connections for tightness.

Items Completed (Tick for Yes): a b c d e f

Special Requirements:

Permits Required	YES	NO	Traffic Management Required	YES	NO

Type of Permit:
1] Permit to Access
2] LV Permit to Work
3] HV Permit to Work
4] LV Permit to Test
5] HV Permit to Test
6] HV/LV Permit to Work or, Test (Hazardous Areas)

Any Special Handling/Lifting Requirements to Carry out Task:
Cranes *Fork Lifts*
Scissors Lifts *Fan Cradles*

Signature:
Date:

SUPERSEDED

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System: Tunnel Ventilation	Unit Identifier: Ventilation Fans

Unit Description: 600 mm diameter reversible jet fan unit manufactured by Company A and comprises a central fan unit with acoustic silencers mounted at each end. The fan is driven by a 12 kW motor at 2900 rpm. The units are suspended from the tunnel ceiling on mounting frames with anti-vibration mountings to isolate any fan vibrations. The fan impeller consists of a central hub onto which is mounted six cast aluminium blades. Fans are mounted in 9 rows of 4 longitudinally along the tunnel.

Number of Units: 36	Maintenance Freq: 12 Months	Manual Ref: Volume 6

Drawing Ref: C4/1-9	Location of Equipment: Westbound bore

Maintenance Tasks:

a) Visually check each fan for any obvious damage/defect.
b) Clean dirt build up from impeller blades.
c) Clean interiors of silencers and dust the exteriors.
d) Run fans in both directions and check for signs of any undue vibration/noise.
e) Ensure the fan mountings are in good order and correctly tightened.
f) Check fan terminal-box connections for tightness.
g) Check fan blade clearances and, if necessary, adjust by means of stay rods holding the motor.
h) Check security and condition of anti-vibration mountings.
I) Check tightness of main support beam bolts holding tunnel fan mounting brackets to tunnel roof.
j) Measure and record fan starting and running currents in each direction.
k) Take vibration readings for each fan as defined by the relevant British Standard.
l) Carry out insulation resistance tests of each fan circuit.

Items Completed (Tick for Yes):	a	b	c	d	e
	f	g	h	i	j
	k	l			

Special Requirements:

Permits Required	YES	NO	Traffic Management Required	YES	NO

Type of Permit:
1] Permit to Access
2] LV Permit to Work
3] HV Permit to Work
4] LV Permit to Test
5] HV Permit to Test
6] HV/LV Permit to Work or, Test (Hazardous Areas)

Any Special Handling/Lifting Requirements to Carry out Task:
Cranes *Fork Lifts*
Scissors Lifts *Fan Cradles*

Signature:
Date:

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System: Tunnel Ventilation		Unit Identifier: Ventilation Fans
Unit Description: 600 mm diameter reversible jet fan unit manufactured by Company A and comprises a central fan unit with acoustic silencers mounted at each end. The fan is driven by a 12 kW motor at 2900 rpm. The units are suspended from the tunnel ceiling on mounting frames with anti-vibration mountings to isolate any fan vibrations. The fan impeller consists of a central hub onto which is mounted six cast-aluminium blades. Fans are mounted in 9 rows of 4 longitudinally along the tunnel.		
Number of Units: 36	Maintenance Freq: 5 Years	Manual Ref: Volume 6
Drawing Ref: C4/1-9		Location of Equipment: Westbound bore

Maintenance Tasks:

a) Carry out complete overhaul of jet fan unit as per manufacturer's instructions to include the following:
Inspect and test motor plus replacement of motor bearings
Replacement of perforated acoustic housing sheet with stainless steel perforated sheet
Bead blast impeller and carry out NDT with dye penetrant
Degrease all painted surfaces, spot prime any damaged areas and paint to conform with original specification

b) Replace all anti-vibration mountings with new units.

Items Completed (Tick for Yes): a b

Special Requirements:

Permits Required	YES	NO	Traffic Management Required	YES	NO

Type of Permit:
1] Permit to Access
2] LV Permit to Work
3] HV Permit to Work
4] LV Permit to Test
5] HV Permit to Test
6] HV/LV Permit to Work or, Test (Hazardous Areas)

Any Special Handling/Lifting Requirements to Carry out Task:
Cranes *Fork Lifts*
Scissors Lifts *Fan Cradles*

Signature:
Date:

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APPENDIX E TYPICAL TUNNEL CLOSURE SCHEDULE

The Table illustrates the typical cyclic nature of maintenance works and how they could be programmed to minimise tunnel closures.

Strategic Maintenance Plan																													
Task Name	Year 1												Year 2												Year 3				
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Eastbound 3 Monthly Routine Maintenance																													
Eastbound 6 Monthly Routine Maintenance																													
Eastbound 12 Monthly Routine Maintenance																													
Eastbound 12 Monthly Luminaire Clean																													
Eastbound 2 Yearly Routine Maintenance																													
Eastbound 5 Yearly Routine Maintenance																													
Westbound 3 Monthly Routine Maintenance																													
Westbound 6 Monthly Routine Maintenance																													
Westbound 12 Monthly Routine Maintenance																													
Westbound 12 Monthly Luminaire Clean																													
Westbound 2 Yearly Routine Maintenance																													
Westbound 5 Yearly Routine Maintenance																													
Split Annual Routine Maintenance (Phase I)																													
Split Annual Routine Maintenance (Phase II)																													
Split Annual Routine Maintenance (Phase III)																													
Split Annual Routine Maintenance (Phase IV)																													
Split Annual Routine Maintenance (Phase V)																													
External Equipment 5 Yearly Routine Maintenance																													
Service Buildings 5 Yearly Routine Maintenance																													

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Volume 3 home page

APPENDIX F GUIDANCE ON EMERGENCY EXERCISES

SUPERSEDED

Introduction

F.1 During the planning and design of a road tunnel potential incidents and emergencies should be identified and related to the tunnel layout and to standards of equipping communications, traffic information and control systems. Formal risk assessments should be carried out and recorded for each of the identified risk scenarios. Having identified, defined and ranked the scenarios, appropriate response strategies should be developed to deal with them and incorporated into the Tunnel Operator's Manual and the Operational Manuals of the Police and the Emergency Services.

F.2 It is important to test the effectiveness of such response strategies in a realistic exercise before the tunnel is opened to traffic and amend them based on lessons learnt from the exercise. It is good practice for the future tunnel operator to be fully involved with the exercise.

F.3 The same procedures are applicable when a road tunnel is refurbished, modified or when there is any change in the organisations operating the road tunnel or attending emergencies.

F.4 Regular emergency exercises should be carried out throughout the operational life of the tunnel to ensure the continued effectiveness of the planned response strategies. It is common practice in the police and the emergency services for personnel to be rotated between postings. Regular emergency exercises help the new staff to become familiar with the response strategies and the road tunnel and to meet colleagues from the other services and develop good relationships in a non-critical setting.

Requirement

F.5 The requirement is defined in BD 53 (DMRB 3.1.6).

Frequency of Exercises

F.6 Exercises should be undertaken:

a) before a new tunnel is opened to traffic;

b) when a tunnel is modified or refurbished;

c) as part of the Principal Mechanical & Electrical inspection, which is normally carried out every 3 years.

Objectives

F.7 An emergency exercise has the following objectives:

a) to demonstrate the adequacy of response by the emergency services;

b) to test the planned response strategies in the Tunnel Operator's Manual and the Operational Manuals of the Police and the Emergency Services;

c) to test emergency services' procedures and effectiveness of their training methods in dealing with large-scale accidents/incidents in the tunnel having regard to inter-service liaison;

d) to test and familiarise all parties with the various tunnel services including power supplies, lighting, ventilation, environmental control, communications, fire fighting, security and traffic surveillance and management;

e) to provide practical combined training for the participants representing the three principal emergency services and the tunnel operating authority;

f) to demonstrate the correct operation of all safety and emergency equipment for the road tunnel;

g) to test the validity of any assumptions made.

Further guidance

F.8 Generic guidance to design and carry out emergency exercises is available in "The Exercise Planners Guide" published by the Home Office. Also available on the website: **www.homeoffice.gov.uk**.

F.9 Further guidance specific to road tunnels can be obtained from: tunnels@highways.gsi.gov.uk.

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