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TUNNELS DATA REPOSITORY

Guides

EQUIPMENT FOR ROAD TUNNELS AND URBAN GUIDED TRANSPORT SYSTEMS

TESTS, ACCEPTANCE AND GUARANTEES

June 2019

Centre d'Études des Tunnels (Centre for Tunnel Studies)

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The purpose of this document is to help those involved in building tunnels in their professional practice. It does not release readers from their obligation to remain vigilant in adapting this text to their own particular circumstances. Accordingly, those involved in tunnel construction are responsible for any choices they make when citing the text or the methods described in this document in a contract and in no case may they oppose the content of this document to the authors. Furthermore, readers are informed that it is incumbent on them to remain vigilant with respect to all the texts cited as regards how relevant they may still be given the document publication date.

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TESTS, ACCEPTANCE AND GUARANTEES

June 2019

Centre d'Études des Tunnels (Centre for Tunnel Studies)
25 Avenue François Mitterrand
69500 BRON – France
Tel. 33 (0)4 72 14 34 00
Fax. 33 (0)4 72 14 34 30

cetu@developpement-durable.gouv.fr
www.cetu.developpement-durable.gouv.fr

Since 2013, CETU has been developing a Tunnels Data Repository the prime goal of which is to improve the manner in which public contracts concerning underground structures are drafted and to make available texts and documents to all players involved in construction projects.

The "Tunnels Data Repository" provides all players involved in public works contracts for the construction and rehabilitation of road and rail tunnels, guided transport systems and inland waterways transport systems, with the references of documents covering all sub-sectors involved in tunnel construction (civil engineering works and operating and safety equipment). These references can be consulted at the following website: http://cetu-tunnels.fr/referentieltunnel/.

A steering and monitoring committee is in charge of governance of the Tunnels Data Repository with its main missions being:

- establish the existing documentary architecture;
- monitor the existing repository and analyse the needs for changes;
- set revision or new document production priorities, and put the working structures required to achieve this goal in place;
- validate production by ensuring that it has been developed based on a consensus approach with all interested parties;
- ensure references to existing documents or documents developed within the framework of the Tunnels Data Repository are integrated into the repository database.

The Steering and Monitoring Committee is chaired by CETU (Éric Premat, Deputy Director) and as of 31 December 2018 comprises:

- owners: Didier Brazillier (DIR Centre-Est), Alain Chabert (TELT), Jean-Frédéric Enderlé (EPSF), Rodolphe Guyon (SYTRAL), Idrissa Mahamadou (VNF), Roland Mistral (La Savoie Department), Frédéric Rocher-Lacoste (DIR Île-de-France), Joaquin Valdes (SNCF Réseau);
- project managers: Elena Chiriotti (INCAS Partners) M. Pré (SETEC-TPI), H. Tournery (EGIS Tunnels);
- contractors: Bernard Pucéat (Vinci Energies), Loïc Thévenot (Eiffage);
- and by a technical committee run by CETU (Florent Robert, Gilles Hamaide and Jean-François Burkhart) and also composed of representatives of owners, project managers and contractors.

This document was written by:

Jean-Pierre Arnau – La Savoie Department
Guillaume Bouvatier – SETEC-ITS
Alain Brehm – SYTRAL
Jean-François Burkhart – CETU
Laurent Guillot – Vinci Energies
Olivier Martinetto – EGIS Tunnels
Michel Roignot – SYTRAL

With the opinions and contributions of:

Laurent Chassagne – RATP
Alexandre Dusserre – STRMTG
David Favre – DIR Centre-Est
Chistian Gaiottino – SFTRF
Sylvie Guesdon – RATP
Matthieu Pihouée – SYSTRA

Reviewer and Contributor:

Daniel Couffignal – Cabinet Clément Associés

Reviewers:

Michel Deffayet – CETU
Éric Premat – CETU
Gilles Hamaide – CETU
Jean-Claude Martin – CETU
Michael Potier – CETU

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FOREWORD

Regardless of the mode of overland transportation – road, rail or urban guided transport – tunnel equipment plays the same essential role for human safety.

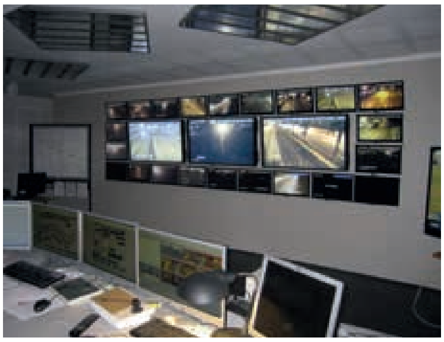
Despite some specificities, the type of equipment installed and the way it is used is very similar from one mode to another, resulting in testing procedures and guarantee conditions that are equally very similar. In all cases, the testing and acceptance phases are essential to prevent accidents.

It follows on from these similarities that it would be very advantageous to bring together recommendations for all three modes in the same document, whether they be common recommendations or recommendations specific to each mode.

However, this document only deals with road and urban guided means of transport, the aim being to supplement it for the rail system so that eventually all overland means of transport are dealt with.

The purpose of this document is to help those involved in building tunnels in their professional practice. It does not release readers from their obligation to remain vigilant in adapting this text to their own particular circumstances. Accordingly, those involved in tunnel construction are responsible for any choices they make when citing the text or the methods described in this document in a contract and in no case may they oppose the content of this document to the authors. Furthermore, readers are informed that it is incumbent on them to remain vigilant with respect to all the texts cited as regards how relevant they may still be given the document publication date.

Finally, this document refers only to the so-called "conventional" contractual arrangements according to Book IV of the Public Procurement Code [1] based on the French MOP Act (Act no. 85-704 of 12 July 1985 on public contracting and its relationship with private contracting) in which the project is designed by a project manager independent of the contractors.



1

CONTEXT AND GOALS

1.1 SAFETY FUNCTIONS AND ROLE OF THE FACILITIES

Tunnel safety regulations lead to the installation of a large number of sophisticated devices organized into systems that interact to form complex assemblies specific to each tunnel. These numerous devices complement each other in order to provide five major safety functions:

- prevention of incidents or accidents;
- detection of incidents or accidents;
- alert and information;
- the protection and evacuation of users and intervention of emergency services in the event of an incident or accident, while limiting the consequences of incidents or accidents;
- restoring normal service after an event.

In addition to the safety functions provided by the equipment when a particular event occurs, some equipment items also provide permanent assistance in the day-to-day running of the tunnel.

1.2 STAKES OF THE TESTING AND ACCEPTANCE PROCESS

Acceptance testing on equipment must enable all systems to operate in their rated condition, within the time limits that are set beforehand. Time limits must be set in a reasonable manner and in no case may be used as an adjustment variable. The goal here is to avoid premature commissioning of projects, i.e. situations where safety conditions are not met or where the projects are not ready to operate correctly, and also avoid imposing commissioning delays in order to have the additional time for final last-minute adjustments.

The stakes are important because these involve:

- checking compliance with specifications, i.e. a stringent, systematic and comprehensive checks on quality, performance and functionality criteria;
- the responsibility of the various participants (owner, project manager, technical inspection firms, operators, contractors…), in particular with regard to safety goals set when designing the project;
- acceptance of the facilities and therefore the conditions for the transfer of custody and the start of statutory and contractual guarantee periods;
- defining an initial (reference) state of the facilities that is legally enforceable and constitutes the genuine technical reference for future detailed inspections.

Additional challenges may be encountered, including:

- work in a context in which operation of the facility cannot be interrupted;
- renovation or renewal of equipment in operation.

Finally, it is essential for the facility operator that testing operations be conducted in a stringent and methodical manner, as they have a direct impact on the level of service of the facility. Indeed, malfunctions and failures of equipment crucial for the safety of the tunnel are likely to cause the structure to be shut down if the equipment no longer meets minimum operating requirements (CME).

1.3 DOCUMENT OBJECTIVES AND CONTENT

1.3.1 Objectives

The scope of the document concerns facilities in road tunnels and urban guided transport systems. These are tunnels in the strict sense and do not include underground urban guided transport stations, with the result being that regulations on premises open to the public (ERP) are not addressed here.

The systems that are discussed in this document are the safety and operating systems in the tunnels excluding, with respect to urban guided transport systems, rolling stock, railway signalling, driving and safety automated systems, as well as the electrical traction energy required for the transport systems.

The document is intended for a broad audience: owners (builders and operators), project managers and contractors. Since existing documents in this area are quite dispersed and since there is a lack of reference documents for certain aspects of the subject dealt with here, the objectives of this document are therefore to:

- propose an approach based on existing texts and "best practices";
- clarify or supplement reference texts, in particular the General Administrative Clauses (CCAG) [2] for Works Contracts, which is widely referred to by the various players;
- share a common vocabulary while respecting the specificities of each means of road transport and urban guided transport.

1.3.2 Content

The content of the four main chapters in this document is set out below and intended to address the above objectives as efficiently as possible:

- a description of **existing reference frameworks** and **current practices** in each road and urban guided transport field with a comparative summary that identifies similarities to be encouraged and shortcomings to be addressed in each of these fields;
- the **objectives** and **standard content** of each **test** to be carried out, including the roles and responsibilities of the main players and the sequencing of tests in different standard or complex cases;
- **the acceptance process**, with a reminder of the principles and proposed additional provisions;
- the sensitive issue of **guarantees**, inseparable from both the technical and administrative aspects of the testing and acceptance process.

2

REFERENCE FRAMEWORKS AND PRACTICES

This chapter lists the existing texts, whether regulatory or not, which constitute the reference framework for the testing, acceptance and guarantee enforcement process. The texts cited are those which have a direct link to tunnel equipment testing and guarantees; the numerous other tunnel security texts as well as specialised technical documents for each set of equipment are not listed here.

The reference framework incorporates French and European regulatory and normative texts, but not the other international texts. For example, North American codes and standards published by the National Fire Protection Association (NFPA) are not cited here.

2.1 ROAD TUNNELS

2.1.1 General texts

2.1.1.1 Legislative and regulatory texts

There are no legislative or regulatory texts relating to road tunnel equipment testing and guarantees.

The Act on the Safety of Transport Infrastructures and Systems (SIST Law) of 3 January 2002 [3] amended the Road Traffic Code [4]. It constitutes the basis of legislative provisions applicable to road tunnels. Supplemented by the decree of 24 June 2005 [5], it defines the prefectoral permit required for tunnels longer than 300 meters before they can be commissioned.

It follows from these texts that when the construction of a new road tunnel longer than 300 meters is being planned, a preliminary safety file (DPS) must be compiled and submitted to an approved expert or accredited qualified organization (OQA). The DPS – systematically processed by CNESOR (National Commission for the Safety Assessment of Highway Engineering Structures) is sent to the prefect of the department concerned by the project for examination. Construction work cannot be undertaken until the prefect grants a favourable opinion on the DPS. The DPS is drawn up in parallel with the technical studies defining the project; it is generally compiled at the same time as the project studies.

The same procedures must be followed when major work is planned in an existing tunnel longer than 300 meters.

The DPS includes a full description of the proposed structure, in which all safety provisions are set out in great detail. This description is supplemented by a specific hazard survey describing the types of events likely to occur in the structure and their possible consequences. The DPS also sets out how the facility will be organized for the operating phase, in terms of human and material resources, as well as the measures planned to be taken by the owner to ensure safe operation and maintenance of the structure. There is no requirement concerning the content of the DPS in relation to the tests to be carried out before commissioning to qualify performance and compliance with the provisions announced.

Once the work has been completed, the commissioning of the work is conditional on approval of the security file (DS) by the prefect. The DS, which is also submitted to an accredited qualified organization, contains the DPS documents – which have been updated – and in particular the future traffic scheme and an intervention and safety plan drawn up in conjunction with the emergency services. There is no requirement concerning the content of the DS with regard to the results of the tests and the conformity of the work carried out with its declared description.

2.1.1.2 Non-regulatory texts

General administrative clauses (CCAG)

The general administrative clauses (CCAG) are not binding, including for government contracts. Application is up to the owner. The CCAG documents contain requirements directly concerning tests, the acceptance process and guarantees from an administrative standpoint, in particular the transfer of custody, the settlement of disputes and deadlines. It should be noted that, as far as these areas are concerned,

- the different CCAG documents (for Works Contracts [2], Current supplies and services [6], Information and communication technologies [7], Industrial contracts [8]) have very different processes;
- the CCAG for Works Contracts is well adapted to civil engineering work in tunnels;
- no one CCAG document is perfectly suited to tunnel equipment work, which requires the drafting of specific clauses.

Also, for road tunnel equipment contracts, it is proposed to use the CCAG for Works Contracts as a basis supplemented by some specific clauses inspired by the other CCAG documents.

Government Instruction of 29 April 2014 and Technical Instruction of 8 November, 2018

For State projects, the government instruction of 29 April 2014 laying down the procedures for carrying out investment and management operations on the national road network [9] has project steering and management provisions aimed in particular at taking greater account of cost control and deadline issues as well as legal security of the procedures involved. The Technical Instruction of 8 November 2018 [10] describes the procedures set down in the governmental instruction in detail.

These two texts highlight the responsibilities of the owner and engineering services in complying with standards, instructions and the rules of the trade, which determine the operating security of the infrastructure. It recalls in particular that "*The time required for controls and for taking account of observations must be incorporated into the operation schedule.* "

Application guide for the technical instruction for the surveillance and maintenance of civil engineering works – Booklet 40: Tunnels, Civil Engineering and Equipment

Booklet 40 [11] applies to all tunnels including cut and cover tunnels in the non-concession national road network. In particular it defines the controls to be carried out throughout the lifetime of the structure, i.e. those carried out during the initial detailed inspection (IDI) after acceptance of the structure, and those to be subsequently carried out every six years in periodic detailed inspections (IDP).

Test reports, inspections and performance assessments of the installations compiled in the as-built file (DOE) are used as the basis for the IDI.

The findings and main lessons drawn from the cases reviewed over the period 2009-2012 – National Commission for the Safety Assessment of Highway Engineering Structures [34]

The findings and main lessons drawn from the cases examined by the National Commission for the Safety Assessment of Highway Engineering Structures (CNESOR) are regularly published in the form of reports by CETU. This document presents a summary of the recommendations and reservations made, and more broadly discusses issues that gave rise to questions and debate, beyond the strict enforcement of regulations, with the purpose of establishing reference principles.

The topic of tests was brought up on a number of occasions during the period 2009-2012.

In general, the Commission recommends remaining vigilant given the complexity of ventilation management systems and recommends that the final development of the smoke exhaust control system be confirmed in normal and degraded mode through real ventilation and fire-resistance tests. In one particular case, the Commission recommended to the owner to draw up a detailed assessment of the tests and experiments carried out before opening.

2.1.1.3 Summary

For each of the issues cited in 1.2, the table below indicates the general texts identified in this chapter which provide the elements required to establish a frame of reference for tunnel equipment testing, acceptance and the application of guarantees.

Issues / Text	CCAG [2] [6] [7] [8]	State Instructions [9] [10]	Booklet 40 [11]
Definition of the responsibility of the parties	√	√	
Definition and guarantee application conditions	√		
Check on compliance with specifications		√	
Acceptance and transfer of custody	√		
Defining an initial state			√

To conclude, the texts gathered cover all the issues, but remain too general and insufficiently adapted to tunnel equipment and its specificities.

2.1.2 Texts specific to technical fields

Beyond the general texts presented in the previous chapter, there are technical documents for some categories of equipment providing useful information on carrying out the testing and acceptance process. Some of these documents, of varying types, are presented below but are in no way exhaustive. The reference framework presented here is that applicable in France taking into account European and international standards.

2.1.2.1 Standards

There are not many standards setting down requirements for testing and accepting equipment. There are standards for only three equipment categories: ventilation, energy and lighting. These standards provide guidance on the content and procedures for factory, platform, or on-site testing, but very rarely set performance and functionality requirements to be met.

There are many other standards – for example, those relating to manufacturers' industrial processes – but which do not concern testing within the meaning of this document.

A few examples of equipment testing standards are given below but this list is not exhaustive.

Ventilation

- NF EN 12101-1 for test method for the determination of fire resistance of powered smoke and heat control ventilators (fans) (Smoke and heat control systems - Part 3 - Specification for powered smoke and heat control ventilators (fans)) [12];
- NF EN ISO 13350 for performance testing of jet fans [13];
- NF ISO 13347-1 to 4 for tests to determine fan sound power levels [14];
- NF EN ISO 5801 et NF EN ISO 5802 for performance testing using standardized airways or performance testing in situ [15].

Energy

- NF C13-100 Delivery stations powered by a public HVA distribution network (up to 33 kV) [16],
- NF C13-200 High voltage electric installations - Supplementary rules for production sites and industrial, tertiary and agricultural facilities [17],
- NF C15-100 Low voltage electric facilities [18].

Lighting

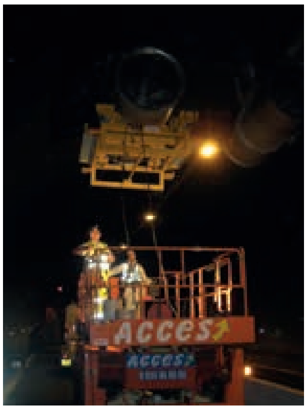
A documentation bundle, which is not standard but is published by the European Committee for Standardization (CEN), deals with lighting in road tunnels:

- FD CEN/CR 14-380 Lighting applications - Tunnel lighting [19].

2.1.2.2 Other technical documents

A few technical documents address the question of testing and controlling tunnel equipment:

- for lighting, the CETU Master Folder - section 4.2 Lighting (November 2000) [20] provides requirements for monitoring the photometric performance of installations, based on illuminance (contractual clauses) and luminance measures;
- for ventilation, CETU information memo No. 14 Anchoring jet fans in tunnels (2005) [21] provides guidance on suitability and control tests to be performed on jet fan fixation devices;
- for video / AID (automatic incident detection), the CETU information document Automatic Incident Detection by Tunnel Image Analysis (May 2015) [22] presents the content and procedures for carrying out the performance tests required prior to acceptance of this type of installation. It also sets out the qualification process to be pursued at a later stage, during the regular service check (VSR) period and provides recommendations on the scope of the guarantee to be provided for contractually.



2.1.3 Practices

The proper functioning of road tunnel equipment requires a series of prior tests and controls which start when the work begins and which continue until the work is accepted, and sometimes even beyond that time when reservations need to be resolved or faults corrected that appear during dry-run operation or at the time of the regular service check (VSR).

Carrying out these tests has a direct impact on the total duration of the operation. These tests are indeed numerous because the number of equipment items to be tested is high and these tests can sometimes take quite a long time. All or part of work site activities may have to be stopped when carrying out these tests.

For large-volume serial equipment items (e.g. an electric motor), tests are carried out by the supplier as part of its quality control process in the manufacturing plant. These **qualification tests** are generally transparent with respect of the work site.

But much of the equipment installed in the tunnel requiring special installations or developments (transformers, low-voltage panels, fans, lighting devices, GTC (centralised technical management), video/AID, RAU (emergency call network), etc.), must undergo specific tests, ranging from factory and platform tests to on-site tests. On-site tests are carried out in a step by step manner. They start with a check that the equipment is correctly installed and integrated into the site (**static tests**) in order to ensure that each piece of equipment is correctly set up and connected to power supplies and control systems; they then continue with **partial acceptance tests** which test the individual workings of each piece of equipment independently. These are then followed by **system acceptance tests** in which each system is checked to ensure it fulfils the function or functions assigned to it within the overall tunnel safety system; and the tests end with the **global acceptance tests**, in which the equipment, taken as a whole, is checked to ensure it meets the requirements set out in the specifications for operating modes identical to those to be encountered in the operating phase.

While the processes implemented, ranging from factory testing to regular service checks, in practice, never differ very much from this layout, the breakdown into phases is not always very explicit, sometimes causing deep misunderstanding between the different parties involved, with this misunderstanding being accentuated by the extremely heterogeneous vocabulary used.

2.2 TUNNELS IN URBAN GUIDED TRANSPORT SYSTEMS

2.2.1 General texts

2.2.1.1 Legislative and regulatory texts

The current scheme was initiated in 2002 by the SIST Act on Transport Infrastructure Safety of 3 January 2002 which introduced articles L1612-1 and L1612-2 into the **Transport Code**. These articles specify, in particular, provisions relating to the undertaking and commissioning of works.

This Code was supplemented by **Decree No. 2017-440 of 30 March 2017** on the safety of guided public transport (STPG Decree) [23], which was itself accompanied by two orders:

- **order of 30 March 2017 amending the order of 23 may 2003** relating to safety files for urban guided public transport systems [24],
- **order of 30 March 2017** concerning safety files for mixed systems [25].

The **STPG Decree of 30 March 2017** [23] states:

- that the Safety Definition File (DDS), required for new lines, line extensions or automation systems and compiled in the course of project definition studies, must present a tentative schedule for the project indicating the dates for completion of on-site tests and dry-run operation;
- that the preliminary safety file (DPS), drawn up before starting the work, must include a tentative schedule for the project indicating the projected dates for the start of any work, for carrying out tests, for dry-run operation and for the start of commercial operation, as well as the planned test programme. The start of the work is conditional on the opinion given on the DPS;
- that the safety file (DS) must include the results of tests. Commissioning is conditional on the opinion given on the DS;
- the possibility of requesting an as-built safety file (DRS) one year after commissioning in order to update the safety file.

The decree of 30 March 2017 explains the GALE principle (Globally At Least Equivalent) that is authorised to demonstrate system safety and requires a second independent opinion on the safety files (from an accredited qualified organization, OQA), based on the DPS.
It also specifies that the transport organising authority must draw up a specific file – **the test authorisation file (DAE)** – with a view to obtaining prior authorisation from the prefect to carry out tests or dynamic tests which may present risks to third parties, residents or users of the transportation system. This file shall contain, in particular, the description of the tests, the places concerned and the scheduled dates or periods. It must also identify the risks incurred and indicate the precautions taken.

The order of 22 November 2005 [26] further states that when tunnels are present in a project for an urban passenger guided public transport system:

- on-site tests must be conducted to assess how passengers evacuate the vehicles;
- acceptance testing must be performed to check the actual performance of the smoke extraction ventilation system.

It should be noted that, in regulatory terms, this order only applies to new tunnels or tunnel extensions over 100 meters long.

In the case of an urban passenger guided transport line, tests may only start when the test authorisation file has been approved by the prefect.

Once the tests have been completed, the safety file with additional tests and reports indicating successful completion, is forwarded to the prefect, who may then approve the file and authorise the commissioning of the structure.

Finally, the Decree No. 2010-1580 on the technical service for ski lifts and guided transport (**STRMTG**) [27] and its circulars and the order of 2 February 2011 [28] specify the organization of STRMTG as regards the technical examination of the STPG files described above. The prefect calls on STRMTG, which checks the file is complete and provides a detailed technical safety opinion on the safety files. This examination provides real added value to the administrative stages, through direct technical exchanges right from the design phase. It also promotes the spread of feedback and good practices from other transport networks in France.


2.2.1.2 Non-regulatory texts

General administrative clauses (CCAG)

The general administrative clauses (CCAG) document is a reference to be used when drafting equipment works contracts for urban guided transport tunnels or road tunnels (see 2.1.1.2).

STRMTG Application Guides

The STRMTG Application Guides are intended to clarify the provisions of current safety regulations (STPG Decree and implementing orders) and to thereby facilitate their implementation and control.

2.2.1.3 Summary

Regulations on urban guided transport systems incorporate the fact that, in addition to technical and safety infrastructures and installations, the public passenger transport system includes vehicles (tramway or metro trains) with their own operating principles and rules. The operating rules for these vehicles contribute directly to establishing system safety – for example on-board autopilot and passenger communication facilities – and to passenger protection (where evacuation is required).

This component is at the root of the regulations specific to urban guided transport systems. In order to control every component in the system including vehicles, the safety demonstration and global tests must be carried out prior to obtaining the operating authorisation order. Thus, the sequence of regulatory files and their expected contents require that the testing and acceptance phases be scheduled sufficiently in advance. These good practices induced by regulatory constraints are described below.

The advantage of extending existing lines is that the GALE approach (Globally At Least Equivalent) can be used in the safety demonstration. In return, such projects have the disadvantage of being subject to constraints and requirements related to the existing infrastructure in operation, in particular for global tests which may require tests during non-operating periods (nights or scheduled stoppages) and this would favour a works schedule that has realistic test times and that accounts for any unforeseen events.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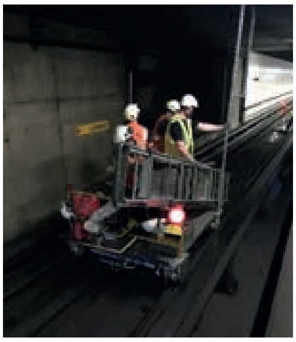
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For each of the issues cited in 1.2, the table below indicates the general texts identified in this chapter which provide the elements required to establish a frame of reference for tunnel equipment testing, acceptance and the application of guarantees.

Issues / Text	CCAG [2] [6] [7] [8]	STPG decree, implementation orders [23] [24] [26] and STRMTG guides
Definition of the responsibility of the parties	√	√
Definition and guarantee application conditions	√	
Check on compliance with specifications		√
Acceptance and transfer of custody	√	
Defining an initial state		√

To conclude, the texts presented cover all the issues identified. The STPG Decree, at once specialised in the area of urban guided transport and explicitly addressing tests with rolling stock in circulation presenting risks to third parties, residents or users of the system concerned, lays down a very useful and directly applicable framework. The CCAG complements it on the more administrative aspects (guarantee, acceptance, transfer of custody) with the disadvantage of being of a much broader scope, i.e. not fully adapted to the specificities of the equipment installed in urban guided transport tunnels.

2.2.2 Texts specific to technical fields

2.2.2.1 Standards

There are not many standards setting down requirements for testing and accepting equipment. These are the same standards as those cited in Chapter 2.1.2.1. for road tunnels, with the exception of the FD CEN/CR 14-380 Lighting applications – Tunnel lighting [19] standard, which is specific to road works.

The Decree of 22 November 2005 on tunnel safety in urban passenger guided transport systems [26] refers to several standards concerning fire resistance of cables, fire protection of railway equipment and the characteristics of the water supply system (dry standpipes or wet standpipes). However, these standards do not contain requirements directly related to on-site testing.

2.2.2.2 Other technical documents

There are no technical documents, other than the standards, containing requirements for equipment testing and acceptance dealt with in this document.

2.2.3 Practices

From a purely technical point of view, tests of urban guided transport equipment are similar to those carried out for road tunnel equipment. There are simple qualification tests for serial equipment (or at least for materials manufactured using strictly defined manufacturing processes), and specific tests where the installed materials are not standard equipment. From this point of view, the practices with regard to urban guided transport are therefore similar to those of road tunnels, detailed in paragraph 2.1.3. The same applies to the progressive nature of tests, from unit tests in the factory or on the platform to global on-site tests.

In the case of urban passenger guided transport, there are however two additional steps compared to road projects. These are dynamic testing of rolling stock, which takes place after global on-site testing, and tests in metro stations for compliance with standards and regulations for premises open to the public (ERP). However, these two points are not developed in this document (see 1.3.1).

The practices observed are guided by the regulatory texts which impose a strict framework both for defining the content of the tests as well as the timing of these tests.

The goal is to obtain the prefectoral order authorising operation. This order is issued based on the opinion given by the SIST[1] sub-committee (Safety of transport infrastructure and systems) the CCDSA (Departmental Advisory Commission on Safety and Accessibility) in the cases identified in the STPG decree. The SIST sub-committee brings together, under the auspices of the DDT (departmental territorial directorate) or the DDTM (departmental territorial and maritime directorate), the STRMTG, emergency services (SDIS, SDMIS, BSPP or BMPM). For metro stations, the mandatory opinion from the Accessibility Commission specific to premises open to the public (ERP) must be added.


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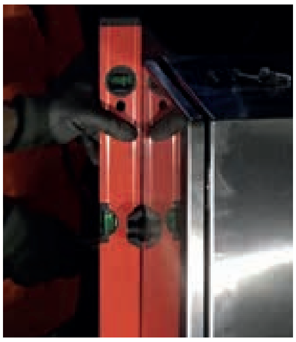
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In order to obtain this authorisation to operate, the safety process compiles the files to be examined by State services in step with the pace of production of studies:

- the safety definition file (DDS) is compiled for new tunnels (extensions or creation) or for line automation projects upon completion of the preliminary studies phase and this file is submitted for the Prefect's opinion;
- the preliminary safety file (DPS), accompanied by reports and certificates from the OQA, and which must be approved by the Prefect before work can begin;
- where applicable, non-regulatory safety milestone files (DJS) on certain safety-related sub-systems, compiled at the end of the EXE phase, and that are the subject of exchanges between suppliers, the designer, the OQA and the operator, prior to examination of the transport system's global safety file.
  Depending on the complexity of the system, the process of compiling DJS files for the various subsystem suppliers may take an additional period of one to three months. This process must address any contradictions and have all requirements carried over to operations and maintenance validated by the operator or its representative;
- the test authorisation file (DAE) must describe safety conditions and the procedures for conducting the tests. These tests cannot start without a favourable opinion authorising them from the Prefecture after examining the test authorisation file, accompanied by the opinion of the OQA.
  The duration of the tests depends on the complexity of the transportation system and the availability of the site. These tests can take one to three months;
- the safety file (DS) must demonstrate the safety of the design and implementation of the transportation system.
  The DS includes the closure of the designer's overall safety analysis including that for vehicles and their operating rules, safety regulations in operation (RSE) and the emergency response plan (PIS) to maintain the safety level over time, OQA reports and certificates and the detailed description of the overall tests and their results[2].
  Once the entire file has been forwarded to the control department, including test results, the prefect may grant authorisation to operate.

1. Only if the tunnel is over 300 meters long, or if is between 100 and 300 meters long and the convoys using it have a capacity of more than 500 passengers, based on 6 standing passengers per m².
2. The results of the tests may be forwarded after the DS is sent (tolerance art.28 of the STPG decree of 30 March 2017).

All regulatory periods must be taken into account when drawing up the overall schedule for the project and therefore a period of some nine months is usually required between the time the installation is completed and the time the infrastructure is commissioned.

However, equipment testing in urban passenger guided transport tunnels is not limited to global testing, which is only the last step in a long process.

2.3 SUMMARY

2.3.1 Beyond apparent differences, many similarities

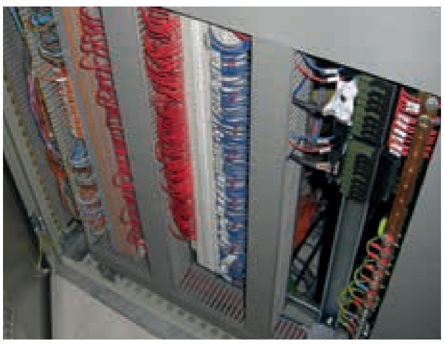
2.2.1.1 Legislative and regulatory texts

Despite apparent differences arising out of historical contexts that vary according to the mode of transport, the practices observed are similar from one field to another both in terms of safety considerations and the organization of project contracting and engineering.

Systematic and progressive tests are conducted in the factory, on the platform and on site, followed by a **dry-run operation** period during which the operator takes over the finished works. At the end of this period, the work is commissioned and then the **regular service check** (VSR) period begins, during which the contractor intervenes to correct any defects revealed by the first months of operation. Such sequencing has become widespread and is more or less correctly formalised. Regardless of the mode of transport, the approach is based on the CCAG for Works Contracts [2] and applicable standards.

Under the SIST Act, systems subject to the STPG procedure have additional regulatory requirements for defining and scheduling tests, as well as for demonstrating the success of tests. This specificity is linked to the fact that, unlike road transport, guided transport systems use guided vehicles to carry passengers under the responsibility of the operator. This is also explained by the fact that tests are in some cases carried out on roads open to public traffic (in the case of tunnel exits for trams), which is a source of additional risks.

Although the Technical Instruction of 25 August 2000 on safety provisions for new road tunnels [29] explicitly provides for the possibility of adopting different requirements from those it recommends if it is shown that the proposed provisions ensure a level of overall safety at least equivalent, this possibility is in fact rarely used, unlike that which is practised in the STPG area. This difference can be explained by the very prescriptive nature of the technical instruction for road transport, unlike the technical instruction appended to the Decree of 22 November 2005 on safety in tunnels in urban passenger guided transport systems [26], which leaves much more leeway in the choice of technical solutions.



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2.3.2 Areas for improvement

2.3.2.1 Areas for improvement common to road and urban guided transport systems

Equipment in road tunnels and urban guided transport tunnels having identical safety issues must undergo the same stringent testing process. Because the STPG regulatory texts have requirements for this aspect, test processes are more naturally integrated into urban guided transport system projects than they are into road projects. However, in both cases, whether the tests are based on an explicit regulatory obligation or simple practice, the relevant provisions, acknowledged and shared by all players, must be reflected in the contracts concerned.

Thus, in order to ensure that the successive steps required to validate the system as a whole are complied with, the tendering files (DCE) for project management or works could indicate more systematically, or more accurately, on the one hand, the respective roles of each of the players in properly conducting the tests related to the commissioning of the structure, and on the other, the different test and acceptance stages to be carried out including the conditions for moving on to and moving on from each one. Associated with hold points, these may be accompanied by penalties or deductions to be mentioned in the CCAP document (CCAP = special administrative specifications).

It is also possible to break a project down into several unit test areas in order to better define test interventions.

In some cases, introducing interim milestones for each system into the works DCE is possible. Thus, it would seem to be possible to better anticipate tasks, better control task progress and detect any drifts off course at an earlier stage. But such clauses need to be given careful thought since they may reduce the integrator's organizational flexibility and ultimately extend the overall time frame, depending on the project's specific task overlapping or sequencing possibilities.

Finally, compiling a management plan type document for tests should become systematic at the outset of the works contract.

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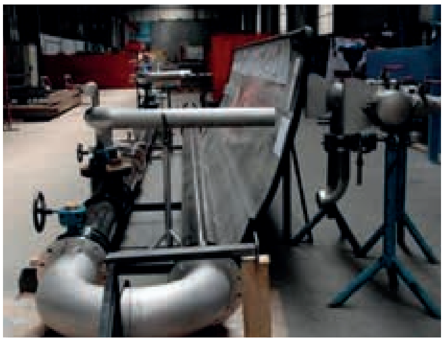

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2.3.2.2 Specific areas for improvement for road tunnels

As for road tunnels, regulatory developments since 2000 have significantly raised the requirement level. One direct consequence is that much more equipment is being installed, equipment that is complex, difficult to develop and time-consuming to control. The potential difficulties that result are failure to comply with the work and test schedule and the lengthening of testing and development times that have sometimes been – and still often are – underestimated. This has led to some very long commissioning delays compared to the schedules announced, despite considerable efforts in terms of resources deployed on the work site. In order to avoid these very delicate situations for the owner and for all the players involved, a more formal organization with standardised practices must be put in place.

A test management plan should here also be systematically drawn up and accompanied by sufficient resources to ensure smooth completion thereof, regardless of the level of control considered (contractor, project manager, assistants to the owner, the owner, etc.).

2.3.2.3 Areas for improvement specific to urban guided transport tunnels

The current authorisation process addresses the needs and requirements to demonstrate the expected level of safety on urban guided transport systems, including with respect to tunnels, at least when projects include new tunnels or tunnel extensions.

This process ensures that the procedures for acceptance of tunnel equipment are carried out and validated positively in order to obtain approval for commercial commissioning.

The technical instruction appended to the decree of 22 November 2005 [26] establishes the minimum technical expectations to be deployed in the tunnels built.

One improvement would be to initiate actions on existing so-called "old" tunnels (i.e. not covered by the above-mentioned technical instruction), and take specific and adapted steps, depending on the possibilities (planned rehabilitation works or actions taken when making changes in the tunnel…), after these points and actions are identified in the regularised safety files compiled by the organising authorities and inspected by the OQAs.

3

TESTS AND CONTROL OF WORKS

Tunnel equipment is a fundamental safety component for a tunnel. This equipment must therefore benefit from stringent testing with no exceptions being allowed, at the risk of weakening the overall safety level of the tunnel and resulting in a level that does not meet regulatory requirements. In view of the above-mentioned issues, this part of the document, like Parts 4, 5 and 6 which follow, is intended to recap the requirements to be met, in particular for project managers who are responsible for contractually defining the content of the tests to be carried out in the framework of the works contracts, whether these be at the contractor's expense (internal control) or not (external control).

It is essential to identify and formalise each phase in the process, the content of which is detailed in the contract signed between the owner and the contractor.

Normally, the sequence is as follows:

1° qualification tests performed by equipment manufacturers, or even more upstream by suppliers of equipment and equipment components;
2° specific tests, themselves progressive with successive factory and platform tests, static on-site tests, partial acceptance tests (EAP) on-site, system acceptance tests (EAS) on-site and global acceptance tests (EAG) on-site;
3° Operations prior to acceptance (OPR), technical operations leading to a proposed acceptance or non-acceptance sent by the project manager to the owner, in light of the results of all the tests;
4° acceptance by the owner;
5° a dry-run operation period (or pre-operating period) by the infrastructure operator;
6° commissioning;
7° a regular service check (VSR).

3.1 KEY PLAYERS: ROLES AND RESPONSIBILITIES

3.1.1 Foreword

The roles of the main players are developed below but do not discuss interventions specific to experts – such as OQAs – or government services.

A block diagram showing the most frequently encountered type of organisation is shown in Figure 1.

The overall schedule of the construction operation is organized around four fundamental successive stages:

- developing the project, responsibility of the owner;
- designing the project, responsibility of the project manager;
- performing the works, the responsibility of the contractor for performance of the work and of the project manager for control;
- operating the structure, responsibility of the operator.

The three construction players are bound by two types of contracts:

- a project management contract between the owner and the project manager;
- a works contract between the owner and the contractor.

It should be remembered that the project manager's authority over the contractor arises out of the contractor's obligations under the contract in accordance with the CCAG for Works Contracts [2].

To these three players must be added the infrastructure operator, the main user of the equipment and the entity responsible for its maintenance.

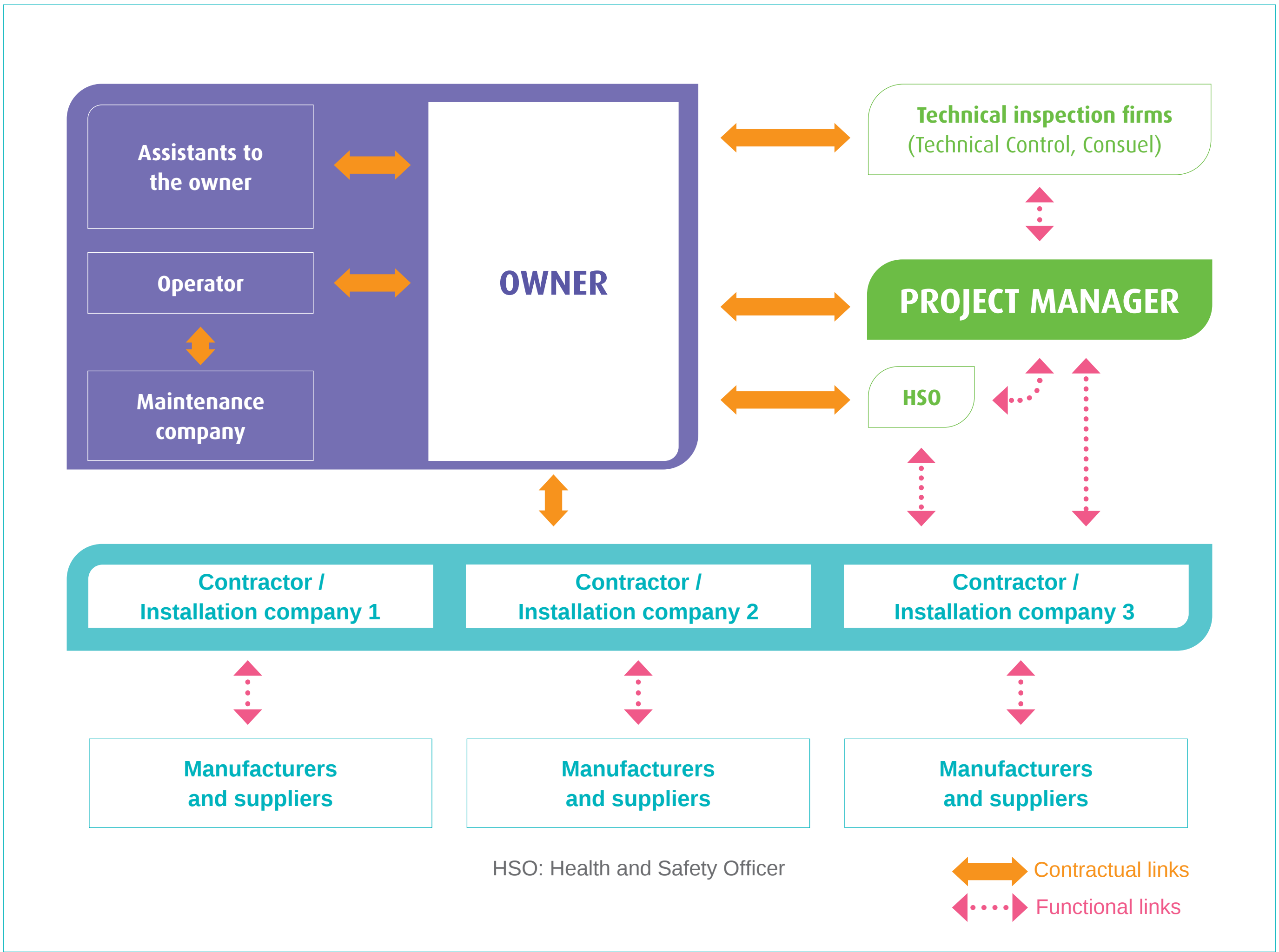


Figure 1: Schematic diagram of the most widespread type of organization between players.

3.1.2 Owner

As defined in Article L.2410-1 of the Public Procurement Code [1], the owner is the purchaser who, planning to build a structure, considers awarding construction contracts.

It is the responsibility of the owner, after having ascertained beforehand the feasibility and timeliness of the proposed operation, to determine the project location, establish the project programme, draw up the projected budget, organize financing, choose the process by which the work will be carried out and enter into public contracts for the purpose of having the engineering studies and work required carried out.

The owner makes available all known elements in its possession required to carry out the work. It pays the agreed price and facilitates performance.

The owner sets the time frame for the operation and ensures it is complied with. It sets a realistic commissioning date, taking into account the time required for testing, resolving any reservations, dry-run operation and safety drills. The owner also incorporates regulatory procedures required for the development, appraisal and approval of the safety file into the schedule, until authorisation to operate is obtained.

The owner ensures that the work carried out is in accordance with the programme and with the operator's requirements.

The owner organizes the handing over of the structure to the operator and ensures coordination between all the players involved in the project and, more broadly, with all services concerned, and in particular those involved in drawing up the safety file (Prefecture, emergency services, etc.).

3.1.3 Operator

The term operator may refer either to the person who is responsible for operating the network or the control station. For example, platform tests on centralised technical management are primarily for the personnel in the control station, whereas tests on low-voltage distribution panels are specifically for the personnel responsible for maintenance. In the following, the same term refers interchangeably to one or the other. In any event, the operator is the first entity to intervene on tunnel equipment. As such, the operator must be actively involved in all stages, from project design to commissioning.

When the project is being designed, the operator must be associated as soon as possible so that it can provide input regarding the functionality of tunnel equipment and ideally this collaboration should start right from the time of project development through to completion of the works contract.

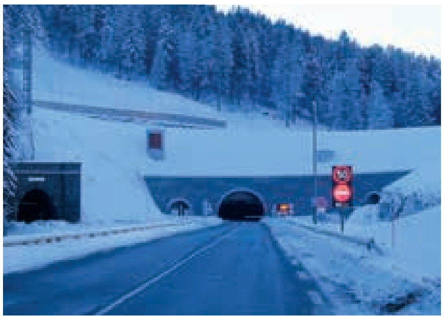
At this stage, the project manager associates the operator to the drafting of the functional specifications for the equipment and defines the elements that must be taken into account in the subsequent project work file (DIUO). In particular, the operator brings its ergonomics experience to the project ensuring procedures and features are consistent with other infrastructures it operates. In other words, designing tunnel equipment should not consist of developing new prototypes – a long and uncertain approach – but rather upgrading existing equipment based on past experience and the latest technological developments.

During the works, the operator must be regularly invited to technical site visits so that it can progressively take ownership of the future structure. In addition, the operator will be consulted on any proposed changes to the equipment.

Before operations prior to acceptance, the operator will be invited by the project manager to attend these pre-OPR operations which involve a visit to the tunnel during which the operator can make any observations it deems necessary (see 4.2).

During dry-run operation, the operator becomes familiar with the use of the equipment, observes the workings of the equipment and determines whether or not it is capable of performing the required functions under normal operating conditions and in degraded modes. The operator reports any malfunctions it observes to the owner, who mandates the contractor to make the necessary corrections.

Once the work has been commissioned, the VSR enables the operator to report to the owner any equipment defects revealed by the first few months of operation.



3.1.4 Project manager

Article L.2431-1 of the Public Procurement Code [1] provides that the project management mission is a global mission which must enable architectural, technical and economic solutions to be brought to the project defined by the owner. As such, the owner may entrust all or part of the following design and assistance items to the project manager as defined by the decree of 22 March 2019 [35]:

1° Preliminary studies;
2° Pre-project studies;
3° Project studies;
4° assistance provided to the owner in awarding works contracts;
5° construction design work or the check on compliance with the project and validation of that design work carried out by the economic operators responsible for the works;
6° responsibility for having works contracts performed;
7° scheduling, steering and coordination of the project;
8° assistance provided to the owner during acceptance operations and during the defects liability guarantee period.

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The project manager is vigilant with respect to any risks that may arise on the site, whether they be technical or concerning the project schedule. The project manager keeps the owner informed at all times of progress on the work site.

The role of the project manager is essential to achieve the level of performance and reliability of safety equipment right from the time of commissioning as backed up by test results.

It is the project manager who defines the content of the tests in the CCTP and who appoints the person responsible for them. The tests are carried out by the contractor (internal and external controls) and possibly by external technical inspection firms (external control). Then, during the works, the project manager deploys the resources required to oversee proper performance of the work at all times and adapts these resources to the actual pace of work on the site if needed. The project manager organizes external control operations and associates the future operator to these operations through the owner when necessary (see 3.1.3).

The project manager is present during the tests carried out by the contractor as the work advances. The results of these tests are recorded in the acceptance test specifications document which the contractor decides to validate or not. At the end of all acceptance tests, the project manager recommends that the owner accept or does not accept the works, taking account of the nature and quantity of any outstanding work (finishing, corrective work, etc.). This is a significant responsibility for the project manager in view of the administrative consequences of the decision to accept the works (see 5) and the impact that persistent defects in safety equipment may have on dry-run operation, and even more so when the structure is commissioned.

In the case of a lot-based contract, the OPC (sequencing, steering, coordination) mission entrusted to the project manager or to an independent third party must enable interventions by the various contractors to be efficiently coordinated, particularly during testing phases.

3.1.5 Contractors - installation companies

The contractor or the group of contractors responsible for performing the works must comply with the contractual commitments binding it to the owner; these commitments concern proper execution of the work within the budgets and deadlines agreed. The CCAG for Works Contracts sets the contractual framework for the collaboration between the contractor and owner.

The contractor advises the owner – it knows and applies the rules of the trade – performs the works, has custody of the works until they are accepted – and guarantees the completed works.

The contractor is responsible for ensuring the finished work is compliant through its choice and verification of the origin and quality of the materials used. The contractor is also responsible for proper use of the said materials in accordance with the specifications. The contractor must ensure the construction is of sufficient quality through an internal and external quality control process determined prior to starting the work. In addition to the works control plan, the contractor establishes an acceptance specifications document specifying the checks that will be carried out on each piece of equipment.

The contractor controls proper execution of the work at all times. Test results are recorded in the acceptance specifications document which is submitted to the project manager for approval.

Based on all acceptance test results, the contractor determines the date the work may be considered as completed and informs the owner and project manager of this so the project manager may organize pre-acceptance operations in the presence of the contractor.

3.1.6 Assistants to the owner

From the outset, the owner must determine its own skills and resources and those required in light of the complexity of the operation and where necessary it must appoint assistants specialised in the fields concerned by the project within the meaning of Article L2422-2 of the Public Procurement Code [1]. These owner assistants (AMOs) can intervene in regulatory, administrative, financial, technical or communication areas.

If the owner detects a new need in the course of the operations, it may call on an additional assistant to help address this need.

3.1.7 Health and Safety Officer (HSO)

The HSO is appointed by the owner at the start of the design phase and intervenes to safeguard the health and safety of workers in two areas:

- during co-activity phases of the works,
- during subsequent interventions on the structure.

It should be noted that the test phases require a great deal of inter-company co-working in situations that are sometimes difficult to plan for in terms of safety.

The general coordination plan (PGC) established by the HSO thus specifies the coordination measures chosen for the operation as well as collective protection arrangements (ventilation, lighting, emergency facilities) maintained in place for workers.

Every construction player must be fully involved in safety actions on the site. The Labour Code (art. L.4531-1) requires that, in addition to the contractors, the owner, project manager and HSO implement general accident prevention principles.

This article states that:

"*These principles are taken into account when making architectural and technical choices as well as when organizing site operations, with a view to:*

1° planning performance of the various works or work phases taking place simultaneously or successively;
2° to anticipate the duration of these phases;
3° to facilitate subsequent interventions on the completed structures. "

3.1.8 Technical inspection firms

Technical inspection firms, regardless of the service requested of them, must be associated to the project at a sufficiently early stage. In some cases, they must intervene right from the initial design studies phase and, almost always, at least when drafting the technical clauses for the works contracts.

3.1.8.1 Technical controllers

While technical controllers are encountered more often in the construction sector, they can nonetheless intervene in the area of the infrastructure concerned by underground works. To do this, the controller must be certified by the Ministry in charge of construction, for the E1 application area (E.1: Civil engineering works, for all inspection missions: terrestrial non-hydraulic infrastructures not intended for the transport of fluids, currents and waves; includes large urban construction works having the same specialised fields as well as the equipment associated to these infrastructures).

Tunnels[3] are not premises open to the public, so they are not subject to a mandatory technical control. In any event, it is the responsibility of the project manager to ensure compliance with regulations and the rules of the trade by inspecting implementation documents, overseeing the works and taking part in tests. However, the owner may decide to call on a technical controller in order to have an external opinion on the risks regarding the robustness of the structure and the safety of persons.

Among the technical control missions defined by the NF P 03-100 standard [32], the choice will mainly concern those missions relating to the solidity of the structure (L + LP + LE missions in the case of rehabilitation works) and the safety of persons (Mission S for provisions relating to the protection against fire and panic risks, fire safety systems, electrical installations, guardrails, etc.). Nothing prevents this provider from being entrusted with other assignments.



3. This document does not deal with underground guided transport stations that are premises open to the public.

3.1.8.2 The accredited qualified organization (OQA)

The OQA is not responsible for the design and implementation missions incumbent on the owner, project manager and contractors and the OQA must not replace these. The verification and validation of the safety system must be carried out under the full responsibility of those whose mission it is to design and build – or renovate – the structure.

The OQA must, however, carry out an assessment and provide its opinion on the system's global level of safety in terms of compliance with current regulations, standards and technical benchmarks, and whether the required level of safety for the system as a whole has been achieved, along with its ability to maintain this level over time.

The STRMTG Implementation Guide "*Urban Passenger Guided Public Transport Systems - Mission of the Accredited Qualified Organization (OQA) in assessing Project Safety*" of 8 February 2012 [33] describes, not in an exhaustive manner, the mission expected of the OQA in assessing the safety level of new systems or of changes to existing urban guided transportation systems.

This guide explicitly states that beyond the design and implementation phases, the mission of the OQA involves testing phases prior to commissioning and operating.

For road tunnels, article R 118-3-2 of the Road Traffic Code [4], simply mentions the fact that an updated safety report from the expert or accredited qualified organization must be included in the safety file on which the commissioning authorisation issued is based. Although the Road Traffic Code does not explicitly mention testing and commissioning, the OQA (designated EOQA, expert or accredited qualified organization) must nevertheless be present during this phase. Its interventions are context-related, but in all cases it must be involved in removing the final reservations, any recommendations made as to the safety file, as well as defining and conducting the safety drill before commissioning.

3.1.8.3 The safety officer

For road tunnels over 500 meters long located on the Trans-European Road Network (TERN), a safety officer is appointed by the owner to coordinate accident prevention and safeguard measures to protect the safety of users and operating personnel.

As such, like the OQA, the security officer, while he/she will not replace the players directly responsible for carrying out, overseeing and controlling the work on the equipment, will ensure that the equipment performs the safety functions assigned to it at all times.

3.1.8.4 The Consuel (national committee for the safety of electricity users)

The owner must provide for intervention by the Consuel, the national committee for the safety of electricity users.

The Consuel committee is an association recognised to be of public interest and responsible for checking and certifying the conformity of electrical installations and without this approval the electrical installation cannot be connected by the distributor.

The Consuel's certificate of conformity is compulsory for any new installation, as well as for any renovation work that requires the power supply to be cut off.

3.1.8.5 The Zone Service for Information and Communication Systems

When the tunnel is fitted out with a radio communications transmission system for emergency services (fire brigade, ambulances, police, gendarmes, CRS riot police) that is part of the national shareable telecommunications infrastructure (INPT), the zone service for information and communication systems (SZSIC) [30] must be called on to check regulatory compliance and the proper functioning of the system in place [31].

The SZSIC performs tunnel tests and measurements and takes part in radio compatibility tests. It gives its opinion on the workings of the system for use and integration into the existing outdoor radio network.

The authorisation to put the device into service is issued by the prefecture, in light of the measures and tests carried out by the SZSIC.

3.1.8.6 Organization responsible for the initial detailed inspection of the equipment

For tunnels and cut and cover tunnels in the non-concession national road network, an initial detailed inspection of the installation must be carried out between acceptance of the structure and the end of the VSR check. The organization – or at least the individuals responsible for the inspection – must be independent of the players directly involved in the construction, control and future operation of the structure.

3.1.8.7 Other inspection bodies

The owner, possibly on the advice of the project manager, appoints external control bodies to check proper completion of the work and the performance of the installation. This may be used to gain an independent opinion if there are any doubts as to the results of certain tests or a desire to have a second opinion on certain sensitive facilities or simply to have tests carried out that require very specific skills.

External inspection bodies may thus be called on to check the stability of certain special structures (gauge control and equipment protection devices, portals, masts), the degree of fire protection for the structure (draught chambers), the quality of corrosion protection applied (galvanizing, painting systems). These checks can be carried out both in the factory and on a platform or on the site.

3.1.9 Manufacturers - Suppliers

Sourcing of the materials required for the work is managed through direct contracts between the contractor and the suppliers and manufacturers. Nevertheless, all materials must comply with the provisions of the contract between the owner and the contractor.

Suppliers and manufacturers must carry out quality checks on their own production and provide certificates to the contractor who will forward them to the project manager if required by the contract.

Many tunnel safety installations (cables, doors, hatches, registers, fans, etc.) require special certification, in particular as regard fire resistance. This may be self-certification, but sometimes approval may only be given by external accredited laboratories. Certification testing by such laboratories remains, however, the responsibility of the supplier.

3.1.10 Emergency services

The fire fighting services to be called upon in the event of a fire must be asked to check that the fire-fighting facilities deployed in the tunnel – dry or wet systems – meet their requirements. These requirements will of course have been defined with them very early in the design phase.

Firefighters test the ease of handling of the components in the fire-fighting network (hydrants, poles, valves, etc.) and check the performance achieved (flow rate, pressure). The advantage of having these tests carried out by the emergency services themselves is that they use their own equipment (fire hoses, pump-and-tank wagon, etc.) and also have the opportunity to check this equipment is compatible with the tunnel's fire-fighting network.

Firefighters should also be involved in checking access and tunnel intervention conditions: how practical is it to get fire-fighting equipment to the site, to handle doors, read markings, how efficient are the lighting system, line guides, fire hose connections and the radio communications system.

More generally, it is useful to make fire-fighters familiar with all safety facilities in the tunnel – and in particular the smoke extraction systems – and how they should be used in the event of an accident.

Firefighters will be invited to attend tests run to check that the smoke extraction system is functioning properly. Tests with the production of hot or warm smoke will be preferred to simple tests with cold smoke (smoke candles) which do not reproduce the behaviour of the smoke produced during a fire. When fire prevention is absolutely critical and where possible, a test with the combustion of vehicle wreckage will be carried out. Indeed, other types of tests cannot reproduce conditions identical to those the fire-fighters will face in the event of a real vehicle fire in terms of both fire kinetics and smoke characteristics (visibility, toxicity and temperature). If such a test is carried out, it is even possible to envisage the fire-fighters themselves extinguishing the fire, so that they can exercise in conditions very close to reality. In any case, the fire-fighters intervene during the safety drill which must be carried out before commissioning.

3.2 GENERAL RECOMMENDATIONS ON TESTING

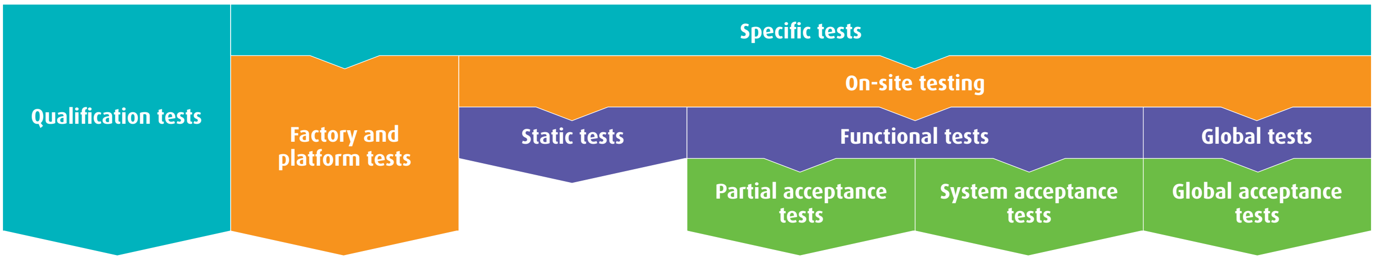


Figure 2: The entire testing process – progressiveness and thoroughness.

The two principles that must be followed are test progressiveness and thoroughness and these require method and meticulousness.

The testing process is a structured, often time-consuming, multi-stakeholder approach that takes place in different locations; the time and resources needed for this mandatory phase must be provided.
The tests must be distinguished according to their type (qualification tests and specific tests), and location (factory, approved test centre, platform, site). All are indispensable.

At each test level, the equipment is tested to ensure that it complies with quality, performance and functionality requirements.
An illustration of the entire testing process is shown in Figure 2. The different stages of the process are then detailed in paragraphs 3.2.2 and 3.2.4.

3.2.1 Developing a test management plan

At the start of the works performance phase, a test management plan must be drawn up by the contractor.

This document is essential in order to define the goals set, the organization, procedure, activities and deliverables to be used to manage all tests. It must specify:

- the overall logic of the tests to be carried out in the factory and on-site, and the hold points proposed along with those proposed by the owner or the project manager;
- the organization chart, descriptive organization notes and the resources mobilised;
- a general description of the organization and the procedures implemented for safety with respect to on-site personnel and third parties;
- a dashboard to visualize test progress;
- a detailed documentation plan.

In the case of a lot-based project, a general test management plan may be prepared by the project manager, integrated into the DCE and applied from the start of the contract.

3.2.2 Qualification tests

Qualification tests must be conducted to qualify serial equipment, or at least for materials manufactured using strictly defined manufacturing processes, to which no adaptations have been made for specific project needs (electric cables, breakout boxes, cameras, optical fibres, computers, image wall screens, fixed traffic signs, technical room fans or exit overpressure fans, air conditioning systems, fire extinguishers, etc.). These tests also cover the control and origin of materials and components.
These tests are most often carried out in the equipment manufacturing plant. They are sometimes carried out in certified laboratories (fire tests).

3.2.3 Factory and platform tests

Where the installed equipment is not standard, special tests must be carried out to ensure it meets the requirements set down in the specifications and to check that it is functioning correctly, including when integrated into the rest of the tunnel equipment.

So we can distinguish several types of tests which follow on progressively from one another in the factory, then on the platform and finally on the site. These tests are for all equipment:

- Factory tests: ventilation, energy (transformers, inverters or variable speed controllers if specific manufacturing models are concerned, generators, low voltage distribution panels and backed-up electrical power cabinets), hydraulic networks (pumps if these concern specific manufacturing models, tests in the presence of the fire-brigade in the case of specific feeder manufacture), lighting (possibly lamp wiring), metalwork (custom doors), signage (unit equipment), etc.;
- Platform tests: GTC, Video / AID (associated to the GTC), RAU (associated to the GTC), Radio transmission, signage (system), air-conditioning system (if applicable), etc. These tests consist of checking that all the functions in a system are properly integrated and properly interfaced before being installed on the site.



3.2.4 On-site tests

3.2.4.1 A progressive and thorough process

On-site tests – sometimes also called field tests – are intended to check that the systems are fit for purpose (VABF).

The goal is to check that the safety and operating equipment is capable of meeting the needs set out in the initial specifications.

The on-site tests must be carried out on each equipment system and each piece of equipment in each system. This is the longest and most delicate testing phase.

The complexity of these tests is due to the fact that all the equipment in a tunnel forms a system which itself comprises numerous systems which interact with each other.

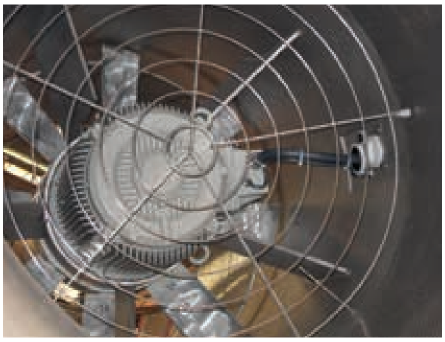
Thus, in the case of a road tunnel, there are some twenty systems and many of them interact with each other:

- HVA power supply;
- LVA power supply;
- automatic incident detection;
- detection of out of gauge vehicles;
- fire detection;
- lighting;
- drainage;
- centralised technical management;
- metalwork;
- gathering traffic data;
- radio transmission;
- emergency call network;
- fire-fighting network;
- networks;
- dynamic signalling, public address;
- supervision;
- tunnel management assistance system;
- telephony;
- ventilation;
- video;
- etc.

These interactions are the reason for the progressiveness of the tests on the different systems. The tests performed on a system are entirely dependent on the results of the tests on the systems to which it is linked. Testing of the ventilation system for example can only be considered to be completed when on the one hand the low-voltage power supply, itself dependent on the high-voltage power supply, is available, and on the other, when the ventilation system can be controlled and managed through the GTC and Supervision systems, the whole being connected through functional networks (see Appendix 4).

The tests to be carried out are therefore numerous and highly inter-dependent. They must take into account unforeseen events and co-activity issues that may increase the time required to carry them out. They must be organized in line with a very precise schedule. Any delay in completing one test or validating the results of a test is likely to have an impact on all remaining tests. This is particularly true for the power supply and GTC system.





3.2.4.2 Progressive nature of on-site tests: four essential steps

On-site validation testing therefore is therefore a progressive process, aimed at ensuring performance and functionality goals specific to the project are achieved. The phases of this process are as follows:

- static tests (ES);
- partial acceptance tests (EAP);
- systems acceptance tests (EAS);
- global acceptance tests (EAG);

These follow on one another and are interwoven as shown in the example in Figure 3 (in this figure, the GTC system has not been integrated into the diagram).

During **static tests**, each piece of equipment is checked individually according to a specific adapted procedure.

Partial acceptance tests are also tests specific to each piece of equipment, but unlike static tests, these are functional tests used to validate the performance of each piece of equipment.

System acceptance tests are functional tests that consist in checking that each piece of equipment is properly integrated into a system. Each system is tested independently of each other.

After the performance and functionality of each system has first been validated **Global acceptance tests** are used to ensure that individual systems are properly integrated into the overall system. This is an overall test.

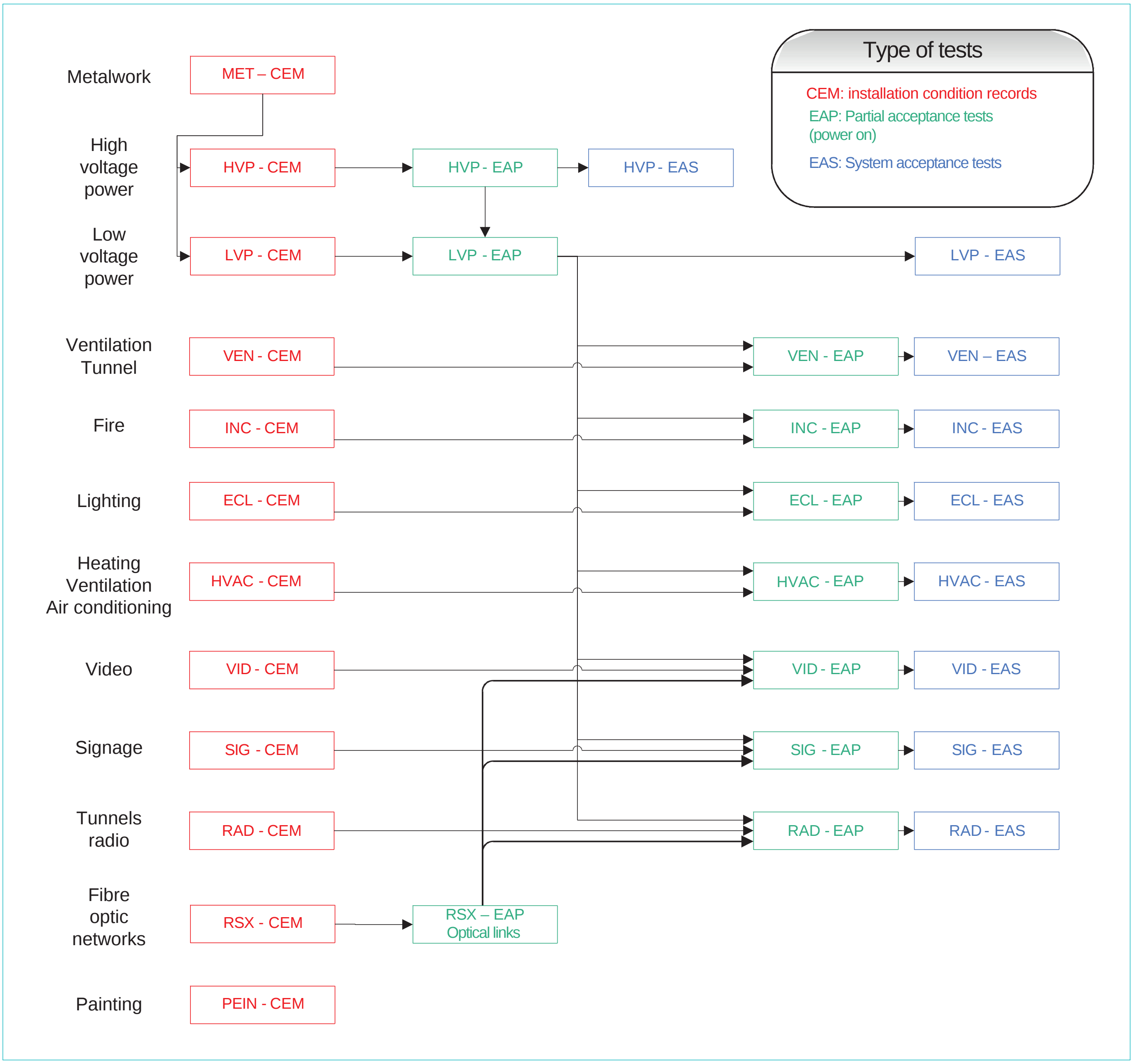


Figure 3: Example of the sequencing of the different test phases (excluding GTC).
Violay Bussière and Chalosset Tunnels (A89 East – Balbigny – La Tour de Salvagny). Author: CEGELEC Mobility

Dynamic tests only concern urban guided transport tunnels. They involve testing rolling stock on the infrastructure. These tests are also rolled out progressively. They start with low-speed operation and this is gradually increased up to normal operating speed and even beyond that speed to check the behaviour of the systems under every circumstance. Traffic in degraded mode is also tested (by stopping then restarting operations, operating when equipment fails, intervening when a train breaks down, running partial services in the case of metro lines, etc.).

Dynamic tests do not come within the scope of this document and will not be discussed here.

3.2.4.3 Thoroughness of testing: the pillar of the safety demonstration

Tests must not only be progressive but also thorough given the human safety implications of compliance with project specifications, in particular the safety objectives that underpin the project design.

This thoroughness takes many shapes:

- check on all equipment and equipment functions: for example, for AID, all detection functions are tested on all cameras; for pollution sensors, all sensors are inspected using titrated gases; for the fire-fighting network, each hydrant undergoes flow and pressure tests, etc.;
- check on all operating modes for the equipment and systems: for example, ventilation should be tested in sanitary and smoke extraction modes and if there are several smoke extraction modes (e.g. "blocked traffic" or "smooth flowing traffic") or several scenarios depending on the location of the fire (example of transverse smoke extraction by means of sliding extraction sections), all must be tested;
- check on all control modes: equipment and system activation must be tested in local manual mode, remote manual mode or automatic mode; these tests must also check that the order of priority among these modes is correctly applied;
- Check on all operating conditions: e.g. the efficiency of the AID system in different tunnel lighting conditions, ventilation performance in different atmospheric conditions, etc.;
- check on all backup systems: faults must be simulated to test all backup modes; fault simulation will also be used to test automatic switching over to backup modes where appropriate;
- check on all degraded modes: tests must ensure the installation is capable of continuing to operate in degraded mode (e.g., that smoke extraction fans in a transverse system continue to operate without damage over their operating curve even with a reduced number of open extraction hatches) and that the performance is up to expectations, without initiating minimum operating conditions.

3.2.5 Documentation to be produced

Acceptance test specifications must be drawn up for each system before testing is started. These specifications will fully describe the test procedure for the system concerned, specifying:

- the tasks performed by the manufacturer, installation or integration company;
- the list of documents to be communicated;
- a list of all tests performed;
- the order of the tests and the schedule;
- the criteria for acceptance of the product or system.

Acceptance test specifications are approved by the project manager.

3.3 GOALS AND STANDARD CONTENT OF THE VARIOUS TESTS

The various tests to be carried out are listed in chronological order (see 3.2). Their standard content is specified as well as their own objectives, location and the players involved.

3.3.1 Qualification tests

3.3.1.1 Objectives

This is quality control in a broad sense (quality and performance compliance, possibly equipment or component level features)

These tests are the responsibility of the equipment manufacturer in its role as the contractor's supplier. These tests apply at the component or equipment level. They are carried out by the manufacturer itself or by third parties.

Contract clauses must indicate that the contractor is required to provide certification test reports attesting to the conformity of the materials with the specific standards or requirements set down in the specifications. An example is the case of fire-doors in road tunnels which must meet the requirements of the technical instruction. Compliance with this technical instruction is set down in a test report.

During this phase, the contractor must ensure that all the materials meet the contract requirements, and more generally that they are fit for the purpose for which they are intended.

The documents produced at the end of this phase are test reports, certifications, declarations of conformity (in particular CE conformity), etc. The list of documents to be provided to the project manager must be indicated in the contract.

3.3.1.2 Standard content

For illustration purposes, the standard content of qualification tests is given for Lighting and Ventilation systems.

3.3.1.3 Players

MOA (Owner)	Operator	MOE (Project Manager)	Technical inspection firm	Con-tractor	Manu-facturer
No	No	No	No	option	yes

3.3.1.4 Location

Qualification tests are conducted on serial production lines or in manufacturing and assembly workshops.

Example of standard content of qualification tests for the lighting system:

- *photometric controls (unit flow of light sources);*
- *control of the apparatus;*
- *control of materials (casing, supports, etc.);*
- *checking of any corrosion prevention systems (thicknesses).*

Example of standard content of qualification tests for the ventilation system:

- *engine control;*
- *control of materials (ferrule, blades…);*
- *checking of any corrosion prevention systems (thicknesses).*

3.3.2 Specific factory tests

3.3.2.1 Objectives

Factory-specific testing is essential as it reduces the time required for on-site testing. Requirements for tests to be carried out prior to the installation of the equipment must therefore be imposed on the different system suppliers.

These are often tests by sampling, for example on "first in series" equipment. These tests apply at the equipment or system level.

In some cases, the factory context can enable tests to be carried out that would not be reasonably feasible on site, since they require very specific test equipment or test conditions: measuring the thrust of a jet fan on a test deck, acoustic measurements of fans in an open field context…

Tests performed in specialised laboratories, such as tests by organizations approved for heat-resistance testing, can also be linked to factory tests. These tests must be carried out according to stringent established procedures, in particular requiring a stove and measuring apparatus which must be perfectly calibrated and controlled.



3.3.2.2 Standard content

For illustration purposes, the standard content of specific factory tests is given for the Lighting and Ventilation systems.

Example of standard content of specific factory tests for the lighting system, on a sampling or first-in-series basis:

- *control of qualification tests reports;*
- *Control of IP (solid body penetration and ingress protection) and IK (impact resistance) ratings;*
- *checking internal wiring;*
- *functional controls;*
- *photometric distribution control.*

Example of standard content of qualification tests for the ventilation system, based on a sample:

- *control of factory-specific test reports;*
- *thrust / flow / pressure / electrical power controls;*
- *sound levels;*
- *dimensional checks.*

3.3.2.3 Players

MOA (Owner)	Operator	MOE (Project Manager)	Technical inspection firm	Con-tractor	Manu-facturer
option	option	yes	option	yes	yes

The presence of the contractor during the factory tests is required. On this occasion, the contractor will examine how equipment production lines are organised and quality control arrangements. During equipment testing, the contractor will check that the tests and performance measurements are carried out in accordance with the contract specifications and the test procedure established beforehand by the contractor, and that the expected performance level is achieved. The stakes are high, both in financial and deadline terms, because once the first in the series has been validated in factory tests, the production of the complete series is launched, and any delays in sourcing certain components may result in a period of several months between the start of manufacture and delivery to the site. Any defect or non-compliance with contract requirements must therefore be detected by the contractor as early as possible.

3.3.2.4 Location

Factory-specific tests are carried out in manufacturing and assembly workshops in the factory and in accredited inspection laboratories.

3.3.3 Specific platform tests

3.3.3.1 Objectives

Platform tests are used to validate custom-developed software tools. They are used to check that the delivery will match the order.

These tests concern the system level, including radio, AID, GTC and supervision systems. They are essential to avoid exceeding deadlines on the site which can have a severe impact on the installation and integration of other systems.

The documents to be produced during this phase are the acceptance test specifications containing the test procedures, which must be approved by the project manager before then after the tests, the test reports and the completed acceptance test specifications. At the end of platform acceptance testing, the software tool developer, installation company and project manager sign an end of platform acceptance testing report which triggers deployment of the software tool on site.

3.3.3.2 Standard content

For illustration purposes, the standard content of platform-specific tests is given for the Video / AID system.

Example of standard content of platform tests for the video/AID system:

The tests are performed on a model consisting of the key elements in the system (1 fixed camera, 1 mobile dome, 1 AID analyser/recorder, 1 digital flow recorder, 1 server with HMI, 1 rack for video encoders, 1 video encoder, 1 decompression PC and display, 1 control console...) :

- *video encoder test:*
  - *video encoder settings,*
  - *integration of the encoder into the system;*
- *test on configuring a camera from the HMI;*
- *automatic incident detection test:*
  - *test of alarm escalation when an incident is automatically detected,*
  - *test for creating a sequence following a AID alarm,*
  - *inhibition test of a detector,*
  - *inhibition/disinhibition test of a AID channel,*
  - *inhibition test of a AID camera,*
  - *inversion test of a AID channel;*
- *video recording tests:*
  - *test for manual recording of a sequence,*
  - *test for playback of recorded sequences,*
  - *test for extracting a sequence from a permanent record,*
  - *sequence export test,*
  - *purge test for recordings and sequences;*
- *display tests and camera control:*
  - *test for viewing camera thumbnails on the HMI,*
  - *test for displaying the video stream from a camera on the HMI,*
  - *test on switching a video stream from a camera to an image wall monitor,*
  - *test for the release of a monitor,*
  - *test for cyclic settings,*
  - *test for assigning a cyclic to an image wall monitor,*
  - *test to control mobile cameras,*
  - *test to set a pre-position for the mobile cameras;*
- *tests on the system's security and control functions:*
  - *test on status management and technical failures,*
  - *testing of process and status monitoring,*
  - *system backup test,*
  - *time synchronisation test.*

3.3.3.3 Players

MOA (Owner)	Operator	MOE (Project Manager)	Technical inspection firm	Con-tractor	Manu-facturer
option	option	yes	option	yes	yes

As for factory tests, the presence of the contractor during platform tests is required, so that a maximum of system specifications can be validated as far upstream as possible. Thus, the development and testing of software systems – and any patches required – can be done in masked time, at the same time as the overall work advances. Conversely, checks carried out by the project manager near the end of the work may lead to delays resulting in a significant extension to the total time for the works.

3.3.3.4 Location

Platform-specific tests are usually performed on the software tool developer's premises.

3.3.4 Specific site tests - Static tests

3.3.4.1 Objectives

Static testing of equipment marks the beginning of on-site testing and thus the work site is transformed into a test site.

Static tests are unit tests on equipment carried out after all power supply and control system wiring has been put in place but the systems are not yet powered up. In particular, these tests enable the nature of the equipment, its installation, assembly, external appearance (absence of any degradation for example), connections and physical and electrical protection systems to be checked off against all the documents and plans concerned.

The results of static tests are recorded in the installation condition records (CEM).

The completion of this phase means it is possible to move on to functional tests.

3.3.4.2 Standard content

For illustration purposes, the standard content of static tests is given for Lighting and Ventilation systems.

For the tunnel lighting circuit, static tests consist of the following checks:

- *check the manufacturing certificates and the completion of all checks in the factory;*
- *check the supporting system (cable tray and pipe hangers) from the point of view of mechanical resistance;*
- *check the light fixtures;*
- *check the location of each lamp individually (types, power, orientation, position...) ;*
- *from time to time check wiring paths and grounding;*
- *check junction box connections;*
- *check upstream cable continuity and insulation tests;*
- *check the mounting of normal/fire junction boxes;*
- *check that lamps are correctly identified (labelling, direction of traffic...) ;*
- *check the values of electrical protection systems in the boxes from time to time;*
- *validate that the assembly complies with the BPE plans;*
- *check the power wiring (labelling, section, type...) ;*
- *check the control wiring (labelling, section, type, etc.).*

For the tunnel ventilation system, and when limited to jet fans only, static tests are as follows:

- *check that reservations arising out of factory tests have been resolved;*
- *check that self-checks have been carried out by the installation company;*
- *check the identification plate, the condition of the ferrule, the presence of deflectors, internal machine cleaning;*
- *check the mounting, the height under the equipment and the ultimate attachment system;*
- *check the tightening torques;*
- *check upstream cable continuity and insulation tests;*
- *check that connections comply with cable specifications;*
- *validate the conformity of the assembly with the execution plans (position, dimensions, etc.);*
- *check the power wiring (labelling, section, type, etc.);*
- *check the control wiring (labelling, section, type, etc.;*
- *check the ground connections.*

3.3.4.3 Players

MOA (Owner)	Operator	MOE (Project Manager)	Technical inspection firm	Con-tractor	Manu-facturer
No	option	yes	No	yes	option

3.3.3.4 Location

Static tests are carried out in the tunnel, in the technical areas, on all ancillary works fitted out with equipment installations and on the tunnel access routes.

3.3.5 Specific site tests - Partial Acceptance Tests

3.3.5.1 Objectives

Partial Acceptance Tests (EAP) follow static tests if these have been successfully completed.

These tests are carried out at the individual equipment or equipment group levels. They concern individual pieces of equipment or equipment sets that operate autonomously. They are carried out with power on and allow an initial operating and performance test to be carried out. These are functional tests. They must check and validate inputs/outputs and interfaces with the control system, pre-setting of operating parameters, unit start-up and operation, safety controls and unit performances of the devices. All possible operating cases are tested.

Partial acceptance records (CAP) are drawn up at the end of EAP tests for each piece of equipment or equipment group.

3.3.5.2 Standard content

For illustration purposes, the standard content of EAPs is given for Lighting and Ventilation systems.

By repeating the example of the lighting circuit, partial acceptance tests are as follows:

- *check that reservations arising out of static tests have been resolved;*
- *validate the lighting and position of the lights by circuit;*
- *validate the functioning of the variation control unit for circuits fitted with it;*
- *Check the wiring of the GTC inputs/outputs.*

For the Ventilation system, for jet fans alone, partial acceptance tests are as follows:

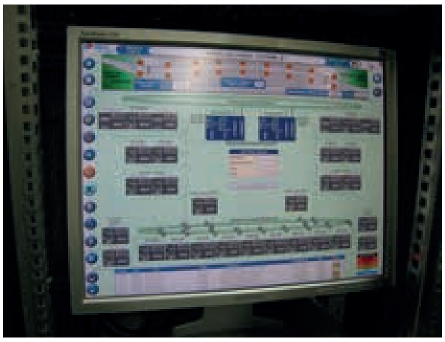
- *check that reservations arising out of static tests have been resolved;*
- *carry out the start-up and operating tests in both the forward and reverse directions;*
- *check the direction of rotation, the absence of vibration and correct return of data from the sensors at the associated interface terminals.*

3.3.5.3 Players

MOA (Owner)	Operator	MOE (Project Manager)	Technical inspection firm	Con-tractor	Manu-facturer
NO	option	yes	No	yes	option

3.3.5.4 Location

Partial acceptance tests are carried out in the tunnel, in the technical areas, on all ancillary works fitted out with equipment installations and on the tunnel access routes.



3.3.6 Specific site tests - System Acceptance Tests

3.3.6.1 Objectives

System acceptance tests (EAS) apply at the level of each system formed by a set of individual pieces of equipment.

The goal is to commission each system in the different operating modes, to check that each operating mode is in conformity with the functional analysis, to check that each system is perfectly integrated into the control system. These are functional tests. All possible operating cases are tested.

Due to the interactions between the different systems, an initial EAS phase will test local control of the equipment (front-end servers or GTC) then a second phase will be carried out to test the systems with supervision.

The purpose of EAS tests is to check that each system is operating in accordance with the expected performance in all operating modes.

System acceptance records (CAS) are established for each system. All EAS testing must be completed to move to the global acceptance testing phase.

3.3.6.2 Non-regression tests

As tests are run and anomalies detected, software tools are corrected which implies non-regression testing to ensure that defects have not been introduced into unmodified parts of the software. These also complement the unit tests and integration tests carried out upstream from EAG tests. These tests are often painstaking since they must be as wide-ranging as possible.

3.3.6.3 Standard content

For illustration purposes, the standard content of EAS tests is given for lighting and ventilation systems.

For the tunnel lighting circuit, the system acceptance tests are as follows:

- *check that reservations following EAP tests have been resolved;*
- *validate the operation, unit controls and status feedback from the GTC system for all equipment in the system;*
- *check the workings of the entire system with the GTC;*
- *validate operation in automatic, remote manual and local manual modes;*
- *measure and control tunnel lighting performance (luminance and illuminance);*
- *validate operation and management from the Supervision station.*

For the Ventilation system, for jet fans alone, system acceptance tests are as follows:

- *check that reservations following EAP tests have been resolved;*
- *validate the operation of unit controls and status feedback from the GTC system for each piece of equipment in the system;*
- *run operating tests on the entire system with the GTC;*
- *determine the correction coefficients to be applied to anemometers by measuring tunnel air speeds;*
- *validate the global performance of the system (tunnel air speeds, air current control, extraction, fire modes, fire-fighting modes, etc.);*
- *validate automatic, manual and degraded operation;*
- *check operational conformity with respect to the detailed functional analysis associated to the system;*
- *validate communication with the GTC front end server;*
- *validate operation and management from the supervision screens.*

3.3.6.4 Players

MOA (Owner)	Operator	MOE (Project Manager)	Technical inspection firm	Con-tractor	Manu-facturer
NO	yes	yes	No	yes	option

The presence of the operator for system tests is required when applying the approach that associates the operator to every phase of the project, from design through to commissioning (see 3.1.3 and 4.2 in particular).

3.3.6.5 Location

EAS testing is most commonly performed from a supervisory control station, with local presence on the equipment.

3.3.7 Specific site tests - Global acceptance tests

3.3.7.1 Objectives

Global acceptance tests are overall functional tests that check that all systems are properly integrated into the GTC system. This is why they are sometimes called integration tests. Checks concern links between systems. All possible operating cases are tested.

These tests must be absolutely exhaustive. Subject to any non-regression testing to be performed the goal of these tests is to demonstrate the overall correct functioning of the various systems in terms of performance, operation and regulatory compliance.

EAG testing tests the installation as a whole and checks synchronisation between systems that must function together, the independence of each system (the operation of one system must not be hindered by the operation of another), demonstrates that global performance objectives are attained, continues staff training and validates operating documents.

Global acceptance test certificates are issued at the end of this phase. In no case are they work acceptance certificates or work acceptance reports. These will be drawn up later during OPR operations.

3.3.7.2 Standard content

EAG tests involve testing functions and events such as reflex actions, checking normal operating conditions, event management, degraded situations, checking CME (minimum operating conditions).

EAG tests also consist of testing system reactions in the event of a failure: for example, when one or more systems fails, loss of ENEDIS supply, loss of the field network, loss of the transport network.

Finally, EAG tests must enable the correct functioning of all operating scenarios to be validated in numerous configurations: fire breakout scenario, scheduled shutdown scenario, emergency closure scenario…

EAG tests are mainly carried out by launching scenarios – or sequences – observing that the expected actions are taken and monitoring system status feedback.

3.3.7.3 Players

MOA (Owner)	Operator	MOE (Project Manager)	Technical inspection firm	Con-tractor	Manu-facturer
option	yes	yes	option	yes	option

3.3.7.4 Location

EAG tests are most commonly performed from a supervisory control station, with local presence on the equipment.

3.4 DRY-RUN OPERATION – PRE-OPERATION DRILLS

Figure 4: Simplified standard sequence for the scenario with dry-run operation positioned after acceptance of the work.

3.4.1 Objectives

Dry-run operation, also known as pre-operation, can vary significantly from one project to another and is in any case closely related to the mode of transport.

Indeed, there is a fundamental difference between dry-run operation for road tunnels, during which there are no vehicles circulating in the tunnel – except for a few service vehicles – and dry-run operation in urban guided transport tunnels when the rolling stock is operated in conditions identical to the future commercial operation, with the sole exception that there are no passengers on board.

In road tunnels, therefore, dry-run operation consists essentially of the operator taking over control of the structure and this phase helps the operator round out its knowledge of the infrastructure and how it is operated. During this period, the operator fine-tunes its routine or exceptional incident response procedures (closure of the infrastructure for example).

Dry-run operation may also reveal malfunctions not detected during testing, even if this is not its role. This is because dry-run operation should only start when the equipment is in its rated operating condition.

In all cases, dry-run operation comes before commissioning.

One month of dry-run operation is the absolute minimum for a new road tunnel project. A period of two to three months is preferable since, as shown in Figure 5, this phase must include training of operating personnel, pre-operation drills or safety drills, as well as the work involved in lifting any reservations and the tests and controls that follow on from such work, and possibly the IDI (compulsory only for tunnels in the non-concession national road network – see 2.1.1.2). Dry-run operation is therefore a phase in the general operation which in itself requires precise scheduling. It is carried out in liaison with all the players concerned in order to find the optimal organization in terms of the hourly and geographical distribution of the crews.

3.4.2 Dry-run operation positioning in time

The decision on where dry-run operation should be positioned is a very weighty one since this phase is the real transition point between the construction work and operating the infrastructure.

Scenario 1: Dry-run operation is positioned before acceptance of the structure. Dry-run operation is then attached to the works and is the final test phase in which defects still present can be detected and corrected. Such positioning helps avoid declaring acceptance of a structure that is not in a condition to be accepted. But it is not without disadvantages. Indeed, dry-run operation prior to acceptance is by definition included within the contract performance period provided and there is therefore the risk that the operator will be handed over a structure for dry-run operation (see 4.4) that is neither fully completed nor functional since the contractor will have cut off the time intended for dry-run operation in order to carry out the final works or tests and correct defects. Such conditions do not enable the operator to take over the work correctly.

Scenario 2, **recommended**: dry-run operation is positioned after acceptance of the structure. Dry-run operation then comes after the works completion period, it protects the time period required for this phase before commissioning, but requires that acceptance be carried out beforehand and as a result that any adjustments and repairs by the contractor be contractually provided for on the equipment that has already been accepted. The sequence of phases according to this scenario is shown in a simplified Figure 4 below and in detail in Figure 5 in paragraph 3.7.3.

The second scenario is the norm systematically for urban guided transport infrastructure because of the scope and complexity of the operations and administrative procedures to be carried out before commissioning all the structures concerned. As for road tunnels, it is best to proceed in this way to avoid the above-mentioned difficulties.

The cases of malfunctions found during dry-run operation will be dealt with by implementing the provisions laid down in Article 41.4 of the CCAG for Works Contracts which provides for the possibility of carrying out "proof tests" after acceptance and, if defects are found, to "postpone" this acceptance, i.e. cancel it.

In the case of an infrastructure in operation, the works are made available as they are completed (see 4.4) and in this case, dry-run operation is carried out while the structure is being operated (see 3.7.4).

3.4.3 Standard content

All operating service agents who are involved in operating the infrastructure are concerned by dry-run operation.

All professions involved in operating the infrastructure are thus concerned: the agents in charge of monitoring the tunnel from the control station, patrolling staff, agents in charge of upkeep, maintenance and repair of the equipment, the staff supervising these agents and all operating service executives who may be on call and asked to intervene in the event of an incident occurring.

At each of these levels, the first stage in dry-run operation is to become familiar with the structure. This is followed by learning the tasks to be performed, both in day-to-day operating and in the event of an incident occurring.

At each of these stages, and for each of the professions involved, the infrastructure is taken over by staff who have had theoretical training, visited the site and carried out the necessary drills. The contractor plays a significant role in providing technical training to staff operating the equipment.

Once these stages have been completed, pre-operating drills must be organized. The approach must be organized. First, the list of drills to be carried out must be drawn up along with the precise content (scenario of goals to be pursued), the pre-requisites in terms of structure and equipment availability and the estimated time required for each drill. A complete data sheet is prepared for each drill. An example is given in the Appendix (drill based on the event "Vehicle at a stop in the tunnel"). The data sheets may be prepared by the project manager, if this comes within the project manager's remit or by an external engineering firm commissioned by the owner. They are completed by the operator with regard to the material and human resources called on, as well as the step by step chronological sequence of the test.

The service responsible for operating the tunnel is not the only one concerned by dry-run operation. The other services that could be called on to intervene on the structure, in particular fire fighters and law enforcement, must be trained and made familiar with the workings of the structure.

It is generally during dry-run operation that the safety drill is organized, this involves the tunnel operator and all the services called upon to intervene in the event of a serious incident in the tunnel.

3.4.4 Players

MOA (Owner)	Operator	MOE (Project Manager)	Technical inspection firm	Con-tractor	Manu-facturer
yes	yes	yes	option	yes	option

3.5 REGULAR SERVICE CHECK (VSR)

3.5.1 Objectives

The purpose of the regular service check (VSR) is to observe that the equipment and systems installed are able to ensure regular service under normal tunnel operating conditions (described in the special contract documents). The start of the VSR is triggered by the commissioning of the structure. The performance of the VSR therefore constitutes a proof test period (within the meaning of Article 41.4 of the CCAG for Works Contracts), as is also the dry-run operation.

In general, a duration of six months is recommended for the VSR check of tunnel equipment. It may take the form of an initial period of three months, renewable by one-month periods if the tests are not satisfactory.

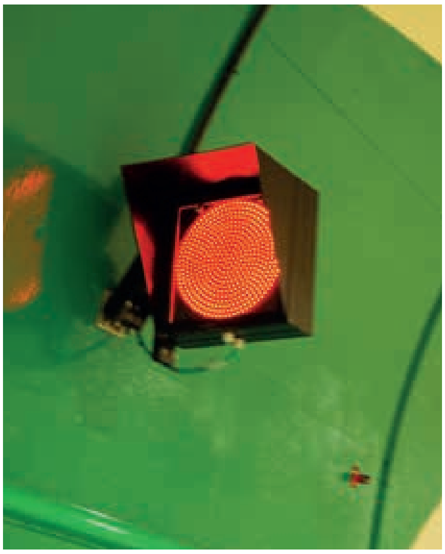
The proper functioning of the system is defined as functioning in accordance with the provisions of the CCTP and construction design documents. Any anomaly with respect to this functioning is considered to constitute unavailability and gives rise to an intervention by the contractor.

The contractor is required to be on-call in order to be able to intervene during the VSR check if called by the operator or project manager. If the intervention request is issued by the operator, then it will have to inform the project manager and this obligation must be indicated in the contract documents.

3.5.2 Standard content

The contract documents define the standard content of the VSR check by which the contractor is bound:

- to assist the operator – and in particular the operators responsible for monitoring the tunnel – in taking over control of the systems by means of permanent telephone support for example (24 h / 24) or adjusted according to the time (day or night) and the day (working or non-working days) with a requirement level that could decrease over time;
- to observe and analyse the operation of the systems and the performance achieved on an on-going basis and make any adjustments required until the performance levels set down in the contract[4] are attained in a stabilised manner. This is typically the case for automatic incident detection (AID) by video analysis;
- to carry out in good time and at its own expense all the work necessary to ensure correct operation of the installations[5], without billing this work or using the stock of parts delivered as part of the maintenance lot, or if so subject to conditions. The services include intervention on site when called by the operator, replacement of defective materials, products and components on the site and all the tests and controls required to ensure the fault is suitably corrected, including tests on equipment and systems not directly concerned by the intervention where this is necessary. In particular, non-regression testing should be performed after any software modification or upgrade. Intervention and repair times are set down in the contract;
- to assist the holders of any contracts that interface with the contract it holds.



4. Performance is judged against the requirements set down in the contract in terms of reliability, availability, maintainability and safety (RAMS), as the contract may provide that, for some systems, the requirement level will become more stringent successively between the start of dry run operating, commissioning and the end of the VSR.
5. The cause of any malfunction should always be analysed in order to attribute its correction to the VSR or to the calling in of the correct operation guarantee.

The time limits for the contractor's VSR intervention are set in association with the future operator. They are tailored to each particular project, taking into account the required level of service of the infrastructure. Interventions can take place on site (tunnel or control station) or remotely (software intervention).

An intervention report is drawn up after the contractor's interventions under the VSR. This report is drawn up on an adversarial basis and indicates:

- the date, time and duration of the intervention;
- the name and capacity of the contractor's personnel who carried out this operation;
- the nature of the failure or incident;
- the operations carried out (in detail);
- any parts and/or components changed (including the nomenclature name, serial and identification numbers and their function in the assembly concerned);
- observed operating after the intervention.

Regular service check
Standard clause to be included in the CCAP of the works contract

The goal of the regular service check (VSR) is to enable equipment and systems to function properly in real-world operating conditions after the start-up. The regular service check is used to observe that the services provided are able to ensure regular service under normal operating conditions.

This phase includes all tests that are "proof tests" within the meaning of Article 41.4 of the CCAG for Works Contracts.

The duration of the VSR period for all systems is set at (3) three months renewable by 1 (one) month periods. It is triggered after validation of the dry-run operation period.

3.5.3 Players

MOA (Owner)	Operator	MOE (Project Manager)	Technical inspection firm	Con-tractor	Manu-facturer
No	yes	yes	No	yes	option

3.6 INITIAL DETAILED INSPECTION

The initial detailed inspection of the equipment is mandatory only for tunnels in the non-concession national road network (see 2.1.1.2).

The IDI is part of an asset management approach and aims to establish a point of reference for the condition and performance of all the equipment in the tunnel.

As stated in the *Application guide for the technical instruction for the surveillance and maintenance of civil engineering works - Booklet 40: Tunnels, Civil Engineering and Equipment* [11], the IDI is a zero-state that will serve as a reference throughout the life of the work.

The controls on the proper design of the structure and the facilities must have been carried out as part of the regulatory requirements. However, in a final step, the IDI must be able to show that there remain no inadequate setups or setups contrary to safety rules, either in terms of design or due to an inappropriate installation mode. The tasks to be carried out during an IDI are the control of the quality certification of equipment and materials, installation performance measurements, functional tests and the performing of specific safety sequences (for example a traffic accident sequence with the tunnel being closed by the operator). This is both document analysis work and work in the field, where the tests are conducted by sampling.

The duration of an Equipment IDI is related to the length of the structure and the amount of equipment concerned. The on site portion of an IDI[6] can hardly be less than 3 days – or 3 nights – for the simplest of tunnels; it can last up to two weeks for longer tunnels with large amounts of equipment.

It is advisable to carry out the IDI at the end of the VSR check, when all teething problems in the structure have been ironed out and all adjustments to the systems – including the AID system – have been made. This avoids having an inspection with very negative findings due to the presence of an excessive number of malfunctions. It must always be borne in mind that the Equipment IDI constitutes neither a second check on the proper performance of the works – a check that is the responsibility of the project manager – nor an attestation certifying that the structure is fit for commissioning.

6. It should be recalled that the on-site intervention is only one part of the IDI, which also includes a significant amount of documentary work.

3.7 GENERAL SEQUENCING SYSTEM

3.7.1 Principles to be followed when devising the project sequencing

Given the large number of tasks to be performed, the number of participants involved and the multiple technical and organizational interactions, it is essential that the owner, assisted by the project manager, define a precise sequence of operations for the project in order to ensure a top quality project is delivered within the budget and deadlines set (see 1).

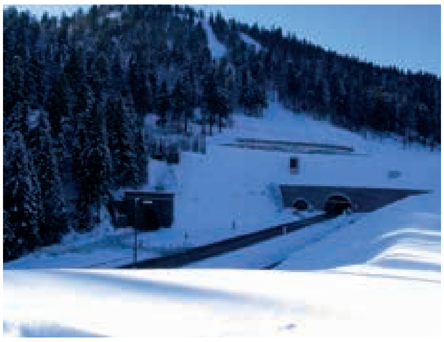
This sequence must first and foremost be based on legislative and regulatory provisions, i.e. be in conformity with the applicable texts, in particular the CCAG documents (see 2.1.1 and 2.2.1). Beyond that, task sequencing must take into account the technical complexity of equipment testing, ensuring these tests are progressive and thorough (see 3.2 and 3.3), without ever by-passing the intervention of any player concerned (see 3.1).

Of course, the sequencing will also have to take the specific characteristics of the mode of transport into account – road or urban guided transport – and those of each project.

The fundamental principle is to adopt reasonable deadlines for each step in the process. It takes time to commission a structure.

Beyond this fundamental principle, the use of interim deadlines is recommended since the steps are numerous and each step must have sufficient time to be completed. By doing so, the specific time frame for each phase is identified and precisely set, which should prevent a delay in one works phase from causing a knock-on delay in a subsequent phase. The use of interim deadlines also allows for more precise monitoring of the progress of the operation in relation to expected deadlines and enables drifts off course to be detected at an early stage.

Despite certain constraints, the organization of works contracts into lots may provide some flexibility in organizing the task sequence (see Figure 5).



3.7.2 Proposed standard project sequence

The minimum recommended is for three interim deadlines: one for the works and system testing, one for dry-run operation and one for the VSR check.

Other interim deadlines may be envisaged, for example to separate the works proper from the tests or even to separate certain works phases or certain tests from each other. While this in theory enables the owner to better sequence each stage in the project, the disadvantage is that it reduces the contractor's freedom in organizing its work site and prevents it from optimising time and costs. Except for particular circumstances, such a fine breakdown is therefore not recommended.

The general sequencing system is given in the diagram in Figure 5 for the simple standard case of works in a non-operating context and a contract signed with a general contractor.

3.7.3 Simple standard case of works in a non-operating context and a contract signed with a general contractor

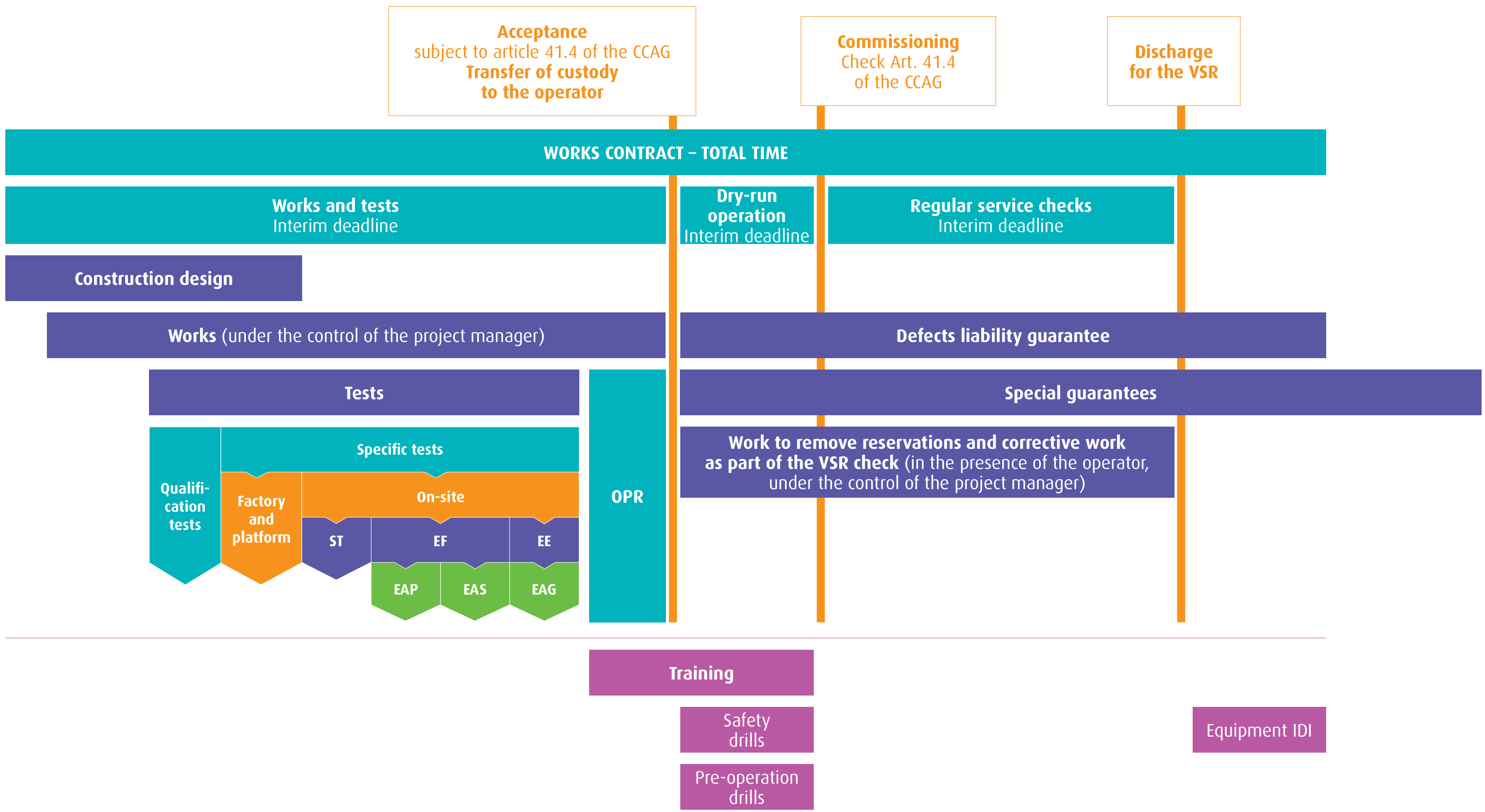


Figure 5: Standard sequencing for the simple standard case of works in a non-operating context and a contract signed with a general contractor.

3.7.4 Cases of work during operation (with long performance times)

Works during operation, i.e. during regular service periods, is certainly the most complex to be handled when the equipment and safety systems are not fully operational.

Therefore, a degraded mode must be taken into account, which must not, however, jeopardise safety conditions in the tunnel.

There are two cases:

Case 1: works in which the equipment is installed progressively, since this equipment is not put into operation while being installed, but at the end of the works, thus forming a coherent whole.

In this configuration, acceptance should be a unique operation once all the works have been completed, and a VSR period must be provided for that incorporates the "proof tests" within the meaning of Article 41.4 of the CCAG for Works Contracts. There is no dry-run operation.

Case 2: works in which equipment is installed and immediately used

In this case, it is necessary to provide for stringent management of the opening/closing phases of the project by providing for the handing over of the installation by the contractors under the conditions specified in 4.4 of this document.

Each time a facility is handed over an inventory of the situation is taken and recorded by the project manager.

Acceptance will be a one-time operation upon completion of the works and will be followed by a VSR period as indicated above. There is no dry-run operation in this case either.

3.7.5 Case of lot-based works – separate contracts

In the case of lot-based works, all the principles seen above remain valid. However, at the end of the design studies, a strategy for drafting the tendering documents (DCE) must be adopted, as it affects the fluidity of construction design work, the sequencing of the works and, ultimately, the testing.

Since we have seen that the different systems inter-act, the challenge is to succeed in coordinating tests in a context in which the work duration specific to each system – thus, normally that of different contracts if the lot structure is based on the different trades – is not the same.

The strategy is to draw up schedules starting from a time in the future that is necessarily common to different systems then working backwards: this strategy must apply to the EAG tests as well as the EAS and EAP phases due to the large number of interactions between them. Thus, for example, lighting needs electrical power to deploy EAP tests and the GTC system to perform EAS tests. The need for synchronisation can even go beyond this and concern ST tests. For example, installing lamps may first require that a vault be heat protected or that a luminance meter be installed which in turn requires a support to be put in place by civil engineering contractors.

Task sequencing also takes account of the fact that even though contracts other than power and the GTC system – e.g. ventilation and lighting in the example shown in Figures 6 and 7 – typically require less time in terms of engineering studies and works, it makes sense to start them first. Indeed, the results of the design work in these other contracts provide indispensable input to the power supply and GTC design work.

Therefore, it is recommended to:

- either produce all the DCE documents at the same time, then start the different lots simultaneously and thus pace the schedule for construction design, the works and tests as required, taking advantage of the fact that all the players are available (Figure 6);
- or first start the lots other than power supply and GTC-supervision, for the construction design phase, so that the latter can then be supplied with the necessary input from the first lots (see Figure 7).

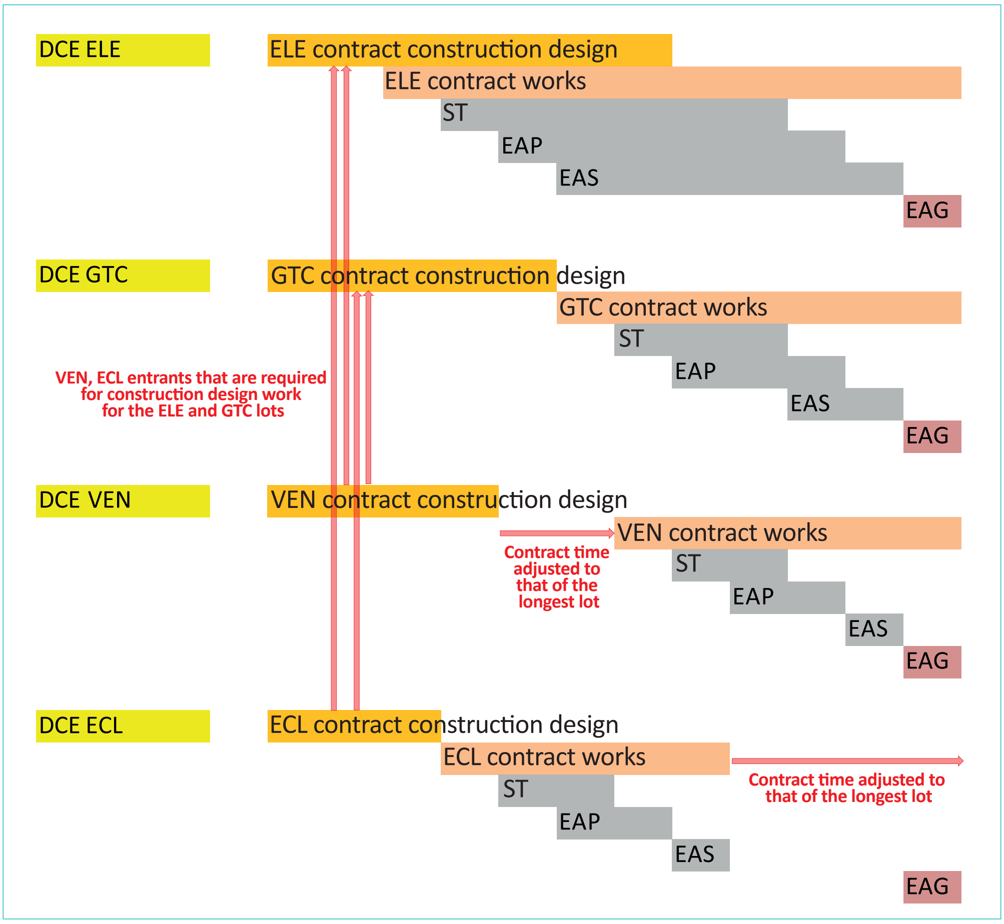


Figure 6: Lot-based project – simultaneous production of DCE documents and parallel advancement with construction design, works and tests for each lot.

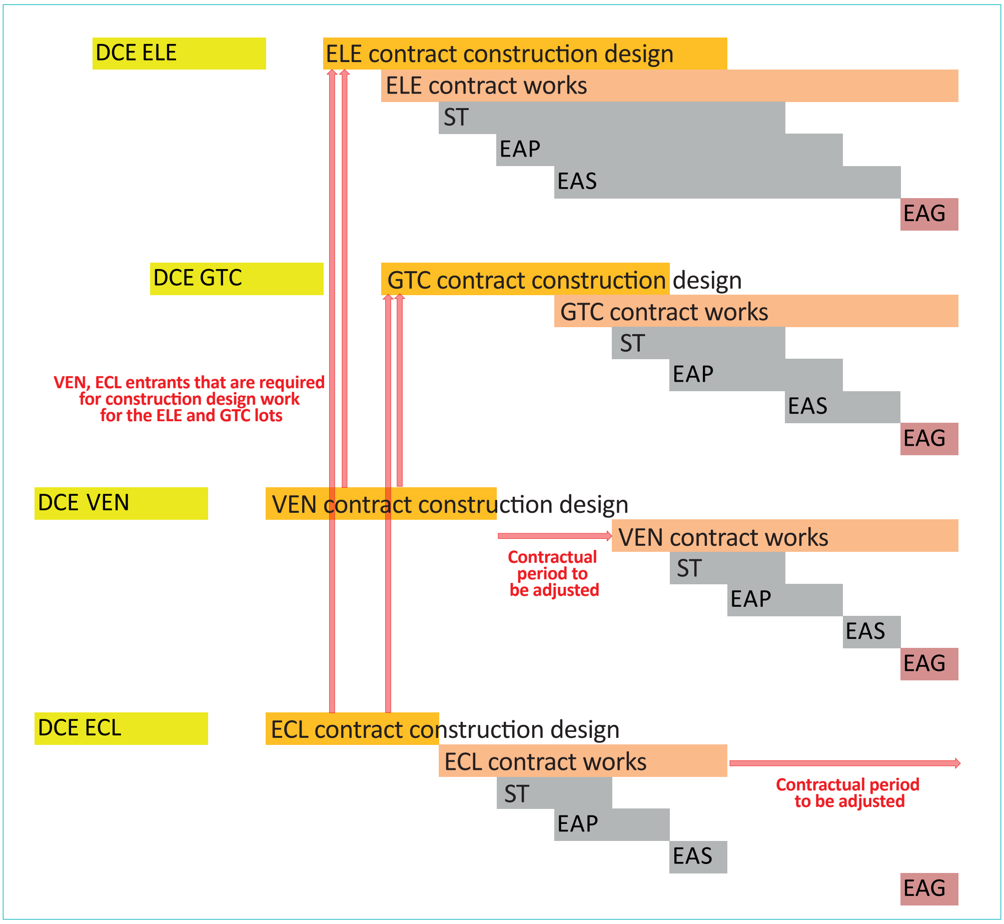


Figure 7: Lot-based project – start other lots before power supply and GTC.

In the first case – produce all the DCE documents at the same time and start up the different lots simultaneously, see Figure 6 –, the contractual time set for each contract must not be the shortest time period for the design, works and tests of the corresponding lot, because in this case, the deadlines for the contracts for the lots requiring the shortest times will have expired before the EAG tests have been carried out. In order for EAG tests to be carried out before the expiry of the contractual deadlines, an identical performance period must be set for all contracts, that of the lot requiring the longest period to be completed. This implies interruptions in activities, during the time period set, for those lots requiring the shortest times, for example between the completion of studies and the start of the works (VEN lot in Figure 6) or between the end of EAS test and EAG tests (ECL (lighting) lot in Figure 6).

In the second case – early start-up of lots other than power supply and GTC – contract deadlines should also be adjusted, according to the start-up dates and the durations necessary to perform the services for the various lots (Figure 7).

The pitfall that must be avoided is to choose the strategy that at first view seems compelling, i.e. that of drawing up schedules starting out from the EAG tests and working backwards to the start and then pacing the various lots based on how long they will take. The longest lot will start first and the shortest will start last (Figure 8). In this case, the construction design studies for the Power Supply and GTC lots will in fact have to be temporarily suspended, since the inputs required from the other lots (ventilation and lighting as in the example in Figure 8) will not yet be available.

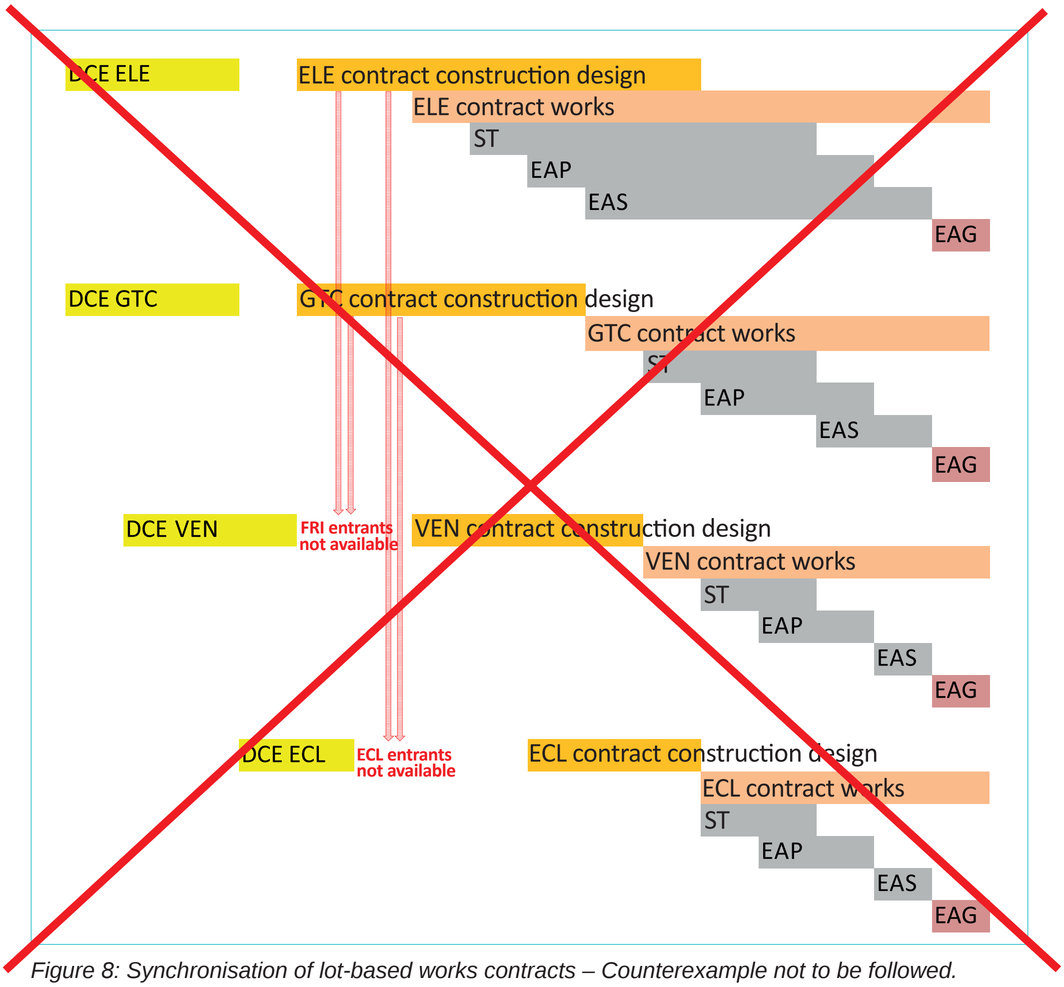


Figure 8: Synchronisation of lot-based works contracts – Counterexample not to be followed.

4

ACCEPTANCE PROCEDURES

Acceptance of the work is the pivot point between the construction phase and the pre-operating and operating phases (see Figure 5 - 3.7.3). It punctuates the long testing process and enables the dry-run operation and regular service check phases described in the previous chapter to be launched.

This chapter sets out how best to organize acceptance, a phase that has very high administrative and financial stakes since acceptance also triggers the transfer of the structure to the owner, the start of the guarantee periods and the initiation of the final payment process.

4.1 FOREWORD (REMINDERS OF THE CCAG FOR WORKS CONTRACTS)

Articles 41 and 42 of the CCAG for Works contracts sets out the process for accepting works involving the contractor, project manager and the owner.

A schematic representation of this procedure is given in Figure 9 which also gives the maximum time limits to be met for each step in the process[7].

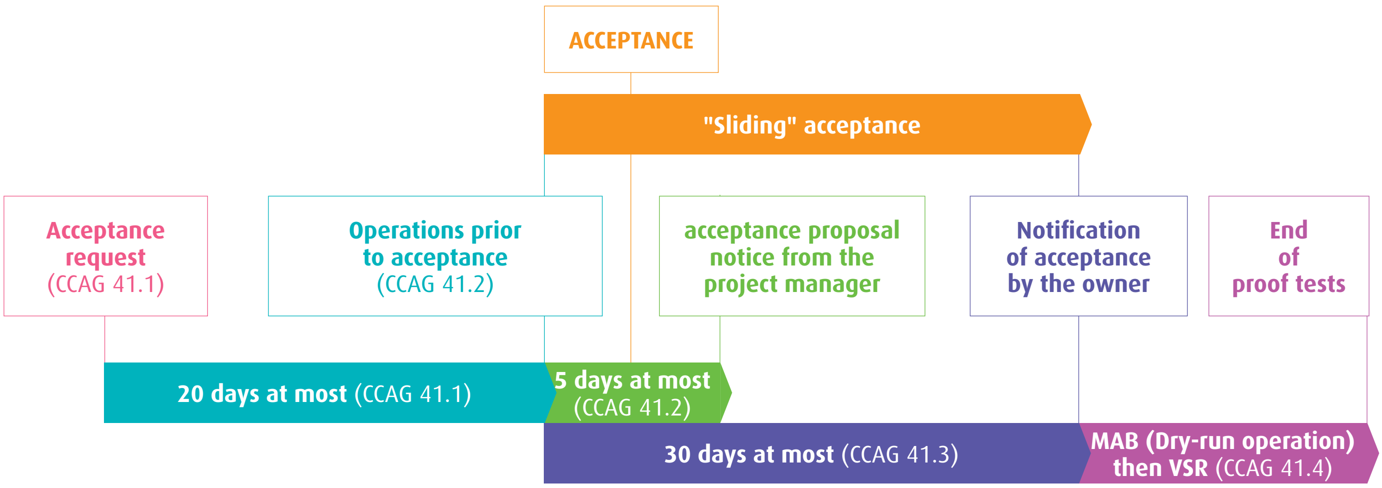


Figure 9: Process for work acceptance according to the CCAG for works contracts.

4.2 PRE-OPERATIONS PRIOR TO ACCEPTANCE (PRE-OPR)

Before the operations prior to acceptance, a formal so-called pre-OPR technical visit is organized by the project manager with the operator. At the end of this visit, a document listing the reservations made and the work remaining for proper operation of the equipment will be drawn up and signed jointly.

However, the operator does not replace the project manager in any way. The project manager keeps all the prerogatives and powers entrusted to it by the owner and remains the sole interface with the contractor.

The following standard clause in the project management contract is intended to formally set down the operator's association according to the recommendations set out above.

7. The representation is not proportional to real time.

Pre-operations prior to acceptance – Standard clause to be included in the CCAP of the project management contract

General framework

Since acceptance implies the transfer of custody to the various operators, the project manager must, prior to the OPR phase, obtain agreement from the operators as to the conformity of the works carried out.

The project manager organizes all technical visits to work sites and installations with operators prior to the OPR phase (the so-called pre-OPR phase), in order to draw up the list of reservations for each contract and indicate any outstanding work they deem is necessary for proper operation of the equipment. The project manager identifies any outstanding discrepancies present at this stage between the work carried out and the provisions of the contract. In addition, the project manager drafts and distributes the reports on these visits and the documents associated with them.

The project manager has operators specify any reservations that could compromise the transfer of the structure in order to resolve them in priority before the date of OPR operations in the contractor's works contract.

If the operator disagrees, the project manager will be responsible for informing the owner so it can decide.

During this process, new requests from operators may appear, not provided for in the contractual clauses of the works contracts and not mentioned until that date.

They must be identified separately from the contract reservations and processed by the project manager, after these requests are ruled on by the owner, by notifying a new price where necessary or as part of the project manager's final completion assignment scheduled to take place during the defects liability guarantee period.

Taken into account in the acceptance phase

The project manager's proposal to the owner drafted after the OPR operations, must contain all the remarks then issued and be countersigned by the future operator.

Link with operations start-up

Before initiating the OPR operations with the contractor, the project manager must get assurances from the operator that documentation and spare parts have been delivered and personnel trained as provided for in the contract and that the start of dry-run operation can go ahead followed by operating proper.

4.3 OPERATIONS PRIOR TO ACCEPTANCE (OPR)

The project manager performs operations prior to acceptance at the request of the contractor and sets the reservations identified in the pre-OPR phase down in a report. These are reservations which were not processed in the meantime. It sends the proposal to accept or to refuse to accept the work to the owner within 5 days with a summary of all the outstanding reservations.

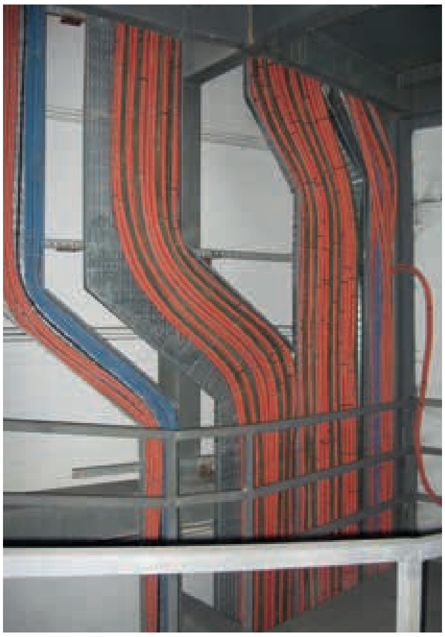
OPR operations are defined in Article 41.2 of the CCAG for Works Contracts, which indicates that they include, as appropriate:

- examination of the works performed;
- any proof tests provided for in the contract;
- recording of any failure to perform the services provided for in the contract;
- check that the conditions under which the equipment was installed comply with the suppliers' specifications on which the guarantee depends;
- recording any imperfections or poor workmanship;
- recording that the work site installations have been taken down and the site and land rehabilitated;
- observations related to the completion of the work.

The OPR operations are based on the results of the multiple technical tests carried out beforehand and in the course of which the conformity of the works carried out will have been verified.

The owner decides to pronounce acceptance or not based on the project manager's proposal and the operator's reservations and any observations.

It is recalled that if the scale of defects and/or unperformed work makes the installation unfit for purpose, then acceptance must be refused.



4.4 PROVISION OF CERTAIN WORKS OR PARTS OF WORKS

The work may be made available before acceptance as provided for under Article 43 of the CCAG for Works Contracts [2] in the case where "*works or parts of works, not yet completed*" are used by the "*owner without the owner taking possession of them*", i.e. before and independently of acceptance or partial acceptance within the meaning of Articles 41 and 42 of the said CCAG. Specifically, Article 43 applies "*in particular*" to enable other contractors to perform or have performed works other than those concerned by the contract. However, this "*in particular*" is not exclusive and the article may also be implemented in the case of works during operation such as the renovation of equipment in a working tunnel, in order to overcome the reluctance of the contractor to make available the works or parts of works before they are accepted contractually.

Provision of certain works or parts of works
A standard clause to be included in the CCAP of the works contract

In order to enable operation to continue during the works, the contractor shall make available under article 43 of the CCAG for Works Contracts the works in accordance with the following arrangements (to be defined).

4.5 ACCEPTANCE

The contractual arrangements for acceptance are set down in Articles 41 and 42 of the CCAG for Works Contracts [2].

Whether global or partial, acceptance has three prime consequences:

- transfer of the structure from the contractor to the owner;
- start of guarantee periods (Article 44) including in case of reservations;
- triggering the final payment request process.

It is recommended that the final payment request be made at the end of the VSR period using the following standard clause:

A standard clause to be inserted into the works contract

By way of exemption with respect to Article 13.3.2 of the CCAG for Works Contracts, the submission of the final payment request shall be postponed until the end of the VSR period and any extensions thereto.

Since dry-run operation then the VSR check take place after acceptance (see 3.4.2 - Scenario 2), the CCAP for the works contract shall indicate that both constitute proof tests within the meaning of Article 41.4 of the CCAG for Works Contracts, so that any defects or malfunctions that appear during these periods are corrected by the contractor as reservations with respect to the proper completion of the works.

As a reminder, Article 41.4 of the CCAG for Works Contracts states that "*in the case where certain proof tests must (...) be carried out after the works have been in service for a specified period (...), acceptance may only be pronounced subject to the conclusive performance of these proof tests*" and that "*if such proof tests, carried out during the guarantee period defined in 1 of Article 44, are not conclusive, acceptance is postponed.* "

In addition, the holdback sum will be a reserve to cover the cost of repairing any inadequate services.

The following standard clause indicates the expected role of the contractor during the reception operations and during the defects liability guarantee period:

Acceptance – A standard clause to be included in the CCAP for Project Management Contracts

The purpose of the assistance provided by the project manager to the owner during acceptance operations and during the defects liability guarantee period is to:

- *collate all notices from the future operator on the work carried out prior to pre-acceptance operations to ensure:*
  - *they are well integrated into the overall reservation resolution process,*
  - *that once the corresponding reservations are removed, there is nothing to prevent the future operator from taking over that part of the structure;*
- *organize operations prior to acceptance of the works;*
- *ensure the future operator undertakes that the list of reservations made is exhaustive;*
- *ensure that reservations made at acceptance of the works are followed up until they are resolved;*
- *examine the disorders reported by the owner or the operators during the defects liability guarantee period and the VSR check;*
- *draft, enter into and monitor the performance of any finishing contracts made necessary by the preceding points;*
  - *recover from the contractor the elements enabling the as-built file (DOE) required to operate the works to be compiled*
  - *compile the workplace maintenance file (DMLT), based on the items retrieved from the contractor.*

To achieve these various goals, the mission to assist the owner carried out by the project manager during acceptance operations (AOR) covers, for each contract, three successive stages (this is a simplified layout which must be adjusted to take account of the testing, dry-run operation and regular service check phases):

1/ pre-OPR operations with the future operator;
2/ OPR operations and recommendations to the owner on acceptance with or without reservations;
3/ the defects liability guarantee period.

It should be noted that the above provisions, set out in the context of full acceptance, are to be transposed in the event of partial acceptance. In this case, and in order to facilitate the task of the future operator, the project manager will require in the DCE documents that there be a single date for the end of all defects liability guarantee periods for all works in the same lot.

4.6 HANDING THE WORK OVER TO THE OPERATOR

The transfer of the works to the operator for management shall occur concurrently with the acceptance of all the works and equipment. However, in the event of work phasing, it shall take place on the date of partial acceptance of each phase. From the time the works are transferred to the operator, the operator carries out maintenance and is responsible for any subsequent modifications that may be made.

Continuing on from this, the subsequent project work file (DIUO) containing, among other items, the as-built file (DOE) and the acceptance reports, is handed over to the operator along with the workplace maintenance file (DMTL).

These files must be provided by the contractor at the time of acceptance and therefore usually prior to dry-run operation, so that the structure can start to be operated in good conditions. The file will be updated by the contractor until the end of the defects liability guarantee (GPA) period, in order to incorporate any changes to the structure that may have occurred during the VSR period.

5

GUARANTEES

Regulatory guarantees are defined by Article 44 of the CCAG [2] and concern all services rendered.

Special guarantees may be provided for in the works contract for certain structures or categories of works.

5.1 REGULATORY GUARANTEES

5.1.1 Definitions

From the date of acceptance, three legal guarantees to be provided by the builder under the Act of 4 January 1978 [36], start to run in favour of the successive owners of the structure. These are:

- the defects liability guarantee (1 year);
- the two-year smooth operation guarantee (2 years);
- the 10-year guarantee.

The two-year guarantee should not be preferred, since it requires that equipment suppliers be called on and these are not bound to the owner by a direct contract. It is therefore recommended that the defects liability guarantee be favoured, accompanied by all the provisions provided for in the CCAG for Works Contracts and supplemented by specific contract clauses, rather than the mere two-year smooth operation guarantee.

As for the 10-year guarantee this is not the norm for equipment installations.

5.1.2 Defects liability guarantee

Pursuant to Article 2 of the CCAG for Works Contracts, the defects liability guarantee period shall start from the effective date of acceptance. This presents several difficulties in the event of partial acceptance operations spread out over a long period of time such as:

- the expiry of a system's guarantee before the overall system has been accepted;
- disputes between suppliers as to who is responsible in the event of a malfunction involving several guarantees;
- the duration of the guarantee is reduced or even expired when the structure is put into operation.

In addition, the duration of the defects liability guarantee (GPA) is set at 1 year by Article 44.1 of the CCAG for Works Contracts.

However, the period between the acceptance of the works and commissioning is often long because of the dry-run operation phase and the time to perform and complete other works (straight section of an open air infrastructure, for example).

However, since Article 44.2 allows "*for certain works or categories of works*" to go beyond the 1-year period and to the extent that contractors today know how to cost extended guarantees negotiated with their suppliers, it is recommended that the defects liability guarantee period be increased to 2 (two) years.

It is also proposed that the works should be made partially available if necessary (see 4.4) and contractual provisions based on the following standard clause should be provided.

Guarantee period
Standard clause to be included in the CCAP of the works contract (GPA increased to 2 years)

By way of exemption with respect to Articles 2 and 44 of the CCAG for Works Contracts, the defects liability guarantee period is set at two years starting from the effective date of Works acceptance.

5.2 SPECIAL CONTRACTUAL GUARANTEES

Special guarantees are somewhat illusory because they are directly linked to the conditions of use, with numerous restrictive clauses. For example, the warranty for UPS batteries is related to the room temperature as recorded by sensors integrated into the said UPS devices.

Work on standardising interfaces and on upkeep and maintenance conditions should therefore be given priority.

For these reasons, only three special guarantees are recommended here.

5.2.1 Special guarantee for LED type lamps

It is recommended that a special 7-year guarantee be provided for LED type lamps. This guarantee covers internal equipment (drivers, LED sources) with housing being covered by the corrosion prevention system guarantee (see 5.2.3).

A longer guarantee, up to 10 years, may possibly be chosen.

Special guarantee for LED type lamps Standard clause to be included in the CCAP of the works contract

The specific guarantee for LED type lamps is 7 years.

5.2.2 Specific battery guarantee

The 10-year lifetime that is required in the CCTP for batteries in charger-battery-UPS units responsible for providing an uninterrupted power supply to the installations must come with a guarantee of the same duration.

Special battery guarantee
Standard clause to be included in the CCAP of the works contract

The special guarantee for batteries in charger-battery-UPS units responsible for providing an uninterrupted power supply to the installations is 10 years.

5.2.3 Special guarantee for corrosion prevention systems

Given how aggressive the atmosphere in underground structures has been shown to be and given the presence of numerous metal devices (doors, fans, jet fans, vents, ventilation doors and dampers, cable trays, signal boxes, various supports, etc.), it is recommended that special guarantees be provided for corrosion prevention systems.

Special guarantee for corrosion prevention systems
Standard clause to be included in the CCAP of the works contract

The special guarantee for corrosion prevention systems for hot-galvanised steel, stainless steel or aluminium products is 7 years for good wear and 5 years for appearance.

5.2.4 Special sourcing duration guarantee

The only obligation for the contractor with respect to sourcing duration is to provide this duration if the contractor is aware of it.

If specific sourcing duration guarantees are set out in the contract, their duration must be consistent with the obsolescence cycle of the equipment concerned. For example, a 10-year period makes sense for a programmable controller but not for a computer server.

In any event, sourcing guarantee clauses cannot set the prices of the parts as these are set unilaterally by the supplier, all the more so when there is no competition pressure in the case of captive parts.

Work on standardising interfaces and on upkeep and maintenance conditions should therefore be given priority.

5.3 EXTENSION OF THE DEFECTS LIABILITY GUARANTEE PERIOD

Article 44.2 of the CCAG for Works Contracts provides that "*if, upon expiry of the guarantee period, the contractor has not performed the work and services set out in article 44.1 and has not performed those required, if any, under article 39 [relating to defects in construction], the guarantee period may be extended if so decided by the representative of the owner, until the work and services are fully carried out, whether this work and these services be carried out by the contractor or automatically in accordance with the provisions of article 41.6*[relating to reservations]".

Note: This guide also recommends that the guarantee period be increased to 2 years (see 5.2)

Extension of the guarantee period
Standard clause to be included in the CCAP of the works contract

In supplement to Article 44.2 of the CCAG, the guarantee period may be extended until the completion of any works or services that are required to achieve the compliance demanded by the project manager or owner through a summons served on the contractor before the end of the guarantee period.

5.4 MAINTENANCE SERVICES DURING THE GUARANTEE PERIOD

During the guarantee period, awarding maintenance services to the contractor who carried out the work helps to avoid any refusal to apply the defects liability guarantee for non-compliance with the manufacturers' recommendations.

The decision to proceed in this manner must be taken upstream, in order to include in the works contract an optional tranche concerning maintenance, or even several segments if one wishes to extend the maintenance duration to several years, even beyond the guarantee period, by linking up several one-year conditional tranches for example. In any case, the date on which the first year of maintenance is converted to a firm tranche must be synchronised with the guarantee period start date.

Such an organization can pose two difficulties.

The first difficulty is in drafting provisions when drawing up the CCTP because the materials to be installed are not yet known, nor therefore are the associated maintenance recommendations as these will only be known after the equipment has been delivered.

The second difficulty lies in the fact that establishing the general contract calculation is deferred over time, leaving the issue of possible remedies or litigation up in the air.

Adding maintenance services to the works contract may also have a perverse effect on the quality of the equipment provided and the services performed in the works phase, since lower quality technical services could result in higher volumes of maintenance work.

Finally, it must be borne in mind that a single contract for works and maintenance does not guarantee that the crew carrying out both will be the same. For maintenance, it is usually local branches that intervene because they are nearby and can react rapidly, whereas the works will have been carried out by the company's personnel specialised in tunnel work and these crews usually operate on a regional or even a nation-wide scale. In practice, maintenance crews therefore do not have highly developed expertise in tunnel equipment, nor do they have in-depth knowledge of the tunnel equipment concerned by the maintenance contract since this equipment will have been installed by another crew.

5.5 INTERVENTION CONDITIONS DURING THE GUARANTEE PERIOD

Contract clauses must define the conditions under which the contractor is required to intervene during the defects liability guarantee period. It is essential that the scope of these interventions be clearly defined, as well as a responsiveness clause. A certificate of intervention must be drawn up by the contractor after each operation carried out.

Conditions of intervention during the guarantee period – Standard clause to be included in the CCAP of the works contract

During the guarantee period, the contractor is bound to guarantee the installations concerned by this contract against any defects and non-compliance with specifications and requirements, i.e. it undertakes to perform, without payment, the corresponding services including among others:

- *intervention on the site by the contractor's qualified personnel for the purpose of corrective maintenance, when called on by the owner, as stipulated in the CCTP Maintenance specifications;*
- *on-site or in-factory repair and, where applicable, the replacement of defective materials, equipment or components, within a maximum of three working days for materials present or not present in the spare parts batch.*

Interventions are conducted in accordance with the DIUO, and the prevention plan where applicable, ensuring that the HSO is consulted if necessary.

Interventions shall give rise to the establishment of a certificate of intervention, drawn up in three copies, signed by both parties, stating:

- *the date, time and duration of the intervention;*
- *the name and capacity of the personnel of the company that carried out this operation;*
- *the nature of the fault, failure or incident;*
- *the operations carried out in detail;*
- *parts and/or components replaced;*
- *recording of correct operation after the intervention.*

The contractor shall have at its disposal the full batch of spare parts provided for in the contract for the purpose of carrying out the maintenance during the guarantee period. This batch (including consumables) must be completely replenished by the contractor as parts are consumed and at the latest by the end of the guarantee period. The cost of replenishing the batch of spare parts shall be borne by the contractor.

Repairs or replacement of the equipment covered by the guarantee do not give rise to a new payment, except where they are made necessary by facts not attributable to the contractor (act of vandalism, accident, ...).

In addition to the CCAP clause concerning interventions during the guarantee period given above, a proposal for a standard clause is given for the CCTP in order to specify the conditions under which corrective maintenance work incumbent on the contractor during the guarantee period is performed and the content of this work.

Corrective maintenance on works and installations – Standard clause to be included in the CCTP of the works contract

Scope of operations

Corrective maintenance of works and installations includes all operations to be carried out following faults, damage, accidents, preventive maintenance reports…

Triggering operations

These operations are systematically triggered by requests for intervention from the owner. These requests are sent to the contractor by email, with acknowledgement of receipt, which initiates an intervention deadline.

This intervention time is linked to a degree of urgency to be defined, in particular depending on the CME and the quality of service desired by the owner.

The contractor must keep within these deadlines.

Intervention deadlines

Intervention deadlines are dependent on the minimum operating conditions. They follow the following rule:

- *level 1: the situation requires low-key monitoring by supervision, the operation is scheduled to take place within 5 working days if no preventive maintenance is scheduled within that time;*
- *level 2: the situation requires monitoring from supervision and low-key compensation actions. The operation is scheduled within 1 working day if no preventive maintenance is scheduled within that time;*
- *level 3: the situation requires close monitoring from supervision and significant compensation actions. The operation is scheduled within 8 hours;*
- *level 4: the situation no longer enables the structure to be operated and requires closure. The operation is scheduled within 4 h.*

Level 1, 2, 3 and 4 response times are provided for routine supply interventions or maintenance lot interventions and should also be considered as the times to repair.

As for interventions requiring specific sourcing times, the time is agreed jointly with the owner.

Processing operations

The contract holder carries out the operations in close relationship with operating services in order to keep them informed of the state of progress and to facilitate a speedy return to normal status.

The contract holder can propose actions to facilitate a speedy return to normal status.

No remote maintenance access has been created.

Spare parts batch

For corrective maintenance, the contract holder shall use the batch of spare parts supplied to the owner under the requalification contract. It must also replenish this batch.

The contract holder will put in place a tool to allow the owner to trace the materials used and track replenishment.

Analysis of operations

If the contract holder deems it necessary, or at the request of the owner, the contract holder shall provide a thorough failure analysis, in addition to the operation report. This analysis will take the form of feedback and will enable other corrective operations to be prevented and avoided by proposing to the owner, for example:

- *to modify preventive operations;*
- *to add preventive operations;*
- *to optimise maintenance planning;*
- *to modify the alarm summary / CME;*
- *to propose renewal operations.*

6

SUMMARY

When building or renovating a tunnel, testing of equipment is essential, because it is these tests that determine whether the equipment complies with regulatory requirements and the owner's specifications.

While experience shows that the utmost care is taken to ensure that a tunnel is not open to traffic if it does not have well-developed and stabilised systems, it is nonetheless clear that this is not without difficulty and may be a long process that exceeds the deadlines initially set.

These difficulties can be explained by the fact that regulations require the installation of a large number of sophisticated devices forming complex groups unique to each tunnel and making checks on these installations both arduous and time-consuming.

Another reason for these difficulties is the fact that currently there are few texts that can be used to define and schedule the testing and acceptance phases for tunnel equipment.

In order for the commissioning of a tunnel to take place in the expected safety conditions and within the deadlines set, the first condition is to identify all the tasks in the process and formally set them down in the project schedule. It is recommended that the sequence be as follows:

- 1°/ there is a wide variety of tests some of which need to take place right at the start of the works and they cannot therefore be separated from the works either in space or in time;
- 2°/ operations prior to acceptance, technical operations leading to a proposal for acceptance or non-acceptance in light of the results of all the tests;
- 3°/ acceptance by the owner;
- 4°/ the period of dry-run operation (or pre-operation) by the infrastructure operator;
- 5°/ commissioning;
- 6°/ the regular service check, after commissioning, which constitutes a final fine-tuning of the system.

A second condition of success is the precise and exhaustive definition of the content of the tests to be carried out and the players who are responsible for them. For this, it is proposed that a common vocabulary and breakdown be used to refer to the many types of tests to be carried out:

- qualification tests performed by equipment manufacturers, or further upstream by suppliers of materials and equipment components;
- specific tests, themselves progressive, with successively,
  - – factory and platform tests,
  - – static on-site testing,
  - – on-site partial acceptance tests,
  - – on-site system acceptance tests,
  - – on-site global acceptance tests.

On the basis of this breakdown, it is recommended that a test management plan type document be systematically drawn up at the beginning of the works contract, in order to set goals, determine the organisation to be set up and the test management procedures, activities and deliverables to be implemented.

The progressive and all-embracing testing process requires a stringent and methodical approach and is of necessity time-consuming. The times required for the smooth running of this phase must be set accordingly. The times accorded must be reasonable and must not be used as adjustment variables to meet the project schedule.

Since there are many players in the long process leading to the commissioning of a tunnel, their individual interventions must be scheduled at a very early stage and integrated into the project and works schedule. The roles of the owner, project manager and contractor are fundamental, but it is also essential that the operator, as the end user, be involved throughout and ideally right from the project studies and design phase. Before operations prior to acceptance (OPR), it is recommended that a formal pre-OPR technical visit be organized to which the operator is invited so it can make any observations it deems necessary.

Once acceptance is confirmed, dry-run operation is essential to ensure the operator can get used to operating the installations. It is recommended that an interim deadline be set for dry-run operation within the works contract and that it be positioned after acceptance of the works, i.e. after the time set for performing the works, in order to preserve the time required for it before commissioning.

Smooth running of tests and dry-run operation is not sufficient to guarantee the proper functioning of certain facilities. This can only be ensured when these facilities have been used in real-life operating conditions. This is the role of the regular service check, during which the contractor intervenes if the operator encounters problems in operating the facilities. In general, a period of six months – with an interim deadline set down in the works contract – is recommended.

Finally, from the time of acceptance, guarantees are the tool available to the owner to keep tunnel safety equipment at its rated level. Among the statutory guarantees, it is recommended to give preference to the defects liability guarantee and increase its duration to two years by way of a derogation to the CCAG for Works Contracts.

GLOSSARY

AOR: Assistance provided to the owner during acceptance operations

AVP: Preliminary project

BMPM: Bataillon des Marins-Pompiers de Marseille (Marseille Naval Fire Brigade)

BSPP: Brigade des Sapeurs-Pompiers de Paris (Paris Fire Brigade)

LV: Low Voltage

CAES: backed-up electrical power cabinet

CAP: partial acceptance record

CAS: system acceptance record

CCAG: general administrative clauses

CCDSA: commission consultative départementale de sécurité et d'accessibilité (Departmental advisory commission on safety and accessibility)

CCP: public procurement code

CE: Conformité Européenne

CEM: installation condition record

CEN: European Committee for Standardization

CETU: Centre d'Études des Tunnels (Centre for Tunnel Studies)

CME: minimum operating condition

CNESOR: Commission Nationale d'Evaluation de la Sécurité des Ouvrages Routiers (National Commission for the Safety Assessment of Highway Engineering Structures)

CONSUEL: Comité National pour la Sécurité des Usagers de l'Electricité (National Committee for the Safety of Electricity users)

DAE: test authorisation file

AID: automatic incident detection

DCE: tendering file

DDS - safety definition file

DDT: departmental territorial directorate

DDTM: departmental territorial and maritime directorate

DIUO: subsequent project work file

DJS: safety milestone files

DMLT: workplace maintenance file

DOE: as-built file

DPS: preliminary safety file

DRS: as-built safety file

DS: safety file

DS1: safety file before testing

DS2: safety file with additional tests

EAP: partial acceptance tests

EAG: global acceptance tests

EAS: system acceptance tests

ENEDIS: formerly Electricité Réseau Distribution France (ERDF)

ERP: premises open to the public

EXE: execution

GALE: globally at least equivalent

GTC: centralised technical management

HVA: High voltage A

HMI: Human Machine Interface

IDI: Initial detailed Inspection

IDP: periodic detailed inspection

LGV: high speed line

MAB: dry-run operation

MOA: owner

MOE: project manager

NFPA: National Fire Protection Association

OPR: operations prior to acceptance

OQA: accredited qualified organization

PC: desktop computer

PIS: emergency response plan

PV: reports

RAU: emergency call network

RSE: safety regulations in operation

SAGT: tunnel management assistance system

SDIS: departmental fire and rescue service

SDMIS: departmental-metropolitan fire and rescue service

SDQ: quality master plan

SDS: safety definition file

SIST: security of transport infrastructure and systems

STPG: guided public transport safety

STRMTG: technical service for ski lifts and guided transport

TGBT: low voltage distribution panels

VABF: verification on the suitability for correct operation

VSR: regular service check

LIST OF FIGURES

LIST OF STANDARD CLAUSES

BIBLIOGRAPHY

[1] Public Procurement Code that integrates the Act No. 85-704 of 12 July 1985 in Book IV

[2] General administrative clauses (CCAG) for public works contracts – March 2014 version

[3] Transport Infrastructure and System Safety Act (SIST Act) of 3 January 2002

[4] Road Networks Code

[5] Decree No. 2005-701 of 24 June 2005 relating to the safety of road network structures

[6] General administrative clauses for public contracts for routine supplies and services

[7] General administrative clauses for public information and communication technology contracts

[8] General administrative clauses for industrial public contracts

[9] Instruction from the Government on 29 April 2014 laying down the procedures for the development of investment and management operations concerning the national road network

[10] Technical instruction on the procedures for the development of investment and management operations concerning the national road network

[11] Application guide for the technical instruction for the surveillance and maintenance of civil engineering works - Booklet 40: Tunnels, Civil Engineering and Equipment

[12] NF EN 12101-1 for test method for the determination of fire resistance of powered smoke and heat control ventilators (fans) (Smoke and heat control systems – Part 3 - Specification for powered smoke and heat control ventilators (fans))

[13] NF EN ISO 13350 for performance testing of jet fans

[14] NF ISO 13347- 1 to 4 for tests to determine fan sound power levels

[15] NF EN ISO 5801 and NF EN ISO 5802 for performance testing using standardized airways or performance testing in situ

[16] NF C13-100 Delivery stations powered by a public HVA distribution network (up to 33 kV)

[17] NF C13-200 High voltage electric installations - Supplementary rules for production sites and industrial, tertiary and agricultural facilities

[18] NF C15-100 Low voltage electric facilities

[19] FD CEN/CR 14-380 Lighting applications – Tunnel lighting

[20] CETU Master Folder – section 4.2 Lighting (November 2000)

[21] CETU information memo No. 14 Anchoring jet fans in tunnels (2005) provides guidance on suitability and control tests to be performed on jet fan fixation systems

[22] CETU Information Document Automatic Incident Detection by Tunnel Image Analysis (May 2015)

[23] Decree No. 2017-440 of 30 March 2017 relating to the safety of guided public transport systems

[24] Order of 30 March 2017 amending the Order of 23 May 2003 relating to safety files for public guided transport systems

[25] Order of 30 March 2017 relating to safety files for mixed systems

[26] Order of 22 November 2005 relating to safety in tunnels in urban passenger guided public transport systems

[27] Decree No. 2010-1580 concerning the technical service for ski lifts and guided transport

[28] Order of 2 February 2011 on the organization of the technical service for ski lifts and guided transport

[29] Technical Instruction of 25 August 2000 relating to the safety provisions in new road tunnels

[30] Decree No. 2003-60 of 21 January 2003 relating to information and communication systems area services

[31] CETU Information Memo No. 24 – Transmission of Radio Communications in road tunnels (July 2014)

[32] Standard NF P 03-100 General criteria for the contribution of technical control to the prevention of technical hazards in the construction sector – September 1995

[33] STRMTG Implementation Guide "Urban passenger public guided transport systems - Mission of the accredited qualified organization (OQA) for project safety assessment" – 8 February 2012

[34] The findings and main lessons drawn from the cases reviewed over the period 2009-2012 – National Commission for the Safety Assessment of Highway Engineering Structures

[35] Order of March 22, 2019 specifying the technical conditions for performing project management missions entrusted by public contracting authorities to private service providers

[36] Law No. 78-12 of 4 January 1978 relating to liability and insurance in the construction industry.

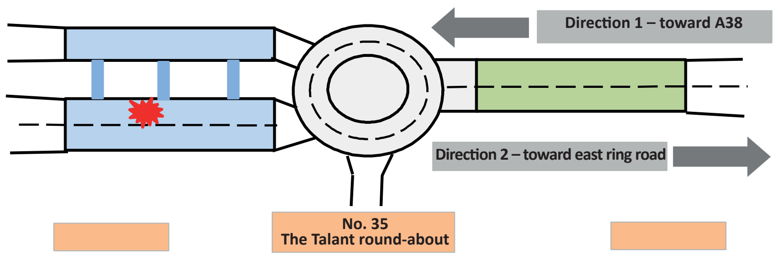
APPENDICES

1 EXAMPLE OF A PRE-OPERATION DRILL SHEET

Complexity level	3	**EPE ref.**	3-07
Theme	STOPPED VEHICLE		

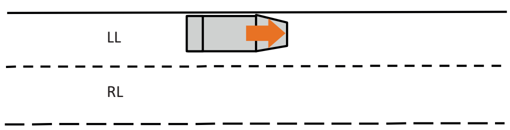
Structure

TALANT Tunnel	X	Location (Pr)	Niveau complexité
DAIX TC		Direction (1 or 2)	Niveau complexité
Interchange no. 35		Lane(s) (Hard shoulder, RL, LL)	Niveau complexité
Other *specify*			



Scenario (Event Description)

Presence of a vehicle at a standstill
Vehicle stopped against the sidewalk in LL
Heavy traffic



Goals of the drill

Check that each participant fully masters the procedures	X
Check the efficiency of the elements used to shut off traffic	X
Check how markings are installed (emergency or non-emergency) and the associated duration	
Check the time required to feedback information from the ground	X
Check the reaction times of the "ground" crews	X
Check the reaction times from the Osiris control station	X
Check intervention times	X
Test the management of the vehicle jam	
Test the openings of the ITPC	
Check event traceability (GTC recording, video, radio, others; handrail; etc.)	X

Pre-requisites (systems and/or equipment available for EPE)

General			
HV Power	X	GTC	X
LV Power	X	Supervision	X
Wave energy	X	Transmission networks	X
Surveillance / Detection			
Video	X	Traffic data collection	
Automatic incident detector	X	Weather data collection	
Communications			
RAU	X	Signage	X
Radio use	X	FM radio	X
User protection			
Closure signage	X	Ventilation	
Other *specify*			
SDIS protection			
Fire-fighting network		Radio (INPT, ...)	

Human pre-requisites

Nb of site participants	-	Including a "simulator" for persons with reduced mobility	
1 "player" light vehicle down + operating personnel			
Triggering element		User	
Patrol personnel / road worker		Automatic incident detector	X
RST / Operator		GTC	
On-call system		Other *specify*	

DIR CE players		**External players**	
Patrol personnel / road worker	X	Police	X
RST / Operator	X	SDIS	
On-call system	X	Tow-truck	
		Other *specify*	
Other *specify*			

DIR CE material resources		**User vehicle(s)** *(total number)*	
Patrol vehicle	X	LV	5
Intervention vehicle		HGV	
Specialised vehicle		TMD	
Please specify		Other	

Environment			
Week	X	Mild weather	X
Weekend		Rain	
Day	X	Snow	
Night		Other *specify*	
Traffic conditions			
Low to normal traffic		Heavy traffic	X
Traffic jam		1-direction closure	
Other *specify*			

Lighting	X
Other *specify*	
Other *specify*	
Telephony / Fax	X
Other *specify*	
Exit locking systems	
Other *specify*	
Nb of Osiris PC participants	.
RAU	
Outside call	
Specify if GSM	
Gendarmerie	
SAMU (ambulance)	
Maintenance contractor	
	.
2-wheeled vehicle	
Bus	
Exceptional convoy	
Please specify	
Fog	
Strong wind (> 50 km/h)	
Black ice risk	
Restriction in progress	
Alternate/timing	

Information about EPE carried out		
Date:	Start times:	End:
Names of participants	Contractor / Department	Function

EPE chronology					
Event / Actions undertaken	**OK / NOK**	**Time**	**System used**	**OK / NOK**	**Time**
Vehicle stoppage			Automatic incident detector		
Event Analysis by TSN			Video		
Traffic shutdown			Supervision		
Police / Gendarmerie call			Telephony / Fax		
SDIS call			Telephony / Fax		
Tow-truck call			Telephony / Fax		
Call to executive on-call			Telephony / Fax		
Lay-by door alarm feedback			GTC / supervision		
User-initiated alarm			PAU		
Arrival of patrol person			Radio		
Arrival of police / gendarmes			Radio		
Arrival of tow-truck			Radio		
Relief road activation					
Road clean-up					
Departure of patrol staff					
End of EPE					

Technical toll

Human toll

Observations by external services

2 EXAMPLE OF A TOOL FOR MONITORING TEST PROCEDURES

No.	Type	Test task	PARTIAL ACCEPTANCE TESTS	SYSTEM ACCEPTANCE TESTS	ACCEPTANCE
HV-LV					
0.01	EAP	Arrival ERDF LT4			
0.02	EAP	Line 1&2 HT - TUS			
0.03	EAP	HV cells of UV 2 to 5			
0.04	EAP	Line 1 HV - UV 2 to 5			
0.05	EAP	LV power supply to UV 2 to 5			
0.06	EAP	TUS Fire-fighters control station power supply			
0.07	EAP	LV power supply to IS via TUS			
Easements					
0.01	EAP	Factor easements			
Ventilation					
0.04	EAP	UV ventilation, excluding UV1			
0.01	EAP	TUS sensors			
0.02	EAP	TUS jet fans			
0.03	EAP	IS Ventilation			
0.05	EAP	TUS Registers			
0.06	EAP	TUS / TUN flue sealing			
Lighting					
0.01	EAP	TUS circuits and lamps			
0.02	EAP	Saône head external lighting			
0.03	EAP	Rhône head external lighting			
0.04	EAP	TUN site lighting			
0.05	EAS	TUS photometric checks			
GTC					
0.01	EAP	GTC-TUN network looping by TUS			
0.02	EAP	GTC-TUS network			
0.03	EAP	GTC-UV network			
0.04	EAP	GTC-system tests			
0.05	EAS	GTC-trades tests			
5.05	EAS	GTC Tests – Set (no more works)			
Tunnel fire detection					
0.01	EAP	DIT Eqts in TUS			
Signage					
0.01	EAP	TUS signage eqts			
0.02	EAP	Rhône / Saône heads signage eqts			
Public address system					
0.01	EAP	TUS side IS eqts			
0.02	EAP	IS eqts			
0.03	EAS	Public address system tests			

RDT		
0.01	EAP	TUS eqts and loops
0.02	EAS	RDT performance control
Fire-fighting network		
0.01	EAP	Ext and TUS network eqts
0.02	EAS	Fire-fighting network load tests
Metalwork		
0.01	EAP	EAS Metalwork (IS doors, TUS lifeline, lifting rings)
Drainage		
0.01	EAP	EAS drainage (Ext and IS)
Separators		
0.01	EAP	TUS separators
RADIO		
0.01	EAP	Radio equipment in LT and TUS
0.02	EAP	Radio system connection to the TSF network
0.03	EAS	RADIO functional tests (IMU)
0.04	EAS	TUS and IS radio measurements campaign
0.05	EAP	GSM equipment in LT and TUN / TUS
0.06	EAP	GSM eqts connection (external)
0.07	EAS	GSM operational tests
DATI		
0.01	EAP	IS / TUS / UV / LT markings
0.02	EAS	DATI functional tests
RIS		
0.01	EAP	RIS TUS and TUN
0.02	EAS	RIS TCR / RIS connection to TSF
Video		
0.01	EAP	Video eqts of IS / UV / EXT / TUS
0.02	EAS	TCR video
0.03	EAS	TSF redundant video server migrated to TCR
0.04	EAS	Functional tests of the AID system
0.05	EAS	In-tunnel AID performance tests
RAU / TEL		
0.01	EAP	RAU/TEL eqts of the IS / UV / EXT / TUS
0.02	EAS	RAU / TEL TCR tests
0.03	EAS	A RAU / TEL server migrated from TSF to TCR
SITG		
0.01	EAP	SITG to TCR server migration
0.02	EAS	No central system regression
0.03	EAS	SITG TCR site pre-acceptance
Aptitude check		
0.01	ER	Analysis of control reports
0.02	ER	Check during a site inspection
0.03	ER	TCR site acceptance testing via SITG
0.04	ER	Emergency services tests (smoke tests)

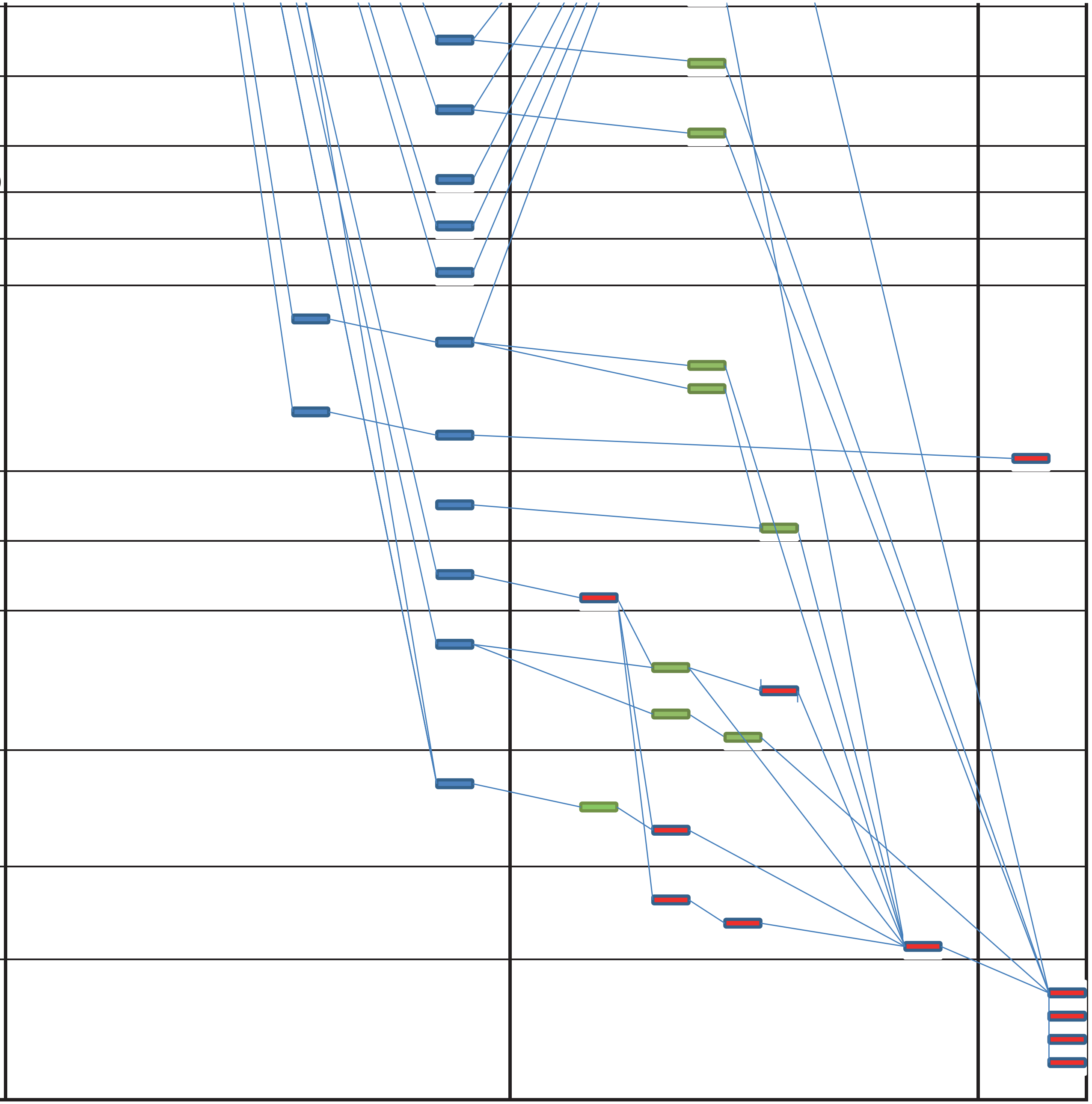


Table to track tests used for the large-scale renovation of the Croix-Rousse Tunnel – Published by SETEC-ITS

3 EXAMPLE OF A LOGIC DIAGRAM OF INTERACTIONS BETWEEN SYSTEMS DURING PARTIAL ACCEPTANCE AND SYSTEM ACCEPTANCE TESTS

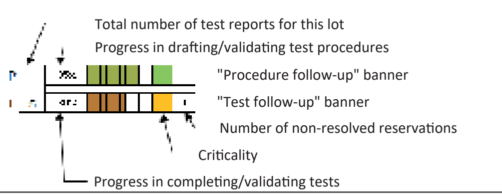
LOTS	EST		EAP	
	UV	TUS / IS / LT	UV	TUS / IS / LT
11.02 VENTILATION	P 50% / E 10 0% 0	P 40% / E 35 0% 0	P 0% / E 5 0% 0	P 0% / E 21 0% 0
11.03 METALLWORK	P 85% / E 5 0% 0	P 85% / E 20 0% 0	P 85% / E 5 0% 0	P 85% / E 14 0% 0
11.04 FIRE-FIGHTING NETWORK		P 95% / E 20 0% 0		P 85% / E 18 0% 0
11.05 DRAINAGE NETWORK		P 85% / E 5 0% 0		P 85% / E 5 0% 0
11.06 SEPARATORS		P 0% / E 3 0% 0		P 0% / E 2 0% 0
11.07 ENERGY	P 100% / E 26 0% 0	P 100% / E 6 0% 0	P 100% / E 30 0% 0	P 96% / E 5 0% 0
11.09 LIGHTING		P 85% / E 8 0% 0		P 0% / E 8 0% 0
11.10 GTC (API)				
11.11 Video and AID	P 100% / E 5 0% 0	P 100% / E 18 0% 0	P 95% / E 5 0% 0	P 95% / E 18 0% 0
11.12 RAU and Telephony	P 100% / E 5 0% 0	P 100% / E 17 0% 0	100% / 5 0% 0	P 100% / E 17 0% 0
11.13 Radio communication	P 85% / E 5 0% 0	P 85% / E 9 0% 0	P 85% / E 5 0% 0	P 85% / E 9 0% 0
11.14 Networks and Telecom		P 100% / E 5 0% 0	P 100% / E 5 0% 0	
11.15 Dynamic signalling		P 100% / E 14 0% 0		P 85% / E 14 0% 0
11.16 DATI system	P 95% / E 5 0% 0	P 95% / E 13 0% 0	P 85% / E 5 0% 0	P 85% / E 13 0% 0
11.17 Fire detection		P 100% / E 2 0% 0		P 100% / E 2 0% 0
11.18 Public Address System		P 85% / E 15 0% 0		P 85% / E 15 0% 0
11.19 Buildings – easements	P 100% / E 5 0% 0	P 100% / E 11 0% 0	P 88% / E 15 0% 0	P 96% / E 17 0% 0
11.21 Traffic data collection		P 85% / E 24 0% 0		P 85% / E 24 0% 0
12 SITG		P 85% / E 2 0% 0		P 85% / E 5 0% 0
xxx Exterior lights		P 85% / E 14 0% 0		P 85% / E 14 0% 0
11.03 Metalwork lot 1	P 80% / E 5 0% 0	P 80% / E 5 0% 0		
11.04 Fire-fighting network lot 1		P 85% / E 1 0% 0		

Logic diagram of partial acceptance and system acceptance tests for the large-scale renovation of the Croix-Rousse Tunnel

EAS

UV	TUS / IS / LT
	P 0% / E 13 0% 0
	P 0% / E 20 0% 0
	P 0% / E 5 0% 0

KEY:



UV	TUS / IS / LT
	P 0% / E 8 0% 0
P 0% / E 5 0% 0	P 0% / E 18 0% 0
0% / 5 0% 0	P 0% / E 17 0% 0
P 0% / E 5 0% 0	P 0% / E 9 0% 0
	P 0% / E 14 0% 0
P 0% / E 5 0% 0	P 0% / E 13 0% 0
	P 0% / E 2 0% 0
	P 0% / E 15 0% 0
	P 0% / E 24 0% 0
	P 0% / E 1 0% 0
	P 0% / E 14 0% 0

ASSESSMENT BY LOCATION

UV

Assessment by phase

EST	Procedures		89%
EAP	Procedures		88%
EAS	Procedures		0%
EST	Tests	71	0%
EAP	Tests	80	0%
EAS	Tests	20	0%

Summary by location

UV	Procedures		78%
	Tests	171	0%

TUN

Assessment by phase

EST	Procedures		NC
EAP	Procedures		NC
EAS	Procedures		NC
EST	Tests	0	NC
EAP	Tests	0	NC
EAS	Tests	0	NC

Summary by location

TUN	Procedures		NC
	Tests	0	NC

TUS / IS / LT

Assessment by phase

EST	Procedures		83%
EAP	Procedures		76%
EAS	Procedures		0%
EST	Tests	247	0%
EAP	Tests	221	0%
EAS	Tests	173	0%

Summary by location

TUS	Procedures		0%
	Tests	641	0%

ASSESSMENT BY PHASE

EST

Assessment by locati

UV	Procedures		89%
TUN	Procedures		NC
TUS	Procedures		83%
UV	Tests	71	0%
TUN	Tests	0	NC
TUS	Tests	247	0%

Summary by phase

EST	Procedures		85%
	Tests	318	0%

EAP

Assessment by locati

UV	Procedures		88%
TUN	Procedures		NC
TUS	Procedures		76%
UV	Tests	80	0%
TUN	Tests	0	NC
TUS	Tests	221	0%

Summary by phase

EAP	Procedures		80%
	Tests	301	0%

EAS

Assessment by locati

UV	Procedures		0%
TUN	Procedures		NC
TUS	Procedures		0%
UV	Tests	20	0%
TUN	Tests	0	NC
TUS	Tests	173	0%

Summary by phase

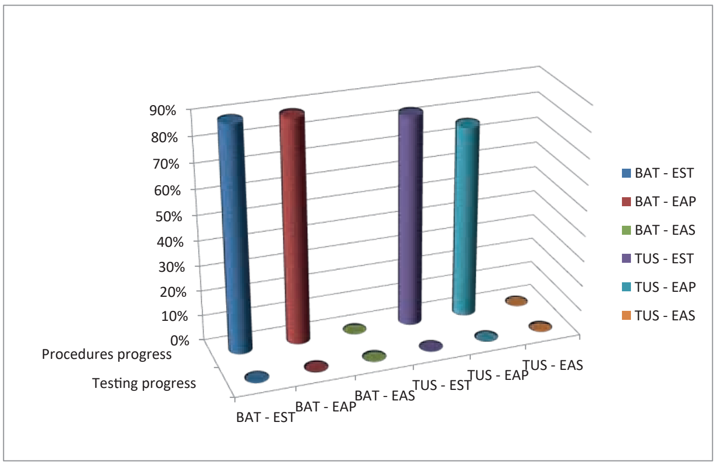
EAS	Procedures		0%
	Tests	193	0%

ASSESSMENT OF STEP 2

Stage 2

Summary all phases, all locations

Stage 2	Procedures		63%
	Tests	812	0%



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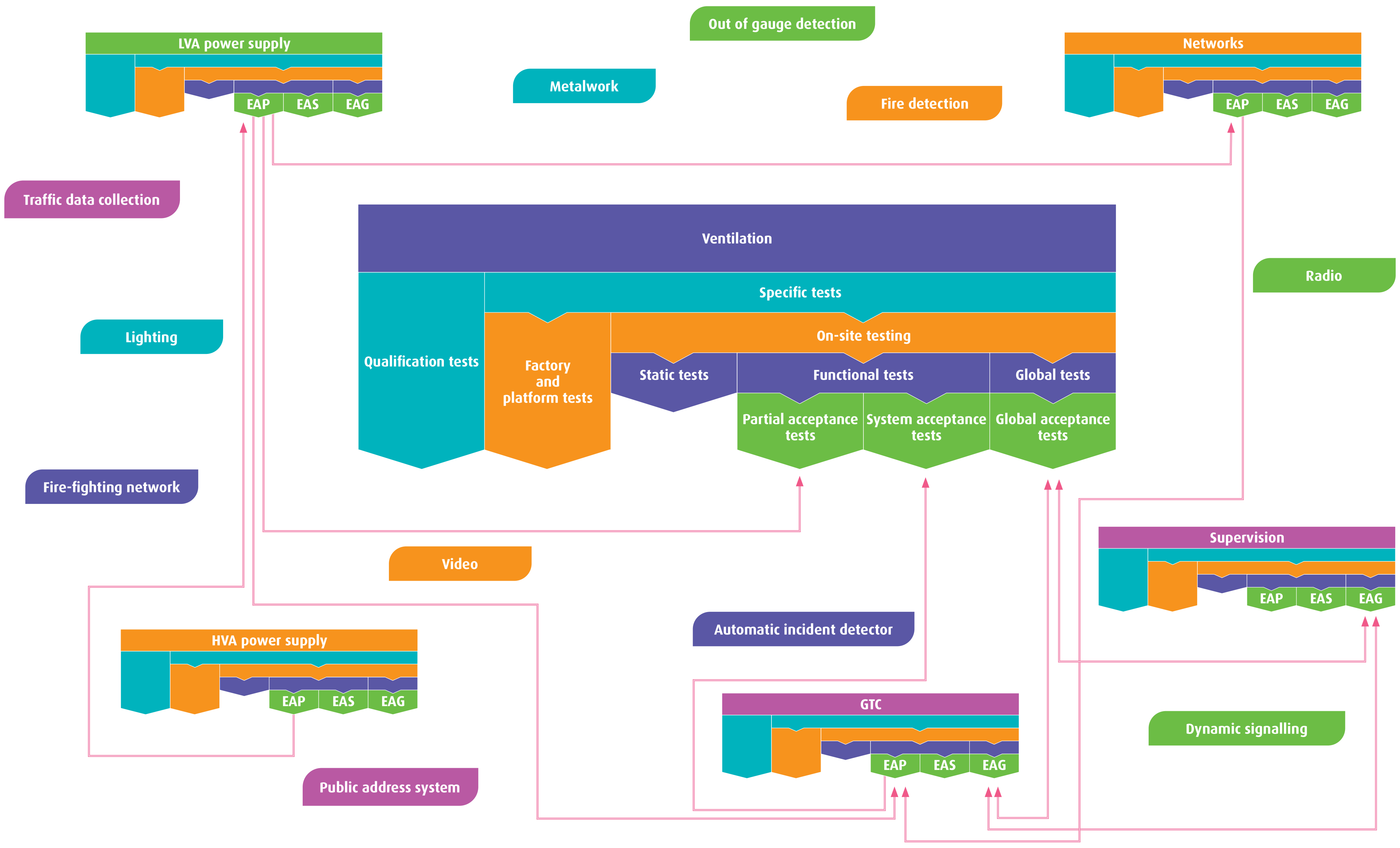
4 SYSTEMS IN INTERACTION - EXAMPLE OF VENTILATION

↔ The initiation of a test phase is entirely dependent on the results of the tests of interacting systems.



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Centre d'Études des Tunnels (Centre for Tunnel Studies)

25 Avenue François Mitterrand
69500, Bron, France
Tel. +33 (0)4 72 14 34 00
Fax. +33 (0)4 72 14 34 30
cetu@developpement-durable.gouv.fr

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