Foreword

In France, for a regulatory viewpoint in order to ensure the maintenance of a tunnel equipment the operator has available:

- General standards (on electrical equipment, maintenance, etc.)
- Specific documents applying most often to facilities likely to be installed in other structures than tunnels (extinguishers, fire detection systems, etc.)
- A technical instruction on monitoring and maintenance of tunnel (ITSEOA 79 leaflet N° 40)

Leaflet N° 40: Table of contents

Initial version drafted in 1979 has been revised recently. The new leaflet has four parts:

- Common part: civil works and equipment
- Boring tunnels
- Cut-and-covers
- Equipment

1. Concerned Equipment
2. Necessary actions
3. Monitoring
4. Maintenance
5. Renewal
All tunnels are not equipped in the same way; generally speaking, there are a few equipment in a short tunnel and there are a lot of equipment in a long or complex tunnel.

In terms of maintenance, the distinction is frequent between:

- The general facilities (essentially equipment based on mechanics and/or electro-mechanics)
- The operating facilities (more sophisticated with a large use of electronics and informatics)

**Concerned Equipment** (2/3)

General facilities
- Power supply distribution
- Lighting
- Ventilation and smoke control
- Fixed signing
- Water network for fire fighting
- Fluid removal (collection, pumping, and treatment)
- Etc.
Concerned Equipment (3/3)

Operating facilities

- Supervisory control and data acquisition system (SCADA)
- Closed circuit television (CCTV)
- Automatic incident detection (AID)

Concerned Equipment (4/3)

Operating facilities

- Supervisory control and data acquisition system (SCADA)
- Closed circuit television (CCTV)
- Automatic incident detection (AID)
- Dynamic signing
- Emergency call network
- Radio-retransmission
- Etc.

1. Concerned Equipment
2. Necessary actions
3. Monitoring
4. Maintenance
5. Renewal

Three areas concerned

Monitoring → Maintenance

Renewal
Three areas concerned

Monitoring

- Continuous monitoring by SCADA for tunnels with human monitoring only
- Systematic operations:
  - Specific controls
  - Detailed inspections

Maintenance

- High requirement on safety
- High aggressiveness of the trafficked area
- Difficult work conditions for the operating staff
- High diversity of the equipment types

Renewal

- For obsolete equipment in case of deterioration of performances

1. Concerned Equipment
2. Necessary actions
3. Monitoring
4. Maintenance
5. Renewal
Monitoring

Continuous

Systematic operations

Supervisory control and data acquisition

or

Visits

Specific controls

Detailed inspections

Specific controls

- Electrical facilities
- Extinguishers
- Lifts
- Handling devices
- Individual protection equipment
- Safety lighting blocks
- Fire detection systems

Opening of the tunnel

<table>
<thead>
<tr>
<th>Opening of the tunnel</th>
<th>Initial detailed inspection (IDI)</th>
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<tbody>
<tr>
<td>3rd year</td>
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<td>6th year</td>
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<td>9th year</td>
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<td>15th year</td>
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<td>18th year</td>
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Detailed inspections

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<td>Periodic detailed inspection</td>
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<tr>
<td>18th year</td>
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</table>

Functional controls:
- Functional sequences
- Safety sequences (each year)
- Individual functioning of equipment

Detailed inspections

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Performance measurements
- Functional tests:
  - per equipment
  - functional sequences
  - safety sequences

Re-assessment (very close to Initial detailed inspection)
1. Concerned Equipment
2. Necessary actions
3. Monitoring
4. Maintenance
5. Renewal

**Types of maintenance**
- Maintenance policy
- Subcontracting
- Organisation
- Tasks to be done

**Maintenance**
- Corrective interventions (to repair)
- Systematic maintenance (working times)
- Preventive interventions (to avoid failure)
- Conditional maintenance (performance measurements)

**Types of maintenance: example**
- **Luminous sources**
  - **Curative treatment** (sources are replaced when out of service)
  - **Systematic** (sources are replaced after 10,000 h)
  - **Preventive interventions**
  - **Conditional** (sources are replaced when the illuminance level is too low)

1. Concerned Equipment
2. Necessary actions
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**Types of maintenance**
- Maintenance policy
- Subcontracting
- Organisation
- Tasks to be done
**Maintenance policy (1/2)**

Corrective interventions
- Non pre-planned intervention
- Time to repair could be long (to solve the problem)
- Availability of spare equipment is not sure
- Abnormal situation
- Operating restrictions (eventually closure)

Preventive interventions
- Pre-planned intervention
- Time to maintain is known
- Availability of spare equipment
- Failures can not be totally eliminated but strongly reduced

Only possible for tunnel with few equipment

Best choice in the majority of tunnels

**Maintenance policy (2/2)**

Choice for a maintenance policy

Equipment (type and complexity)

Staff (competence and knowledge)

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**Ideal distribution between maintenance type according French manufacturers**

- **Corrective interventions** 10%
- **Preventive interventions** 90%
- **Systematic maintenance** 55%
- **Conditional maintenance** 35%

**Maintenance**

1. Concerned Equipment
2. Necessary actions
3. Monitoring
4. **Maintenance**
5. Renewal

Definitions
- Maintenance policy
- Subcontracting
- Organisation
- Tasks to be done
The operator performs rarely all equipment tasks, most often they are handed over to subcontractors.

Several choice are possible:

- **Subcontracting only maintenance operations of a determined technical level**

### Subcontracting by levels (example)

<table>
<thead>
<tr>
<th>Equipment (non exhaustive list)</th>
<th>Power supply</th>
<th>lighting</th>
<th>ventilation</th>
<th>CCTV</th>
<th>radio</th>
<th>etc.</th>
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</thead>
</table>

<table>
<thead>
<tr>
<th>Maintenance levels (ranging from simple to complex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Maintenance done by operator</td>
</tr>
<tr>
<td>2. Subcontractor</td>
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<tr>
<td>3. Subcontractor</td>
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</tbody>
</table>

### Subcontracting per equipment family (example)

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<tr>
<td>1. Operator</td>
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<tr>
<td>2. Operator</td>
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<tr>
<td>3. Operator</td>
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<tr>
<td>4. Operator</td>
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</tbody>
</table>

SC : subcontractor
Subcontracting (5/6)

The operator performs rarely all equipment tasks, most often they are handed over to subcontractors. Several choices are possible:

- Subcontracting only maintenance operations of a determined technical level
- Subcontracting all tasks regarding one or several equipment
- Combine the two previous approaches

Subcontracting (6/6)

Combined subcontracting (example)

<table>
<thead>
<tr>
<th>Equipment (non exhaustive list)</th>
<th>SC</th>
<th>SC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power supply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>lighting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ventilation</td>
<td></td>
<td></td>
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<td>radio</td>
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<tr>
<td>etc.</td>
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</tbody>
</table>

SC: subcontractor

Maintenance levels (ranging from simple to complex)

1. Operator
2. Operator
3. SC, Operator
4. SC

Organisation (1/5)

Intervention conditions are dependent on:

- Type of intervention
  - planned (preventive)
  - non-planned (corrective)

- Intervention location

- Operating conditions
Intervention conditions are dependent on:

- **Type of intervention**
- **Intervention location**
- **Operating conditions**

**Intervention location**:
- in the tunnel (ceiling)
- in technical rooms
- in the control centre

**Operating conditions**:
- one tube closure
- tunnel closure
- one lane closure

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The various tasks to be performed must be defined and described in a status document: the maintenance plan.

**Maintenance plan**:
- is set up by the operator
- Then adapted regularly (feedback on experience)

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**Feedback on experience**

Maintenance plan:  

Evaluation  

Improvements
1. Concerned Equipment
2. Necessary actions
3. Monitoring
4. Maintenance
5. Renewal

Types of maintenance
- Maintenance policy
- Subcontracting
- Organisation

Tasks to be done

1. Power supply
2. Lighting
3. Ventilation
4. Hydraulic networks (pumping and water network for fire fighting)
5. Traffic signs
6. Closed Circuit Television (including Automatic incident detection)
7. Communication equipment to user (emergency call network, radio retransmission, etc.)
8. Supervisory control and data acquisition system
9. Various safety equipment

Tunnel facilities are gathered into 9 families to facilitate maintenance works

Tasks to be done (1/8)

The preventive maintenance interventions are classified into 5 items:

- Visual controls
  - Visual control of aspect
  - Control of the displayed values
  - Control of supports and/or fixings
  - Control of electrical connections
  - Control of luminous signs readability
  - Control of marking glasses visibility
  - Control of lamps (out of service or not)

Tasks to be done (2/8)

- Visual controls
  - Sweeping technical rooms and premises the users can access to
  - Dust removal from the devices (cabinets, cases, ferrules, boards, etc.)
  - Washing sidewalls, traffic signs
  - Internal and/or external facility cleansing

Tasks to be done (3/8)
The preventive maintenance interventions are classified into 5 items:

- **Visual controls**
- **Cleansing**
- **Interventions on equipment**
- **Measurement of characteristics values**
- **Functional testing**

### Tasks to be done (4/8)

- Changing the filters
- Lubricating
- Tightening connections
- Adjusting amplifiers
- Changing the lamps (luminaries, road signs, etc.)

### Tasks to be done (5/8)

- Calibration
- Checking the starting thresholds and delay times
- Checking electrical values (voltage, power, frequency, etc.)
- Lighting and illuminance measurements
- Air flow measurements

### Tasks to be done (6/8)

- Equipment command from the electric control panel
- Barriers closure/opening
- Checking safety (including emergency stopping)
- Control of safety equipment, including information transfer (emergency exits, pulling down extinguishers, fire station valves, etc.)
- Operation from the control centre

### Tasks to be done (7/8)

<table>
<thead>
<tr>
<th>5 items</th>
<th>Visual controls</th>
<th>Cleansing</th>
<th>Interventions</th>
<th>Measurements</th>
<th>Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power supply</td>
<td>Tasks to be done for Power supply facilities</td>
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<tr>
<td>Lighting</td>
<td>Tasks to be done for lighting facilities</td>
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<td>Ventilation</td>
<td>Tasks to be done for ventilation facilities</td>
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<td>Hydraulic networks</td>
<td>Tasks to be done for hydraulic networks facilities</td>
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<td>Traffic signs</td>
<td>Tasks to be done for traffic signs facilities</td>
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<td>CCTV</td>
<td>Tasks to be done for CCTV facilities</td>
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<tr>
<td>Communication devices</td>
<td>Tasks to be done for communication facilities</td>
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<tr>
<td>SCADA</td>
<td>Tasks to be done for SCADA facilities</td>
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<tr>
<td>Various equipment</td>
<td>Tasks to be done for various equipment</td>
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</table>
Tasks to be done : example (8/8)

Power supply

Various equipment of power supply

Actions to be done (visual controls, cleansing, etc)

Periodicity of interventions

1. Concerned Equipment
2. Necessary actions
3. Monitoring
4. Maintenance
5. Renewal

Renewal (1/2)

The renewal of equipment can be very expensive; so we have to anticipate this taking into account the following aspects:

- Direct risk resulting from deterioration of the equipment for the users or operating staff
- Breakdown of the equipment that cannot be repaired or too high breakdown frequency
- Obsolete character of the equipment leading to impossible maintenance or repair if any breakdown occurs
- Excessive deterioration of equipment performances

Renewal (2/2)

Other aspects to make a renewal:

- Service life of Equipment
- Conditions of the Equipment
- Performances of the Equipment
Conclusion

In France, a new version of the leaflet on maintenance of tunnels led to define more detailed requirements in three fields:

- monitoring
- maintenance
- renewal

Thank you for your attention