SVS1-T Sentry™
Visibility Sensor

Road & Rail Tunnel Application Guidelines

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Guidelines for Installing & Operating the Sentry™ Visibility Sensor in Road & Rail Tunnels

A. Introduction

The Model SVS1-T Sentry™ Visibility Sensor has been installed in road tunnels in several countries including Spain, United Arab Emirates, and Saudi Arabia. The function of the Sentry™ is to optically measure atmospheric visibility. The Sentry™ is used around the world to measure visibility at airports, coastal & off-shore sites, and road & bridges. For the specific use in road and rail tunnels, the Sentry™ has 2 major applications:

- Ventilation system control – using a visibility sensor to measure the clarity of the air allows the ventilation system operation to be optimized while reducing energy usage
- Smoke detection – using a visibility sensor in conjunction with temperature sensors and other fire detectors, the location, severity, and spread of a tunnel fire can be quickly determine leading to an optimal fire escape plan and potential for saving lives

The Sentry™ uses the forward scatter measurement of atmospheric extinction coefficient to determine the visibility in the tunnel. Forward scatter is accepted worldwide as the most practical method of measuring visibility. Instruments exist that determine the light loss over a certain distance (15 to 30 m) by measuring the amount of light transmitted through the atmosphere along an optical path. In use, however, these transmitted light instruments (transmissometers) call for very precise installation and frequent servicing efforts.

A more practical method is measurement of the scattered light rather than the transmitted light. Instead of measuring the attenuation over a certain distance, it measures the intensity of the light scattered by the illuminated dust particles. Because there is no need for a long measuring distance, measurement takes place adjacent to the Sentry™. Further information on measuring techniques can be found at [http://www.envirotechsensors.com/FAQ.htm](http://www.envirotechsensors.com/FAQ.htm).

Additional information on the Sentry™ including product brochures and application notes may be obtained at [www.envirotechsensors.com](http://www.envirotechsensors.com). Note that a new model, the SVS1-T is designed with the optimal extinction coefficient range of 15 to 0.03 km⁻¹.

B. Arrangement Of The Measuring Locations In The Tunnel

The number and location of the measuring points within the tunnel is determined by several factors including:

- Tunnel profile type
- Type of ventilation system and the number & location of the fans
- Traffic design (single lane vs. opposing traffic)
- Local regulations
C. Selection Of Measuring Location Criteria - See Figures 1a & b:

- With half and cross-ventilation, an even distribution across the length of the tunnel is recommended, with at least 2 measuring points per ventilation section.

- With a main tunnel with traffic in more than one direction, opposing traffic cannot be ruled out completely. According to the German Federal “Guidelines for Equipping and Operating Road Tunnels, RABT”, therefore, tunnels with longitudinal ventilation must contain at least 3 measuring points; one at a distance of ~ 150 m from each portal and at least one at the center of the tunnel.

- The distance between measuring locations should be between 200-500 m depending on the tunnel ventilation design and local regulations.

- If there is a risk of fog intake in the tunnel, additional fog sensors should be provided at a maximum distance of 10 m from the tunnel portal. Fog effects can intensify in the main tunnel since dust particles act as further condensation particles. This fog can penetrate into the tunnel up to a distance of 150 m.
D. Sensor Mounting Location Criteria - See Figure 2:

- Since the air in the tunnel is mixed well, the height is not an important criterion. But to prevent large vehicles from causing scattered light, the sensors should be installed at a height between 3.5 and 4.5 meters.

- Ensure that the sensors are mounted at a safe distance from the traffic area.

- The Sentry™ should be installed with the sensor cross-arm parallel to the tunnel wall.

- Ensure that access is provided for maintenance and monitoring by mounting the sensor ~0.6 m from the side wall.

- The mounting location should not be within the range of tunnel cleaning services.

- To ensure that the measurement value reflects the actual concentration, the sensors must not be located within the immediate vicinity of the ventilators or fresh-air flow of an exhaust fans.

--- Notes ---

1) Mount sensor near top of side wall of the tunnel, 3.5-4.5 m above road bed.
2) Mount the sensor ~0.6m inches out from the side wall so it can be rotated for access to the main electronics enclosure during calibration.
3) Mount sensors a safe distance from the traffic area & tunnel cleaning services.
4) Not to scale.
E. Sensor Mounting Specifics – See Figure 3:

The Sentry™ should be installed following the guidelines in the Sentry™ User’s Guide. The sensor has a 1-1/2” pipe flange on the bottom of the main electronics enclosure. To mount the Sentry™ on the side wall of the tunnel, the customer must provide a mounting bracket. Figure 3 shows a typical design that is constructed of commonly available materials.

For complete details on sensor installation, refer to the Section 2 of the Sentry™ User’s Guide.

--- Notes ---
1) All material 1-1/2 inch IPS Schedule 40 Galvanized Pipe.
2) Pipe may be either threaded or welded construction.
3) Mount the sensor ~0.6 m out from the side wall so it can be rotated for access into the main electronics enclosure during maintenance.
4) Not to scale.

Figure 3 – Sentry™ Mounting Bracket Details
F. Interpreting The Sentry™ Data For Tunnel Applications

Complete information on the Sentry™ operation is included in the Sentry™ User’s Guide. Output protocols, data collection routines, and other relevant materials are included in User’s Guide Section 3. Table 1 provides additional information specific to road & rail tunnel applications. As shown in the table, the maximum extinction levels and equivalent visibility are shown for 4 countries, Australia, Hong Kong, Switzerland, and Saudi Arabia. Typically, the desired extinction level is less than 0.005 m$^{-1}$ or greater than 600 m visibility. The extinction levels are shown as examples only. Each tunnel authority must make a determination as to the maximum extinction level for the specific tunnel. Note that the recommended averaging time for the visibility sensor extinction coefficient is a long 15 minute average.

Table 1 – Typical Extinction Levels for Tunnels around the World

<table>
<thead>
<tr>
<th>Country</th>
<th>Tunnel Operation Mode</th>
<th>Extinction Level (m$^{-1}$)</th>
<th>Visibility (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Australia Tunnels</strong></td>
<td>Incident</td>
<td>&lt;0.012</td>
<td>&gt;</td>
</tr>
<tr>
<td></td>
<td>Stationary Traffic</td>
<td>&lt;0.009</td>
<td>&gt;333</td>
</tr>
<tr>
<td></td>
<td>Congested Traffic</td>
<td>&lt;0.007</td>
<td>&gt;428</td>
</tr>
<tr>
<td></td>
<td>Design Condition</td>
<td>&lt;0.005</td>
<td>&gt;600</td>
</tr>
<tr>
<td><strong>Hong Kong Tunnels</strong></td>
<td>At all times</td>
<td>&lt;0.005</td>
<td>&gt;600</td>
</tr>
<tr>
<td><strong>Switzerland Tunnels</strong></td>
<td>Fluid peak traffic @ 80 km/h</td>
<td>&lt;0.005</td>
<td>&gt;600</td>
</tr>
<tr>
<td></td>
<td>Standstill all lanes</td>
<td>&lt;0.007</td>
<td>&gt;428</td>
</tr>
<tr>
<td><strong>Mecca Saudi Arabia Tunnels</strong></td>
<td>Normal (Medium Traffic)</td>
<td>&lt;0.005</td>
<td>&gt;600</td>
</tr>
<tr>
<td></td>
<td>Normal (High Traffic)</td>
<td>&lt;0.0075</td>
<td>&gt;400</td>
</tr>
</tbody>
</table>

G. References & Relevant Quotations

Fifth International Conference for Safety in Road an Rail Tunnels, 6 - 9 Oct. 2003, Marseille, France; SMOKE DETECTION OF LOW TEMPERATURE FIRES IN ROAD TUNNELS USING VISIBILITY SENSORS; Matthias Wehner, HBI HAERTER Ltd., Tunnel Ventilation, Heidenheim, D Ingrid Simon, Regional Council of Karlsruhe

“For sensors measuring the CO-concentrations and the opacity of the air in road tunnels are considered to be standard equipment. Therefore, deterioration of visibility and/or high CO-concentrations should be used for smoke detection.”

International Conference “Tunnel Safety and Ventilation” 2004, Graz; NEW EMISSION DATA FOR VENTILATION DESIGN FOR ROAD TUNNELS; Sturm P.J., Prettherhofer G., Rodler J., Almbauer R.A., Graz University of Technology, Austria

“For many tunnels visibility is now the dominating parameter. As turbidity is caused by exhaust particles as well as by non-exhaust ones, the new calculation scheme has to take this into account.”

EUROTEST 2002 TUNNEL TESTS; Safety of Road Tunnels in Europe; Results of the 2002 Pan-European Tunnel Testing Programme

“Equip all tunnels longer than 1000 m with automatic fire warning systems; improve fire detection, using combined systems (heat detectors & visibility measurements installed at particular points)”

RABT: Guidelines for Equipping and Operating Road Tunnels; Germany

PIRAC (Permanent International Association of Road Congresses) / AIPCR: Road Tunnels: Emission, Ventilation, Environment; Montreal 1995