Research on the Comprehensive Climate Environment Test Methods for Railway Vehicles in Climate Wind Tunnel

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ABSTRACT

A climatic wind tunnel provides the opportunity to investigate the impact of weather on rail vehicles and components under realistic operating conditions. Any weather conditions can be produced at the push of a button – from intense solar radiation through to snow, rain and ice. The combination with wind, load and drive cycle simulations allows the implementation of realistic test scenarios. Thermal comfort, functionality, energy efficiency and aerodynamics are the key focus of rail vehicle testing. In order to ensure comparable results reproducible conditions and defined requirements are essential. For the investigation of thermal comfort different standards like EN 13129, EN 14750, EN 14813 and UIC 553 are existing. Several functional tests for various components are described in the new Technical Report CEN/TR 16251. The focus of this paper is to present the requirements and testing methods.

INTRODUCTION

Any successful operator of passenger transport services must make sure that they come as close as possible to satisfying passengers’ expectations as regards the cost and quality of the travel experience (timetable, punctuality, safety, security, comfort and so on). To achieve this, they need to have railway vehicles that are safe, dependable and ecological. They ought also to satisfy passengers’ comfort and convenience expectations, whatever the weather conditions. When it comes to the development and production of new or converted vehicles, it is thus indispensable to test and optimise them from the point of view of how their technical systems react to the weather conditions.

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Such tests can be performed either outdoors on normal railway lines or by making use of the extensive options offered by the “artificial” weather conditions in a climatic wind tunnel. The big advantage of such a facility is the availability at any time of precisely reproducible climate conditions under realistic operating conditions, making it possible to produce meaningful climatic appraisals of whole vehicles. In this way, measures intended to produce improvements can be checked immediately, which helps save both time and money.

As things stand at present, the role of climate tests is almost solely for providing proof of the conformity of components (i.e., their correct functioning), for documenting passenger comfort and for analysing problems after malfunctions have occurred during operations. On the other hand, the use of climate tests as a preventive measure of quality assurance is very much the exception, although they would be a suitable instrument for making significant contributions to markedly reducing the technical risk and the incidence of operational problems.

Since new developments repeatedly have to satisfy new demands and since new problems need to have solutions found for them, adaptations to the test procedures or even completely new developments are also essential. The climatic wind tunnel in Vienna is developing these further, as the needs of its clients are changing, and it is also working on research projects in new fields, such as the analysis of the energy requirements of heating, ventilation and air-conditioning (HVAC) installations. This report concentrates on describing those climate tests that are currently the most important ones as far as railway vehicles are concerned.[1]

1. THERMAL COMFORT IN RAIL VEHICLES

Improving the comfort conditions of rail vehicles is an important measure for increasing the attractiveness of public transport systems.

Over the past decades, many experiments and measurements were carried out in the Vienna Climatic Wind Tunnel and its predecessor in the Vienna Arsenal to determine thermal comfort in rolling stock.

Based on the results of this work, comfort criteria for rail vehicles were defined in the UIC 553[2] guideline on “Ventilation, heating and air conditioning of passenger carriages” over thirty years ago. The related UIC 553-1[3] guideline describes the tests that are necessary to prove compliance with these criteria.

Later on the following European standards were developed for thermal comfort, taking into account the different operating requirements of rail vehicles (type of use, climatic zone, etc.):

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1 (Haller, Rail-vehicle tests in the climatic wind tunnel in Vienna, 2010)
2 (UIC International Union of Railways, 2003)
3 (UIC International Union of Railways, 2005)
• EN 13129-1:2002 Railway applications - Air conditioning for main line rolling stock - Part 1: Comfort parameters[
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• EN 13129-2:2004 Railway applications - Air conditioning for main line rolling stock - Part 2: Type tests[
]
• EN 14750-1:2006 Railway applications - Air conditioning for urban and suburban rolling stock - Part 1: Comfort parameters[
]
• EN 14750-2:2006: Railway applications - Air conditioning for urban and suburban rolling stock - Part 2: Type tests[
]
• EN 14813-1:2006: Railway Applications - Air conditioning for driving cabs - Part 1: Comfort parameters[
]
• EN 14813-2:2006 Railway Applications - Air conditioning for driving cabs - Part 2: Type tests[
]

As the list shows, Part 1 of the standards specifies the comfort parameters and, by extension, the capacity of the air conditioning systems under defined conditions, while Part 2 describes the testing programme and the measurement procedures for evaluating the air conditioning systems.

In the meanwhile EN 13129-1 and EN 13129-2 have been revised and merged to EN 13129:2016[]. Although all the European standards are focusing on the European requirements and conditions they can be used also worldwide of course.

ISO/TC 269 WG 2 is now working on a set of ISO standards concerning Heating, Ventilation and Air Conditioning for Rolling Stock. The first part of the ISO 19659 is already finished by the working group and will be published soon. The complete title of this standard is ISO 19659-1 Railway Applications – Heating, Ventilation and Air Conditioning for Rolling Stock – Part 1: Terms and definitions.

1.1. Aerodynamic effects on the HVAC system

The airflow around a driving vehicle can have important influence on the ventilation system inside. Hence, it is very important to check these effects in a

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4 (CEN European Committee of Standardisation, Railway applications - Air conditioning for main line rolling stock - Part 1: Comfort parameters, 2002)
5 (CEN European Committee of Standardisation, Railway applications - Air conditioning for main line rolling stock - Part 2: Type tests, 2004)
6 (CEN European Committee of Standardisation, Railway applications - Air conditioning for urban and suburban rolling stock - Part 1: Comfort parameters, 2006)
7 (CEN European Committee of Standardisation, Railway applications - Air conditioning for urban and suburban rolling stock - Part 2: Type tests, 2006)
8 (CEN European Committee of Standardisation, Railway applications - Air conditioning for driving cabs - Part 1: Comfort parameters, 2006)
9 (CEN European Committee of Standardisation, Railway applications - Air conditioning for driving cabs - Part 2: Type tests, 2006)
10 (CEN European Committee of Standardisation, Railway applications - Air conditioning for main line rolling stock - Comfort parameters and type tests, 2016)
climatic wind tunnel. High driving speeds have a direct impact on the heat transfer of the body but also on air change through increased leakages which leads in an increasing heating or cooling power.

The pressure distribution along the driving vehicle has an influence on the flow rate of different air in- and outlets. Especially static outlets would not work properly if they are in a range of over pressure.

In some situations, a fresh air intake catches hot air of an outlet for example at a condenser of a cooling plant on the roof like a ventilation shortcut. Also some effects of a heat footprint may decrease the efficiency the cooling plant on long vehicles with units one behind others.

2. FUNCTIONAL TESTING FOR DIFFERENT CLIMATES OF VARIOUS SUBSYSTEMS

Standardised tests under critical weather conditions can make a valuable contribution to reducing the risk of malfunctions as well as improving vehicle reliability.

2.1. Standards for Functional Testing

The new Technical Report CEN/TR 16251:2016 02 “Railway applications – Environmental conditions – Design guidance for rolling stock” contains design recommendations and test procedures for rail vehicles and components under defined operating and environmental conditions. The Vienna Climatic Wind Tunnel provides a unique opportunity for carrying out these tests under standardised and reproducible conditions. A powerful wind turbine, spray and sprinkler installations and snow nozzles are available to investigate the impact of extreme temperatures, rain, snow and ice on rail vehicles, components and systems.\(^\text{[11]}\)

2.2. Functional Testing for Different Climates

The standard EN 50125-1 “Environmental conditions for equipment - Part 1: Equipment on board rolling stock” defines specific environmental parameters such as temperature, relative humidity, wind speed, solar radiation, rain etc. for different climate zones. However, it lacks provisions for typical scenarios, which usually result from the interaction of several individual parameters during in-service operation.

Both operating and climatic conditions must therefore be simulated simultaneously in order to identify potential problems in advance. Experience has also shown that testing components within the vehicle is essential, since even the

\(^{11}\) (Haller, Functional Tests for Increasing the Reliability of Rail Vehicles, 2006)
best inspection cannot exclude the potential mutual interference between components and systems which may occur in regular service.

RTA has longstanding expertise in customer-specific functional tests under different climatic conditions and has systematically collected relevant data about the susceptibility of individual components and systems from railway operators and the rail vehicle industry. This information has provided the basis for developing customised test procedures for critical scenarios and operating modes, which are now being applied as “standard test procedures” in the Vienna Climatic Wind Tunnel. The majority of these “standard test procedures” have been included in the new CEN/TR 16251.

Ongoing innovation and progress in the sector require these test procedures to be continuously adapted to new functionalities or operating conditions and new test procedures to be developed.

The following table lists the tested systems/components along with the relevant climatic test conditions as defined in CEN/TR 16251. The list also contains additional, more recent climatic test conditions and systems/components which have not (yet) been included in the CEN/TR 16251.
## TABLE I. OVERVIEW OF FUNCTIONAL TESTS OF DIFFERENT COMPONENTS UNDER SPECIFIED CLIMATIC CONDITIONS.\(^\text{[12]}\)

<table>
<thead>
<tr>
<th>System/Component</th>
<th>Clause acc. CEN/TR 16251</th>
<th>Ice</th>
<th>Dry snow</th>
<th>Wet snow</th>
<th>Rain</th>
<th>Humidity</th>
<th>High temperature</th>
<th>Low temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle</td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td><strong>Subsystems</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Snow plough</td>
<td>6.1</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bogie and running gear</td>
<td>6.2</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brakes</td>
<td>6.3</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compressed air</td>
<td>6.4</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sanding equipment</td>
<td>6.5</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level control system</td>
<td>6.6</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tilting system</td>
<td>6.7</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flange lubrication system</td>
<td>6.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>View ahead</td>
<td>6.9</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side mirror/cameras</td>
<td>6.10</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lights</td>
<td>6.11</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horns</td>
<td>6.12</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Doors</td>
<td>6.13</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moving door steps</td>
<td>6.14</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pantograph</td>
<td>6.15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Automatic couplers</td>
<td>6.16</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling systems</td>
<td>6.17</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traction</td>
<td>6.18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Battery</td>
<td>6.19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toilet and water systems</td>
<td>6.20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>External cabinets, boxes for equipment, cables and connectors</td>
<td>6.21</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Driver door and steps</strong></td>
<td></td>
<td>-</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Front cover for coupler</td>
<td></td>
<td>-</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Destination display</td>
<td></td>
<td>-</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Magnet track brake</td>
<td></td>
<td>-</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**Legend**

- **x** test procedure according to CEN/TR 16251
- **x** additional tests

\(^{12}\) (Knöbl, Mayer, & Haller, 2016)
As can be seen from the above table, different climatic conditions are relevant for different components/systems\(^{[13]}\):

- Extreme temperatures and humidity levels have a negative impact on mechanical, electrical, electronic and pneumatic components.
- The ingress of rain and wind, notably via the connecting corridors, doors and windows, gives an indication of leakage; proper functioning of the windscreen wipers is also essential.
- Wet snow has an impact on all mechanical components exposed to outside conditions, such as doors, steps, couplings and roof equipment.
- Ingress of dry snow into air intakes and gaskets often leads to problems.
- Ice formation on mechanical components, such as the pantograph, doors, steps and couplers may cause malfunctioning or blocking of the subsystem.

2.3. Vehicle

The thermal insulation and (vapour) tightness of the vehicle body is essential for both passenger comfort and proper functioning of components and systems. Insufficient insulation and/or leaks in the vehicle body often have a negative impact on interior temperatures and may cause condensate to form in the passenger areas or driving cab. This may cause the floor surface temperatures in the vestibules to fall below freezing point at low outside temperatures, leading to ice formation. It is therefore important to check the proper functioning of the whole vehicle in different scenarios.

A typical test which is also included in CEN/TR 16251 involves checking the functionality of the entire vehicle following sudden changes in climatic conditions, as for example experienced by a train travelling through warm humid tunnels in winter. For this test, the vehicle is soaked at temperatures < −10°C for a minimum of 5 h with all systems in operation. The vehicle is then shunted to an environment with temperatures > +20 °C and a dew point > +15°C. After > 10 min of operation, the condensation effects on the windows and signal lights (visibility) are checked. Following the functional test, the vehicle is again returned to the winter environment (temperatures < −10 °C). After a minimum of 1 h, the proper functioning of all relevant components is checked. If required, the test can be repeated several times to demonstrate freeze/thaw capability.\(^{[14]}\)

\(^{13}\) (Knöbl, Mayer, & Haller, 2016)

\(^{14}\) (Knöbl, Mayer, & Haller, 2016)
2.4. Subsystems

2.4.1. BOGIE COMPONENTS

Bogie components such as the axle and gear box, suspension components, sanding, level control, tilting and flange lubrication systems are safety relevant components that should never fail under any circumstances. These components are very exposed to outside conditions and are thus extremely prone to the accumulation of snow and ice. The consequences of ice or snow build-up may range from partial malfunction to complete failure, as in the case of ice formation on the sanding system, which is decisive for proper friction between wheel and rail. All winter conditions with a negative impact on underframe components can be realistically simulated on the dynamometer in a climatic wind tunnel. The tests help both in developing measures to reduce the problems, such as fitting a heater or housing to the sanding system, and for validating their effectiveness. [15]

2.4.2. VIEW AHEAD

Driver visibility is of key importance for safe train operation. Inadequately functioning windscreen heaters or air inlets in the driving cab may cause the windscreen and/or side windows to mist up. Visibility may also be impaired by snow and ice build-up on the windscreen, which may restrict or even prevent operation of the wiper blade. One possible reason for these problems may be poor adjustment between the windscreen washer, wiper and heating systems and the air conditioning unit of the driving cab. Climatic tests make it possible to adjust the settings of these components under different climatic conditions and thus help eliminate visibility problems under extreme service conditions.[16]

Also it is very important to check the functionality of the wiper system at high driving speeds under rain conditions. In the climatic wind tunnel are tests up to speeds of 250 km/h with heavy rain conditions possible to check the wiping quality (no particular lift of the blades).

2.5. Improvement of Reliability

The functional tests described above are only some examples of the comprehensive set of standardised test procedures available for different components and systems. Each procedure includes a detailed description of the test conditions and assessment methods used to verify whether the specified

[15] (Knöbl, Mayer, & Haller, 2016)
[16] (Knöbl, Mayer, & Haller, 2016)
compliance criteria have been met. The tests and functional requirements laid down in these procedures have been adapted to real-world conditions based on many years of experience in climatic wind tunnel testing and feedback from regular service operation. They ensure a high degree of comparability, providing a sound basis for further standardisation of functional tests on rail vehicles at a European level.

Functional tests in a climatic wind tunnel make a substantial contribution to reducing the risk of failure in service and increasing the reliability of rail vehicles in all weather conditions. The biggest advantage of climatic wind tunnel tests is that the climatic conditions can be reproduced with great accuracy. This helps to immediately verify the effects of improvements and modifications, thus saving time and money.[17]

3. CONCLUSIONS

The possible investigations that can be carried out in a climatic wind tunnel, as presented in this report, make an essential contribution to reducing risks and enhancing the reliability of railway vehicles, no matter what the weather conditions. As the practical experience of tests has repeatedly shown, there is a need for such examinations to look at each railway vehicle in its entirety, given that even the best possible checks of each of a its subassemblies cannot guarantee that it will function properly as a whole.

The big advantage of performing examinations in a climatic wind tunnel is the precise reproducibility of the climate conditions and thus the possibility of being able to check consequential improvements immediately, which saves time and money.

REFERENCES


17 (Haller, Functional Tests for Increasing the Reliability of Rail Vehicles, 2006)
11. Haller, G. (1 2010). Rail-vehicle tests in the climatic wind tunnel in Vienna. RTR.