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Performance testing of a locomotive engine aftertreatment pre--prototype in a passenger cars chassis dynamometer laboratory

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Abstract

The aim of this work is the definition of a pilot test procedure to carry on the system testing and validation tests with a locomotive engine aftertreatment pre-prototype called ENSPIRIT system, developed in the framework of the FP7 European Project *Eliminating NO_x, SO_x & Particulate in Rail Transportation*. Here it is described the study, processing and definition of the test procedure. A study has been conducted investigating the legislation (both European and US EPA) dealing with emission standards and tests for locomotives, gathering the fundamental information to create a driving cycle, suitable for tests with passenger cars, taking into account the main features of the locomotive test cycle. The first version of the ENSPIRIT Driving Cycle (EDC) has been tested in laboratory with two 2.0 l diesel experimental vehicles in order to refine it to better reproduce the locomotive test procedure, in particular with respect to notches duration, speed and rpm increase. The refined and definitive version of the EDC has been tested as well and the obtained results are here reported. The developed EDC was then inserted in a pilot testing protocol whose aim is to determine, through the EDC laboratory execution, the ENSPIRIT pre-prototype effectiveness in reducing the emission of NO_x > 75% and the emission of PM2.5 > 98%. This can be done comparing the emissions of the two experimental vehicles, deprived of all the emission abatement systems (DPF, EGR, Oxy cat), with and without the use of the ENSPIRIT pre-prototype.

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Keywords: locomotive engines; aftertreatment; Tier 4; passenger cars; chassis dynamometer testing

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1. Introduction

Locomotive engines are significant contributors to air pollution in many cities and ports. The 2008 Clean Air Non-road Diesel Rule establishes long-term, Tier 4, standards for newly-built engines based on the application of high-efficiency catalytic aftertreatment technology, beginning in 2015.

Concerning legislation, the most relevant dealing with locomotive emission standards and tests is the US EPA-420-R-98-101 (1998) where the test cycle used to determine the locomotive emissions is described. Since the European legislation on diesel locomotive emissions, Directive 2004/26/EC of the European Parliament (2004), has been harmonized with the U.S. one, an analysis of the US legislation has been conducted for the implementation of the testing protocol for the ENSPIRIT pre-prototype and the Electronic Code of Federal Regulations Part 1033 Control of emissions from locomotives was chosen as a reference. It reports the exhaust emission limits from new locomotives referring to the year of original manufacture, the Tier of standards and the emissions of NO_x, PM, HC, CO reported in g/Kwh (g/bhp-hr) (Table 1). Also CO_2, N_2O, CH_4, smoke emissions are regulated.

Table 1. Emission standards for line-haul locomotives – Electronic Code of Federal Regulations Part 1033 Control of emissions from locomotives. Subpart B §1033.101.

Year of original manufacture	Tier of standards	Standards (*g/bhp-hr*)			
		NO_x	PM	HC	CO
1973–1992	Tier 0	8.0	0.22	1.00	5.0
1993–2004	Tier 1	7.4	0.22	0.55	2.2
2005–2011	Tier 2	5.5	0.10	0.30	1.5
2012–2014	Tier 3	5.5	0.10	0.30	1.5
2015 or later	Tier 4	1.3	0.03	0.14	1.5

The Code also reports the discrete-mode steady state emission tests of locomotives and locomotive engines: the test cycle is composed of 3 idle settings followed by 8 progressive notches corresponding to 8 locomotive speed and engine loads. The total duration of the test cycle is 1 hour.

Table 2. Locomotive Test Cycle – Electronic Code of Federal Regulations Part 1033 Control of emissions from locomotives. Subpart F §1033.515.

Test mode	Notch setting	Time in mode (minutes)	Sample averaging period for emissions
Pre-test idle	Lowest idle setting	10 to 15	Not applicable
A	Low idle	5 to 10	300 ± 5 seconds
B	Normal idle	5 to 10	300 ± 5 seconds
C	Dynamic brake	5 to 10	300 ± 5 seconds
1	Notch 1	5 to 10	300 ± 5 seconds
2	Notch 2	5 to 10	300 ± 5 seconds
3	Notch 3	5 to 10	300 ± 5 seconds
4	Notch 4	5 to 10	300 ± 5 seconds
5	Notch 5	5 to 10	300 ± 5 seconds
6	Notch 6	5 to 10	300 ± 5 seconds
7	Notch 7	5 to 10	300 ± 5 seconds
8	Notch 8	10 to 15	600 ± 5 seconds

Regarding literature, McDonald et al. (2011) reported how testing real emissions directly from locomotive engines is a daunting task due to the facilities requirements for testing, the exhaust mass flow rates involved and the