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Approval tests for diesel engines of motive power units

*Essai d'homologation des moteurs diesel d'engins moteurs
Zulassungsprüfung für Dieselmotoren der Triebfahrzeuge*



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The person responsible for this leaflet is indicated in the UIC Code

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Summary

This leaflet defines the procedure and conditions applicable to the approval testing of diesel engines for motive power units.

On completion of the test procedure, the engine shall be approved by UIC for unrestricted use in railway motive power units within the area of application. It shall be guaranteed, in particular, that the engine meets current exhaust requirements.

1 - Field of application

1.1 - The purpose of these international regulations is to define type approval tests for new types of diesel engines intended for installation in railway motive power units.

1.2 - These regulations apply to diesel traction engines for use in railway motive power units, with the exception of engines intended for special locomotives (e.g. refinery or mine locomotives) as well as traction engines with an effective output of less than 130 kW.

1.3 - These regulations may be applied by the railways for their own use if they wish to obtain a comprehensive guarantee of service reliability for any particular type of diesel traction engine.

2 - Definitions

2.1 - Engine

In the following document, the term "engine" shall describe a diesel engine fitted with its after treatment system.

The term "diesel engine" shall describe the engine alone.

2.2 - Choice of units

All units used in these international regulations must comply with the SI International System in accordance with *UIC Leaflet 800-00* (see [Bibliography](#)).

2.3 - Auxiliaries

The definitions of the dependent/independent, essential/non-essential auxiliaries comply with those in *ISO Standard 3046-1* (see [Bibliography - page 52](#)).

However, the input power of engine cooling fans is an exception to *ISO Standard 3046-1* since the power absorbed by these fans depends on their arrangement in the vehicle, therefore they will be considered in railway applications to be essential independent auxiliaries, whether they are powered directly by the diesel engine or indirectly.

2.4 - Kinds of power output

The nominal power and speed indicated on the engine have to correspond to the maximum power and speed in service.

Effective power output: power available at the drive shaft minus the power required for the essential dependent auxiliaries, if they are driven directly or indirectly by the engine.

UIC nominal power output (referred to as "nominal output" in the text): according to *ISO Standard 3046-1*, UIC nominal power output is equal to:

- the **ISO standard power output** if the essential dependent auxiliaries are driven directly or indirectly by the engine;
- the **ISO continuous brake power** minus the power absorbed by the essential dependent auxiliaries if they are driven by an outside power source. In this case, the power used by each of these auxiliaries and measured in performance test conditions should be noted separately.

The cooling fans of water cooled engines are considered, according to [point 2.3](#), essential independent auxiliaries.

2.5 - Speed

The engine speed associated with the UIC nominal power output is the nominal speed.

3 - Documents to be provided by the manufacturer

3.1 - General

The characteristics to be tested during the approval procedure of the engine submitted shall be specified in:

- a dimensional installation drawing,
- a technical data table,
- a change control log as described in [Appendix G - page 51](#).
- characteristic curves.

The numbering of the cylinders and the direction of rotation of the diesel engine shall comply with *international standard ISO 1204* (see [Bibliography - page 52](#)).

The engine shall be provided with a metal plate indicating the name and identification letters of the manufacturer, the engine type, the production number, and year of manufacture.

3.2 - Dimensional installation drawings

The engine manufacturer shall provide two drawings.

3.2.1 - A dimensional installation drawing shall indicate the contour of the diesel engine without after treatment system, including the direct drive auxiliary machines. It shall also include the centre of gravity of the dry diesel engine together with the length, width and height dimensions measured:

- overall and,
- with reference to the centre line of the crankshaft.

3.2.2 - An additional dimensional drawing of the after treatment system, also including the centre of gravity of the after treatment system and the location of exhaust gas inlets and outlets.

3.3 - Table of technical engine data

The table of technical engine data shall contain the following information, quoting tolerances where applicable:

1. Engine type.
2. Manufacturer.
3. UIC nominal output.
4. Nominal engine speed.
5. Normal idling speed.

6. Mode of operation: 2 or 4 strokes.
7. Characteristics of supercharging:
 - Method of supercharging.
 - Designation of type of turbo-compressor(s): with or without intercooling turbo-charger(s).
 - Method of cooling the supercharging air (water with or without pressure, air).
8. Injection characteristics:
 - Injection method (direct, pre-chamber or similar).
 - Type of injection pump.
 - Type and nature of injector.
 - Orifice pressure of injector.
 - Maximum admissible fuel temperature at input.
 - Resulting maximum fuel temperature at return.
9. Number, arrangement and angle of cylinders.
10. Cylinder bore.
11. Piston stroke.
12. Total piston displacement.
13. Compression ratio.
14. Firing order.
15. Timing diagram (to be appended to engine file).
16. Mean piston velocity at nominal speed.
17. Mean effective pressure at nominal output.
18. Maximum combustion pressure at nominal output.
19. Start of injection pump delivery at nominal output:
 - static (angle before upper dead centre),
 - dynamic (angle before upper dead centre).
20. Minimum idling speed.
21. Maximum idling speed.
22. Maximum permitted speed.
23. Speed ranges not permitted to be continuously operated in service.
24. Cylinder cooling method:
 - water, with or without pressure,
 - air.

25. Piston cooling method.
26. Temperature of the high temperature cooling water at engine outlet:
 - normal,
 - maximum permitted.
27. Temperature of the low temperature cooling water at the cooling air intake (if circuit exists):
 - normal,
 - maximum permitted.
28. Characteristic curves of the water pump(s) showing flow against overall pressure drop in the form of curves at constant speed and in particular for the nominal and minimum speed used.
29. Relationship between diesel engine speed and speed of the water pump.
30. Prescribed oil:
 - Classification of viscosity (for example: SAE, ISO,...).
 - Performance level (for example: ACEA, API, etc.).
31. Lowest possible starting temperature with oil defined above (without additional aid).
32. Starting (peak) torque at this temperature.
33. Minimum ignition speed at this temperature.
34. Torque overcome at ignition speed at this temperature.
35. Temperature of lubricating oil at the engine outlet:
 - normal,
 - maximum permitted.
36. Lubrication oil consumption:
 - at nominal output (kg/h),
 - at idling speed (kg/h),
 - oil change interval in normal service.

The measurements shall be carried out after the engine has run for 80 - 100 h.
37. Total delivery of the lubricating oil pump(s) at nominal speed.
38. Maximum oil volume effectively circulating in the engine.
39. Lubricating oil pressure at nominal speed at the engine intake after the regulator valve at normal working temperature.
40. Lubricating oil pressure at minimum operating speed at the engine intake after the regulator valve at normal working temperature.
41. Maximum permitted air intake pressure reduction.

- 42. Maximum permitted exhaust gas back-pressure, at the outlet of the turbochargers.
 - 42.1 With clean after treatment system.
 - 42.2 With fully-loaded after treatment system.
- 43. Intake air volume (kg/s) at nominal output in the atmospheric reference conditions (according to point 4.2 - page 11).
- 44. Supercharging relative pressure at nominal output.
- 45. Supercharging rpm at nominal output:
 - normal,
 - maximum permitted.
- 46.1 Supercharged air temperature before and after charging air cooler (wherever present) at nominal output:
 - normal,
 - maximum permitted.
- 46.2 Air temperature at the cylinder head intake at nominal output:
 - normal (= T_{SCRef} in accordance with ISO 8178-1, see Bibliography - page 52)
 - maximum permitted.
- 47. Exhaust gas temperature at nominal output, measured:
 - at the cylinder head outlets:
 - normal,
 - maximum permitted;
 - at the inlet to the turbine(s):
 - normal,
 - maximum permitted;
 - at the outlet of the turbine(s):
 - normal,
 - maximum permitted;
 - at the inlet of the after treatment system:
 - normal,
 - maximum permitted;
 - at the outlet of the after treatment system:
 - normal,
 - maximum permitted.

48. Thermal balance of the engine at nominal output (see Appendix D - page 68):
 - Heat from fuel.
 - Heat dissipated in:
 - high-temperature cooling water,
 - low-temperature cooling water,
 - cooling air,
 - fuel for cooling system,
 - lubricating oil,
 - exhaust gas,
 - radiated heat from diesel engine,
 - radiated heat from after treatment system.
49. Mass:
 - of diesel engine (with auxiliary equipment installed as per installation drawing), not including water and lubricating oil,
 - of after treatment system, without piping,
 - of water contained in the engine,
 - of oil contained in the engine.
50. Characteristics of external after treatment system:
 - Type of system (DPF, SCR, DOC, etc.),
 - Number of elements, total volume,
 - Minimum/maximum distance to engine,
 - Type of regeneration,
 - Maximal consumption of the after treatment system:
 - Electrical power,
 - Fuel,
 - Air,
 - Reagent product,
 - Energy consumption of burner at rated power.

3.4 - Characteristic curves of the diesel engine

The following characteristic curves are established under the prescribed conditions for the rig test as a function of the engine speed from the nominal speed to the minimum working speed. Specific fuel consumption shall be derived linearly in relation to the fuel with a minimum calorific reference value of 42 700 kJ/kg.

3.4.1 - Curves of torque, power and specific fuel consumption in g/kWh, as a function of engine speed indicating the tolerances for various injection pump settings, viz.:

- setting at which the engine develops the nominal output when running at nominal speed;
- setting at which the engine develops 3/4 of the nominal output when running at nominal speed;
- setting at which the engine develops 1/2 of the nominal output when running at nominal speed;
- setting at which the engine develops 1/4 of the nominal output when running at nominal speed.

3.4.2 - Constant specific fuel consumption curves of the engine.

3.4.3 - Torque curve which, based on the point corresponding to the nominal output at nominal speed, specifies the maximum torque for all rpm.

3.4.4 - Fuel consumption curve without a load (expressed in kg/h) from the minimum idling speed to the maximum speed and expressed in kg/h.

3.5 - Configuration control

3.5.1 - Identification

In order to ensure the customer that the purchased engine is compliant with the certified specifications the manufacturer has to present a list of components with their relevant part numbers as per [Appendix G - page 51](#).

3.5.2 - Post-certification modifications

If in the context of technical development of the engine modifications become necessary for the components mentioned in [Appendix G](#) a brief description of the modification, as well as an indication of the reason why it has been made, has to be submitted to UIC.

3.5.3 - Post-certification process

UIC, as the body in charge of engine approvals will examine the application and has the right to request further proof of the engine's endurance.

Based on the evidence submitted for the modifications, UIC will examine whether the leaflet's provisions are observed:

- accepted modifications will be included in the approval report,
- unaccepted modifications will invalidate the certificate.

3.6 - The engine environment

3.6.1 - Exhaust gas emission

(see Appendix A - page 23).

CO, NO_x, CH and PM emissions are measured as per *ISO 8178*. The measuring cycle is indicated in *UIC Leaflet 624, Appendix A* (see Bibliography - page 52).

The following characteristic diagrams are to be drawn up for these emissions:

- absolute emission in kg/h as a function of power and speed;
- specific emission in g/kWh as a function of effective mean pressure and speed.

The characteristic diagrams of the NO_x emissions are contained in point A.3 - page 25 as an example.

Gaseous pollutants and particle emissions are assessed according to *ISO 8178-4*.

Determining the PM emission diagram of an engine equipped with after treatment devices is not compulsory; however the iso-pollutant PM diagram must be provided. It may be derived from existing smoke measurements performed by the manufacturer. If results from such existing measurements are not available, the manufacturer shall at least provide individual measurement values from each cycle point.

3.6.2 - Noise emission

The manufacturer must provide:

- the level of acoustic output per octave band and/or weighted (dBA);
- a reference to the standard specifying the measuring method.

4 - Approval test

4.1 - General

The general conditions for type approval test are set out in *UIC Leaflet 623-1* (see [Bibliography - page 52](#)).

The test rig, on which the type approval test is carried out, must at least be equipped with the measuring instruments listed in the diagram of [point B.1 - page 26](#). Point [B.2 - page 27](#) contains an example of information to be provided in the report.

The measurement instruments should be regularly calibrated by a certification body which is recognized by the managing RU. It is recommended that the *ISO 9000 standards* be used. Their measuring accuracy must correspond to *ISO Standard 3046-3* (see [Bibliography](#)).

If the engine requires running-in, this must be carried out before presenting the engine for the test.

The engine shall be coupled to a brake, which will make it possible to carry out the programmes of the different test cycles and it is desirable that provision be made for a suitable automatic regulating system to perform these programmes insofar as torque and speed variations are concerned.

The accuracy of the torque measurements (if a brake type with direct reading of the torque is used) or power measurements (if a wattmeter with calibrated generator is used) shall be $\pm 2 \%$ of the full torque value.

4.2 - Rig test conditions

4.2.1 - Atmospheric conditions

The atmospheric conditions, barometric pressure, ambient temperature and relative air humidity shall be measured at a distance from the air intake of the engine where the flow is laminar and the temperature homogeneous.

The following atmospheric reference conditions shall apply:

- overall atmospheric pressure: 100 kPa,
- ambient temperature: 25 °C,
- relative air humidity: 30 %.

The test shall be performed with a power corresponding to the corrected nominal output in accordance with *ISO 3046-1*.

4.2.2 - Fuel

Determination of the pollutant diagrams as well as the control of the exhaust emissions against *ISO 8178-4* shall be performed with a reference fuel: *ISO 8178-5* (see Bibliography - page 52).

The performance and the endurance test may be performed with commercial fuel. It has to be selected by the manufacturer from a list of commercial fuels prepared by the managing railway.

The fuel temperature on entry into the engine must be 20 °C or above.

4.2.3 - Lubricating oil

No oil change is permitted during the endurance test. At most, an oil change is allowed between the performance test and the endurance test.

The lubricating oil shall be used in a closed circuit as in normal operation. No additional pump is permitted.

The approval test shall be performed with a lubricating oil to be selected by the manufacturer from a list of commercial grade oils prepared by the managing railway. This is to ensure that the test will be performed using an oil currently used by one of the railways. A request for a deviation from this requirement should be duly justified and discussed during the preparatory meeting. The choice of oil shall be recorded in the minutes of the preparatory meeting.

The lubricating oil temperature shall be maintained at the normal value contained in the table of technical engine data.

The pressures shall be measured:

- behind the regulator valve of the lubricating oil pump,
- at the farthest accessible point from the pump.

4.2.4 - Cooling circuit

The normal operating temperature is equivalent to the temperature of the high temperature cooling water at the normal outlet. It should be equal to the normal value given in the table of technical engine data with a tolerance of ± 3 °C. If a temperature range is specified for the normal value, the highest value should be taken.

4.2.5 - Air intake

The pressure loss at the inlet should be greater than or equal to 80 % of that specified in the table of technical engine data.

The air temperature at the cylinder head inlet should be equal to the maximum permitted value specified in the table of technical engine data with a tolerance between of 0 °C to - 5 °C.

4.2.6 - Supercharging

The air pressure for supercharging at the cylinder head outlet should be equal to the normal value specified in the table of technical engine data with a tolerance of ± 5 %.

4.2.7 - Exhaust circuit

The temperature of the exhaust gas at the cylinder head outlet should be equal to the normal value specified in the table of technical engine data.

The back-pressure at each turbine outlet should be greater than or equal to 80 % of the value specified in the table of technical engine data.

4.2.8 - Diesel engines with electronic engine control

The functions and the regulating characteristics of the electronic engine control system shall be identical within the nominal rating of the engine to those demonstrated by the standard control device used on the engine for which approval is requested. Type or list numbers can be used to document this for software and hardware.

In order to prevent software parameter modifications during the test run, the principal influencing variables shall be recorded and documented during the measurements (in accordance with [Appendix C - page 28](#)). For Common Rail Systems, this could be the start and duration of injector activation. The respective parameters to be considered shall be established in the preparatory meeting.

The manufacturer has to confirm that the main parameters of the software version used during the test are identical to the serial version in terms of:

- fuel consumption,
- emissions,
- durability, reliability.

4.2.9 - Notations

If an engine is not supercharged, the back-pressure at the exhaust immediately after leaving the engine shall be measured and recorded in the test report.

In order to avoid the need for the continuous presence of an inspector with the engine during the test, suitable calibrated and inviolable recording equipment shall be installed, thus making it possible to check whether the prescribed programme has been fully implemented and that the normal test conditions were maintained. All the measured results in column M of [Appendix C](#) should be accessible at all times (except oil consumption).

All information required to prepare the test report shall be kept in a detailed log.

The log shall indicate in particular:

- date and time,
- operating times,
- overall oil consumption,
- incidental stopping periods, interruptions for maintenance,

- maintenance operations and conditions observed,
- irregularities and damage as well as the resulting corrective measures and assessments.

4.2.10 - Retrieval of samples

The test engineer from the managing RU takes a one-litre sample of fuel from the reference fuel used for emission testing and one sample of commercial fuel at the beginning of the performance test. These samples are sealed and marked with the engine number, the date and the test engineer's name.

It is recommended that the manufacturer check the fuel quality regularly, especially when replenishing the tank.

Oil samples are taken according the requirements as per [Appendix C - page 28](#).

A sample of after treatment reagent has to be taken before the emission test.

The laboratory or laboratories entrusted with the analyses shall be designated at the preparatory meeting.

4.3 - Performance testing

The test should be performed on a warm engine.

4.3.1 - Test cycles

The performance test consists of a continuous run of 100 hours carried out in the following order:

- 80 hours at nominal output,
- 1 hour under overload,
- 10 hours with partial loads,
- 8 hours under alternating load,
- 1 hour at nominal output.

4.3.2 - Specific test cycles

4.3.2.1 - Overload test

The overload tests shall be carried out:

- for the first 45 minutes at nominal speed and with a torque corresponding to 110 % of the torque at the nominal output;
- for the last 15 minutes with a torque corresponding to the nominal output and a speed of 110 % of the nominal speed.