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Test method for energy consumption of refuse collection vehicles

Méthode d'essai pour mesurer la consommation énergétique de carburant des véhicules de collecte et de transport des déchets

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 297, *Waste collection and transportation management.*

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

As a result of the development of new drive unit concepts for refuse collection vehicles (RCV), as well as (from a European point of view) the provisions from the procurement guideline 2009/33/EC, there is now a demand for universal processes and provisions for determining the environmental effects of RCVs, with the objective of achieving a uniform evaluation for environmental efficiency.

The environmental effects in the utilization phase for RCVs are essentially determined by their energy consumption, from which the relevant CO_2 emissions will result.

In order to be able to define appropriate characteristic numbers for the environmental effect of RCVs, it is therefore necessary to differentiate between refuse collection and transport trips with and without loads. The complete logistics shall be considered for an effective comparison of the various vehicle models and their respective drive units.

The objective is to be able to issue an environmental efficiency ID for various vehicle models.

Policymakers, planners, administrators, manufacturers and users should be able to decide in the future whether consumption measuring should be executed as a simulation or by means of actual, existing test circuits.

Test method for energy consumption of refuse collection vehicles

1 Scope

This document specifies a uniform, reproducible testing process for various drive units, chassis, constructions and lifting devices for the refuse collection vehicles described in EN 1501 (all parts, excluding EN 1501-4), with which a comparison for energy consumption can be performed.

This specification defines criteria for a reference area with regard to a synthesized tour (test circuit). This therefore serves to determine a representative test circuit and/or data for a software calculation tool, e.g. VECTO[1)].

NOTE VECTO (Vehicle Energy Consumption calculation TOol) is a simulation tool that has been developed by the European Commission for determining CO_2 emissions and fuel consumption from heavy duty vehicles with a gross vehicle mass above 3 500 kg. URL: https://ec.europa.eu/clima/policies/transport/vehicles/vecto_en#tab-0-0

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1501-1, *Refuse collection vehicles — General requirements and safety requirements — Part 1: Rear loaded refuse collection vehicles*

EN 1501-2, *Refuse collection vehicles — General requirements and safety requirements — Part 2: Side loaded refuse collection vehicles*

EN 1501-3, *Refuse collection vehicles — General requirements and safety requirements — Part 3: Front loaded refuse collection vehicles*

EN 1501-5, *Refuse collection vehicles — General requirements and safety requirements — Part 5: Lifting devices for refuse collection vehicles*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
energy consumption
amount of mechanical, electrical, hydraulic and pneumatic energy which is needed for the defined cycles of the body

1) VECTO is an example of a suitable product available free of charge. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

3.2
load simulation valve
valve in the hydraulic circuit of the compaction unit (packing unit) of an RCV for generating a hydraulic load

3.3
pre-control valve
valve in the hydraulic circuit for controlling the *load simulation valves* (3.2)

3.4
ballasting
loading of the collection container for an RCV and the refuse collection container with mass

3.5
measuring turbine
measuring device for the consumption of fuel using differential measurement in the fuel system

3.6
measurement run
sum of all test cycles on the test track

3.6.1
reference run
run of the *test cycle* (3.11) only with the chassis and without any further energy-consuming components

3.6.2
compaction run
run of the *test cycle* (3.11) with the chassis and the bodywork with one loading cycle

3.6.3
lifting run
run of the *test cycle* (3.11) with the chassis and one cycle of the lifting device

3.6.4
discharge run
one discharge cycle of the body with the chassis in standstill

3.7
test bench run
sum of all test cycles on the test bench

3.8
vehicle mass
mass of the RCV in a ready-to-drive and ready-for-refuse-collection status with full fuel and urea tank, full hydraulic and cooling systems

Note 1 to entry: The mass is stated in kg.

3.9
discontinuous compaction system
components of the compacting equipment, which always traverse the same route curve in the operation in cycles and return to their defined starting position after one cycle

3.10
continuous compaction system
compacting devices which continuously and without reversing follow the direction of movement of individual components after commissioning and which have no defined starting position

3.11
test cycle
sum of the defined time proportions with different operating conditions

Note 1 to entry: See Table 4 for the time proportions of the *test cycle* (3.11).

3.12
steady state
temperature level of all operating fluids which does not vary during the *test bench run* (3.7) and/or the test run

3.13
working cycle
procedures which are to be performed during the vehicle standstill

3.14
maximum pressure
maximum hydraulic pressure during the *working cycle* (3.13) in the compacting system

3.15
container emptying cycle
succession of sequences to pick up from the ground, lift, hold and empty the container into the hopper of the RCV and put it back on the ground

3.16
compaction cycle
cycle by *discontinuous* (3.9) or *continuous* (3.10) *compaction system*

Note 1 to entry: The continuous compaction system is the given (fix) time in Table 4.

4 Minimum requirements

4.1 Refuse collection vehicle (test item)

— The operating conditions shall be in accordance with the operating instructions.

— The steady state shall be achieved.

— The load simulation components shall be installed in accordance with the respective specifications from the bodywork manufacturer.

— The vehicle configuration shall be documented in accordance with Annex A.

4.2 Load simulation

The load simulation shall be carried out hydraulically.

NOTE For an example of the installation of a hydraulic load simulation, see Annex B, Figure B.1.

4.3 Test conditions

— Temperature (°C/°F):

Range A: (10 ± 5) °C/(50 ± 9) °F;

Range B: (20 ± 5) °C/(68 ± 9) °F;

Range C: (30 ± 5) °C/(86 ± 9) °F;

Range D: (40 ± 5) °C/(104 ± 9) °F.

— Air pressure (1 013 ± 100) hPa.

— Wind speed (maximum 5 m/s).

— Dry road surface condition.

4.4 Test circuit

— The test circuit shall be a circular course.

— The road surface finish shall be asphalt or concrete.

— Gradient within the test circuit shall not exceed ± 2 %.

— Curves on the test circuit shall have a curve radius of at least 15 m.

— The stopping points shall be clearly marked, for example with traffic cones.

5 Implementation

5.1 On the test track

— The time required for a measurement run shall not exceed 60 min.

— The test should only be performed by trained personnel.

— At least three measurement runs of the same type shall be performed, taking Formula (1) into account in order to obtain valid measurement values:

$$\frac{M_{\min}}{M_{\max}} \geq 0{,}95 \tag{1}$$

where

$M_{\min}$ is the minimum measurement value;

$M_{\max}$ is the maximum measurement value.

— The number of test cycles within a measurement run shall correspond to Table 4.

— The energy consumption shall be indicated for each test run in kilowatt hours (kWh), in accordance with the conversion factors in Table 5.

— To measure any energy sources, a measurement procedure according to the valid state of science and technology shall be used, such as measuring the fuel consumption using measuring turbines or comparable technologies.

— To measure the energy consumption of plug-in battery systems, only the stored energy of batteries shall be considered; the energy needed for charging the batteries is not taken into account.

— The regeneration of diesel particulate filters during the test run shall be excluded.

— In addition to energy-consuming components, such as rotating beacons and air conditioning, working lights of the vehicle shall be switched off.

— Ballasting shall be carried out in accordance with Table 1.

5.2 Software calculation

5.2.1 General

With the described method, it should be possible to achieve the same results with the software calculation as those stated in 5.1. For this it is necessary to transfer the test cycles from the test circuit to the software. This is to be performed by means of various data files which shall match the form and content with the criteria set out in Table 1 to Table 4, respectively.

NOTE The data for the chassis and the common profile to drive into the collection area and return are part of VECTO, which is the official European software calculation tool.

5.2.2 Data for the driving cycle

Driving the vehicle on the test circuit from stopping point to stopping point will be illustrated by a speed curve which shall be provided both graphically and as a readable data file (by agreement with the test bench operators). The number of test cycles shall correspond to the values in Table 4.

5.2.3 Data for the working cycle

5.2.3.1 General

The power consumption of the body shall be represented by a torque curve and an operating speed associated with this torque curve on the auxiliary drive. The duration of the working cycle shall correspond to the vehicle standstill in accordance with Table 4.

5.2.3.2 Determination of the working cycle

It is the bodywork manufacturer's responsibility to describe the working cycle. For this purpose, the requirements according to Table 3 shall be observed.

The working cycle shall proceed as follows:

— The construction test bench is equipped with a device for providing the drive capacity, generally an electrical engine. It shall be equipped with a measuring instrument for the output torque (torque measuring shaft) and a speed controller. Record the measurement values from the torque measuring shaft in a table; the working speed shall be indicated as an individual value.

— Connect the hydraulic or electric pump for the construction configuration which shall be tested to the construction test bench with the assembled and adjusted load simulation components.

— Record the measurement values at timed intervals of 0,1 s (f = 10 Hz).

— Repeat the relevant cycles for conditioning the bodywork until the steady state has been set.

— Start the measurement and repeat it 20 times for structural safety.

— Execute the test cycles in accordance with Table 2 and record the measurement values. Maintain breaks between the separate test cycles with respect to the driving times according to Table 4.

— Stop the measurement.

— Determine an average using 20 corresponding values (corresponds to the table rows) and save it in a separate table.

— Save the resulting table as the torque progression. Take this torque progression as the basis for the working cycle.

In a further measurement procedure, the drag losses of the bodywork configuration shall be determined with the construction switched off. Proceed as follows:

— Put the bodywork configuration connected to the bodywork test bench into the state intended to be used during real operation while moving from waste bin to waste bin.

— Accelerate the electrical engine from 600 min^{-1} to 3 000 min^{-1} linear within 20 s and then decelerate to the initial value within another 20 s.

— Record the torque measurement values in a table as a function of the engine speed.

— During the measurements on the vehicle test bench, the torques from the torque progression table above are taken into account, as the torque on the auxiliary drive depending on the auxiliary drive speed during the phases that simulate the movement from stop to stop.

The gear change characteristic (i.e. transmission programme) shall be identical for the chassis reference run and in the collective mode.

The determined values i) torque progression over the course of time at a constant speed and ii) torque over speed shall also be used as a basis for calculations, for example in the VECTO, municipal cycle programme.

Table 1 — Arrangement of the ballasting mass for vehicle configuration in the test cycle

	Ballasting kg		
Chassis configuration	2-axis vehicle up to 5 t GVM[a]	2-axis vehicle up to 10 t GVM	2-axis vehicle up to 20 t GVM
Ballasting mass	500 ± 50	1 500 ± 100	3 000 ± 250
	Ballasting kg		
Chassis configuration	3-axis vehicle up to 30 t GVM	4-axis vehicle up to 40 t GVM	Any vehicle configuration beyond 4-axis and 40 t GVM
Ballasting mass	6 000 ± 250	9 000 ± 250	10 000 ± 250

[a] The gross vehicle mass (GVM) is the maximum allowable mass.

Table 2 — Load simulation during the vehicle standstill in the test cycle

RCV models	**Compaction mechanism pressure to be simulated**[a]	**Total lifting device ballast mass, including container**[b,c] kg
Rear-loaded RCV, EN 1501-1 Continuous compaction system (e.g. rotating drum or rotating plate)	35 ± 5 % of the maximum pressure	50
Rear-loaded RCV, EN 1501-1 Discontinuous compaction system (e.g. compaction plate)	75 ± 5 % of the maximum pressure	50
Side-loaded RCV, EN 1501-2 Continuous compaction system (e.g. screw compressor)	35 ± 5 % of the maximum pressure	50

[a] The percentage of the maximum hydraulic pressure of the system is needed to calculate the specific pressure for mounted components and used ratios which has to be adjusted to the load simulation valves.

[b] The maximum possible number of the defined containers shall be utilized depending on the loading application. The ballast mass tolerance is maximum 5 %.

[c] If lifting device is fitted.

Table 2 *(continued)*

RCV models	Compaction mechanism pressure to be simulated[a]	Total lifting device ballast mass, including container[b,c] kg
Side-loaded RCV, EN 1501-2 Discontinuous compaction system (e.g. pendulum press)	25 ± 5 % of the maximum pressure	50
Side-loaded RCV, EN 1501-2 Discontinuous compaction system (e.g. pendulum press)	25 ± 5 % of the maximum pressure	350
Front-loaded RCV, EN 1501-3	40 ± 5 % of the maximum pressure	250

[a] The percentage of the maximum hydraulic pressure of the system is needed to calculate the specific pressure for mounted components and used ratios which has to be adjusted to the load simulation valves.

[b] The maximum possible number of the defined containers shall be utilized depending on the loading application. The ballast mass tolerance is maximum 5 %.

[c] If lifting device is fitted.

Table 3 — Working cycle during the vehicle standstill

RCV models	Reference run Measurement run 1	Compaction run Measurement run 2[a]	Compaction and lifting run Measurement run 3	Lifting run Measurement run 4[a]	Discharge run Measurement run 5
Rear-loaded RCV[b] EN 1501-1		Run following cycle: one compaction cycle	Run following cycle: container emptying cycle and one compaction cycle	Run following cycle: container emptying cycle	Run following cycle: one discharge cycle without hopper cleaning
Side-loaded RCV EN 1501-2			Run following cycle: container emptying cycle and one compaction cycle		Run following cycle: one discharge cycle
Front-loaded RCV EN 1501-3			Run following cycle: container emptying cycle and one compaction cycle		Run following cycle: one discharge cycle

[a] For vehicles in accordance with EN 1501-2 and EN 1501-3, measurement runs 2 and 4 shall not be performed because there is currently no way to separate the loading and compaction system components.

[b] Vehicles with continuous compaction are always in operation during the complete vehicle standstill period.

The prescribed intervals stated in Table 4 shall be overcome in the energy-efficient driving mode in accordance with the prescribed times. For rear-loaded RCVs in accordance with EN 1501-1, a compaction cycle shall be fully completed during the vehicle standstill period. For front-loaded RCVs in accordance with EN 1501-3, 50 % of the maximum path of the compaction plate shall be retracted and extended during the vehicle standstill period.

Table 4 — Time proportion of the test cycle according to RCV model

Procedure	Time for RCV s		
	EN 1501-1	EN 1501-2	EN 1501-3
Driving 20 m	10	10	10
Vehicle standstill period	25	15	100
Driving 40 m	15	15	15
Vehicle standstill period	25	15	100
Total duration of the test cycle	75	55	225
Number of test cycles per measurement run	**48**	**66**	**16**

Table 5 — Energy values from energy sources according to 2009/33/EC

Fuel	Energy value	Energy value
Diesel	36 MJ/l	10 kWh/l
Gasoline	32 MJ/l	8,9 kWh/l
Natural gas	33 to 38 MJ/Nm^3	9,2 kWh/Nm^3 to 10,6 kWh/Nm^3
Liquid gas (LPG)	24 MJ/l	6,7 kWh/l
Ethanol	21 MJ/l	5,8 kWh/l
Biodiesel	33 MJ/l	9,2 kWh/l
Emulsion fuel	32 MJ/l	8,9 kWh/l
Hydrogen	11 MJ/Nm^3	3,1 kWh/Nm^3

Annex A
(normative)

Sample data collection sheet for measuring energy consumption

Location:

Date:

1 Vehicle data				Remarks
1.1 Chassis				
Make				
Model				
Chassis number				
Motor				
Emission standard				
Output (kW)				
Transmission				
Manual version	Automatic	Automated	Manual	
Active auxiliary drive	Switchable		—	
	Yes	No	—	
			—	
Engine dependent	Yes	No	—	
			—	
Transmission dependent	Yes	No	—	
			—	
Wheelbase				
Tyres				
Wheel formula				
Particularities, e.g. drive unit system; hybrid				
1.2 Design				
Make				
Model				
Serial number				
Design volumes According to the EN 1501 series (others have to be described)				
Lifting device (make, model)				
Serial number				
Hydraulic system e.g. single circuit or dual circuit system				
NOTE The maximum time of each measurement run is limited to 60 min.				

Hydraulic pump(s) e.g. constant pump, adjustable pump				
Switchable	Can be switched off	Unpressurised circulation	Zero-point conveying	
Operating pressure, loading unit maximum (kPa)				
Hydraulic oil (ISO viscosity class according to ISO 3448)				
Description of the drive unit system – design, e.g. alternative drive unit system, plug-in, electrical lifting device				
2 Measurement conditions (measured parameter)				
Vehicle mass (kg)				
Vehicle mass, ballasted (kg)				
Tyre pressure measured according to the manufacturer's specifications (kPa)				
Load simulation description (attach circuit diagram)				
Load simulation pressure, measured on loading unit (kPa)				Compare with Table 2
Working speed bodywork				
Lifting device working speed (min^{-1})				
Ballasting the refuse collection container, measured for the lifting device (kg)				Mass according to Table 2
Measurement process, described as energy consumption				
Details relating to the utilized load simulation components				
Environmental conditions				
Temperatures				
Start	°C			
End	°C			
All additional non-stated specifications shall be met according to the manufacturer's specifications.				

3 Measuring runs			
Synthesized measurement circuits according to ISO 24162:		Fuel consumption	Energy consumption
		l	kWh
Measurement run 1 (M1)	Transport trip (reference run)		
Measurement run 2 (M2)	Loaded trip, only in set-up mode		
Measurement run 3 (M3)	Loaded trip, only in lifting mode		
Measurement run 4 (M4)	Loaded trip, set-up plus lifting mode		
Measurement run 5 (M5)	Discharge		
NOTE The maximum time of each measurement run is limited to 60 min.			