International Standard

789/4

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Agricultural tractors — Test procedures — Part 4 : Measurement of exhaust smoke

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

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Agricultural tractors — Test procedures — Part 4 : Measurement of exhaust smoke

0 Introduction

This International Standard specifies test procedures for agricultural tractors. This part deals with the measurement of exhaust smoke. Other parts of this International Standard will be as follows.

Part 1 : Power tests.

Part 2 : Hydraulic power and lifting capacity.

Part 3 : Turning and clearance diameters.

Part 5 : Partial power p.t.o. - non-mechanically transmitted power.

Part 6 : Centre of gravity.

Part 7 : Power and torque of drive wheels.

Part 8 : Engine air cleaner.

1 Scope and field of application

This part of ISO 789 specifies a method of measuring the smoke emitted by the engines of agricultural tractors operating at a steady speed.

2 References

ISO 789/1, *Agricultural tractors — Test procedures — Part 1 : Power tests.*

ISO 2288, *Agricultural tractors and machines — Engine test code (bench test) — Net power.*

3 Apparatus

The following apparatus is required.

3.1 Dynamometer.

3.2 Opacimeter, complying with the requirements of annex A, and installed and used as described in annex B.

4 Test conditions

4.1 Test laboratory

The temperature and atmospheric pressure in the test laboratory shall be such that the factor F, when determined from the following formula, is greater than 0,98 and less than 1,02 :

$$F = \left(\frac{750}{p}\right)^{0,65} \times \left(\frac{T}{298}\right)^{0,5}$$

where

p is the atmospheric pressure, in millimeters of mercury[1], in the test laboratory;

T is the thermodynamic temperature, expressed in kelvins, in the test laboratory.

4.2 Engine or tractor

The engine or tractor shall be submitted in good mechanical condition. The engine shall have been run in.

The engine shall be tested with the equipment fitted, as specified in ISO 789/1.

The engine settings shall be those prescribed by the manufacturer and specified in ISO 789/1.

The exhaust device shall not have any orifice through which the gases emitted by the engine could be diluted.

The engine shall be in the normal working condition prescribed by the manufacturer. In particular, the cooling water and the oil shall each be at the normal temperature indicated by the manufacturer.

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[1] 1 mmHg = 133,322 Pa

4.3 Fuel

If possible, a reference fuel shall be used (see specification in annex C). If a reference fuel is not used, the specifications of the fuel shall be given in the same manner as in annex C. The test report shall state the type of fuel used.

5 Procedure

5.1 The test may be carried out either on an engine or on a tractor.

5.2 The opacity of the exhaust smoke produced by the engine shall be measured with the engine running under 80 % of the maximum load[1] and at steady speed. Six measurements shall be made at engine speeds spaced out uniformly between :

a) the speed corresponding to maximum power;

and

b) the higher of the following two speeds :

- 55 % engine speed at maximum power;
- 1 000 min^{-1}.

The extreme points of measurement shall be situated at the limits of the interval defined above.

5.3 In the case of a diesel engine which is fitted with an air pressure charger which is accompanied by an increase in the quantity of fuel injected, the measurements shall be made both with and without the air pressure charger working, if so designed.

For each engine speed, the result of the measurement shall be the higher of the two figures obtained.

5.4 For each of the six engine speeds at which the opacity is measured, the nominal gas flow rate, q, expressed in litres per second, shall be calculated by means of the formula

a) for two-stroke engines :

$$q = \frac{V \cdot n}{60}$$

b) for four stroke engines :

$$q = \frac{V \cdot n}{120}$$

where

V is the cylinder capacity, in litres, of the engine;

n is the engine speed (frequency of rotation), per minute (min^{-1}).

6 Test report (see annex D)

The test report shall include the following information :

a) tractor manufacturer's name and address;

b) tractor model and serial number;

c) engine make, model and serial number;

d) emission levels :

  1) limit values,

  2) measured absorption values;

e) make and type of opacimeter;

f) details of the fuel used in the test.

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[1] Maximum load shall be interpreted as the maximum torque at each of six relevant engine speeds.

Annex A

Characteristics of opacimeters

A.1 Basic specification

A.1.1 The gas to be measured shall be confined in an enclosure having a non-reflecting internal surface.

A.1.2 In determining the effective length of the light path through the gas, account shall be taken of the possible influence of devices protecting the light source and the photoelectric cell. This effective length shall be indicated on the instrument.

A.1.3 The indicating dial of the opacimeter shall have two measuring scales, one in absolute units of light absorption from 0 to ∞ (m^{-1}) and the other linear from 0 to 100; both scales shall range from 0 at total light flux to full scale at complete obscuration.

A.2 Construction

A.2.1 General

The design shall be such that, under steady-speed operating conditions, the smoke chamber is filled with smoke of uniform opacity.

A.2.2 Smoke chamber and opacimeter casing

A.2.2.1 The impingement on the photoelectric cell of stray light due to internal reflections or diffusion effects shall be reduced to a minimum (for example by finishing internal surfaces in matt black and by a suitable general layout).

A.2.2.2 The optical characteristics shall be such that the combined effect of diffusion and reflection does not exceed one unit on the linear scale when the smoke chamber is filled with smoke having an absorption coefficient near to 1,7 m^{-1}.

A.2.3 Light source

The light source shall be an incandescent lamp with a colour temperature in the range from 2 800 to 3 250 K.

A.2.4 Receiver

A.2.4.1 The receiver shall consist of a photoelectric cell with a spectral response curve similar to the photopic curve of the human eye (maximum response in the range 550 to 570 nm, less than 4 % of the maximum response being below 430 nm and above 680 nm).

A.2.4.2 The construction of the electrical circuit, including the indicating dial, shall be such that the current output from the photoelectric cell is a linear function of the intensity of the light received over the operating temperature range of the photoelectric cell.

A.2.5 Measuring scales

A.2.5.1 The light-absorption coefficient k shall be calculated using the formula

$$\phi = \phi_0 e^{-kL}$$

where

L is the effective length of the light path through the gas to be measured;

ϕ_0 is the incident flux;

ϕ is the emergent flux.

If the effective length L of a type of opacimeter cannot be assessed directly from its geometry, the effective length L shall be determined in one of the following ways :

a) by the method specified in clause A.3;

b) by correlation with another type of opacimeter for which the effective length is known.

A.2.5.2 The relationship between the linear scale (0 to 100) and the light absorption coefficient k is given by the formula

$$k = -\frac{1}{L}\log_e\left[1 - \frac{N}{100}\right]$$

where N is a reading on the linear scale.

A.2.5.3 The indicating dial of the opacimeter shall enable an absorption coefficient of 1,7 m^{-1} to be read with an accuracy of 0,025 m^{-1}.

A.2.6 Adjusting and testing the measuring apparatus

A.2.6.1 The electrical circuit of the photoelectric cell and of the indicating dial shall be adjustable so that the pointer can be reset at zero when the light flux passes through the smoke chamber filled with clean air or through a chamber having identical characteristics.

A.2.6.2 With the lamp switched off and the electrical measuring circuit open or short-circuited, the reading on the absorption-coefficient scale shall be infinite (∞), and it shall remain at this value when the measuring circuit is reconnected.

A.2.6.3 An intermediate check shall be carried out by placing in the smoke chamber a screen representing a gas of known absorption coefficient k, measured as described in A.2.5.1, between 1,6 and 1,8 m^{-1}. The value of k shall be known to within 0,025 m^{-1}. The check comprises verification that this value does not differ by more than 0,05 m^{-1} from that read on the opacimeter indicating dial when the screen is introduced between the source of light and the photoelectric cell.

A.2.7 Pressure of the gas to be measured and of scavenging air

A.2.7.1 The pressure of the exhaust gas in the smoke chamber shall not differ by more than 735 Pa from the atmospheric pressure.

A.2.7.2 The variations in the pressure of the gas to be measured and of the scavenging air shall not cause the absorption coefficient to vary by more than 0,05 m^{-1} in the case of a gas having an absorption coefficient of 1,7 m^{-1}.

A.2.7.3 The opacimeter shall be equipped with appropriate devices for measuring the pressure in the smoke chamber.

A.2.7.4 The limits of pressure variation of gas and scavenging air in the smoke chamber shall be indicated by the manufacturer of the apparatus.

A.2.8 Temperature of the gas to be measured

A.2.8.1 At every point in the smoke chamber, the gas temperature at the instant of measurement shall be between 70 °C and a maximum temperature, specified by the opacimeter manufacturer, such that the readings over this temperature range do not vary by more than 0,1 m^{-1} if the chamber is filled with a gas having an absorption coefficient of 1,7 m^{-1}.

A.2.8.2 The opacimeter shall be equipped with appropriate devices for measuring the temperature in the smoke chamber.

A.3 Determination of effective length L of the opacimeter

A.3.1 General

A.3.1.1 In some types of opacimeter, the gas between the light source and the photoelectric cell, or between transparent parts protecting the source and the photoelectric cell, is not of constant opacity. In such cases, the effective length L shall be that of a column of gas of uniform opacity, which is necessary in order to obtain the same light absorption as that obtained when the gas is admitted in the normal manner into the opacimeter.

A.3.1.2 The effective length of the light path is obtained by comparing the reading N of the opacimeter operating normally with the reading N_0, obtained with the opacimeter modified so that the test gas fills a well defined length L_0.

A.3.1.3 It will be necessary to take comparative readings in rapid succession in order to determine the correction to be made for shifts of the "zero".

A.3.2 Procedure

A.3.2.1 The test gas shall be exhaust gas of constant opacity or a light-absorptive gas of density similar to that of the exhaust gas.

A.3.2.2 Determine a length L_0 of the opacimeter, which can be filled uniformly with the test gas, and the ends of which are substantially at right angles to the light path. This length shall be close to the presumed effective length of the opacimeter.

A.3.2.3 Measure the mean temperature of the test gas in the smoke chamber.

A.3.2.4 If necessary, an expansion tank of compact design and of sufficient capacity to damp the pulsations may be incorporated in the sampling line as near to the probe as possible. A cooler may also be fitted. The addition of the expansion tank and of the cooler shall not unduly disturb the composition of the exhaust gas.

A.3.2.5 Determine the effective length by passing a sample of test gas alternately through the opacimeter operating normally and through the same apparatus modified as indicated in A.3.1.2.

A.3.2.5.1 Record the opacimeter readings continuously during the test using a recorder having a response time equal to or less than that of the opacimeter.

A.3.2.5.2 With the opacimeter operating normally, record the reading on the linear scale of opacity N and the mean gas temperature T, in kelvins.

A.3.2.5.3 With the known length L_0 filled with the same test gas, record the reading on the linear scale of opacity N_0 and the mean gas temperature T_0, in kelvins.

A.3.2.6 The effective length is given by the formula

$$L = L_0 \frac{T}{T_0} \frac{\log_e \left[1 - \frac{N}{100} \right]}{\log_e \left[1 - \frac{N_0}{100} \right]}$$

A.3.2.7 Repeat the test using at least four test gases giving readings evenly spaced between 20 and 80 on the linear scale.

A.3.2.8 Take, as the effective length L of the opacimeter, the arithmetic mean of the effective lengths calculated as specified in A.3.2.6, for each of the gases.

Annex B

Installation and use of the opacimeter

B.1 Sampling opacimeter

B.1.1 The ratio of the cross-sectional area of the probe to that of the exhaust pipe shall not be less than 0,05. The back pressure measured in the exhaust pipe at the intake of the probe shall not exceed 735 Pa.

B.1.2 The probe shall be a tube with an open end facing upstream in the axis of the exhaust pipe, or of the extension pipe if one is required. It shall be situated in a section where the distribution of smoke is approximately uniform. To achieve this, the probe shall be placed as far downstream in the exhaust pipe as possible or, if necessary, in an extension pipe so that, if D is the diameter of the exhaust pipe at the outlet, the end of the probe is situated in a straight portion at a distance of at least $6D$ upstream and $3D$ downstream from the sampling point. If an extension pipe is used, no air shall be allowed to enter the joint.

B.1.3 The pressure in the exhaust pipe and the characteristics of the pressure drop in the sampling line shall be such that the probe collects a sample substantially equivalent to that which would be obtained by isokinetic sampling.

B.1.4 If necessary, an expansion tank of compact design and of sufficient capacity to damp the pulsations may be incorporated in the sampling line as near to the probe as possible. A cooler may also be fitted. The addition of the expansion tank and cooler shall not unduly disturb the composition of the exhaust gas.

B.1.5 A butterfly valve or other means of increasing the sampling pressure may be placed in the exhaust pipe at a distance at least $3D$ downstream from the sampling probe.

B.1.6 The connecting pipe between the probe, the cooling device, the expansion tank (if required) and the opacimeter shall be as short as possible while satisfying the pressure and temperature requirements described in annex A, A.2.7 and A.2.8. The pipe shall be inclined upwards from the sampling point to the opacimeter, and sharp bends, where soot could accumulate, shall be avoided. If not embodied in the opacimeter, a bypass valve shall be provided upstream.

B.1.7 A check shall be carried out during the test to ensure that the requirements of annex A, A.2.7, for pressure, and those of A.2.8, for the temperature in the measuring chamber, are observed.

B.2 Full-flow opacimeter

The only general precautions to be observed are as follows :

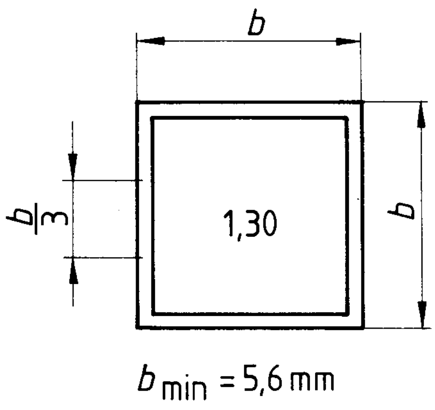
B.2.1 Joints in the connecting pipes between the exhaust pipe and the opacimeter shall not allow air to enter from outside.

B.2.2 The pipes connecting with the opacimeter shall be as short as possible, as in the case of sampling opacimeters. The pipe system shall be inclined upwards from the exhaust pipe to the opacimeter, and sharp bends, where soot could accumulate, shall be avoided. A bypass valve may be provided upstream of the opacimeter to isolate it from the exhaust gas flow when no measurement is being made.

B.2.3 A cooling system may also be required upstream of the opacimeter.

B.3 Example of symbol of corrected absorption coefficient

This symbol indicates that, for the purpose of this example, the corrected absorption coefficient is 1,30 m^{-1}.



Annex C

Reference fuel specifications for approval tests and to verify conformity of production

NOTE — The fuel shall be based on straight-run distillates, hydrosulphurized or not, and shall not contain additives.

Property	Specification	Method of test
Density at 15 °C	0,830 ± 0,005 g/ml	ASTM D 1298-67
Distillation		ASTM D 86-67
— 50 %	245 °C min.	
— 90 %	330 ± 10 °C	
Final boiling point	370 °C max.	
Cetane index	54 ± 3	ASTM D 976-66
Kinematic viscosity at 100 °F (37,8 °C)	3 ± 0,5 cSt1)	ASTM D 445-65
Aniline point	69 ± 5 °C	ASTM D 611-64
Carbon residue of 10 % distillation residue	0,2 % (*m*/*m*) max.	ASTM D 524-64
Net calorific value2)	10 250 ± 100 kcal/kg3) 18 450 ± 180 Btu/lb4)	ASTM D 2-68 (appendix VI)

1) 1 St = 10^{-4} m^2/s (exactly)

2) Specific internal energy

3) 1 kcal/kg = 4,184 kJ/kg

4) 1 Btu/lb = 2 326 J/kg (exactly)

Annex D

Specimen test report

1 Manufacturer's name and address : ....

....

2 Tractor type : .... Model : ....

3 Serial No. : ....

4 Engine

— Make : .... Model : ....

— Type : .... Serial No. : ....

— Rated speed : .... min^{-1}

5 Emission levels

Engine speed (min^{-1})	**Nominal flow rate** q (l/s)	**Measured absorption values** (m^{-1})
1	....	....
2	....	....
3	....	....
4	....	....
5	....	....
6	....	....

6 Make and type of opacimeter : ....

7 Fuel [attach specification if reference fuel is not used (see annex C)]

8 Comments : ....

9 Date of test : .... Measured by : ....