INTERNATIONAL STANDARD

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Diesel fuels — Determination of ignition quality — Cetane method

Carburants pour moteurs diesel — Détermination de la qualité d'inflammabilité — Méthode cétane

Reference number
ISO 5165:1992(E)

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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 5165 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, Sub-Committee SC 4, *Classifications and specifications*.

This second edition cancels and replaces the first edition (ISO 5165:1977), which has been technically revised.

Annex A of this International Standard is for information only.

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Introduction

The purpose of this International Standard is to accord official ISO status to a test procedure which is already used in a standardized form all over the world. The procedure in question is published by the American Society for Testing and Materials (ASTM) as method ASTM D 613-86.

By publishing this International Standard, ISO recognizes that this method is used in its original text in many member countries and that the standard equipment and many of the accessories and materials required for the method are obtainable only from specific manufacturers or suppliers. To carry out the procedure requires reference to the seven annexes to ASTM D 613-86, contained in the 1990 Annual Book of ASTM Standards, Section 5, Volume 05-04.[1] These comprise over 100 pages of text and include many half-tone block illustrations which are essential to the installation, operation and maintenance of the ASTM-CFR[2] engine.

From the accumulated experience in many countries of testing the ignition quality characteristics of diesel fuels using the ASTM-CFR engine, the conclusion has been drawn that initiation of work with a view to using a different engine for ISO purposes would represent unnecessary duplication of effort. Furthermore, the petroleum industry has world-wide demands for diesel fuels meeting ignition quality characteristic specification requirements based on the ASTM-CFR engine test and it is under the necessity, therefore, of having this test requirement standardized.

It is further recognized that this method for rating diesel fuels constitutes an exceptional case in that "metrication" of operating conditions other than those already recognized would be extremely difficult. In a metricated engine, the dimensions and tolerances would be strict numerical conversions and would not reflect metric engineering practice. The engine and directly associated equipment are currently manufactured only to non-metric dimensions and tolerances, and inspection equipment to maintain these tolerances is also only available to non-metric dimensions. The essentials of the procedures for using the test

1) Copies may be purchased directly from the publisher, the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, USA, or from The Institute of Petroleum, 61 New Cavendish Street, London W1M 8AR, UK. It may be ordered through any national standards organization or through the ISO Central Secretariat.

A new edition of the ASTM Book of Standards is issued annually incorporating all actions accepted at least six months before issue date. Users of the method should ensure that they have the most recent issue.

For the purpose of this International Standard, the corresponding French Standard NF M 07-035, published by the Association française de normalisation, should be regarded as equivalent to the English text of the joint ASTM/IP method referenced herein.

2) The sole authorized manufacturer of the ASTM-CFR engine is the Waukesha Engine Division, Dresser Industries, Waukesha, WI 53186, USA.

engine and equipment must be strictly adhered to if comparable results are to be obtained in different laboratories.

For all these reasons, it has been considered desirable by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, to adopt without change the method as published in the 1990 Annual Book of ASTM Standards, Section 5, Volume 05-04, rather than to attempt the conversion of the basic method and annexes into an International Standard.

Diesel fuels — Determination of ignition quality — Cetane method

WARNING — The use of this International Standard involves potentially hazardous materials, operations and equipment. This International Standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user to consult the relevant safety and health regulations, determine the applicability of regulatory limitations, and establish appropriate safety and health practices, prior to use.

1 Scope

This International Standard specifies a test for determining the ignition quality of diesel fuels in terms of ASTM cetane number, on the basis of ASTM D 613-86.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ASTM D 613-86, *Standard Test Method for Ignition Quality of Diesel Fuels by the Cetane Method.*[3)]

ANSI/ASTM D 4057-88, *Standard Practice for Manual Sampling of Petroleum and Petroleum Products.*

3 Definitions

3.1 cetane number: A measure of the ignition performance of a diesel fuel obtained by comparing it to reference fuels in a standardized engine test.

NOTE 1 In the context of this test method, ignition performance is understood to mean the ignition delay of the fuel as determined in a standard test engine under controlled conditions of fuel flow rate, injection advance, and compression ratio.

3.2 ignition delay: That period of time between the start of fuel injection and the start of combustion. It is expressed in degrees of crank angle.

3.3 injection timing; injection advance: That time in the combustion cycle at which fuel injection into the combustion chamber is initiated. It is expressed in degrees of crank angle.

3.4 handwheel reading: A numerical indication of the position of the expansion plug which establishes the volume of the precombustion chamber of the cetane engine and is thus related to compression ratio.

3.5 ignition delay meter: Electronic instrument which accepts input pulses from four pickups and indicates the ignition delay of fuels in terms of crank angle degrees.

3.6 reference pickups: Two magnetic transducers mounted near the flywheel that are triggered by a flywheel pointer to establish a top-dead-centre (tdc) reference and a 25-crank-angle-degree time base used to calibrate the ignition delay meter crank angle span and top-dead-centre reference.

3.7 injection pickup: A magnetic transducer mounted on the injector to detect motion of the injector pintle, thereby indicating the beginning of fuel injection.

3) This is published in: 1990 Annual Book of ASTM Standards, Section 5, Volume 05.04, *Test Methods for Rating Motor, Diesel and Aviation Fuels.* (See introduction.)

3.8 combustion pickup: A magnetic transducer mounted in the cylinder head and exposed to cylinder pressure to indicate the start of combustion.

3.9 primary reference fuels: *n*-Cetane, heptamethylnonane (HMN) and volumetrically proportioned mixtures of these materials which define the cetane number (CN) scale by the relationship

$$CN = \%\ n\text{-cetane} + 0{,}15\ (\%\ HMN)$$

3.10 secondary reference fuels: Volumetrically proportioned mixtures of two fuels, designated "T" (high cetane) and "U" (low cetane) where each batch of T and U have been calibrated in various combinations by comparison with primary reference fuel blends by the National Exchange Group.

3.11 check fuels: Diesel fuels calibrated by the National Exchange Group providing a means for an individual laboratory to check the cetane number rating qualification of a specific engine unit.

NOTE 2 The National Exchange Group of ASTM Sub-Committee D02.01 is composed of petroleum industry, governmental and independent laboratories. It conducts regular monthly exchange sample analyses to generate precision data for the engine test methods and calibrates reference materials used by all laboratories.

4 Principle of test method

The cetane number of a diesel fuel is determined by comparing its ignition quality with those for blends of reference fuels of known cetane numbers under standard operating conditions. This is done by varying the compression ratio for the sample and each reference fuel to obtain a fixed "delay period", that is, the time interval between the start of injection and ignition. When the compression ratio for the sample is bracketed between those for two reference fuel blends differing by not more than five cetane numbers, the rating of the sample is calculated by interpolation.

5 Significance and use

5.1 The cetane method provides a means of determining the compression/ignition characteristics of diesel fuels. The method utilizes a single-cylinder engine and requires critical adjustment of the fuel-air ratio and compression ratio to produce a standard ignition delay (the interval between the beginning of fuel injection and the beginning of combustion). The compression/ignition quality of a diesel fuel is determined by relating it to primary reference fuel blends whose volumetric composition establishes the cetane scale. Commonly, secondary reference fuels are used which have been laboratory-engine calibrated with primary reference fuels.

5.2 The ignition delay period affects the optimum injection timing of diesel engines, as it influences the crank angle interval between injection and the development of peak combustion pressure.

5.3 This test is used by engine manufacturers, petroleum refiners and marketers, and in commerce as a primary specification measurement to ensure proper matching of fuel and engines.

6 Ignition quality test unit

As illustrated in ASTM D 613-86, figure 1, this consists of a single-cylinder engine of continuously variable compression ratio, with suitable loading and accessory equipment and instruments, mounted on a stationary base. The engine and equipment specified in ASTM D 613-86, annex A1 (Apparatus) shall be used without modification. It is important to provide a proper foundation for the unit as described in ASTM D 613-86, annex A6 (Building and Utility Requirements), A6.5.

7 Reference fuels

ASTM primary cetane reference fuels, conforming to the specifications and requirements in ASTM D 613-86, annex A2 (Reference Materials and Blending Accessories), are the following.

7.1 ASTM *n*-cetane.

7.2 ASTM heptamethylnonane (HMN).

Normally, secondary reference fuels (see ASTM D 613-86, annex A2, A2.2) that have been calibrated against these primary reference fuels are used for routine testing.

8 Sampling

Sampling shall be carried out in accordance with the applicable procedure described in ANSI/ASTM D 4057.

9 Operating conditions

The following standard operating conditions [see ASTM D 613-86, annex A3 (Operation) for further details] shall be used.

9.1 Engine speed: 900 rpm ± 9 rpm, with a maximum variation of 9 rpm during a test.

9.2 Injection advance: 13,0° before tdc.

9.3 Injector opening pressure: 10,3 MPa ± 0,34 MPa (1 500 psi ± 50 psi).

9.4 Injection quantity: 13,0 ml/min ± 0,2 ml/min (that is, 13,0 ml in 60 s ± 1 s).

Make this adjustment for each sample.

9.5 Injection pump setting: See ASTM D 613-86, annex A4 (A4.45) for checking and adjusting the setting of the injection pump.

9.6 Injector pintle valve lift: 0,005 in ± 0,001 in.

9.7 Injector water jacket temperature: 38 °C ± 3 °C (100 °F ± 5 °F).

9.8 Valve clearances: 0,008 in ± 0,001 in, measured with the engine hot and running under standard operating conditions on a typical diesel fuel.

9.9 Crankcase lubricating oil: SAE 30, having a kinematic viscosity of 9,62 mm^2/s to 12,93 mm^2/s (cSt) at 99 °C (210 °F) and a viscosity index of not less than 85. Oils containing viscosity index improvers or multigraded oils shall not be used.

9.10 Oil pressure: 0,17 MPa to 0,20 MPa (25 psi to 30 psi) gauge under operating conditions.

9.11 Oil temperature: 57 °C ± 8 °C (135 °F ± 15 °F), with the temperature-sensitive element completely immersed in the crankcase oil.

9.12 Coolant temperature: 100 °C ± 2 °C (212 °F ± 3 °F), constant within ± 1 °F during a test.

9.13 Intake air temperature: 66 °C ± 0,5 °C (150 °F ± 1 °F).

9.14 Basic clearance volume and hand wheel setting: See ASTM D 613-86, annex 3 (A3.1) for detailed procedure.

10 Starting and stopping the engine

Detailed instructions for starting and stopping the engine are given in ASTM D 613-86, annex A3 (A3.4 and A3.5).

11 Ignition delay meter

11.1 A commercially available transistorized meter[4] is approved for measuring ignition delay by this method. The meter has a selector switch marked CALIBRATE, INJECTION ADVANCE and IGNITION DELAY, and controls for making basic calibration settings.

11.2 After the engine is started, the instrumentation shall be calibrated.

Detailed instructions for calibration and use of the preferred instrument are given in ASTM D 613-86, annex A3 (Operation).

12 Operating procedure

After the engine operating conditions have been properly adjusted as directed in ASTM D 613-86, annex 3 (A3.6), observe the following instructions for rating samples.

12.1 Fuel sample

Pour the sample into an empty fuel tank. Flush the lines by leaving the drain valve open for 2 s or 3 s, and then open and close the valve a few times to remove entrained air from the passages. This is important because entrained air affects injection and causes erratic engine operation. Turn the fuel selector valve to the tank containing the sample.

CAUTION — Since the fuel pump is partly dependent on fuel for lubrication, do not allow it to run dry, except during the momentary periods required for fuel changes.

NOTE 3 If the fuel to be tested has a high cloud point so that precipitated wax is present, it should be heated to a temperature at least 10 °C above its cloud point for at least 1 h, or until the wax has dissolved completely.

12.2 Burette

The burette is filled automatically when the selector valve is set to draw fuel from one of the three tanks. Drain and flush the burette each time the engine is changed from one tank to another. Be careful to prevent intermixing during the process.

12.3 Measurement of fuel injection rate

The specified rate of fuel injection is 13,0 ml/min ± 0,2 ml/min or 13 ml in 60 s ± 1 s. To measure the rate, turn the fuel-selector valve K (see figure 6 of ASTM D 613-86) to a neutral position so that the injection pump draws fuel from the burette only. Using an electric stop-clock (or stop-watch), measure the fuel consumption by starting the clock as the meniscus passes a millilitre graduation on the burette and stopping the clock as the meniscus passes the mark 13 ml below the starting point. Turn the fuel-selector valve back to its previous position to draw fuel again from the tank containing the

4) Manufactured and available from the Waukesha Engine Div., Dresser Industries, Waukesha, WI 53186, USA. This meter is an example of a suitable product available commercially. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of this product.

sample. Do not let the pump run dry. If the time registered by the clock is not 60 s ± 1 s, readjust the micrometer as described in 12.4 until correct flow rate is obtained.

12.4 Adjustment of fuel injection rate

If the rate of fuel injection needs adjustment, turn the micrometer G (see figure 6 of ASTM D 613-86) clockwise (as viewed from the front of the engine) to increase the fuel flow, and counterclockwise to decrease it. Record the micrometer setting required for correct injection rate.

12.5 Adjustment of injection timing

While still operating on the test sample, rotate the selector switch of the main chassis of the ignition-delay meter to INJECTION ADVANCE. Adjust the injection timing by turning the micrometer H (see figure 6 of ASTM D 613-86) to give a reading of 13,0° on the meter. With this reading, fuel injection occurs 13,0° before tdc.

12.6 Measurement of ignition delay

Rotate the selector switch on the main chassis by the ignition delay meter to IGNITION DELAY. Adjust the combustion-chamber length D (see figure 7 of ASTM D 613-86) with the handwheel B for a meter reading of 13,0°. Make the final adjustment of the compression ratio by turning the handwheel clockwise to eliminate a false reading because of backlash in the handwheel mechanism. Record the handwheel setting (combustion-chamber length) required for a meter reading of 13,0°. With this reading, ignition occurs at tdc which is 13,0° after the start of fuel injection.

12.7 Cetane number

Using the handwheel setting obtained in 12.6, the approximate cetane number of the test sample can be estimated from previous information on the same engine.

13 Bracketing the test fuel

13.1 Operate the engine on a trial blend of reference fuels, based on the estimated cetane number of the sample. Check and, if necessary, adjust the injection rate to 13,0 ml ± 0,2 ml of fuel per minute. Record the micrometer setting giving the correct injection rate. Adjust the injection timing in accordance with 12.5 to 13,0° before tdc. Then adjust the handwheel as described in 12.6 to give an ignition delay of 13,0° and record the handwheel reading.

13.2 Operate the engine on a second trial blend of the reference fuels, differing from the first by not more than five cetane numbers, and repeat the procedure described in 13.1. Because the reference fuel blends are sufficiently similar, no measurement or adjustment of injection rate should be necessary when changing from one reference-fuel blend to the other.

13.3 If the handwheel setting for the sample is bracketed by those for the reference fuels, continue the test; otherwise try additional blends until this requirement is satisfied. Repeat the operation on both the sample and each of the final reference blends at least twice, adjusting the injection rate and timing as necessary to maintain standard conditions. In changing fuels, allow several minutes before taking readings to ensure thorough flushing of the injection system and to let the engine reach equilibrium.

14 Calculating and reporting

14.1 Average the handwheel readings obtained in accordance with clause 13 for the sample and each of the final reference fuels.

14.2 Use the average handwheel readings and calculate the cetane number to the second decimal place by interpolation of the handwheel readings proportioned to the cetane numbers of the bracketing reference fuels.

14.3 Round the calculated cetane number to the nearest tenth. Any cetane number ending exactly in 5 in the second decimal place shall be rounded to the nearest even tenth numbers, for example, round 35,55 and 35,65 to 35,6.

14.4 Report the cetane number to the nearest tenth as calculated.

15 Precision

The precision of this International Standard as determined by the statistical examination of interlaboratory test results[5] is as follows.

5) The precision limits were calculated from the cetane number results obtained by the National Exchange Diesel Fuels Group (NEG) participating in cooperative testing programmes from 1978 to 1982. The data were analysed by procedures detailed in reference [1].

15.1 Repeatability

The difference between two test results, obtained by the same operator with the same apparatus under constant operating conditions on identical test material would, in the long run, in the normal and correct operation of the test method, exceed the values given in table 1 only in 1 case in 20.

15.2 Reproducibility

The difference between two single and independent results obtained by different operators working in different laboratories on identical test material would, in the long run, in the normal and correct operation of the test method, exceed the values given in table 1 only in 1 case in 20.

Table 1

Average cetane No. level	Repeatability limits, cetane No.	Reproducibility limits, cetane No.
40	0,6	2,5
44	0,7	2,6
48	0,7	2,9
52	0,8	3,1
56	0,9	3,3

NOTE — For cetane numbers intermediate to those listed above, values of repeatability or reproducibility limits may be obtained by linear interpolation.