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Fourth edition
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Petroleum products — Determination of the ignition quality of diesel fuels — Cetane engine method

Produits pétroliers — Détermination de la qualité d'inflammabilité des carburants pour moteurs diesel — Méthode cétane

Reference number
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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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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

For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 28, *Petroleum products and related products of synthetic or biological origin*.

This fourth edition cancels and replaces the third edition (ISO 5165:1998), which has been technically revised. It has been aligned with ASTM D613-15ae1.

The main changes compared to the previous edition are as follows:

— the Scope has been extended to paraffinic diesel from synthesis or hydrotreatment, in line with the outcome of the interlaboratory study organized by CEN/TC 19 in 2013[1];

— the possibility to use, as an alternative, the new digital (XCP) cetane panel has been added;

— the possibility to rate a sample with primary reference fuels (hexadecane and heptamethylnonane) has been added;

— a determinability limit has been introduced;

— a new procedure for measuring samples having cetane numbers expected to be greater than “T” secondary reference fuel has been introduced;

— cross-references to annexes that have been deleted in ASTM D613-15ae1 have been removed.

Petroleum products — Determination of the ignition quality of diesel fuels — Cetane engine method

WARNING — The use of this document can involve hazardous materials, operations and equipment. This document does not purport to address all of the safety problems associated with its use. It is the responsibility of users of this document to take appropriate measures to ensure the safety and health of personnel prior to the application of the document.

1 Scope

This document establishes the rating of diesel fuel oil in terms of an arbitrary scale of cetane numbers (CNs) using a standard single cylinder, four-stroke cycle, variable compression ratio, indirect injected diesel engine. The CN provides a measure of the ignition characteristics of diesel fuel oil in compression ignition engines. The CN is determined at constant speed in a pre-combustion chamber-type compression ignition test engine. However, the relationship of test engine performance to full scale, variable speed and variable load engines is not completely understood.

This document is applicable for the entire scale range from 0 CN to 100 CN but typical testing is in the range of 30 CN to 65 CN. An interlaboratory study executed by CEN in 2013 (10 samples in the range 52,4 CN to 73,8 CN)[1] confirmed that paraffinic diesel from synthesis or hydrotreatment, containing up to 7 % (*V*/*V*) fatty acid methyl ester (FAME) can be tested by this test method and that the precision is comparable to conventional fuels.

This test can be used for unconventional fuels such as synthetics, vegetable oils, etc. However, the relationship to the performance of such materials in full scale engines is not completely understood.

Samples with fluid properties that interfere with the gravity flow of fuel to the fuel pump or delivery through the injector nozzle are not suitable for rating by this method.

NOTE This document specifies operating conditions in SI units but engine measurements are specified in inch-pound units because these are the historical units used in the manufacture of the equipment, and thus some references in this document include these units in parenthesis.

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.

ISO 3170, *Petroleum liquids — Manual sampling*

ISO 3171, *Petroleum liquids — Automatic pipeline sampling*

ISO 3696, *Water for analytical laboratory use — Specification and test methods*

ISO 4787, *Laboratory glassware — Volumetric instruments — Methods for testing of capacity and for use*

ASTM D613-15ae1, *Standard Test Method for Cetane Number of Diesel Fuel Oil*

ASTM E832-81, *Standard Specification for Laboratory Filter Papers*

3 Terms and definitions

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

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

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

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

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

Note 1 to entry: Ignition performance is understood to mean the *ignition delay* (3.3) of the fuel as determined when the standard test engine is operated under controlled conditions of fuel flow rate, *injection timing* (3.4) and *compression ratio* (3.2).

3.2
compression ratio
ratio of the volume of the combustion chamber including the pre-combustion chamber with the piston at bottom-dead-centre (b.d.c.) to the comparable volume with the piston at top-dead-centre (t.d.c.)

3.3
ignition delay
period of time between the start of fuel injection and the start of combustion expressed in degrees of crank angle rotation

3.4
injection timing
injection advance
time in the combustion cycle at which fuel injection into the combustion chamber is initiated expressed in degrees of crank angle

3.5
handwheel reading
arbitrary numerical value, related to *compression ratio* (3.2), obtained from a micrometer scale that indicates the position of the variable compression plug in the pre-combustion chamber of the engine

3.6
cetane meter
ignition delay meter
electronic instrument which displays *injection timing* (3.4) and *ignition delay* (3.3) derived from input pulses of multiple transducers (pickups)

Note 1 to entry: Three generations of apparatus have been approved for use as cetane meters. These are (with the year of introduction in parenthesis) the Mark II Ignition Delay Meter (1974), the Dual Digital Cetane Meter (1990) and the XCP Cetane Panel (2014).

3.7
injector nozzle opening pressure
fuel pressure that overcomes the resistance of the spring which normally holds the injector nozzle pintle closed, and thus forces the pintle to lift and release an injection spray from the nozzle

3.8
reference pickup
transducers or optical sensors mounted over the flywheel of the engine, triggered by a flywheel pointer, used to establish a top-dead-centre (t.d.c.) reference and a time base for calibration of the *cetane meter* (3.6)

3.9
injector pickup
transducer to detect motion of the injector pintle, thereby indicating the beginning of injection

3.10
combustion pickup
pressure transducer exposed to cylinder pressure to indicate the start of combustion

3.11
primary reference fuel
PRF
hexadecane (*n*-cetane), heptamethylnonane (HMN) and volumetrically proportioned mixture of these materials

Note 1 to entry: These PRFs now define the cetane number (CN) scale by the relationship given in the following formula:

$$\mathrm{CN} = \%\,\mathrm{cetane} + 0{,}15\left(\%\,\mathrm{HMN}\right)$$

Note 2 to entry: Alphamethylnaphthalene (1-methylnaphthalene), in its pure form, was originally defined as 0 and *n*-cetane (hexadecane) as 100 for the CN scale. With blends of the two chemicals being used for the intervening values, alphamethylnapthalene was subsequently replaced in 1962 by heptamethylnonane as the low reference material, with an assigned value of 15, as it was more readily available and experience had shown that it had better storage stability.

3.12
secondary reference fuel
SRF
volumetrically proportioned blend of two selected, numbered and paired hydrocarbon mixtures designated “T fuel” (high CN) and “U fuel” (low CN) where each numbered paired set of “T fuel” and “U fuel” is rated by the ASTM Diesel National Exchange Group (NEG) in various combinations by comparison to *primary reference fuel* (3.11) blends

3.13
check fuel
diesel fuel oil having a *cetane number* (3.1) value determined by an interlaboratory comparison which provides a guide for an individual laboratory to check the cetane rating performance of a specific engine unit

4 Principle

The CN of a diesel fuel oil is determined by comparing its combustion characteristics in a test engine with those for blends of reference fuels of known CN under standard operating conditions. This is accomplished using the bracketing handwheel procedure, which varies the compression ratio (handwheel reading) for the sample and each of two bracketing reference fuels to obtain a specific ignition delay permitting the interpolation of CN in terms of handwheel reading.

5 Reagents and reference materials

5.1 Cylinder jacket coolant, water conforming to grade 3 of ISO 3696.

Water shall be used in the cylinder jacket for laboratory locations where the resultant boiling temperature is 100 °C ± 2 °C (212 °F ± 3 °F). Water with commercial glycol-based antifreeze added in a sufficient quantity to meet the boiling temperature requirement shall be used when the laboratory altitude dictates. A commercial multi-functional water-treatment material should be used in the coolant to minimize corrosion and mineral scale that can alter heat transfer and rating results.

5.2 Engine crankcase lubricating oil, an SAE 30 viscosity grade oil[2] meeting current American Petroleum Institute (API) service classification or compatible previous API service classification for engines shall be used. It shall contain a detergent additive and have a kinematic viscosity of 9,3 mm^2/s

to 12,5 mm^2/s at 100 °C (212 °F) and a viscosity index of not less than 85. Oils containing viscosity index improvers shall not be used. Multi-graded lubricating oils shall not be used.

The suggested oil change interval is 50 engine-running hours.

5.3 Cetane primary reference fuel (PRF), hexadecane with a minimum purity of 99,0 %, as determined by chromatographic analysis, shall be used as the designated 100 CN component.

5.4 Heptamethylnonane PRF, 2,2,4,4,6,8,8-heptamethylnonane with a minimum purity of 98 %, as determined by chromatographic analysis, shall be used as the designated 15 CN component.

WARNING — PRFs are combustible and vapour harmful.

IMPORTANT — Store and use PRFs at temperatures of 20 °C or higher to avoid solidification of hexadecane, which has a melting point of 18 °C.

5.5 Secondary reference fuels (SRFs), volumetric blends of two diesel fuels having widely different CNs that have been round-robin engine calibrated by a recognized exchange testing group.

Storage and use of “T fuel” and “U fuel” should be at temperatures above 0 °C (32 °F) to avoid potential solidification, particularly of “T fuel”. Before a container that has been stored at low temperature is placed in service, it should be warmed to a temperature of at least 14 °C (26 °F) above its cloud point as determined in accordance with ISO 3015. It should be held at this temperature for a period of at least 30 min and then the container should be thoroughly remixed.

SRF blends are rated in numbered pairs and are not interchangeable with SRF blends from other batches.

WARNING — SRFs are combustible and the vapours harmful.

NOTE Blends of “T fuel” and “U fuel” that have been engine calibrated by the ASTM Diesel National Exchange Group can be, and typically are, used for routine testing. The calibration data are incorporated in blend tables that list the CNs assigned for various volume percentage blends of “T fuel” and “U fuel”. “T fuel” is typically in the range of 73 CN to 75 CN and “U fuel” is typically in the range of 20 CN to 22 CN.

5.6 Check fuels, diesel fuel oils typical of the middle distillate type having a CN value determined by an interlaboratory comparison.

WARNING — Check fuels are combustible and the vapours harmful.

NOTE Low cetane check fuel will typically be in the range of 38 CN to 42 CN. High cetane check fuel will typically be in the range of 50 CN to 55 CN.

6 Apparatus

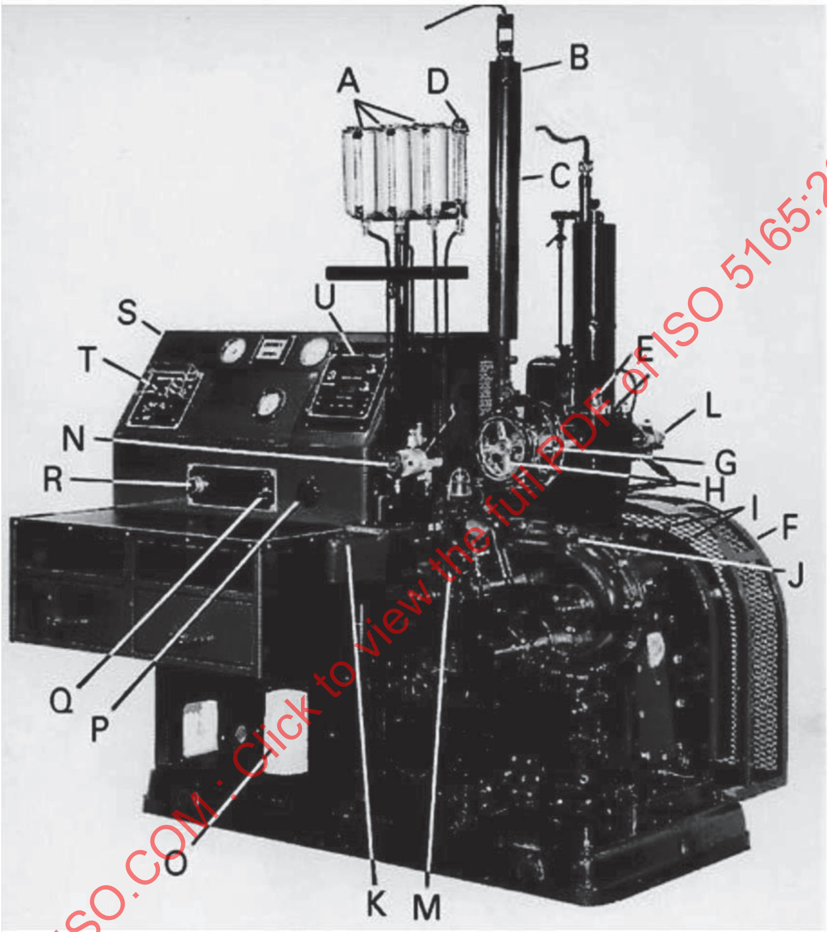
6.1 Test engine assembly.

As shown in Figure 1. It comprises a single cylinder engine consisting of a standard crankcase with fuel pump assembly, a cylinder with separate head assembly of the pre-combustion type (see Figure 2), thermal-siphon recirculating jacket coolant system, multiple fuel tank system with selector valving, injector assembly with specific injector nozzle, electrical controls and a suitable exhaust pipe. Figure 3 shows the software screen interface of the XCP digital panel. The engine shall be belt connected to a special electric power-absorption motor, which acts as a motor driver to start the engine and as a means to absorb power at constant speed when combustion is occurring (engine firing).

6.2 Instrumentation.

An electronic instrument to measure injection and ignition delay timing as well as conventional thermometry, gauges and general purpose meters.

NOTE Engine equipment and instrumentation are available from the single source manufacturer, CFR Engines Inc.1), N8 W22577 Johnson Drive, Pewaukee WI 53186, USA. CFR Engines Inc. also has authorized sales and service organizations in selected geographic areas.

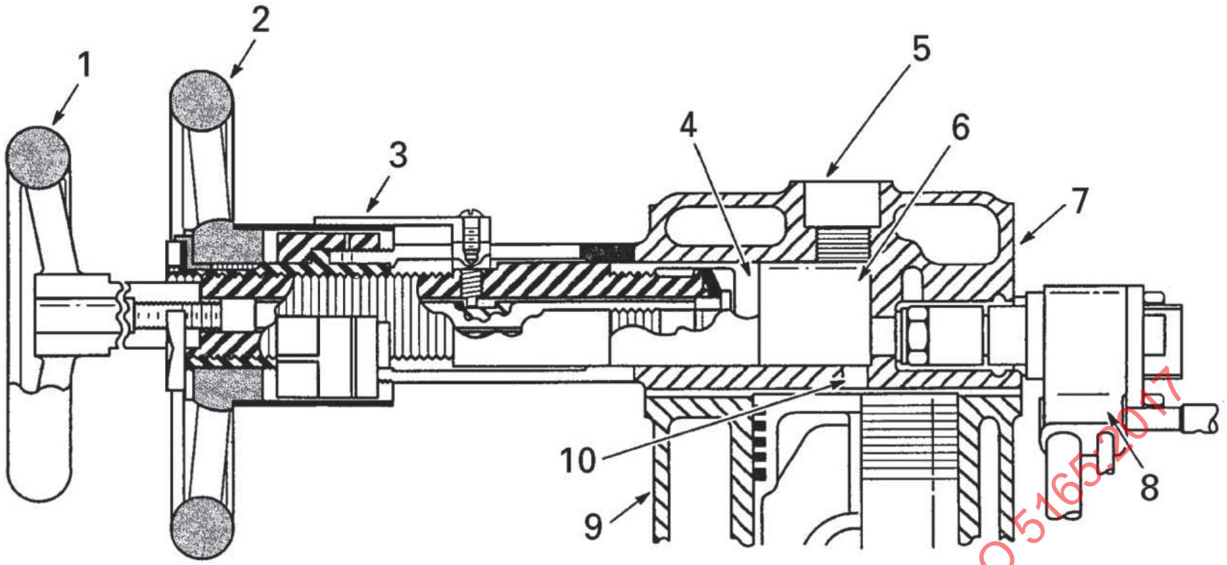


Key

A fuel tanks
B air heater housing
C air intake silencer
D fuel flow-rate burette
E combustion pickup
F safety guard
G variable compression plug (VCP) handwheel
H VCP locking handwheel
I flywheel pickups
J oil filter cap
K injection pump safety shutoff solenoid
L injector assembly
M fuel injection pump
N fuel selector valve
O oil filter
P crankcase oil heater control
Q air heater switch
R engine start-stop panel
S instrument panel
T intake air temperature controller
U Dual Digital Cetane Meter

Figure 1 — Cetane method test engine assembly

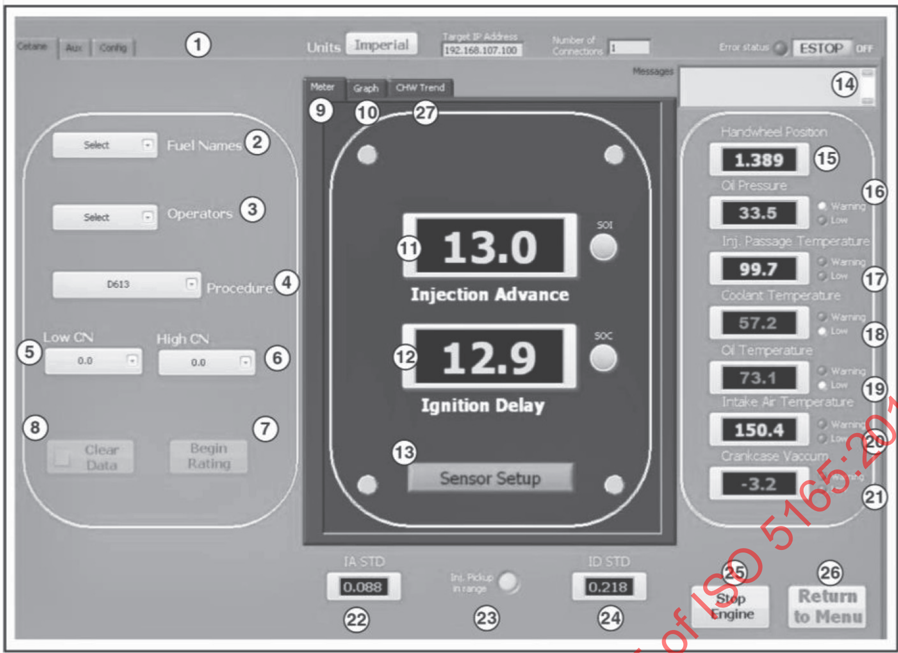
1) This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.



Key

1 VCP locking wheel
2 VCP handwheel
3 VCP micrometer
4 VCP
5 combustion pickup hole
6 precombustion chamber
7 cylinder head
8 injector nozzle assembly
9 cylinder
10 turbulence passage

Figure 2 — CFR engine cylinder head and handwheel assembly



Key

1 cetane rating toolbar
2 fuel names
3 operators
4 procedure
5 low CN
6 high CN
7 begin rating
8 clear data
9 meter
10 graph
11 injection timing
12 ignition delay
13 sensor setup
14 messages
15 handwheel position
16 oil pressure
17 injector passage temperature
18 coolant temperature
19 oil temperature
20 intake air temperature
21 crankcase vacuum
22 injection timing standard deviation
23 injector pickup in range
24 ignition delay standard deviation
25 start/stop engine
26 return to menu
27 for future use

Figure 3 — XCP digital panel: software screen interface

6.3 Reference fuels dispensing equipment.

Calibrated burettes or volumetric ware having a capacity of 400 ml or 500 ml and a maximum volumetric tolerance of ± 0,2 %. Calibration shall be verified in accordance with ISO 4787. Burettes shall be outfitted with a delivery valve and delivery tip to accurately control dispensed volumes. The delivery tip shall be of such size and design that shut-off tip discharge does not exceed 0,5 ml. The rate of delivery from the dispensing system shall not exceed 500 ml/min.

NOTE ASTM D613-15ae1, Appendix X1 (Volumetric Reference Fuel Blending Apparatus and Procedures) provides additional information for application of this document.

The use of blending systems for the preparation of the volumetrically defined blends by gravimetric (mass) measurements, based on the density at 15 °C (60 °F) of the individual components, is allowed provided the blending system meets the requirement of ±0,2 % blending tolerance limits.

6.4 Injector nozzle tester.

The injector nozzle assembly shall be checked whenever the injector nozzle is removed and reassembled to ensure that the initial pressure at which fuel is discharged from the nozzle is properly set.

IMPORTANT — It is also important to inspect the type of spray pattern which occurs. Commercial injector nozzle testers which include a lever-operated pressure cylinder, fuel reservoir and pressure gauge are available from several sources as common diesel engine maintenance equipment.

6.5 Special maintenance tools.

A number of speciality tools and measuring instruments are available for easy, convenient and effective maintenance of the engine and testing equipment.

NOTE Lists and descriptions of these tools and instruments are available from the manufacturers of the engine equipment and those organizations offering engineering and service support for this document.

7 Sampling and sample preparation

Samples shall be collected in accordance with ISO 3170, ISO 3171 or an equivalent national standard.

To minimize exposure to UV emissions, collect and store samples in opaque containers such as dark brown glass bottles, metal cans or minimally-reactive plastic containers.

Samples shall be brought to room temperature, typically 18 °C to 32 °C, before engine testing. If necessary, samples shall be filtered through a Type 1, Class A filter paper, conforming to ASTM E832-81, at room temperature and pressure before engine testing.

Inspect the sample for wax precipitation: if precipitates are present, bring the test sample to a temperature of at least 14 °C above the expected cloud point of the material being tested, taking care not to lose any lower boiling range components. The fuel sample should be homogeneous before engine testing or filtration.

8 Basic engine and instrument settings and standard operating conditions

8.1 Installation of engine equipment and instrumentation

Locate the cetane test engine in an area where it will not be affected by certain gases and fumes that can have a measurable effect on the CN test result.

Installation of the engine and instrumentation requires placement of the engine on a suitable foundation and hook-up of all utilities. Engineering and technical support for this function is required, and the user shall be responsible for conformity with all applicable codes and installation requirements. Proper operation of the test engine requires assembly of a number of engine components and adjustment of a series of engine variables to prescribed specifications. Some of these settings are established by component specifications, others are established at the time of engine assembly or after overhaul and still others are engine-running conditions that shall be observed and/or determined by operator adjustment during the testing process.

8.2 Engine speed

The engine speed shall be 900 r/min ± 9 r/min when the engine is operating with combustion with a maximum variation of 9 r/min occurring during a rating. Engine speed when combustion is occurring shall not be more than 3 r/min greater than for motoring without combustion.

8.3 Valve timing

The engine shall use a four-stroke cycle with two crankshaft revolutions for each complete combustion cycle. The two critical valve events are those that occur near top-dead-centre (t.d.c.): intake valve opening and exhaust valve closing. Intake valve opening shall occur 10,0° ± 2,5° after-top-dead-centre (a.t.d.c.) with closing at 34° after-bottom-dead-centre (a.b.d.c.) on one revolution of the crankshaft and flywheel. Exhaust valve opening shall occur 40° before-bottom-dead-centre (b.b.d.c.) on the second revolution of the crankshaft or flywheel with closing at 15,0° ± 2,5° a.t.d.c. on the next revolution of the crankshaft or flywheel.

8.4 Valve lift

Intake- and exhaust-cam lobe contours, while different in shape, shall have a contour rise of 6,223 mm to 6,350 mm (0,245 in to 0,250 in) from the base circle to the top of the lobe so that the resulting valve lift shall be 6,045 mm ± 0,05 mm (0,238 in ± 0,002 in).

8.5 Fuel pump timing

Closure of the pump plunger inlet port shall occur at a flywheel crank angle between 300° and 306° on the engine compression stroke when the fuel flow-rate-micrometer is set to a typical operating position and the variable timing device lever is at full advance (nearest to operator).

8.6 Fuel pump inlet pressure

A minimum fuel head is established by assembly of the fuel tanks (storage reservoirs) and flow-rate-measuring burette so that the discharge from them is 635 mm ± 25 mm above the centreline of the fuel injection pump inlet.

8.7 Direction of engine rotation

Clockwise rotation of the crankshaft shall occur when observed from the front of the engine.

8.8 Injection timing

This shall occur 13,0° b.t.d.c. for the sample and reference fuels.

8.9 Injector nozzle opening pressure

This shall be 10,3 MPa ± 0,34 MPa (1 500 psi ± 50 psi).

8.10 Injection flow rate

This shall be (13,0 ± 0,2) ml/min [(60 ± 1)s/13,0 ml].

8.11 Injector coolant passage temperature

This shall be 38 °C ± 3 °C (100 °F ± 5 °F).

8.12 Valve clearances

Engine running and hot clearance for both intake and exhaust valves shall be set to 0,20 mm ± 0,025 mm (0,008 in ± 0,001 in) measured under standard operating conditions with the engine running at equilibrium conditions on a typical diesel fuel oil.

8.13 Oil pressure

This shall be 172 kPa to 207 kPa (25 psi to 30 psi).

NOTE The CFR engine unit is normally equipped with a pressure gauge in psi.

8.14 Oil temperature

This shall be 57 °C ± 8 °C (135 °F ± 15 °F).

NOTE The CFR engine unit is normally equipped with a temperature gauge in degrees Fahrenheit.

8.15 Cylinder jacket coolant temperature

This shall be 100 °C ± 2 °C (212 °F ± 3 °F).

8.16 Intake air temperature

This shall be 66 °C ± 0,5 °C (150 °F ± 1 °F).

8.17 Basic ignition delay

This shall be 13,0° for the sample and the reference fuels.

8.18 Cylinder jacket coolant level

Treated coolant added to the cooling condenser/cylinder jacket to a level just observable in the bottom of the condenser sight-glass, with the engine cold prior to being operated, will typically provide the controlling engine, running and hot operating level.

8.19 Engine-crankcase lubricating oil level

The controlling engine-running and hot operating level of the oil in the crankcase shall be approximately mid-position in the crankcase sight-glass.

NOTE Oil added to the crankcase so that the level is near the top of the sight-glass, with the engine cold prior to being operated, will typically provide this condition.

8.20 Crankcase internal pressure

As measured by a gauge or manometer connected to an opening to the inside of the crankcase through a snubber orifice to minimize pulsations, the pressure shall be less than zero (a vacuum) and typically from 25 mm to 150 mm (1 in to 6 in) of water less than atmospheric pressure. Vacuum shall not exceed 254 mm (10 in) of water.

8.21 Exhaust back-pressure

As measured by a gauge or manometer connected to an opening in the exhaust surge tank or main exhaust stack through a snubber orifice to minimize pulsations, the static pressure should be as low as possible, but shall not create a vacuum nor exceed 254 mm (10 in) of water differential in excess of atmospheric pressure.

8.22 Exhaust and crankcase breather system resonance

The exhaust and crankcase breather piping systems shall have internal volumes and be of such length that gas resonance does not result.

8.23 Piston over-travel

Assembly of the cylinder to the crankcase shall result in the piston protruding above the top of the cylinder surface 0,381 mm ± 0,025 mm (0,015 in ± 0,001 in) when the piston is at t.d.c. Proper positioning is accomplished through the use of plastic or paper gaskets, available in several thicknesses, and selected by trial and error for assembly between the cylinder and crankcase deck.

8.24 Belt tension

The belts connecting the flywheel to the absorption motor shall be tightened, after the initial break-in so that, with the engine stopped, a 2,25 kg weight suspended from one belt halfway between the flywheel and motor pulley depresses the belt by approximately 12,5 mm.

8.25 Injector opening or release pressure

The pressure adjusting screw is adjustable and shall be set to release fuel at a pressure of 10,3 MPa ± 0,34 MPa. This setting shall be checked each time the nozzle is reassembled and after cleaning.

The use of a commercial injector nozzle bench tester is recommended. ASTM D613-15ae1, Annex A2, provides details which should apply for this document.

CAUTION — Personnel shall avoid contact with the spray pattern from injector nozzles because of the high pressure which can penetrate the skin. Spray pattern performance checks shall be made in a hood or where adequate ventilation ensures that inhalation of the vapours is avoided

8.26 Injector spray pattern

The injector nozzle spray pattern shall be checked for symmetry and characteristics by inspection of the impression of a single injection made on a piece of filter paper or other slightly absorbent material placed at a distance of approximately 76 mm (3 in) from the nozzle.

8.27 Indexing handwheel reading

8.27.1 General

Handwheel readings are a simple and convenient indication of engine compression ratio which is a critical variable in the cetane method of test.

NOTE The actual compression ratio is not important but an indication of compression ratio which relates to CN is a useful guide for selecting reference fuels to bracket the sample of diesel fuel oil. Indexing the handwheel when the engine is new, or any time the matched handwheel assembly/cylinder head combination is interchanged or mechanically reassembled, involves setting the variable compression plug, setting the micrometer drum and scale and setting the handwheel reading.

8.27.2 Basic setting of variable compression plug

Position the variable compression plug so that the flat surface is just visible and exactly in line with the edge of the threads of the combustion pickup hole, as verified with a straightedge.

8.27.3 Setting handwheel micrometer drum and scale

With the variable compression plug at the basic setting, set the handwheel drum and scale so that the handwheel reads 1,000 regardless of the bore diameter of the cylinder in use.

8.27.4 Setting handwheel reading

Tighten the small locking handwheel snugly by hand to ensure that the variable compression plug is held in place in the bore. Loosen the lock nut of the large handwheel and remove the locking “L” shaped key.

Turn the large handwheel so that the edge of the drum is in alignment with the 1,000 or other selected graduation on the horizontal scale.

Reinstall the L-shaped key in the nearest keyway slot of the large handwheel with the shorter leg in the handwheel. Any slight shifting of the handwheel to achieve slot line-up will not affect the indexing.

Tighten the lock nut hand-tight to hold the key in place.

Remove the locating screw from the drum and rotate the drum so that the zero graduation mark is in line with the selected reading.

Locate the screw hole in the drum which lines up with the handwheel hub hole and reinstall the locating screw.

Wrench tighten the large handwheel lock nut and recheck that the variable compression plug is properly positioned and the handwheel reading is in accordance with the selected value.

8.28 Basic compression pressure

At a handwheel reading of 1,000, the compression pressure for an engine operated at a standard barometric pressure of 101,3 kPa shall be 3 275 kPa ± 138 kPa (475 psi ± 20 psi) when read as quickly as possible after shutdown of the engine which has been at standard operating conditions. If the condition is not within limits, recheck the basic handwheel setting and, if necessary, perform mechanical maintenance.

For engines operated at other than standard barometric pressure, the compression pressure will typically be in proportion to the ratio of the local barometric pressure divided by standard barometric pressure. As an example, an engine located where the barometric pressure is 94,6 kPa would be expected to have a compression pressure of approximately 3 060 kPa ± 138 kPa according to Formula (1):

$$CP_L = 3\,275 \times P_L/P_{std} \quad (1)$$

where

CP_L is the compression pressure at the local barometer, in kilopascals;

P_L is the barometric pressure at the engine location, in kilopascals;

P_{std} is the standard barometric pressure, in kilopascals.

NOTE The ratio P_L/P_{std} is independent of measuring units, provided both elements are in the same units.

ASTM D613-15ae1, Annex A2 (Apparatus Assembly and Setting Instructions) provides instructions for checking compression pressure which shall apply for this document.

Compression pressure testing using a compression pressure gauge shall be completed in as short a period of time as possible, to avoid the possibility of combustion occurrence due to the presence of any small amount of oil in the gauge or combustion chamber.

8.29 Fuel pump lubricating oil level

With the engine stopped, sufficient engine-crankcase lubricating oil shall be added to the pump sump so that the level is at the mark on the dip stick.

As a result of engine operation, especially when the pump barrel/plunger assembly begins to wear, the level in the sump will increase due to fuel dilution as observed through a clear plastic side-plate on the pump housing. When the level rises appreciably, the sump should be drained and a fresh charge of oil added.

The recommended oil change interval is 50 engine-running hours.

8.30 Fuel pump timing gear-box oil level

With the engine stopped, unplug the openings on the top and at the mid-height of either side of the gear box. Add sufficient engine-crankcase lubricating oil through the top hole to cause the level to rise to the height of the side opening. Replace both openings.

NOTE The pump and timing gear box oil sumps are not connected to each other and the lubrication for the two is independent.

8.31 Setting instrumentation reference pickups

Positioning of the reference pickups is important to ensure that timing of the injection and ignition delay functions is uniform and correct. The two reference pickups, which are identical and interchangeable, are installed in a bracket positioned over the flywheel so that they clear the flywheel indicator which triggers them. Position each pickup in the bracket so that it is properly referenced to the flywheel indicator in accordance with the instructions supplied with the specific pickup. Measurement of pickup to flywheel indicator clearance, if required, shall be made using a non-magnetic feeler gauge.

8.32 Setting injector pickup gap

Set the air gap to typically 1 mm (0,040 in) with the engine stopped.

Individual pickups can require more or less air gap to obtain steady meter operation when the engine is ultimately running. However, too little gap can cause the ignition delay angle display to drive off scale.

9 Engine qualification

9.1 Engine conformity

The engine shall be commissioned in a manner that all settings and operating conditions are at equilibrium and in conformity with basic engine and instrument settings and standard operating conditions.

NOTE Engine warm-up requires typically 1 h to ensure that all critical variables are stable.

9.2 Checking performance on check fuels

This engine test does not have any satisfactory standardization fuel blend or blends to qualify the engine. Test one or more of the check fuels as a guide to engine performance.

Engine performance may be judged to be satisfactory if the CN rating obtained on a check fuel is within the tolerance range shown in Formula (2):

$$\text{Tolerance limits} = CN_{\mathrm{CF}} \pm 1{,}5 \times s_{\mathrm{CF}} \qquad (2)$$

where

CN_{CF} is the average CN of the check fuel calibration data;

1,5 is a selected tolerance limit factor (K) for normal distributions;

s_{CF} is the standard deviation of the check fuel calibration data.

NOTE This statistical tolerance limit factor (K), based on a sample size (n), permits an estimation of the percentage of engines that would be able to rate the check fuel within the calculated tolerance limits. Based on a calibration data set of 17 to 20 ratings, and a value of K = 1,5, it is estimated that, in the long run, in 19 cases out of 20, at least 70 % of the engines would rate the check fuel within the calculated tolerance limits.

9.3 Check in the case of nonconformity

If the results are outside this tolerance range, check all operating conditions, followed by mechanical maintenance which can require critical parts replacement.

The injector nozzle can be a very critical factor and this should be the first item checked or replaced.

10 Procedure

10.1 General

Check that all engine operating conditions are in conformity and equilibrated with the engine running on a typical diesel fuel oil.

NOTE ASTM D613-15ae1, Appendix X2 (Operating Techniques — Adjustment of Variables) provides additional useful details of engine operation and the adjustment of each of the individual operating variables for application of this document.

Always position the mode selector switch on the Mark II Ignition Delay Meter to “calibrate” before proceeding with fuel switching, so that violent meter-needle full-scale pegging does not occur. Calibration adjustment should be checked before each rating but never changed during a rating.

10.2 Sample introduction

Pour the sample into an empty fuel tank, rinse the fuel burette, purge any air from the fuel line to the pump and position the fuel-selector-valve to operate the engine on this fuel.

10.3 Fuel flow rate

Check the fuel flow rate and adjust the flow-rate-micrometer of the fuel pump to obtain 13 ml/min consumption. The final flow-rate measurement shall be made over a full 60 s ± 1 s period. Note the flow-rate-micrometer reading for reference.

10.4 Fuel injection timing

After establishing the fuel flow-rate, adjust the injection-timing-micrometer of the fuel pump assembly to obtain a 13,0° ± 0,2° injection timing reading. Note the injection-timing-micrometer reading for reference.

10.5 Ignition delay

Adjust the handwheel to change the compression ratio and obtain a 13,0° ± 0,2° ignition delay reading. Make the final handwheel adjustment in the clockwise direction (viewed from the front of the engine) to eliminate backlash in the handwheel mechanism and a potential error.

10.6 Equilibration

Achieve stable injection timing and ignition delay readings.

NOTE Stable readings typically occur within 5 min to 10 min.

The time used for the sample and each of the reference fuels should be consistent and shall not be less than 3 min.

10.7 Handwheel reading

Observe and record the handwheel reading as the representative indication of the combustion characteristic for this fuel sample.

10.8 Reference fuel no. 1

Select a reference fuel blend close to the CN of the sample.

If PRFs are being used for the rating, select a blend of hexadecane and heptamethylnonane having a CN close to the estimated CN of the sample.

If SRFs are being used for the rating and the CN of the sample is expected to be less than the CN of T fuel, select a SRF ("T fuel" and "U fuel") blend close to the CN of the sample.

If SRFs are being used for the rating and the CN of the sample is expected to be greater than CN of T fuel, select a blend of T fuel and hexadecane from Table 1 and calculate the CN of the selected blend in accordance with Formula (4).

Prepare a fresh batch of the selected reference fuel blend of at least 400 ml. Introduce reference fuel no. 1 to one of the unused fuel tanks, taking care to flush the fuel lines in the same manner as noted for the sample.

Perform the same adjustment and measurement steps used for the sample and record the resulting handwheel reading.

NOTE The handwheel reading versus CN relationship based on this procedure is engine- and overhaul-dependent but it can be established for each engine as testing experience is gained after each overhaul. A plot or table of handwheel readings provides a simple guide to selection of the reference fuel.

Table 1 — Reference fuel blends for samples with CN > T fuel

Blend	T fuel % (*V*/*V*)	Hexadecane % (*V*/*V*)
1	100	0
2	75	25
3	50	50
4	25	75
5	0	100

10.9 Reference fuel no. 2

Select another reference fuel blend which can be expected to result in a handwheel reading that causes the two reference-fuel handwheel readings to bracket that for the sample.

If PRFs are being used for the rating, select another blend of hexadecane and heptamethylnonane. The difference in hexadecane content between the two PRF blends shall not exceed 7 % (*V*/*V*). PRFs blends differing by 7 % (*V*/*V*) of hexadecane have defined CNs that differ by 5,95.

If SRFs are being used for the rating and the CN of the sample is expected to be less than the CN of T fuel, select another SRF (“T fuel” and “U fuel”) blend.

The difference between the two reference-fuel blends shall not exceed 5,6 CN. Typically, blends differing by 5 % (*V*/*V*) “T fuel” will span approximately 2,7 CN and those differing by 10 % (*V*/*V*) “T fuel” will span approximately 5,3 CN.

If SRFs are being used for the rating and the CN of the sample is expected to be greater than the CN of T fuel, select a blend of T fuel and hexadecane from Table 1 that is adjacent to the T fuel/ hexadecane blend tested above.

Prepare a fresh batch of the selected reference fuel blend of at least 400 ml. Introduce reference fuel no. 2 to the third fuel tank, taking care to flush the fuel lines in the same manner as noted for the sample. Perform the same adjustment and measurement steps used for the sample and reference fuel no. 1 and record the resulting handwheel reading.

Typically, the fuel-flow-rate should be the same for both reference fuels because they are sufficiently similar in composition.

10.10 Number of blends of reference fuels

If the handwheel reading for the sample is bracketed by those of the reference fuel blends, calculate the CN, in accordance with Formula (3), from the handwheel readings of the sample and each of the bracketing reference fuels and continue the test. Otherwise try an additional reference fuel blend(s) until this requirement is satisfied.

10.11 Repeat readings

After operation on a satisfactory second reference fuel blend, perform the necessary steps to rerun reference fuel no. 1, then the sample, and finally reference fuel no. 2. For each fuel, be certain to check all parameters carefully and allow operation to reach equilibrium before recording the handwheel readings. The fuel switching shall be as shown in Figure 4, sequence A.

Sample and reference fuel reading sequence A

Handwheel readings

Reference fuel no. 1		2		4		
Sample	1				5	
Reference fuel no. 2			3			6

Sample and reference fuel reading sequence B

Handwheel readings

Reference fuel no. 1			3		5	
Sample		2				6
Reference fuel no. 2	1			4		

Figure 4 — Sample and reference fuel reading sequence

Calculate the CN, in accordance with Formula (3), from the second set of handwheel readings from the sample and each of the bracketing reference fuels. The CN calculated from the average of the two handwheel readings for the sample fuel and the average of the two handwheel readings for each of the