International Standard

ISO 8217

Products from petroleum, synthetic and renewable sources — Fuels (class F) — Specifications of marine fuels

Produits d'origine pétrolière, synthétique ou renouvelable — Combustibles (classe F) — Spécifications des combustibles pour la marine

Seventh edition
2024-05

Reference number
ISO 8217:2024(en)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

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 document 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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

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 28, *Petroleum and related products, fuels and lubricants from natural or synthetic sources*, Subcommittee SC 4, *Classifications and specifications*.

This seventh edition cancels and replaces the sixth edition (ISO 8217:2017), which has been technically revised.

The main changes are as follows:

— terms and definitions (Clause 3) have been updated;

— the Scope and the general requirements in Clause 5 have been amended;

— Tables 2 and 3 have been added;

— former Table 2 has been modified and has become Table 4;

— changes to the distillate fuels, including the following:

  — the requirement to report the fatty acid methyl ester(s) content (FAME) of DF grades has been changed, allowing up to 100 %;

  — the distinction between winter and summer quality for cloud point and cold filter plugging point has been removed;

  — the requirement to report the net heat of combustion for DF grades has been added;

  — a minimum cetane number requirement for DF grades has been added;

  — the requirement for oxidation stability for DF grades has been added;

— Clauses 9 and 10 have been added;

— new Annexes F, H and K have been added (the former Annex F has become Annex G, the former Annex G has become Annex I, and the former Annex H has become Annex J);

— existing annexes have been reviewed and updated.

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

This document was prepared in cooperation with ship owners, ship operators, shipping associations, national standards bodies, classification societies, fuel testing services, engine designers, fuel treatment equipment manufacturers, marine fuel suppliers, fuel additive suppliers and the petroleum industry to meet the requirements for marine fuels supplied on a world-wide basis for consumption on board ships.

The increased focus on environmental concerns and legislation to address them is leading to a transition in the nature of marine fuels. There is a shift away from marine fuels supplied from traditional oil products derived from the processing of petroleum crude, and a shift towards oil products derived from synthetic and renewable, recycled or alternative sources. This document takes into consideration the diverse nature of these fuels and incorporates a number of categories of distillate and residual fuels, even though it is possible that not all categories are available in every supply location. This document facilitates the transition, however sustainability aspects and accounting are not within the scope.

The categories of fuel in this document have been classified according to ISO 8216-1 and include the distillate fuel categories DMX, DMA, DMB, DMZ, DFA, DFB, DFZ and the residual fuel categories RMA, RME, RMG, RMK and RF.

In the instances where a fuel, which does not conform exactly to any of these distillate or residual fuel categories, is offered to a purchaser, the fuel characteristics or limits can be agreed between the buyer and the seller, and defined by both a category of fuel given by this document, together with any different or additional fuel characteristics or limits, as necessary to adequately define that fuel.

This document specifies the permitted minimum flash point limits following the provisions given in the SOLAS Convention.[3]

MARPOL Annex VI,[4] which controls air pollution from ships, includes a requirement that either the fuel does not exceed a specified maximum sulfur content, or an approved equivalent alternative means is used. During the lifetime of this document, regional and/or national authorities can introduce their own local emission requirements, which can impact the allowable sulfur content. It is the buyer’s and the user’s responsibility to establish which statutory requirements are necessary to meet and specify on that basis the corresponding maximum fuel sulfur content to the seller.

Products from petroleum, synthetic and renewable sources — Fuels (class F) — Specifications of marine fuels

WARNING — The handling and use of products specified in this document can be hazardous if precautions as mentioned in the Safety Data Sheet (SDS) are not taken into consideration when product is handled. This document does not purport to address all the safety and health considerations that can be associated with its use. It is the responsibility of the users of this document to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.

1 Scope

This document in its entirety defines the general requirements and specifications for fuels used in marine diesel engines and boilers, prior to onboard fuel handling (storage, settling, centrifuging, filtration, heating) before use.

For the purposes of this document, the term "fuels" comprises of the following:

— hydrocarbons from petroleum crude oil, oil sands and shale oil;

— synthetic hydrocarbons, renewable hydrocarbons or hydrocarbons from recycled sources, with molecular structures that are indistinguishable from petroleum hydrocarbons;

— fatty acid methyl ester (FAME), where permitted as specified in this document;

— blends of any of the above, where permitted as specified in this document.

The general requirements and specifications for fuels in this document can also be applied to fuels used in stationary diesel engines of the same or similar type as those used for marine purposes.

This document specifies seven categories of distillate fuels, one of which is for diesel engines used for emergency purposes. It also specifies four categories of residual fuels for sulfur content at or below 0,50 % by mass, five categories of residual fuels containing FAME and five categories of residual fuels for sulfur content exceeding 0,50 % by mass.

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 2719, *Determination of flash point — Pensky-Martens closed cup method*

ISO 3015, *Petroleum and related products from natural or synthetic sources — Determination of cloud point*

ISO 3016, *Petroleum and related products from natural or synthetic sources — Determination of pour point*

ISO 3104, *Petroleum products — Transparent and opaque liquids — Determination of kinematic viscosity and calculation of dynamic viscosity*

ISO 3675, *Crude petroleum and liquid petroleum products — Laboratory determination of density — Hydrometer method*

ISO 3733, *Petroleum products and bituminous materials — Determination of water — Distillation method*

ISO 4259-2, *Petroleum and related products — Precision of measurement methods and results — Part 2: Interpretation and application of precision data in relation to methods of test*

ISO 4264, *Petroleum products — Calculation of cetane index of middle-distillate fuels by the four variable equation*

ISO 5165, *Petroleum products — Determination of the ignition quality of diesel fuels — Cetane engine method*

ISO 6245, *Petroleum products — Determination of ash*

ISO 8754, *Petroleum products — Determination of sulfur content — Energy-dispersive X-ray fluorescence spectrometry*

ISO 10307-1, *Petroleum products — Total sediment in residual fuel oils — Part 1: Determination by hot filtration*

ISO 10307-2, *Petroleum products — Total sediment in residual fuel oils — Part 2: Determination using standard procedures for ageing*

ISO 10370, *Petroleum products — Determination of carbon residue — Micro method*

ISO 10478, *Petroleum products — Determination of aluminium and silicon in fuel oils — Inductively coupled plasma emission and atomic absorption spectroscopy methods*

ISO 12156-1, *Diesel fuel — Assessment of lubricity using the high-frequency reciprocating rig (HFRR) — Part 1: Test method*

ISO 12185, *Crude petroleum, petroleum products and related products — Determination of density — Laboratory density meter with an oscillating U-tube sensor*

ISO 12205, *Petroleum products — Determination of the oxidation stability of middle-distillate fuels*

ISO 12937, *Petroleum products — Determination of water — Coulometric Karl Fischer titration method*

ISO 14596, *Petroleum products — Determination of sulfur content — Wavelength-dispersive X-ray fluorescence spectrometry*

ISO 14597, *Petroleum products — Determination of vanadium and nickel content — Wavelength-dispersive X-ray fluorescence spectrometry*

EN 116, *Diesel and domestic heating fuels — Determination of cold filter plugging point — Stepwise cooling bath method*

EN 14077, *Petroleum products — Determination of organic halogen content — Oxidative microcoulometric method*

EN 14078, *Liquid petroleum products — Determination of fatty methyl ester (FAME) content in middle distillates - Infrared spectrometry method*

EN 14214, *Liquid petroleum products — Fatty acid methyl esters (FAME) for use in diesel engines and heating applications — Requirements and test methods*

EN 15195, *Liquid petroleum products — Determination of ignition delay and derived cetane number (DCN) of middle distillate fuels by combustion in a constant volume chamber*

EN 15751, *Automotive fuels — Fatty acid methyl ester (FAME) fuel and blends with diesel fuel — Determination of oxidation stability by accelerated oxidation method*

EN 15940, *Automotive fuels — Paraffinic diesel fuel from synthesis or hydrotreatment — Requirements and test methods*

EN 16329, *Diesel and domestic heating fuels — Determination of cold filter plugging point — Linear cooling bath method*

EN 16715, *Liquid petroleum products — Determination of ignition delay and derived cetane number (DCN) of middle distillate fuels — Ignition delay and combustion delay determination using a constant volume combustion chamber with direct fuel injection*

EN 17155, *Liquid petroleum products — Determination of indicated cetane number (ICN) of middle distillate fuels — Primary reference fuels calibration method using a constant volume combustion chamber*

ASTM D240, *Standard Test Method for Heat of combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter*

ASTM D664, *Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration*

ASTM D2622, *Standard Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry*

ASTM D4294, *Standard Test Method for Sulfur in Petroleum and Petroleum Products by Energy Dispersive X-ray Fluorescence Spectrometry*

ASTM D6751, *Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels*

ASTM D6890, *Determination of Ignition Delay and Derived Cetane Number (DCN) of Diesel Fuel Oils by Combustion in a Constant Volume Chamber*

ASTM D7371, *Standard Test Method for Determination of Biodiesel (Fatty Acid Methyl Esters) Content in Diesel Fuel Oil Using Mid Infrared Spectroscopy (FTIR-ATR-PLS Method)*

ASTM D7668, *Standard Test Method for Determination of Derived Cetane Number (DCN) of Diesel Fuel Oils—Ignition Delay and Combustion Delay Using a Constant Volume Combustion Chamber Method*

ASTM D7963, *Standard Test Method for Determination of Contamination Level of Fatty Acid Methyl Esters in Middle Distillate and Residual Fuels Using Flow Analysis by Fourier-Transform Infrared Spectroscopy-Rapid Screening Method*

ASTM D8183, *Standard Test Method for Determination of Indicated Cetane Number (ICN) of Diesel Fuel Oils using a Constant Volume Combustion Chamber—Reference Fuels Calibration Method*

IP 470, *Determination of aluminium, silicon, vanadium, nickel, iron, calcium, zinc and sodium in residual fuel oil by ashing, fusion and atomic absorption spectrometry*

IP 500, *Determination of the phosphorus content of residual fuels by ultra-violet spectrometry*

IP 501, *Determination of aluminium, silicon, vanadium, nickel, iron, sodium, calcium, zinc and phosphorus in residual fuel oil by ashing, fusion and inductively coupled plasma emission spectrometry*

IP 570, *Determination of hydrogen sulfide in fuel oils — Rapid liquid phase extraction method*

IP 631, *Determination of the contamination level of fatty acid methyl esters in middle distillate and residual fuels using Flow Analysis by Fourier Transform Infrared Spectroscopy — Rapid Screening Method*

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
ultra low sulfur fuel oil
ULSFO
marine fuel with a maximum sulfur content of 0,10 % by mass

3.2
very low sulfur fuel oil
VLSFO
marine fuel with a maximum sulfur content of 0,50 % by mass

3.3
high sulfur fuel oil
HSFO
marine fuel with a sulfur content exceeding 0,50 % by mass

3.4
fatty acid methyl ester
FAME
ester derived by transesterification or esterification of fats and oils of vegetal or animal origin

Note 1 to entry: See Annex A for information on bio-based liquid fuels including fatty acid methyl ester(s).

3.5
bio-based
wholly or partly derived from *biomass* (3.7)

[SOURCE: ISO 16559:2022, 3.23, modified — “wholly or partly” added.]

3.6
biofuel
fuel produced directly or indirectly from *biomass* (3.7)

[SOURCE: ISO 16559:2022, 3.27, modified — “solid, liquid or gaseous” deleted.]

3.7
biomass
material of biological origin excluding material embedded in geological formations and/or fossilized

[SOURCE: ISO 16559:2022, 3.32, modified — Example and Note 1 to entry deleted.]

3.8
biodiesel
generic name for *bio-based* (3.5) fuel with properties similar to diesel or diesel containing bio-based blends

Note 1 to entry: The term is often used to describe *fatty acid methyl ester (FAME)* (3.4), but it is not exclusive to describe FAME or fuel containing FAME.

3.9
bio-distillate marine fuel
blend of a petroleum distillate marine fuel with *bio-based* (3.5) liquid fuel

Note 1 to entry: DF grade is used to describe bio-distillate marine fuel grade.

3.10
bio-residual marine fuel
blend of a petroleum residual marine fuel with *bio-based* (3.5) liquid fuel

Note 1 to entry: RF grade is used to describe bio-residual marine fuel grade.

3.11
synthetic hydrocarbon
liquid hydrocarbon obtained from synthesis

3.12
renewable hydrocarbon
liquid hydrocarbon produced from renewable resources

Note 1 to entry: *Biomass* (3.7) is an example of a renewable resource.

3.13
paraffinic diesel fuel
liquid hydrocarbons obtained by synthesis or hydrotreatment

EXAMPLE Synthetic diesel, renewable diesel, *hydrotreated vegetable oil (HVO)* (3.14).

3.14
hydrotreated vegetable oil
HVO
liquid hydrocarbon produced from renewable feedstock by hydrotreatment

Note 1 to entry: Also called renewable diesel or *paraffinic diesel fuel* (3.13).

3.15
gas to liquid
GTL
liquid hydrocarbons obtained by the conversion of natural gas or other fossil gaseous hydrocarbons

3.16
biomass to liquid
BTL
liquid hydrocarbons obtained by the conversion of *biomass* (3.7) via thermochemical processes (gasification)

3.17
power to liquid
PtL
liquid hydrocarbons obtained by conversion of electricity

3.18
stability
stability of a residual fuel
resistance to the breakdown and precipitation of asphaltenic sludge despite being subjected to forces, such as thermal and ageing stresses, while stored, handled and treated under normal operating conditions

[SOURCE: ISO/PAS 23263:2019, 3.1, modified — “handled and stored” replaced by “stored, handled and treated”.]

3.19
compatibility
ability of two or more fuels to be commingled at a defined ratio without evidence of material separation, which can result in the formation of multiple phases, such as flocculation, where dispersed particles of asphaltenes form bigger clusters which can lead to sludge formation

[SOURCE: ISO/PAS 23263:2019, 3.2, modified — “could” and “might” replaced by “can”.]

3.20
cloud point
CP
temperature at which a cloud of wax crystals first appears in a transparent liquid when it is cooled under specified conditions

[SOURCE: ISO/PAS 23263:2019, 3.4]

3.21
cold filter plugging point
CFPP
highest temperature at which a given volume of distillate fuel fails to pass through a standardized filtration device in a specified time when cooled under standardized conditions

[SOURCE: ISO/PAS 23263:2019, 3.5]

3.22
pour point
PP
lowest temperature at which a fuel will continue to flow when it is cooled under specified standard conditions

[SOURCE: ISO/PAS 23263:2019, 3.6]

3.23
existent total sediment
TSE
sum of insoluble organic and inorganic material, separated from the bulk of the sample by filtration through a specified filter, and also insoluble in a predominantly paraffinic solvent

Note 1 to entry: TSE is obtained by hot filtration.

[SOURCE: ISO 10307-1:2009, 3.1, modified — “existent” added to the term; “TSE” added as a preferred term; Note 1 to entry added.]

3.24
potential total sediment
TSP
total sediment after ageing a sample of residual fuel for 24 h at 100 °C under prescribed conditions

[SOURCE: ISO 10307-2:2009, 3.1, modified — “TSP” added as a preferred term; “determined by ISO 10307-1,” deleted from the definition.]

3.25
accelerated total sediment
TSA
total sediment after dilution of a sample of residual fuel with hexadecane in the ratio of 1 ml per 10 g of sample under carefully controlled conditions, followed by storage for 1 h at 100 °C

[SOURCE: ISO 10307-2:2009, 3.2, modified — “TSA” added as a preferred term; “determined by ISO 10307-1,” deleted from the definition.]

3.26
unrefined used lubricating oil
unrefined ULO
oil that has not been processed and filtered to remove lube oil additives and contaminants

Note 1 to entry: Refined used lubricating oil can be suitable as blend stock for marine fuel.

4 Application and sampling

This document specifies the required properties for a fuel at the time and place of custody transfer, prior to onboard handling and treatment.

NOTE Appropriate guidance about fuel treatment systems for diesel engines can be found in Reference [5].

Sampling of a fuel is an important part of the fuel’s quality verification and should be carried out in accordance with ISO 13739 or an equivalent national standard. The sample shall be representative for the entire quantity of fuel loaded onto the receiving ship and may be taken in any location agreed between the parties.

Testing of the fuel shall be carried out in accordance with the test methods given in Table 1, Table 2, Table 3 or Table 4, as appropriate.

5 General requirements

5.1 The fuel as supplied shall be homogeneous and conform to the characteristics and limits given in Table 1, Table 2, Table 3 or Table 4, as appropriate, when tested in accordance with the methods specified. The test methods and references listed in Tables 1, 2, 3 and 4 shall apply.

The fuel composition shall consist of:

— predominantly hydrocarbons from petroleum sources;

or

— hydrocarbons, with molecular structures that are indistinguishable from petroleum hydrocarbons, derived from:

  — synthetic or renewable sources such as paraffinic diesel e.g. hydrotreated vegetable oil (HVO), gas to liquid (GTL), biomass to liquid (BTL) and power to liquid (PtL);

  — co-processing of renewable or recycled feedstock at refineries with petroleum feedstock;

or

— fatty acid methyl ester (FAME) as defined in this document;

or

— a mixture of the above.

With regards to FAME, there are grades in this document for fuels not including FAME and for fuels including an agreed percentage of FAME.

For fuels not including FAME:

— The DMA, DMZ, DMB and RM grades shall not include FAME other than a de minimis level. In the context of this document, de minimis amount of FAME means an amount not exceeding approximately 0,5 %. DMX shall be free of FAME.

  NOTE See Annex A for further information.

For fuels with an agreed FAME content:

— the DF and RF grades are fuels including an amount of FAME where the FAME used for blending of the fuel shall be in accordance with the requirements of EN 14214, except for

  a) sulfur content, which is a statutory requirement;

  b) cloud point (CP) and cold filter plugging point (CFPP) requirements as these are covered by the final marine blend specifications in Table 1 of this document;

or ASTM D6751, except for sulfur content.

— The FAME content of the fuel (percentage by mass or volume) and the FAME standards (EN 14214 or ASTM D6751) shall be reported prior to the time of the delivery and in line with original equipment manufacturer's guidance. In the event that other national FAME standards are offered, see Annex A.

5.2 The fuel shall be free from any materials, including added substances and chemical species, at a concentration that causes the fuel to be unacceptable for use by way of:

a) jeopardizing the safety of the ship; or

b) adversely affecting the performance of the machinery; or

c) being harmful to personnel.

NOTE See Annex B for information on the composition of marine fuels.

5.3 The fuel shall be free from inorganic acids and organic chlorides (chlorinated hydrocarbons).

NOTE 1 See 6.6 and 6.17.

NOTE 2 See Annex B for information on the composition of marine fuels.

5.4 Subject to the requirements of 5.1, 5.2 and 5.3, additives that improve some aspects of the fuel's characteristics or performance are permitted.

6 Test methods

6.1 Density

In case of disagreement concerning density, all parties shall agree, prior to additional testing, upon the test method to be used.

6.2 CCAI

The calculated carbon aromaticity index (CCAI) shall be as specified in Table 2, Table 3 or Table 4.

The CCAI value, I_{CCA}, is calculated in accordance with Lewis, et al.[6], using Formula (1):

$$I_{\mathrm{CCA}} = \rho_{15} - 81 - 141 \cdot \lg[\lg(v + 0{,}85)] - 483 \cdot \lg\left[\frac{T + 273}{323}\right] \quad (1)$$

where

ρ_{15} is the density at 15 °C, expressed in kilograms per cubic metre;

v is the kinematic viscosity at temperature T, expressed in square millimetres per second;

T is the temperature, expressed in degrees Celsius, at which the kinematic viscosity is determined.

Density, ρ_{15}, and viscosity, v, shall be determined in accordance with the test methods specified in Tables 2, 3 or 4.

NOTE 1 See Annex C for information on ignition characteristics of residual marine fuels.

NOTE 2 For engines and/or applications where the ignition quality is known to be particularly critical, Annex C provides a basis for buyers and sellers of residual fuels to agree on tighter ignition quality characteristics.

NOTE 3 For some fuels when blending at or close to the maximum density, the CCAI limit restricts the combination of density and viscosity.

NOTE 4 CCAI was originally developed for petroleum-derived fuels. As such, its applicability to bio-residual marine fuels and the density/viscosity correlation to ignition performance has not been established.

6.3 Sulfur

Table 1, Table 3 and Table 4 do not set sulfur limits, since the buyer is responsible for specifying the maximum sulfur content when ordering the fuel, based on the regulatory requirement applicable to where the fuel will be used or any existing exhaust gas cleaning system requirement. For fuels ordered to Table 2, the buyer shall still specify the required sulfur content to the seller.

Sulfur test precision for fuels containing FAME has not been established for the test methods specified in ISO 8754 and ISO 14596. The sulfur test precision for distillate fuels containing FAME has been established for the test method specified in ASTM D4294.

The reference test method shall be as specified in ISO 8754 for distillate marine (DM) and residual marine (RM) fuels, in ASTM D4294 for distillate fuels including FAME (DF), and in ASTM D4294 or ASTM D2622 for residual fuels including FAME (RF).

In case of disagreement concerning sulfur content, all parties shall agree, prior to additional testing, upon the same sulfur certified reference material, and for RF grades upon the reference test method.

6.4 Flash point

The International Convention for Safety of Life at Sea (SOLAS)[3] sets the flash point limit for all fuels at 60 °C minimum. An exception to this is DMX, which has a flash point limit of 43 °C minimum.

Fuels have the potential to produce a flammable atmosphere in a tank headspace, even when stored at a temperature below the measured flash point. Appropriate precautions are necessary, therefore, to ensure the safety of the ship and personnel. Further information and advice on precautionary measures are given in References [7] to [9].

The flash point is not a physical constant, but is dependent on the test method, the apparatus and the procedure used.

The flash point for fuels in Table 1 shall be determined in accordance with ISO 2719, Procedure A. For 100 % FAME, ISO 2719, Procedure C shall be applied. The flash point of fuels in Table 2, Table 3 and Table 4 shall be determined in accordance with ISO 2719, Procedure B.

6.5 Hydrogen sulfide

The reference test method shall be IP 570, Procedure A.

WARNING — Hydrogen sulfide (H_2S) is a highly toxic gas. Exposure to any significant vapour concentrations is hazardous and, in extreme cases, can be fatal. It is critical that ship owners, operators and other responsible parties continue to maintain appropriate safety practices designed to protect the crew and others who can be exposed to H_2S vapours.

NOTE See Annex D for further information.

6.6 Acid number

The fuel shall be free of inorganic acids. The acid number of DM and RM fuels shall be determined in accordance with ASTM D664, Procedure A. The acid number of DF and RF fuels shall be tested in accordance with ASTM D664, Procedure B.

In case of dispute concerning acid number, all parties shall agree, prior to additional testing, upon which procedure of ASTM D664 shall be used.

NOTE See Annex E for further information.

6.7 Oxidation stability

The oxidation stability shall be as specified in Table 1.

For fuels not including FAME or containing less than 2 % of FAME by volume, oxidation stability shall be tested in accordance with ISO 12205.

For DF grades, oxidation stability shall be tested in accordance with EN 15751.

NOTE See Annex A for further information.

6.8 Total sediment

6.8.1 Existent total sediment

If the appearance of DMB or DFB is assessed as not clear and bright (see 6.11), the total sediment by hot filtration, typically called existent total sediment (TSE) shall be determined in accordance with the test method ISO 10307-1.

For the fuels listed in Table 2 and Table 3, the existent total sediment shall be reported.

NOTE The International Council on Combustion Engines (CIMAC) has developed a guideline regarding the interpretation of total sediment test results.[10]

6.8.2 Accelerated and potential total sediment

For the fuels listed in Table 2 and Table 4, statistical analysis of data gathered since 2020 on residual type very low sulfur fuel oil (VLSFO) and high sulfur fuel oil (HSFO) shows that HSFO are more sensitive to chemical ageing whereas VLSFO with viscosity typically below 200 mm^2/s (200 cSt) at 50 °C are sensitive to both thermal and chemical ageing, due to the different nature of the fuels.

For fuels in Table 3, there is insufficient data at the time of writing to assess the sensitivity of bio-residual marine fuels to thermal versus chemical ageing.

Therefore, the following applies:

— For the fuels listed in Tables 2 and 3 only potential total sediment (TSP) shall be used.

— Accelerated total sediment (TSA) shall be reported for all fuels listed in Tables 2 and 3.

— For the fuels listed in Table 4, either of the standard procedures for ageing in ISO 10307-2 can be used: the TSA or TSP test. The reference test method for the fuels listed in Table 4 shall be the TSP in accordance with ISO 10307-2.

NOTE 1 See Annex H for information on stability of residual fuels.

NOTE 2 The International Council on Combustion Engines (CIMAC) has developed a guideline regarding the interpretation of total sediment test results.[10]

6.9 Fatty acid methyl ester(s)

The test methods specified in ASTM D7963 and IP 631 are applicable to all DM and RM, DF and RF grades. The test method specified in EN 14078 is not applicable to RM and RF grades at the time of preparation of this document. Test method specified in ASTM D7371 is applicable to DF grades.

The reference test method shall be as specified in EN 14078 for DM and DF grades, and ASTM D7963 or IP 631 for RM and RF grades. In case of disagreement concerning FAME content, all parties shall agree, prior to additional testing, upon the test method to be used.

FAME content can be reported in content by mass or content by volume according to the test method used. Alternatively, suppliers can report the FAME content by blend ratio on a mass or volume basis.

NOTE See Annex A.

6.10 Pour point/cloud point/cold filter plugging point

For distillate fuels, the buyer should confirm that the cold flow characteristics (pour point, cloud point, cold filter plugging point) are suitable for the ship's design and intended voyage.

NOTE 1 See Annex F for information on cold flow characteristics.

NOTE 2 More information can be found in the CIMAC guideline for managing cold flow properties of marine fuels.[11]

6.11 Appearance/water

For distillate fuels, the appearance of a sample shall be assessed by visual inspection in good light, free from glare and shadow, at a sample temperature between 20 °C and 25 °C.

DMX, DMA, DFA, DMZ and DFZ shall appear clear and bright. It has been reported that in some countries, these grades of fuel are dyed (e.g. black) and not transparent. This affects the compliance with the requirement for clear and bright appearance and, in such circumstances, the water content shall not exceed 200 mg/kg, as determined by the Coulometric Karl Fischer titration method in accordance with ISO 12937.

If the appearance of DMB and DFB affords visual inspection and appears clear and bright, then testing for existent total sediment and for water is not required. If the appearance is not clear and bright, the water content shall be determined in accordance with ISO 3733.

6.12 Lubricity

The lubricity shall be as specified in Table 1.

NOTE The lubricity limit is based on the existing requirements for high-speed automotive and heavy-duty industrial diesel engines.

6.13 Vanadium

The reference test method shall be IP 501.

NOTE See Annex G for information on ash.

6.14 Sodium

The reference test method shall be IP 501.

NOTE See Annex G for information on ash.

6.15 Aluminium plus silicon

The aluminium plus silicon limits in Tables 2, 3 and 4 restrict the catalyst fines to levels at which fuel treatment plants onboard (settling tanks, centrifuges and filters), when operated in accordance with both good practice and the manufacturers' operating procedures, are expected to reduce the catalyst fines to an acceptable level at the engine inlet.[5][12]

The reference test method shall be IP 501.

6.16 Unrefined used lubricating oil

The fuel shall be free of unrefined used lubricating oil (ULO). In the context of this document, a fuel can be considered to contain unrefined ULO when combinations of calcium and zinc or calcium and phosphorus are above the levels specified in Tables 2, 3 and 4. The reference test method shall be IP 501.

NOTE See Annex I.

6.17 Organic chlorides

A fuel shall be considered to be free from organic chlorides (chlorinated hydrocarbons) when the total organic halogen content as chlorine is not exceeding 50 mg/kg when tested in accordance with EN 14077.

NOTE See Annex B for information on the composition of marine fuel.

6.18 Specific energy

The gross and net specific energy of marine fuels not containing FAME can be calculated as given in Annex J.

For fuels containing FAME, gross and net specific energy cannot be calculated using the formulae in Annex J but can be measured using ASTM D240.

6.19 Cetane index/cetane number

FAME blends are outside the scope of the cetane index (CI) test method specified in ISO 4264. Therefore, for DF grades, the cetane number (CN), or the derived cetane number (DCN)/indicated cetane number (ICN) shall be measured.

The test methods specified in ISO 5165 can be used for the CN; ASTM D6890 or EN 15195 and ASTM D7668 or EN 16715 can be used for the DCN; and ASTM D8183 or EN 17155 can be used for the ICN.

NOTE In case CN, DCN or ICN are not available or precise knowledge of CN is not required, CI can provide guidance. When at or above 40, the CN requirement will mostly be met.

In case of dispute, the reference test method for DF grades shall be as specified in ISO 5165.

The minimum cetane number for DF grades as specified in Table 1 is based on the direct correlation between CI and CN from distillate marine fuels not containing FAME or ignition improver additives.

CN is a required input for some electronically controlled engines. In case this is not a requirement, the decision can be made not to test for CN and use CI only. The original equipment manufacturers' recommendations should be considered.

7 Characterization of marine fuels

Annex K provides an indicator of the aromatic or paraffinic nature of a petroleum-derived marine residual fuel that does not contain FAME.

8 Precision and interpretation of test results

The test methods specified in Table 1 for DM grades, as well as the test methods in Table 2 and Table 4, contain a statement of precision (repeatability and reproducibility).

For DF grades in Table 1 and for all grades in Table 3, the test methods listed have proven to be relevant and can be used. However, at the time of publication of this document, it is possible that precision statements are not available for some test methods.

The determination of reproducibility for CCAI should be according to Annex C.

In cases of dispute, the procedures specified in ISO 4259-2 for resolving the dispute and interpreting the results based on test method precision shall be used.

NOTE More information is provided in the CIMAC guideline on the interpretation of marine fuel oil analysis test results.[13]

9 Requirements for marine fuel consisting of 100 % FAME or paraffinic diesel fuel

9.1 Marine fuel consisting of 100 % FAME

In cases where marine fuel consisting of 100 % FAME is used, the following requirements apply:

— FAME shall meet EN 14214 [except for sulfur, cloud point (CP) and cold filter plugging point (CFPP) requirements] or ASTM D6751 (except for sulfur requirement);

— the product as delivered shall meet the applicable grade in Table 1.

Special attention should be given to the cold flow properties.

9.2 Marine fuel consisting of 100 % paraffinic diesel fuel

In cases where marine fuel consisting of 100 % paraffinic diesel fuel is used, the following requirements apply:

— paraffinic diesel fuel shall meet EN 15940 (except for requirements in EN 15940:2023, Tables 2 and 3);

— the product as delivered shall meet the applicable grade in Table 1.

Special attention should be given to the flash point since EN 15940 has a lower minimum flash point than specified in Table 1. Paraffinic diesel fuel can have a higher cetane number. This can impact the combustion temperature and pressure.

10 Generally applicable requirements and related test methods

10.1 General

When choosing the desired fuel grade, use the applicable table among Tables 1 to 4, find the required grade, and specify the grade when ordering.

When tested in accordance with the applicable test methods specified in Table 1, Table 2, Table 3 or Table 4, marine fuel shall be in accordance with the limits specified in the applicable table.

NOTE Paraffinic diesel fuel is considered as a petroleum distillate and does not impact the categorization of blends with paraffinic diesel fuel. For information on 100 % paraffinic diesel fuel, see Clause 9.

10.2 Distillate and bio-distillate marine fuels containing FAME

Marine DM grades, ultra low sulfur fuel oil (ULSFO)-distillate type marine fuels and marine DF grades containing FAME up to 100 % shall comply with the specifications given in Table 1.

NOTE DF grades can contain up to 100 % FAME. DM grades can contain up to 100 % paraffinic diesel fuel (see Clause 9).

10.3 Residual marine fuels with sulfur content below or at 0,50 % by mass

Residual type marine fuels having a maximum sulfur content of either 0,50 % by mass (VLSFO) or 0,10 % by mass (ULSFO) shall comply with the specifications given in Table 2. The grade name includes a reference to the sulfur content.

10.4 Bio-residual marine fuels

All residual type fuels (ULSFO, VLSFO and HSFO) containing FAME shall comply with the specifications given in Table 3.

NOTE For information on 100 % FAME, see Clause 9.

10.5 Residual marine fuels with sulfur content above 0,50 % by mass

Residual type marine fuels having a sulfur content above 0,50 % by mass (HSFO) for use on ships in conjunction with approved equivalent alternative abatement technologies such as exhaust gas cleaning systems (SO_x scrubbers) shall comply with the specifications given in Table 4.

Table 1 — Distillate and bio-distillate marine fuels

Characteristics	Unit	Limit	Category ISO-F-[m]							Test method(s) and references
			DMX	DMA	DFA	DMZ	DFZ	DMB	DFB	
General requirements			Clauses 5 to 10							
Kinematic viscosity at 40 °C	mm^2/s[a]	max.	5,500	6,000				11,00		ISO 3104
		min.	1,400	2,000		3,000		2,000		
Density at 15 °C	kg/m^3	max.	—	890,0				900,0		ISO 3675 or ISO 12185; see 6.1
Cetane index		min.	45,0	40,0	—	40,0	—	35,0	—	ISO 4264; see 6.19
Cetane number		min.	—	—	40,0	—	40,0	—	35,0	ISO 5165 or ASTM D6890/EN 15195 or ASTM D7668/EN 16715 or ASTM D8183/EN 17155; see 6.19
Sulfur content by mass	%	max.	Statutory requirements[b]							ISO 8754 or ISO 14596, ASTM D4294; see 6.3
Flash point	°C	min.	43,0	60,0						ISO 2719; see 6.4
Hydrogen sulfide	mg/kg	max.	2,00							IP 570; see 6.5
Acid number[c]	mg KOH/g	max.	0,5							ASTM D664; see 6.6
Existent total sediment (TSE) content by mass	%	max.	—					0,10[d]		ISO 10307-1; see 6.8

[a] 1 mm^2/s = 1 cSt.

[b] The buyer is expected to define the maximum sulfur content according to relevant statutory limitations.

[c] See Annex E.

[d] If the sample is not clear and bright, the existent total sediment and water tests shall be required. See 6.8 and 6.11.

[e] If the sample is not clear and bright, the test cannot be undertaken and therefore, compliance with this limit cannot be shown.

[f] See 5.1 and Annex A. De minimis level amount of FAME means an amount not exceeding approximately 0,5 %.

[g] The seller shall report the FAME content according to the test method given or as per blend ratio (stating whether it is a mass or volume ratio).

[h] The value shall be reported according to the test method given.

[i] Pour point cannot guarantee operability for all ships in all climates. The buyer should confirm that the cold flow characteristics (pour point, cloud point, cold filter plugging point) are suitable for the ship's design and intended voyage. See 6.10.

[j] For some products, it is possible that this test does not work due to appearance, therefore other means to evaluate usability of the product should be considered.

[k] If the sample is dyed and not transparent, then the water limit and test method as given in 6.11 shall apply.

[l] This requirement is applicable to fuels with a sulfur content below 500 mg/kg (0,050 % by mass).

[m] These categories are defined in ISO 8216-1.

Table 1 *(continued)*

Characteristics	Unit	Limit	Category ISO-F-[m] DMX	DMA	DFA	DMZ	DFZ	DMB	DFB	Test method(s) and references
Oxidation stability	g/m^3	max.	25	25	—	25	—	25[e]	—	ISO 12205; see 6.7
	h	min.	—	—	8,0	—	8,0	—	8,0[e]	EN 15751; see 6.7
Fatty acid methyl ester (FAME) content by mass or volume	%		[f]	[f]	Report[g]	[f]	Report[g]	[f]	Report[g]	ASTM D7963 or EN 14078/ASTM D7371; see 6.9
Net heat of combustion	MJ/kg		—	—	Report[h]	—	Report[h]	—	Report[h]	ASTM D240; see 6.18
Carbon residue content by mass – Micro method on the 10 % volume distillation residue	%	max.	0,30					—		ISO 10370
Carbon residue content by mass – Micro method	%	max.	—					0,30		ISO 10370
Cloud point[i]	°C	max.	−16	Report[h]				[j]	Report[h,j]	ISO 3015; see 6.10
Cold filter plugging point[i]	°C		—	Report[h]						EN 116 or EN 16329; see 6.10
Pour point (upper)[i] Winter	°C	max.	—	−6				0		ISO 3016; see 6.10
Pour point (upper)[i] Summer	°C	max.	—	0				6		
Appearance			Clear and bright[k]					[d]		See 6.11

[a] 1 mm^2/s = 1 cSt.

[b] The buyer is expected to define the maximum sulfur content according to relevant statutory limitations.

[c] See Annex E.

[d] If the sample is not clear and bright, the existent total sediment and water tests shall be required. See 6.8 and 6.11.

[e] If the sample is not clear and bright, the test cannot be undertaken and therefore, compliance with this limit cannot be shown.

[f] See 5.1 and Annex A. De minimis level amount of FAME means an amount not exceeding approximately 0,5 %.

[g] The seller shall report the FAME content according to the test method given or as per blend ratio (stating whether it is a mass or volume ratio).

[h] The value shall be reported according to the test method given.

[i] Pour point cannot guarantee operability for all ships in all climates. The buyer should confirm that the cold flow characteristics (pour point, cloud point, cold filter plugging point) are suitable for the ship's design and intended voyage. See 6.10.

[j] For some products, it is possible that this test does not work due to appearance, therefore other means to evaluate usability of the product should be considered.

[k] If the sample is dyed and not transparent, then the water limit and test method as given in 6.11 shall apply.

[l] This requirement is applicable to fuels with a sulfur content below 500 mg/kg (0,050 % by mass).

[m] These categories are defined in ISO 8216-1.

Table 1 *(continued)*

Characteristics	Unit	Limit	Category ISO-F-[m]							Test method(s) and references
			DMX	DMA	DFA	DMZ	DFZ	DMB	DFB	
Water content by volume	%	max.	—					0,30[d]		ISO 3733
Ash content by mass	%	max.	0,010							ISO 6245
Lubricity, wear scar diameter (WSD) at 60 °C[l]	µm	max.	520					520[e]		ISO 12156-1

[a] 1 mm^2/s = 1 cSt.

[b] The buyer is expected to define the maximum sulfur content according to relevant statutory limitations.

[c] See Annex E.

[d] If the sample is not clear and bright, the existent total sediment and water tests shall be required. See 6.8 and 6.11.

[e] If the sample is not clear and bright, the test cannot be undertaken and therefore, compliance with this limit cannot be shown.

[f] See 5.1 and Annex A. De minimis level amount of FAME means an amount not exceeding approximately 0,5 %.

[g] The seller shall report the FAME content according to the test method given or as per blend ratio (stating whether it is a mass or volume ratio).

[h] The value shall be reported according to the test method given.

[i] Pour point cannot guarantee operability for all ships in all climates. The buyer should confirm that the cold flow characteristics (pour point, cloud point, cold filter plugging point) are suitable for the ship's design and intended voyage. See 6.10.

[j] For some products, it is possible that this test does not work due to appearance, therefore other means to evaluate usability of the product should be considered.

[k] If the sample is dyed and not transparent, then the water limit and test method as given in 6.11 shall apply.

[l] This requirement is applicable to fuels with a sulfur content below 500 mg/kg (0,050 % by mass).

[m] These categories are defined in ISO 8216-1.

Table 2 — Residual marine fuels with sulfur content below or at 0,50 % by mass

Characteristics	Units	Limit	Category ISO-F [j]				Test method(s) and references
			RMA 20-0,5 RMA 20-0,1	RME 180-0,5 RME 180-0,1	RMG 380-0,5 RMG 380-0,1	RMK 500-0,5 RMK 500-0,1	
General requirements			Clauses 5 to 10				
Kinematic viscosity at 50 °C[a]	mm^2/s[b]	max.	20,00	180,0	380,0	500,0	ISO 3104
		min.	2,000[c]	20,00	120,0	150,0	
Density at 15 °C	kg/m^3	max.	955,0	991,0		1 010,0	ISO 3675 or ISO 12185; see 6.1
CCAI		max.	860	870			See 6.2
Sulfur content by mass	%	max.	0,50 or statutory requirement, whichever is lower[d]				ISO 8754 or ISO 14596 or ASTM D4294; see 6.3
Flash point	°C	min.	60,0				ISO 2719; see 6.4
Hydrogen sulfide	mg/kg	max.	2,00				IP 570; see 6.5
Acid number[e]	mg KOH/g	max.	2,5				ASTM D664; see 6.6
Carbon residue content by mass – Micro method	%	max.	10,00	15,00	18,00	20,00	ISO 10370
Pour point (upper)[f]	°C	max.	6	30			ISO 3016
Water content by volume	%	max.	0,30	0,50			ISO 3733
Ash content by mass	%	max.	0,070	0,100		0,150	ISO 6245
Vanadium	mg/kg	max.	150	350		450	IP 501, IP 470 or ISO 14597; see 6.13

a Actual viscosity to be reported to the ship. For fuels with high pour point, the viscosity can be calculated provided that the kinematic viscosities at two temperatures are known.

b 1 mm^2/s = 1 cSt.

c For fuels with viscosity in the range of 2 mm^2/s to 5 mm^2/s (2 cSt to 5 cSt), the minimum viscosity requirement of the engine should be checked against the original equipment manufacturers' recommendations.

d The buyer is expected to define the maximum sulfur content according to relevant statutory limitations.

e See Annex E.

f The buyer should confirm that this pour point is suitable for the ship's intended area of operation.

g This limit applies to 10 g of test specimen only. Failure to complete filtration of 10 g within 25 min means the fuel does not meet the specification. In such case and for information only, 5 g filtration results can be reported according to the test method.

h The value shall be reported in accordance with the test method given.

i See 5.1 and Annex A. De minimis level amount of FAME means an amount not exceeding approximately 0,5 %.

j These categories are defined in ISO 8216-1.

Table 2 *(continued)*

Characteristics	Units	Limit	Category ISO-F [j]				Test method(s) and references
			RMA 20-0,5 RMA 20-0,1	RME 180-0,5 RME 180-0,1	RMG 380-0,5 RMG 380-0,1	RMK 500-0,5 RMK 500-0,1	
Sodium	mg/kg	max.	50	100			IP 501, IP 470; see 6.14
Aluminium plus silicon	mg/kg	max.	40	60			IP 501, IP 470 or ISO 10478; see 6.15
Unrefined used lubricating oil (ULO) present: Calcium and zinc or Calcium and phosphorus	mg/kg		Calcium > 30 and zinc > 15 or Calcium > 30 and phosphorus > 15				IP 501 or IP 470, IP 500; see 6.16
Potential total sediment content by mass (TSP)	%	max.	0,10[g]				ISO 10307-2, Procedure A; see 6.8
Accelerated total sediment content by mass (TSA)	%		Report[h]				ISO 10307-2, Procedure B; see 6.8
Existent total sediment content by mass (TSE)	%		Report[h]				ISO 10307-1; see 6.8
Fatty acid methyl ester (FAME) content by mass or volume	%		[i]				ASTM D7963; see 6.9

[a] Actual viscosity to be reported to the ship. For fuels with high pour point, the viscosity can be calculated provided that the kinematic viscosities at two temperatures are known.

[b] 1 mm^2/s = 1 cSt.

[c] For fuels with viscosity in the range of 2 mm^2/s to 5 mm^2/s (2 cSt to 5 cSt), the minimum viscosity requirement of the engine should be checked against the original equipment manufacturers' recommendations.

[d] The buyer is expected to define the maximum sulfur content according to relevant statutory limitations.

[e] See Annex E.

[f] The buyer should confirm that this pour point is suitable for the ship's intended area of operation.

[g] This limit applies to 10 g of test specimen only. Failure to complete filtration of 10 g within 25 min means the fuel does not meet the specification. In such case and for information only, 5 g filtration results can be reported according to the test method.

[h] The value shall be reported in accordance with the test method given.

[i] See 5.1 and Annex A. De minimis level amount of FAME means an amount not exceeding approximately 0,5 %.

[j] These categories are defined in ISO 8216-1.

Table 3 — Bio-residual marine fuels

Characteristics	Units	Limit	Category ISO-F-[j]					Test methods(s) and references
			RF 20	RF 80	RF 180	RF 380	RF 500	
General requirements			Clauses 5 to 10					
Kinematic viscosity at 50 °C[a]	mm^2/s[b]	max.	20,00	80,00	180,0	380,0	500,0	ISO 3104
		min.	2,000[c]	20,00	80,00	120,0	380,0	
Density at 15 °C	kg/m^3	max.	955,0	991,0			1 010,0	ISO 3675 or ISO 12185; see 6.1
CCAI		max.	860	870				See 6.2
Sulfur content by mass	%		Statutory requirements[d]					ISO 8754 or ISO 14596 or ASTM D4294; see 6.3
Flash point	°C	min.	60,0					ISO 2719; see 6.4
Hydrogen sulfide	mg/kg	max.	2,00					IP 570; see 6.5
Acid number[e]	mg KOH/g	max.	2,5					ASTM D664; see 6.6
Carbon residue content by mass – Micro method	%	max.	10,00	15,00		18,00	20,00	ISO 10370
Pour point (upper)[f]	°C	max.	6	30				ISO 3016
Water content by volume	%	max.	0,30	0,50				ISO 3733
Ash content by mass	%	max.	0,070	0,100			0,150	ISO 6245
Vanadium	mg/kg	max.	150	350			450	IP 501, IP 470 or ISO 14597; see 6.13
Sodium	mg/kg	max.	50	100				IP 501, IP 470; see 6.14

[a] Actual viscosity to be reported to the ship. For fuels with high pour point, the viscosity can be calculated provided that the kinematic viscosities at two temperatures are known.

[b] 1 mm^2/s = 1 cSt.

[c] For fuels with viscosity in the range of 2 mm^2/s to 5 mm^2/s (2 cSt to 5 cSt), the minimum viscosity requirement of the engine should be checked against the original equipment manufacturers' recommendations.

[d] The buyer is expected to define the maximum sulfur content according to relevant statutory limitations.

[e] See Annex E.

[f] The buyer should confirm that this pour point is suitable for the ship's intended area of operation.

[g] This limit applies to 10 g of test specimen only. Failure to complete filtration of 10 g within 25 min means the fuel does not meet the specification. In such case and for information only, 5 g filtration results can be reported according to the test method.

[h] The value shall be reported in accordance with the test method given.

[i] The seller shall report the FAME content in accordance with the test method given or as per blend ratio (stating whether it is a mass or volume ratio).

[j] These categories are defined in ISO 8216-1.

Table 3 *(continued)*

Characteristics	Units	Limit	Category ISO-F-[j]					Test methods(s) and references
			RF 20	RF 80	RF 180	RF 380	RF 500	
Aluminium plus silicon	mg/kg	max.	40	60				IP 501, IP 470 or ISO 10478; see 6.15
Unrefined used lubricating oil (ULO) present: Calcium and zinc or Calcium and phosphorus	mg/kg		Calcium > 30 and zinc > 15 or Calcium > 30 and phosphorus > 15					IP 501 or IP 470, IP 500; see 6.16
Potential total sediment content by mass (TSP)	%	max.	0,10[g]					ISO 10307-2 Procedure A; see 6.8
Accelerated total sediment content by mass (TSA)	%		Report[h]					ISO 10307-2 Procedure B; see 6.8
Existent total sediment content by mass (TSE)	%		Report[h]					ISO 10307-1; see 6.8
FAME content by mass	%		Report[i]					ASTM D7963 or IP 631; see 6.9
Net heat of combustion	MJ/kg		Report[h]					ASTM D240; see 6.18

[a] Actual viscosity to be reported to the ship. For fuels with high pour point, the viscosity can be calculated provided that the kinematic viscosities at two temperatures are known.

[b] 1 mm^2/s = 1 cSt.

[c] For fuels with viscosity in the range of 2 mm^2/s to 5 mm^2/s (2 cSt to 5 cSt), the minimum viscosity requirement of the engine should be checked against the original equipment manufacturers' recommendations.

[d] The buyer is expected to define the maximum sulfur content according to relevant statutory limitations.

[e] See Annex E.

[f] The buyer should confirm that this pour point is suitable for the ship's intended area of operation.

[g] This limit applies to 10 g of test specimen only. Failure to complete filtration of 10 g within 25 min means the fuel does not meet the specification. In such case and for information only, 5 g filtration results can be reported according to the test method.

[h] The value shall be reported in accordance with the test method given.

[i] The seller shall report the FAME content in accordance with the test method given or as per blend ratio (stating whether it is a mass or volume ratio).

[j] These categories are defined in ISO 8216-1.

Table 4 — Residual marine fuels with sulfur content above 0,50 % by mass

Characteristics	Unit	Limit	Category ISO-F- [j]					Test method(s) and references
			RME 180H	RMG 180H	RMG 380H	RMK 500H	RMK 700H	
General requirements			Clauses 5 to 10					
Kinematic viscosity at 50 °C[a]	mm^2/s[b]	max.	180,0	180,0	380,0	500,0	700,0	ISO 3104
		min.	20,00[c]	20,00[c]	120,0	150,0		
Density at 15 °C	kg/m^3	max.	991,0			1 010,0		ISO 3675 or ISO 12185; see 6.1
CCAI[d]		max.	860	870				See 6.2
Sulfur content by mass	%	max.	Statutory requirements[e]					ISO 8754 or ISO 14596 or ASTM D4294; see 6.3
Flash point	°C	min.	60					ISO 2719; see 6.4
Hydrogen sulfide	mg/kg	max.	2,00					IP 570; see 6.5
Acid number[f]	mg KOH/g	max.	2,5					ASTM D664; see 6.6
Accelerated or potential total sediment content by mass	%	max.	0,10[g]					ISO 10307-2; see 6.8.2
Carbon residue content by mass – Micro method	%	max.	15,00	18,00		20,00		ISO 10370
Pour point (upper)[h]	°C	max.	30					ISO 3016
Water content by volume	%	max.	0,50					ISO 3733
Ash content by mass	%	max.	0,070	0,100		0,150		ISO 6245
Vanadium	mg/kg	max.	150	350		450		IP 501, IP 470 or ISO 14597; see 6.13

[a] For fuels with high pour point, the viscosity can be calculated provided that the kinematic viscosities at two temperatures are known.

[b] $1\ mm^2/s = 1$ cSt.

[c] Fuels with viscosity below 20,00 mm^2/s (20,00 cSt) can be agreed between seller and buyer. It is recommended to check the minimum viscosity requirement with the original equipment manufacturer recommendations.

[d] See Annex C.

[e] The buyer is expected to define the maximum sulfur content according to relevant statutory limitations.

[f] See Annex E.

[g] This limit applies to 10 g of test specimen only. Failure to complete filtration of 10 g within 25 min means the fuel does not meet the specification. In such case and for information only, 5 g filtration results can be reported according to the test method.

[h] The buyer should confirm that this pour point is suitable for the ship's intended area of operation.

[i] See 5.1 and Annex A. De minimis level amount of FAME means an amount not exceeding approximately 0,5 %.

[j] These categories are defined in ISO 8216-1.

Table 4 *(continued)*

Characteristics	Unit	Limit	Category ISO-F-[j]					Test method(s) and references
			RME 180H	RMG 180H	RMG 380H	RMK 500H	RMK 700H	
Sodium	mg/kg	max.	50	100				IP 501 or IP 470; see 6.14
Aluminium plus silicon	mg/kg	max.	50	60				IP 501, IP 470 or ISO 10478; see 6.15
Unrefined used lubricating oil (ULO) present: Calcium and zinc or Calcium and phosphorus	mg/kg		Calcium > 30 and zinc > 15 or Calcium > 30 and phosphorus > 15					IP 501 or IP 470, IP 500; see 6.16
Fatty acid methyl ester (FAME) content by mass or volume	%		[i]					ASTM D7963; see 6.9

[a] For fuels with high pour point, the viscosity can be calculated provided that the kinematic viscosities at two temperatures are known.

[b] 1 mm^2/s = 1 cSt.

[c] Fuels with viscosity below 20,00 mm^2/s (20,00 cSt) can be agreed between seller and buyer. It is recommended to check the minimum viscosity requirement with the original equipment manufacturer recommendations.

[d] See Annex C.

[e] The buyer is expected to define the maximum sulfur content according to relevant statutory limitations.

[f] See Annex E.

[g] This limit applies to 10 g of test specimen only. Failure to complete filtration of 10 g within 25 min means the fuel does not meet the specification. In such case and for information only, 5 g filtration results can be reported according to the test method.

[h] The buyer should confirm that this pour point is suitable for the ship's intended area of operation.

[i] See 5.1 and Annex A. De minimis level amount of FAME means an amount not exceeding approximately 0,5 %.

[j] These categories are defined in ISO 8216-1.

Annex A
(informative)

Bio-based liquid fuels including fatty acid methyl ester(s)

A.1 General

Bio-based liquid fuels (often referred to as biodiesel) and blends with petroleum products (biofuels) are considered to be within the range of potential alternative energy sources by the marine industry, since they are renewable and can result in reduced greenhouse gases (GHGs) (see A.2) and sulfur oxides emissions (SO_x).

The bulk of bio-based liquid fuels currently available are the products of a transesterification or an esterification process of vegetable oils, animal fats and oils or waste cooking oils to produce fatty acid methyl ester(s) (FAME).

This document includes the use of FAME in accordance with EN 14214 (except for sulfur content, cloud point and cold filter plugging point) or ASTM D6751 (except for sulfur content) as a blend component in both distillate and residual fuels up to 100 %.

Other national FAME standards, not referenced in this document, and alternative bio-based products such as off-spec FAME or FAME production distillation bottoms are all being considered and used by the marine industry. To align with the minimum requirements set by the scope of this document, comparisons should be made against EN 14214 or ASTM D6751. A.4 provides guidance on the use of alternative biomass- based products.

A.2 Bio-distillate and residual marine fuels containing FAME

In the couple of years preceding the publication of this document, many sea trials were conducted with a large variety of FAME blends (up to 100 %), all with satisfactory results. In the light of this experience, this document introduces additional grades for residual marine fuels containing FAME (RF grades) and removes a blend ratio limit for distillate marine fuels (DF grades).

This document maintains, however, the requirement for DM and RM grades to contain no more than a de minimis amount of FAME, which is taken to be approximately 0,5 %.

For the purpose of this document, DMX shall be free of FAME, and, with exception of DF and RF grades, fuel producers and suppliers should ensure that:

— there is no deliberate blending of FAME into the fuel;

— adequate controls are in place so that the resultant fuel, as delivered, does not exceed the de minimis amount;

— the fuel is compliant with the requirements of Clauses 5 to 10.

When ordering a distillate or residual fuel with an intended FAME component, the renewable content should be agreed between the buyer and seller. The sustainability aspects should be taken into consideration and reviewed prior to purchase; however, these sustainability aspects fall outside the scope of this document.

Exhaust gas emission regulations are subject to change of legislation and change of the interpretation of such legislation. Different entities develop their own legal requirements covering subjects such as greenhouse gases (GHGs), sulfur oxides (SO_x), nitrogen oxides (NO_x) and black carbon emissions. It is expected that the use of renewable fuels will be supported; however, ship owners and operators are also expected to be aware of all international and national requirements and changes thereof implicated by the use of renewable fuels.

A.3 Storage and handling of bio-distillate and residual marine fuels containing FAME

Where the use of fuels containing FAME is being contemplated, it should be ensured that the ship's storage, handling, treatment, service and machinery systems, together with any other machinery components, are compatible with such fuels, in terms of materials and operational performance. Prolonged contact of materials such as bronze, brass, copper, lead, tin and zinc with FAME should be avoided as these can oxidize FAME, thereby creating sediments and deterioration of the material itself.

FAME has good ignition and lubricity properties together with environmental benefits. However, there are potentially specific complications with respect to the storage and handling of fuels with a FAME component in a marine environment, such as:

— a tendency for oxidation (potentially resulting in additional corrosion) and long-term storage issues to occur;

— an affinity to water and risk of microbial growth;

— degraded low-temperature flow properties;

— FAME material deposition on exposed surfaces, including filter elements.

Additionally, there is a variety of differently sourced FAME products, each with their own particular characteristics suitable for the climate of the supply location. This can have implications with respect to storage, handling, treatment, and engine operations.

While this document has provisions on oxidation stability and requirements for cold flow properties, good housekeeping rules are required, avoiding prolonged storage, build-up of water and appropriate temperature management throughout the entire fuel system.

NOTE 1 The International Council on Combustion Engines (CIMAC) has developed a guideline on handling of marine fuels containing FAME.[14] This guideline also contains information on testing marine biofuels for potential complications related to onboard storage and handling.

NOTE 2 More guidance on handling and housekeeping of marine fuels containing FAME can be found in the Concawe report 9/09 "Guidelines for handling and blending FAME".[15]

The typical calorific value of FAME is lower than its petroleum counterpart. Therefore, consideration should be given to the quantity of fuel required to complete the planned voyage. This document specifies the measurement of gross and net heat of combustion to facilitate this. The calorific value can also be required as an input to the control system of electronically controlled engines.

A.4 Use of alternative biomass-based products

Alternative bio-based products such as off-spec FAME or FAME production distillation bottoms are being considered and used by the marine industry. When such products are considered, an evaluation should be made of where these products differ from the FAME reference specification (such as the specifications included in EN 14214 or ASTM D6751). This can be used as the basis for a risk assessment in the use of such a product. Consideration can be given to include some additional trials/tests prior to putting such a grade/blend into use on board a ship. Approval from the appropriate authorities can be required.

When an alternative biomass-based product is used, the requirements as stated in this document should be adhered to as much as possible.

Annex B
(informative)

Composition of marine fuels

Marine fuels consist of a wide range of hydrocarbons from sources such as petroleum crude oil, synthetic or renewable sources, shale oil, oil sands and where specifically agreed, fatty acid methyl ester(s) (FAME). This document is largely based on parameters related to operational performance/experience rather than a compositional standard. As such, the fuel should be able to be used on board a ship.

As the buyer/user cannot control the composition of the fuel as delivered, it is the responsibility of fuel producers, suppliers, traders, fuel terminals and supply facilities to have in place adequate quality control procedures to ensure that the fuel supplied to the ship meets all requirements specified in this document.

While such occurrences are infrequent, and despite the efforts of the ship to appropriately manage the fuel by applying best industry practices, marine fuel that meets the characteristics as listed in Table 1, Table 2, Table 3 or Table 4 can subsequently cause operational issues with potential damage and loss of power and propulsion. After all best industry practices have been carried out, it can come into question whether the fuel fails to meet the general requirements of this document, in particular Clause 5.

In cases where a ship suspects the specific fuel in use on board to be the possible cause of an operational issue, applicable evidence should be gathered to support correct storage, cleaning, handling and use of the fuel and further investigation of the cause of the problem. Such evidence includes but is not limited to:

— logging the case in detail and chronological sequence of events;

— collecting in-use fuel system samples for comparison to previous bunkers in use;

— documenting and securing the evidence leading up to, during and after the operational problem was experienced;

— records of any mitigating actions taken.

Furthermore, additional analytical investigation can be considered.

Advanced analytical investigative test methods are often carried out either to screen the fuel for compositional anomalies such as the presence of deleterious material and/or to attempt to explain the cause of the operational issue experienced.

It remains however difficult to determine the exact composition of a marine fuel and for most fuels supplied, this is neither needed nor feasible. While there have been improvements in the capability to detect an increasing range of chemical species which could not be identified in the past, it remains unknown if these species have been present in marine fuels previously. It is therefore also unknown if such marine fuels were consumed by vessels without operational issues or whether those specific species do warrant further consideration. As such, there is no recognized reference baseline of all species that can be found in marine fuels, the associated risk of them being harmful/harmless and at what concentration/combination. To the benefit of the entire industry, continuous efforts are required by the industry to establish links between identified species, the performance of the fuel and the probability of encountering operational issues.

Experience has shown that non-fuel related factors, including but not limited to human, mechanical and operational factors or the incorrect addition of additives on board the ship, can contribute to the experienced operational issues. However, when there is substantiated evidence that the fuel in use is the cause of the operational issues, the fuel in use is deemed not to meet this document.

It is challenging to predict the potential behaviour of a fuel and whether it meets Clause 5 solely based on the presence of what can be perceived as deleterious materials. If however, cause and effect between the presence of one or more chemical species and operational issues has factually been ascertained, the fuel is deemed to have not met this document.

The following list identifies a number of chemical species or materials, but is not exhaustive, where experiences have shown strong links between the chemical species and operational problems.

— Organic chlorides (chlorinated hydrocarbons): corrosion of ship's fuel system and other engine components;

  For dispute resolution, EN 14077 should be used to measure the total organic halogen content as chlorine.

  There are other investigative techniques [such as those using gas chromatography mass spectrometry (GC-MS)] being used in the industry to screen for organic chloride compounds, however they lack standardized test methods which include the required test precision data.

  NOTE Information on organic chlorides and marine fuels incidents can be found in the CIMAC publication.[16]

— Polymers such as polystyrene, polyethylene, polymethacrylates: filter blocking and fuel pump sticking;

— Inorganic acids (see 6.6 and Annex E).

Annex C
(informative)

Ignition characteristics of residual marine fuels

C.1 Application

A diesel engine's sensitivity to a fuel's ignition characteristics depends not only on the fuel's chemical composition but also the particular engine type and design, together with its maintenance and operating conditions. Where the same fuel is intended to be used for both main and auxiliary engines, the calculated carbon aromaticity index requirements of those engines with the least tolerance towards poor ignition characteristics should be considered when ordering residual fuels.

C.2 Calculated carbon aromaticity index

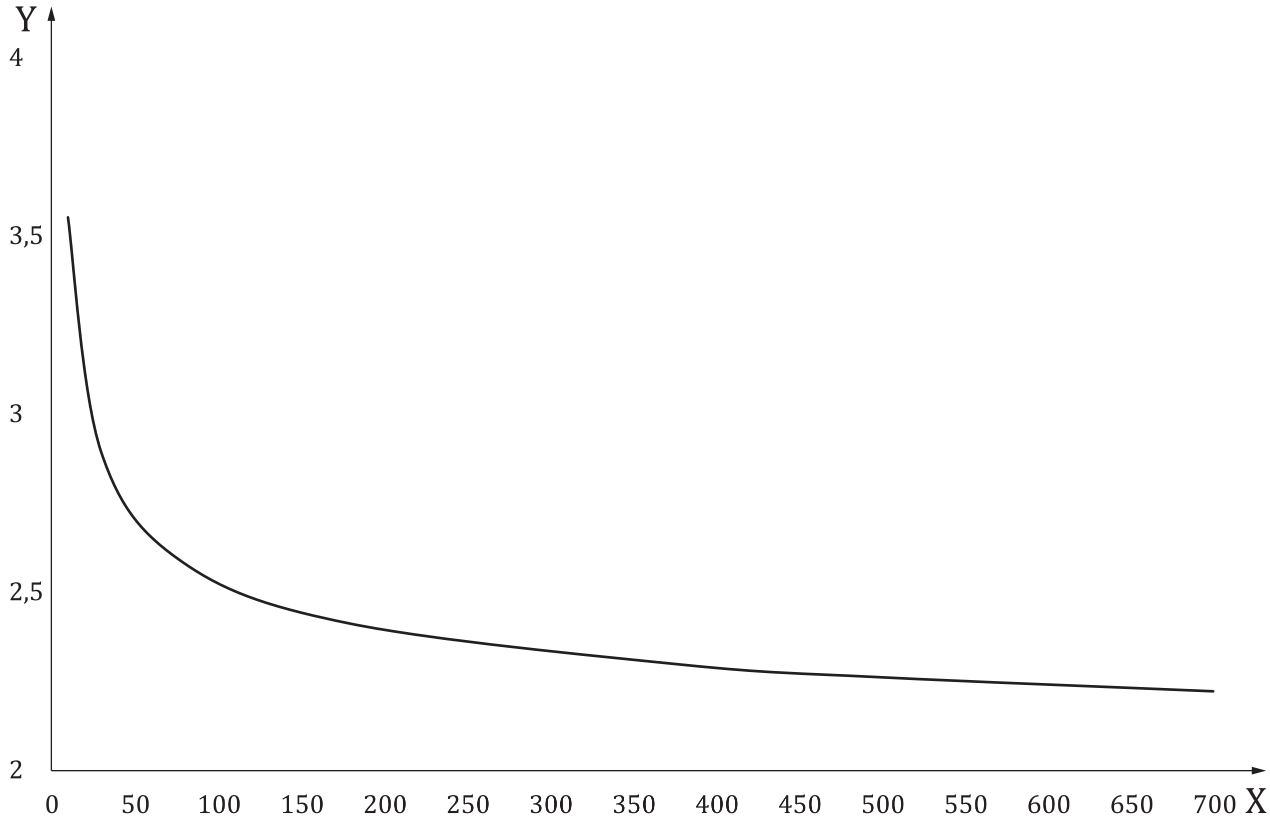
The calculated carbon aromaticity index (CCAI) was developed as an indicator of the ignition performance of petroleum derived residual fuels and is determined from the density and viscosity values.

The applicability to the ignition performance of bio-residual marine fuel blends has not yet been fully established. It however remains valid as a viscosity-density correlation. It is expected that the FAME-component will improve the ignition and combustion properties.

CCAI is primarily included in Table 2, Table 3 and Table 4 to avoid residual fuels with uncharacteristic density-viscosity relationships.

The reproducibility of the CCAI value of a particular residual fuel is dependent on the reproducibility, *R*, of the density and viscosity values from which that CCAI value has been calculated. The interaction of these CCAI factors is such that the highest positive CCAI reproducibility is achieved when the reproducibility for density is added to the density value and the reproducibility for viscosity is subtracted from the viscosity value.

The curve of CCAI reproducibility plotted against viscosity is given in Figures C.1 and C.2. The reproducibility of density is a constant (independent of the density value) and, therefore, the CCAI reproducibility varies only with the viscosity of the fuel.

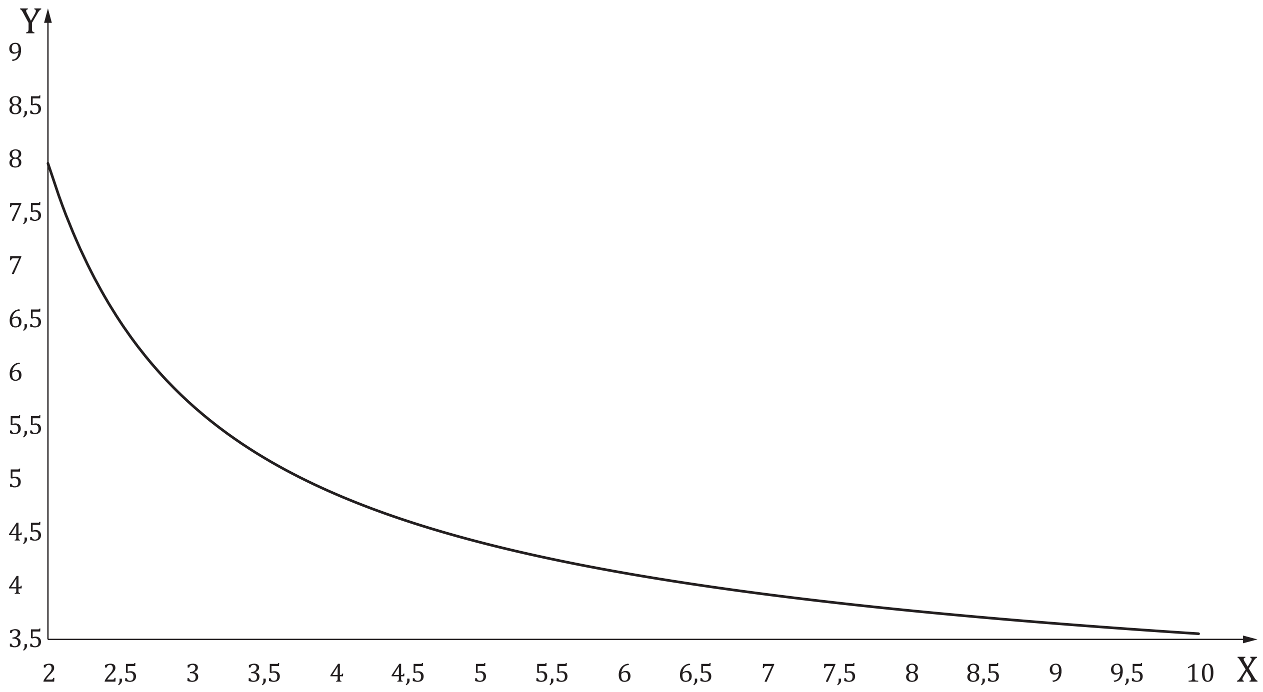


Key

X viscosity at 50 °C, expressed in square millimetres per second

Y CCAI reproducibility

Figure C.1 — Plot of CCAI reproducibility against viscosity, 10 mm²/s to 700 mm²/s



Key

X viscosity at 50 °C, expressed in square millimetres per second

Y CCAI reproducibility

Figure C.2 — Plot of CCAI reproducibility against viscosity, 2 mm^2/s to 10 mm^2/s

C.3 IP 541 ignition and combustion test method

It has been recognized that fuels with similar densities and viscosities (i.e. similar CCAIs) can have significantly different ignition and combustion properties. Consequently, in order to address both ignition and combustion characteristics of a residual fuel, a standard test method, commonly known as FIA-100/FCA, has been established using a constant volume combustion chamber (CVCC); see IP 541.[17] The International Council on Combustion Engines (CIMAC) has developed a guideline regarding fuel ignition and combustion quality for diesel engines.[18]

Annex D
(informative)

Hydrogen sulfide

Hydrogen sulfide (H_2S) is a highly toxic gas. Exposure to any significant vapour concentration is hazardous and in extreme cases, can be fatal. At very low concentrations, the gas has the characteristic smell of rotten eggs. However, at higher concentrations, it causes a loss of smell, headaches and dizziness and at very high concentrations, is immediately fatal.

H_2S can be formed during the refining process and can evolve from the fuels in shoreside storage tanks, in product barges or ships' storage tanks. H_2S can be present in both liquid and vapour phase and the degree and speed of partitioning between the liquid and vapour phase depends on several factors, e.g. the fuel chemistry, temperature, viscosity, level of agitation, storage time, heating applied, ambient conditions, tank shape, ullage and venting.

Contact with H_2S vapours can occur when personnel are exposed to fuel vapours, such as when dipping tanks, when opening tank hatch covers, when entering empty tanks, from vent pipes when tanks are being filled and/or heated, in purifier rooms, when opening up fuel lines and during filter changing operations.

The risks are highlighted in safety data sheets (SDSs) and the dangers presented to health and exposure guidelines are documented. A useful reference guidance is provided in ISGOTT 6, section 2.3.6.[7]

The liquid-phase limit, introduced in the fourth edition of this document, of 2,00 mg/kg, was included to provide an improved margin of safety over the previous edition and reduce the risk of H_2S vapour exposure. This limit alone does not constitute a safe level or eliminate the operational risk of concentrations of H_2S vapour being present in enclosed spaces. It is critical that ship owners and operators continue to maintain appropriate safety processes and procedures designed to protect the crew and others (e.g. surveyors), who can be exposed to H_2S vapour.

NOTE More information on issues associated with H_2S in marine fuels can be found in the CONCAWE report no. 8/13.[19]

Annex E
(informative)

Acid number

Fuels with high acid number test results arising from acidic compounds occasionally cause accelerated damage to marine diesel engines. Such damage is found primarily within the fuel injection equipment.

Testing fuels for acid number (AN; previously known as total acid number or TAN) as specified in ASTM D664 can give indications as to the likely presence of acidic compounds. Although all fuels have a naturally occurring, measurable acid number, these are generally (but not always) less than 0,5 mg KOH/g for distillate fuels and generally (but not always) less than 2,5 mg KOH/g for residual fuels.

However, fuels manufactured from naphthenic crudes can have an acid number that, while greater than those stated in Tables 1, 2, 3 or 4, is acceptable for use. Confirmation that a fuel was manufactured from naphthenic crudes can be established by non-standard, specialized detailed analysis. In such circumstances, it is the responsibility of the seller and the buyer to agree on an acceptable acid number.

Acid number levels significantly higher than those stated above can indicate high amounts of acidic compounds and, possibly, other contaminants.

NOTE More information on the composition of marine fuels can be found in Annex B.

Acid numbers below the values stated above do not guarantee that the fuel is free from problems associated with the presence of acidic compounds. There is currently no recognized correlation between an acid number test result and the corrosive activity of a fuel.

Notwithstanding that an acid number limit is given, the fuel shall be free from inorganic acids (strong acids). A fuel in which a strong acid compound [strong acid number (SAN)] is present, even at a low level below the reporting limit of ASTM D664 test method, is not compliant with this document as there is a correlation between the presence of a strong acid and the corrosive activity of a fuel.

Annex F
(informative)

Cold flow characteristics

The majority of HSFO are predominantly aromatic in nature and contain asphaltenes.

VLSFO typically consist of components having a different nature compared to HSFO. These fuels can contain large amount of high boiling asphaltene-free material from petroleum refining.

These VLSFO typically exhibit good ignition quality, a high flash point and good lubricity characteristics; they are cleaner, deposit less ash than HSFO and VLSFO normally have a higher kinematic viscosity and pour point than distillate marine fuel grades.

The paraffinic/waxy nature and physical characteristics of RM VLSFO preclude the use of cloud point (CP) and cold filter plugging point (CFPP) (introduced for distillate fuels in the previous edition of this document ISO 8217:2017[1)]for determining RM VLSFO cold flow characteristics. Cold flow behaviour of VLSFO fuels however can best be characterized by the pour point (PP). In storage and transfer, these fuels should be heated/kept at a temperature at least 10 °C above the pour point.

When purchasing a residual type fuel, the ship's fuel storage tanks heating capabilities should be considered and any constraints included in the ordering specification of the fuel. Where there are any constraints, the pour point and storage requirements should be obtained from the seller prior to delivery.

For distillate fuels in particular, the buyer should verify that the cold flow characteristics (CP, CFPP, PP) of the ordered fuel are suitable for the ship's fuel storage and management system design, and the climate conditions expected to be encountered while the fuel is on board. Table 1 of this document includes the requirement to report CP and CFPP for DMA, DFA, DMZ, DFZ and DFB grades.

NOTE More information on storage and handling of fuels can be found in Reference [20].

1) Withdrawn.

Annex G
(informative)

Ash

All residual fuels contain some metallic elements, either those that are naturally present from the crude oil feedstock used such as vanadium, sodium, calcium and nickel, or those introduced primarily from external sources such as sodium, aluminium, silicon, potassium and iron. When a fuel is combusted, some of these metals are converted into solid particles of oxides, sulfates or more complex compounds, collectively known as ash. At certain temperatures, these solid ash particles become partly fluid and, in this state, can adhere to components in a combustion system if the component surface temperatures are high enough. These adhering ash deposits can cause damage to components (piston crowns, exhaust valves, turbocharger blade surfaces in diesel engines and the waterwall, superheater and reheater tube surfaces of boilers), either by a process termed “hot corrosion” or by other mechanisms. The temperature at which the ash particles start to become fluid and to stick to surfaces, often referred to as the “stiction” temperature, is lowest for ashes that are rich in vanadium and/or sodium. For this reason, particular attention is paid to the amounts of these metals in fuels.

A sodium/vanadium ratio of 1:3 is generally claimed to yield the lowest ash-melting temperature. The 1:3 sodium/vanadium ratio assumes increasing importance as the vanadium content of the fuel rises (typically above 150 mg/kg) because the ash becomes increasingly vanadium-rich. While vanadium levels in some residual fuels can extend up to 450 mg/kg, other metals do not usually reach such levels and, therefore, their influence on “stiction” temperatures is limited. Also, at high vanadium levels, the total ash burden is greater, thus exacerbating any problems that can arise due to ash deposition. The recommendations regarding fuel quality for diesel engines (21/2003), Annex 7,[21] of the International Council on Combustion Engines provides an in-depth review of this subject.

Annex H
(informative)

Stability of residual fuels

The composition of residual fuels is complex as it depends on crude and refining processes. However, it generally includes asphaltenes, resins and liquid hydrocarbons. Asphaltenic sludge can precipitate when the asphaltenes, which are high molecular mass polar molecules having a predominantly aromatic structure, are not kept in colloidal suspension. This can occur when the fuel is subject to forces, such as thermal and ageing stresses, the degree of which is a function of time, temperature, and aromaticity of the oil matrix.

Good stability of a residual fuel is essential for the safe handling and use on board ships. In this document, the measure of the resistance of the fuel to precipitate asphaltenes is covered by potential total sediment (TSP) with a maximum limit of 0,10 % by mass.

To enable long term stability, every fuel should be manufactured with sufficient stability to withstand normal on-board use and storage conditions.

To evaluate the stability of a fuel, different test methods are available:

— Existent total sediment (TSE), which measures the amount of sediment present in the fuel at the time of testing by filtration and weighing the amount of sediment on the filter. This method provides indication of the amount of organic and inorganic sediments present in the fuel.

— Total sediment aged, which is divided into two ageing procedures:

  — Potential total sediment (TSP) is the total sediment after ageing a sample of residual fuel for 24 h at 100 °C. This method provides indication of the maximum amount of sediment that is likely to form when applying thermal stress to the fuel.

  — Accelerated total sediment (TSA) is the total sediment after dilution of a sample of residual fuel with a paraffinic solvent, followed by storage for 1 h at 100 °C. This method provides indication of the maximum amount of sediment that is likely to form when applying a combination of chemical and reduced thermal stress. TSA is generally carried out as an alternative to TSP in view of its quicker process.

TSP is representative of the resistance of the fuel against thermal stress whereas TSA represents the tolerance of a fuel to retain asphaltenes in suspension when comingling with a paraffinic fuel under limited thermal stress.

Until the introduction of the VLSFO in 2020, TSA proved to be a convenient (quicker) alternative to the TSP test method and provided confidence that when TSA was tested and within the specification limit, TSP would also be within the limit. The introduction of VLSFO resulted in a wider range of blend formulations with different characteristics than the conventional HSFO, typically in fuels having lower viscosity (below 200 mm^2/s).

Experience has shown that some of these VLSFO fuels with lower viscosity exhibit a different relationship between TSA and TSP than the higher sulfur fuels. Whereas TSA for the higher sulfur fuels typically exceeds the TSP (and therefore can be used as an alternative to TSP when evaluating if a fuel meets the specification), this is not the case for the VLSFOs. This means that when only TSA is tested for and is meeting the specification limit, it is no longer an indication that TSP will also meet the specification.

In view of this, for fuels in Table 2 and Table 3, it is no longer technically valid to allow only TSA to be used to assess if the sediment level of a fuel is within the sediment limit set in this document; TSP shall be the primary test. This is reflected in Table 2 and Table 3 where it is required that TSP meets the limit, and that TSA and TSE are reported. The reporting requirements are intended to better inform fuel management operators on the stability characteristics of VLSFO.

Statistical analysis of data gathered since 2020 suggests that when fuels in Table 2 have a relatively high viscosity (above 200 mm^2/s), the historical relationship of TSA and TSP is seen. Thus, for such fuels it is likely that if TSA is within the specification limit, TSP will also be within the limit. The statistical analysis also showed that the total sediment aged requirement for high sulfur residual fuels in Table 4 has not changed and TSA still provides a high level of confidence that if TSA is within the specification limit, TSP will also be within the limit.

Despite the above observations from the statistically analysis of data, TSP is the reference test method for fuels in Tables 2, 3 and 4.

Mixing of fuels, which are individually deemed to be stable can result in a product which is not stable. This can result in the deposition of sediments and asphaltenic sludge. In such scenarios, the fuels are described as being incompatible.

To avoid incompatible mixtures of fuels, every attempt should be made to segregate different fuels on board the ship. Where this cannot be achieved, additional test methods and indicators can provide supplementary information. Information about these methods can be found in ISO/PAS 23263 and Reference [22]. Additional test methods referenced are the spot test in ASTM D4740[23] and the determination of stability parameters based on optical detection of asphaltenes flocculation in ASTM D7060,[24] ASTM D7112[25] and ASTM D7157.[26]

NOTE More detailed guidance on the stability of marine fuels and managing compatibility through interpretation of TSA, TSP and TSE results can be found in the CIMAC Guideline 03/2024.[10]

Annex I
(informative)

Unrefined used lubricating oil

The addition of unrefined used lubricating oil (ULO) as a fuel blend component collected from inland sources (e.g. spent motor vehicle crankcase oils), with no or inadequate environmental regulations and controls, can provide a route for waste materials to enter the residual fuel pool.

Potentially, unrefined ULO is highly variable, but it is comprised predominantly of used vehicle crankcase oils which contain significant amounts of lubricant detergent and anti-wear additives. Lube oil detergent additives are based mainly on calcium. While the anti-wear additives are usually zinc-phosphorus compounds, some are zinc-free. Therefore, the principle used in setting limits for this document is that the residual fuel is considered to contain unrefined ULO if either of the two groups of elements, calcium and zinc or calcium and phosphorus (and not the individual elements) are above the limits specified in Table 2, Table 3 or Table 4.

Limits for the selected elements of zinc, phosphorus and calcium have been set at levels that are as low as possible, taking into account both the background levels of these elements in residual fuel which is free from unrefined ULO and the reproducibility of the test methods. It is therefore not possible to set a zero-upper limit on these “fingerprint” elements.

The limits on zinc, phosphorus and calcium given in Tables 2, 3 and 4 serve as the basis for determining whether or not a fuel meets the specification, but do not imply that a fuel that is judged to contain unrefined ULO is necessarily unsuitable for use.

It should however be noted that there are other sources of calcium, zinc and phosphorous that can be considered before concluding that unrefined used lubricating oil is present in the supplied fuel.

Annex J
(informative)

Specific energy

Specific energy is not usually controlled in the manufacture of fuel although it will be in a secondary manner by the specification of other properties. For fuels not containing FAME it can either be measured by bomb calorimeter as described in ASTM D240 or calculated from typically determined fuel characteristics. For distillate and residual fuels containing FAME, gross and net heat of combustion cannot be calculated using the formulae in this annex but should, where required, instead be measured using ASTM D240.

For residual marine fuels not containing FAME, net specific energy, Q_{Rnp}, and gross specific energy, Q_{Rgv}, both expressed in megajoules per kilogram, can be calculated with a degree of accuracy acceptable for normal purposes from Formulae (J.1) and (J.2), [27] respectively:

$$Q_{\mathrm{Rnp}} = \left(46{,}704 - 8{,}802\rho_{15}^{2} \cdot 10^{-6} + 3{,}167\rho_{15} \cdot 10^{-3}\right) \cdot \left[1 - 0{,}01\left(w_{\mathrm{w}} + w_{\mathrm{a}} + w_{\mathrm{s}}\right)\right] + 0{,}094\,2 w_{\mathrm{s}} - 0{,}024\,49 w_{\mathrm{w}} \quad \text{(J.1)}$$

$$Q_{\mathrm{Rgv}} = \left(52{,}190 - 8{,}802\rho_{15}^{2} \cdot 10^{-6}\right) \cdot \left[1 - 0{,}01\left(w_{\mathrm{w}} + w_{\mathrm{a}} + w_{\mathrm{s}}\right)\right] + 0{,}094\,2 w_{\mathrm{s}} \quad \text{(J.2)}$$

where

ρ_{15} is the density at 15 °C, expressed in kilograms per cubic metre;

w_{w} is the water content, expressed as a mass percentage;

w_{a} is the ash content, expressed as a mass percentage;

w_{s} is the sulfur content, expressed as a mass percentage.

For distillate marine fuels not containing FAME, net specific energy, Q_{Dnp}, and gross specific energy, Q_{Dgv}, both expressed in megajoules per kilogram, can be calculated with a degree of accuracy acceptable for normal purposes from Formulae (J.3) and (J.4), respectively:

$$Q_{\mathrm{Dnp}} = \left(46{,}423 - 8{,}792\rho_{15}^{2} \cdot 10^{-6} + 3{,}170\rho_{15} \cdot 10^{-3}\right) \cdot \left[1 - 0{,}01\left(w_{\mathrm{w}} + w_{\mathrm{a}} + w_{\mathrm{s}}\right)\right] + 0{,}094\,2 w_{\mathrm{s}} - 0{,}024\,49 w_{\mathrm{w}} \quad \text{(J.3)}$$

$$Q_{\mathrm{Dgv}} = \left(51{,}916 - 8{,}792\rho_{15}^{2} \cdot 10^{-6}\right) \cdot \left[1 - 0{,}01\left(w_{\mathrm{w}} + w_{\mathrm{a}} + w_{\mathrm{s}}\right)\right] + 0{,}094\,2 w_{\mathrm{s}} \quad \text{(J.4)}$$

where

ρ_{15} is the density at 15 °C, expressed in kilograms per cubic metre;

w_{w} is the water content, expressed as a mass percentage;

w_{a} is the ash content, expressed as a mass percentage;

w_{s} is the sulfur content, expressed as a mass percentage.

Annex K
(informative)

Characterization of residual marine fuels

K.1 Purpose

The characterization of petroleum derived fuels not including FAME, in terms of their aromatic and paraffinic nature, has become increasingly of interest by the marine industry, having moved to lower sulfur fuels which resulted in moving away from the dominance of high sulfur heavier residual fuels of the past.

For the marine industry to have a consistent approach, this annex provides an indicator to defining whether a petroleum-derived fuel not including FAME as supplied to a ship is more aromatic or paraffinic in nature. This therefore provides additional onboard handling information of marine fuels irrespective of sulfur content. It is important to note that VGC values should not be taken as a hard-cut limit value in determining the nature of the fuel. Instead, it should be used as a range to evaluate whether a product leans more towards being paraffinic or aromatic in nature when comparing one fuel to another.

K.2 Approach

An ASTM publication[28] was selected as the most established and applicable guidance document for the petroleum industry to base its approach on the characterization of marine fuels.

K.3 Method selected

Reference [28] refers to two methods:

1) the Bureau of Mines Correlation Index [BMCI, often also referred to as CI (Correlation Index)];

2) the viscosity-gravity constant (VGC).

Both BMCI and VGC provide an indication of a fuel tendency to be more paraffinic or aromatic. VGC has been selected as the more practical approach for the purposes of this document as VGC is defined in the method for calculation and interpretation specified in ASTM D2501.[29]

NOTE See ISO/TR 18588 for further details on the characterization of marine fuels and understanding of VGC.

K.4 VGC Calculation

ASTM D2501 calculates VGC, C_{VG}, on the basis of the viscosity and density of the fuel from Formula (K.1). The sulfur content has no influence on the VGC value.

$$C_{VG} = \frac{[\rho_{15} - 0{,}108 - 0{,}1255 \times \lg(\eta - 0{,}8)]}{0{,}90 - 0{,}097 \times \lg(\eta - 0{,}8)} \quad \text{(K.1)}$$

where

ρ_{15} is the density at 15 °C, expressed in kilograms per litre;

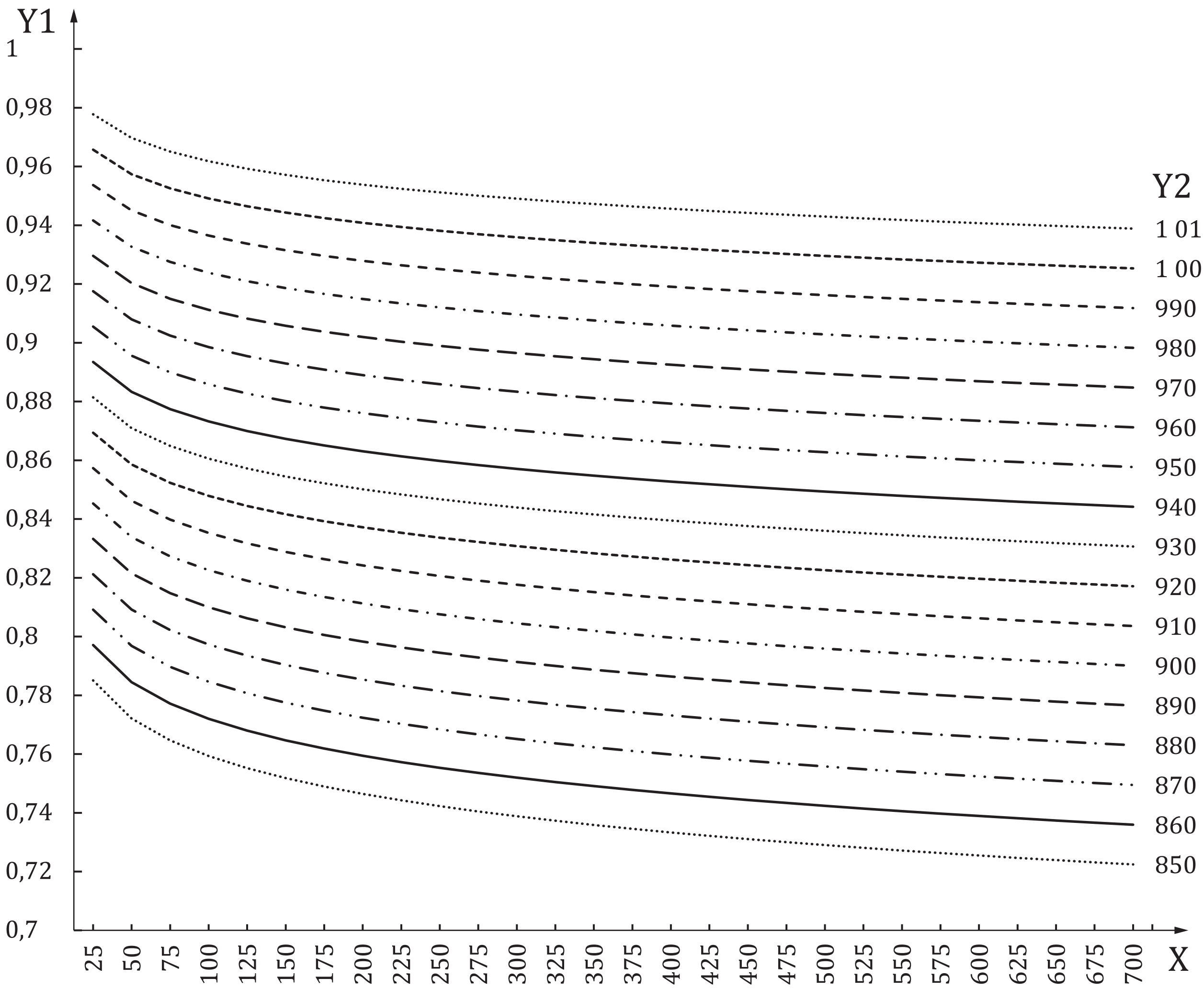
η is the kinematic viscosity at 100 °C, expressed in mm^2/s.

NOTE ASTM D2501 also includes a formula to calculate VGC basis viscosity at 40 °C.

K.5 Significance and use of the VGC

In applying the VGC formula to the standard density and viscosity tested parameters of a residual marine fuel, values of the VGC can provide an indication of the character of the fuel.

Values of VGC near 0,80 indicate the fuel of a paraffinic character, while values close to 1,00 indicate a preponderance of aromatic structures (see Figure K.1).



Key

X viscosity at 50 °C, expressed in square millimetres per second

Y1 viscosity-gravity constant

Y2 density at 15 °C, expressed in kg/m^3

Figure K.1 — Plot of VGC against viscosity, 25 mm^2/s to 700 mm^2/s for different densities

As an example, the calculated VGC for a residual fuel with a viscosity of 100 mm^2/s at 50 °C and a density of 900,0 kg/m^3 is 0,82, which is indicative of the fuel leaning more towards being paraffinic in nature.

Bibliography

[1] ISO 8216-1, *Products from petroleum, synthetic and renewable sources — Fuels (class F) classification — Part 1: Categories of marine fuels*

[2] ISO/PAS 23263, *Petroleum products — Fuels (class F) — Considerations for fuel suppliers and users regarding marine fuel quality in view of the implementation of maximum 0,50 % sulfur in 2020*

[3] INTERNATIONAL MARITIME ORGANIZATION (IMO). International Convention for the Safety of Life at Sea (SOLAS), 1974, as amended, Chapter II- 2, Part B, Regulation 4, Section 2.1

[4] International Convention for the Prevention of Pollution from Ships (MARPOL). Annex VI, Regulations for the Prevention of Air Pollution from Ships, as amended.

[5] INTERNATIONAL COUNCIL ON COMBUSTION ENGINES (CIMAC) Recommendation No. 25, *Recommendations concerning the design of heavy fuel treatment plants for diesel engines* (25/2006)

[6] LEWIS C.P.G. SCHENK C. STASSEN W.J.M. *Ignition quality of residual fuel oils.* Conference paper in Proceedings of the 22nd CIMAC International Congress on Combustion Engines, Volume 2, Copenhagen, Denmark, 18-21 May 1998[2)]

[7] *International Safety Guide for Oil Tankers and Terminals* (ISGOTT), 6th edition, ISBN 978-1-85609-918-9

[8] ISO/TR 29662, *Petroleum products and other liquids — Guidance for flash point and combustibility testing*

[9] OIL COMPANIES INTERNATIONAL MARINE FORUM (OCIMF). *The Flammability Hazards Associated with the Handling, Storage and Carriage of Residual Fuel Oils*, December 1989

[10] INTERNATIONAL COUNCIL ON COMBUSTION ENGINES (CIMAC) — CIMAC *Guideline*. *Overview and interpretation of total sediment test results in the context of ISO 8217:2024* (03/2024)

[11] INTERNATIONAL COUNCIL ON COMBUSTION ENGINES (CIMAC) — CIMAC *Guideline*. *Cold flow properties of marine fuels* (01/2015)

[12] MAN Service letter SL2017-638/DOJA — *Cleaning of heavy fuel oil and max. 0,10 % sulfur fuels*

[13] INTERNATIONAL COUNCIL ON COMBUSTION ENGINES (CIMAC) — CIMAC *Guideline. The interpretation of marine fuel analysis test results* (01/2024)

[14] INTERNATIONAL COUNCIL ON COMBUSTION ENGINES (CIMAC) — CIMAC *Guideline. Marine fuels containing FAME: A guideline for shipowners and operators* (04/2024)

[15] CONCAWE report no. 9/09 — *Guidelines for handling and blending FAME*

[16] INTERNATIONAL COUNCIL ON COMBUSTION ENGINES (CIMAC) — *Organic chlorides, marine fuel incidents*

[17] IP 541, *Determination of ignition and combustion characteristics of residual fuels — Constant volume combustion chamber method*

[18] INTERNATIONAL COUNCIL ON COMBUSTION ENGINES (CIMAC) — *Fuel quality guide — Ignition and combustion (*2011*)*

[19] CONCAWE report no. 8/13 — *Marine fuels and hydrogen sulphide*

[20] Joint Industry Guidance *The supply and use of 0,50 % sulfur-marine fuels*

[21] INTERNATIONAL COUNCIL ON COMBUSTION ENGINES (CIMAC). Recommendation No. 21, *Recommendations regarding fuel quality for diesel engines (21/*2003*)*

2) This paper describes the CCAI calculation and is available from www.cimac.com.

[22] CONCAWE report no. 11/19 — *Study to evaluate test methods to assess the stability and compatibility of marine fuels in view of the IMO MARPOL Annex VI Regulation 14.1.3 for* 2020 *Sulphur requirements*

[23] ASTM D4740, *Standard Test Method for Cleanliness and Compatibility of Residual Fuels by Spot Test*

[24] ASTM D7060, *Determination of the Maximum Flocculation Ratio and Peptizing Power in Residual and Heavy Fuel Oils (Optical Detection Method)*

[25] ASTM D7112, *Determining Stability and Compatibility of Heavy Fuel Oils and Crude Oils by Heavy Fuel Oil Stability Analyzer (Optical Detection)*

[26] ASTM D7157, *Determination of Intrinsic Stability of Asphaltene-Containing Residues, Heavy Fuel Oils, and Crude Oils (n-Heptane Phase Separation; Optical Detection)*

[27] ISO/TR 18455[3)], *Petroleum products — Calculation of specific energy of residual fuels from physical and compositional properties — Basic data*

[28] Riazi M. R., Characterisation and properties of petroleum fractions. ASTM International, 2005

[29] ASTM D2501, *Standard Test Method for Calculation of Viscosity-Gravity Constant (VGC) of Petroleum Oils*

[30] ISO/TR 18588, *Petroleum products — Characterization of marine fuels by viscosity-gravity constant*

[31] ISO 8217:2017[4)], *Petroleum products — Fuels (class F) — Specifications of marine fuels*

[32] ISO 13739, *Petroleum products — Procedures for the transfer of bunkers to vessels*

3) Withdrawn.

4) Withdrawn.

ICS 75.160.20

Price based on 41 pages

iso.org