
**Petroleum products — Fuels (class F) —
Specifications of marine fuels**

*Produits pétroliers — Combustibles (classe F) — Spécifications des
combustibles pour la marine*

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Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 8217 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, Subcommittee SC 4, *Classifications and specifications*.

This fourth edition cancels and replaces the third edition (ISO 8217:2005), which has been technically revised.

Introduction

0.1 General

The specifications in this International Standard were prepared in co-operation with ship owners, ship operators, shipping associations, national standards bodies, classification societies, fuel testing services, engine designers, fuel suppliers and the petroleum industry to meet the requirements for fuels supplied on a world-wide basis for consumption on board ships. Crude oil supplies, refining methods, ships' machinery, environmental legislation and local conditions vary considerably. These factors have led historically to a large number of categories of residual fuels being available internationally, even though locally or nationally there can be relatively few categories available.

0.2 Classification

The categories of fuel in this International Standard have been classified in accordance with ISO 8216-1.

0.3 International statutory requirements

This International Standard takes into account the SOLAS Convention^[1] in respect of the allowable minimum flash point of fuels.

The Revised MARPOL Annex VI^[2], which controls air pollution from ships, includes a requirement either that the fuel not exceed specified maximum sulfur content or that an approved equivalent alternative be used. During the lifetime of this International Standard, regional and/or national bodies can introduce their own local emission requirements, which can impact the allowable sulfur content, for example EU Sulfur Directive^[3]. It is the users' responsibility to establish the requirement to comply with such statutory requirements and to specify the maximum sulfur content of the fuel to the supplier.

0.4 Changes from ISO 8217:2005

This fourth edition of this International Standard reflects several important and significant changes. These include category rationalizations of both distillate and residual fuels and substantial amendments to Clause 5. These changes reflect market demand, recognize regulatory developments and current industry experiences with the use of fuels.

The limits contained in Tables 1 and 2 now reflect the test method reporting requirements. For example, viscosity limits are given to four significant figures.

a) Changes to the distillate fuels (4 categories) include the following.

- An additional grade, DMZ, has been added with a minimum viscosity of 3,000 mm²/s at 40 °C, but is otherwise identical in its characteristics to the DMA.
- The previous DMC category has been modified and moved to Table 2 as RMA10.
- Specifications for the following characteristics have been added to Table 1: hydrogen sulfide, acid number, oxidation stability and lubricity.
- The minimum viscosity requirement for DMA has been raised to 2,000 mm²/s.
- A minimum viscosity requirement of 2,000 mm²/s has been added for DMB.
- The specifications for the "appearance" characteristic in Table 1 have been amended.

- b) Changes to the residual fuels (6 categories) include the following.
- RMA 10 has been added.
 - RMG and RMK have been expanded to include additional viscosity grades.
 - RMF and RMH categories have been removed.
 - To Table 2 have been added the Calculated Carbon Aromaticity Index (CCAI) and specifications for the following characteristics: hydrogen sulfide, acid number and sodium content.
 - Sulfur limits have not been tabulated, as these are controlled by statutory requirements. See 0.3 and Annex C.
 - Potential Total Sediment (TSP) has been assigned as the reference test method. Accelerated Total Sediment (TSA) has been added as an alternative test method.
 - Ash limit values have been reduced for many of the categories.
 - Vanadium limit values have been reduced, with the exceptions of those for RMB 30 where the limit value is unchanged and for RMG 380 where the limit value has been slightly increased.
 - Aluminium-plus-silicon limit values have been reduced.
 - The criteria for assessing whether a fuel contains used lubricating oil have been amended.
- c) Changes to the informative annexes include the following.
- Amendments have been made to a number of the annexes.
 - Annex C of the previous edition, dealing with viscosity conversions, has been deleted.
 - The equations dealing with specific energy in Annex E of this new edition have been revised and a gross specific energy equation for distillate fuel has been added.
 - Four new annexes have been added:
 - Annex A, dealing with bio-derived products;
 - Annex B, dealing with deleterious materials;
 - Annex C, dealing with sulfur content;
 - Annex D, dealing with hydrogen sulfide.

Petroleum products — Fuels (class F) — Specifications of marine fuels

WARNING — The handling and use of products as specified in this International Standard can be hazardous, if suitable precautions are not observed. This International Standard does not purport to address all of the safety and health considerations that can be associated with its use. It is the responsibility of the users of this International Standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1 Scope

This International Standard specifies the requirements for petroleum fuels for use in marine diesel engines and boilers, prior to appropriate treatment before use. The specifications for fuels in this International Standard can also be applicable to fuels for stationary diesel engines of the same or similar make and type as those used for marine purposes.

This International Standard specifies four categories of distillate fuel, one of which is for diesel engines for emergency purposes. It also specifies six categories of residual fuel.

NOTE 1 For the purpose of this International Standard, the term “petroleum” is used to include oil from tar sands and from shale.

NOTE 2 Appropriate guidance about fuel treatment systems for diesel engines is published by the International Council on Combustion Engines (CIMAC)^[4].

NOTE 3 Requirements for gas turbine fuels used in marine applications are specified in ISO 4261^[5].

NOTE 4 For the purposes of this International Standard, the terms “mass %” and “volume %” are used to represent the mass and volume fractions respectively.

2 Normative references

The following referenced documents are indispensable for the application 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 91-1:1992, *Petroleum measurement tables — Part 1: Tables based on reference temperatures of 15 °C and 60 °F*

ISO 2719:2002, *Determination of flash point — Pensky-Martens closed cup method*

ISO 3015:1992, *Petroleum products — Determination of cloud point*

ISO 3016:1994, *Petroleum products — Determination of pour point*

ISO 3104:1994, *Petroleum products — Transparent and opaque liquids — Determination of kinematic viscosity and calculation of dynamic viscosity*

ISO 3675:1998, *Crude petroleum and liquid petroleum products — Laboratory determination of density — Hydrometer method*

ISO 8217:2010(E)

ISO 3679:2004, *Determination of flash point — Rapid equilibrium closed cup method*

ISO 3733:1999, *Petroleum products and bituminous materials — Determination of water — Distillation method*

ISO 4259:2006, *Petroleum products — Determination and application of precision data in relation to methods of test*

ISO 4264:2007, *Petroleum products — Calculation of cetane index of middle-distillate fuels by the four-variable equation*

ISO 6245:2001, *Petroleum products — Determination of ash*

ISO 8216-1:2010, *Petroleum products — Fuels (class F) classification — Part 1: Categories of marine fuels*

ISO 8754:2003, *Petroleum products — Determination of sulfur content — Energy-dispersive X-ray fluorescence spectrometry*

ISO 10307-1:2009, *Petroleum products — Total sediment in residual fuel oils — Part 1: Determination by hot filtration*

ISO 10307-2:2009, *Petroleum products — Total sediment in residual fuel oils — Part 2: Determination using standard procedures for ageing*

ISO 10370:1993, *Petroleum products — Determination of carbon residue — Micro method*

ISO 10478:1994, *Petroleum products — Determination of aluminium and silicon in fuel oils — Inductively coupled plasma emission and atomic absorption spectroscopy methods*

ISO 12156-1:2006, *Diesel fuel — Assessment of lubricity using the high-frequency reciprocating rig (HFRR) — Part 1: Test method*

ISO 12185:1996, *Crude petroleum and petroleum products — Determination of density — Oscillating U-tube method*

ISO 12205:1995, *Petroleum products — Determination of the oxidation stability of middle-distillate fuels*

ISO 12937:2000, *Petroleum products — Determination of water — Coulometric Karl Fischer titration method*

ISO 13739:2010, *Petroleum products — Procedures for transfers of bunkers to vessels*

ISO 14596:2007, *Petroleum products — Determination of sulfur content — Wavelength-dispersive X-ray fluorescence spectrometry*

ISO 14597:1999, *Petroleum products — Determination of vanadium and nickel content — Wavelength-dispersive X-ray fluorescence spectrometry*

EN 14078:2009, *Liquid petroleum products — Determination of fatty acid methyl ester (FAME) content in middle distillates — Infrared spectrometry method*

EN 14214, *Automotive fuels — Fatty acid methyl esters (FAME) for diesel engines — Requirements and test methods*

IP 470:2005, *Determination of aluminium, silicon, vanadium, nickel, iron, calcium, zinc and sodium in residual fuel oil by ashing, fusion and atomic absorption spectrometry*

IP 500:2003, *Determination of the phosphorus content of residual fuels by ultra-violet spectrometry*

IP 501:2005, *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 570:2009, *Determination of hydrogen sulfide in fuel oils — Rapid liquid phase extraction method*

ASTM D664-09, *Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration*

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

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, DK, May 18-21, 1998¹⁾

3 Application

This International Standard specifies the required properties for fuels at the time and place of custody transfer. Samples for quality verification may be taken in any location agreed between the parties.

4 Sampling

The sampling of petroleum fuels for analysis shall be carried out in accordance with the procedures given in ISO 13739 or an equivalent national standard. Where specific sampling requirements are documented in the referenced test methods, these shall be adhered to.

5 General requirements

5.1 The fuel shall conform to the characteristics and limits given in Table 1 or Table 2, as appropriate, when tested in accordance with the methods specified.

5.2 The fuel shall be a homogeneous blend of hydrocarbons derived from petroleum refining. This shall not preclude the incorporation of additives intended to improve some aspects of the fuel's characteristics and performance. The fuel shall be free from inorganic acids and used lubricating oils.

5.3 Fuels shall be free from any material that renders the fuel unacceptable for use in marine applications.

5.4 The fuel shall be free from bio-derived materials other than '*de minimis*' levels of FAME (FAME shall be in accordance with the requirements of EN 14214 or ASTM D6751). In the context of this International Standard, "*de minimis*" means an amount that does not render the fuel unacceptable for use in marine applications. The blending of FAME shall not be allowed.

NOTE See Annex A.

5.5 The fuel shall not contain any additive at the concentration used in the fuel, or any added substance or chemical waste that

- a) jeopardizes the safety of the ship or adversely affects the performance of the machinery; or
- b) is harmful to personnel; or
- c) contributes overall to additional air pollution.

NOTE See Annex B.

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

6 New requirements

6.1 Requirements for distillate and residual fuels

- a) The hydrogen sulfide, H₂S, concentration shall be as specified in Table 1 or Table 2.

NOTE H₂S is a highly toxic gas. Exposure to high 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 H₂S; see Annex D.

- b) Acidity shall be as specified in Table 1 or Table 2.

NOTE Acid number limits are included in this International Standard; see Annex H.

6.2 Requirements for distillate fuels

- a) Oxidation stability shall be as specified in Table 1.

NOTE The refinery processes used to manufacture distillate fuels can lead to products that can have limited oxidation stability. In addition, today's non-marine distillate fuels can contain a significant amount, for example in some areas currently 5 volume % to 7 volume %, of bio-derived products i.e., fatty acid methyl esters (FAMES) that can impact on the oxidation stability of the fuel. Furthermore, the transportation of pure distillate fuel and distillate fuel containing bio-derived material (FAME), especially through multi-product pipeline installations, have shown that some FAME is transferred into the pure distillate fuel; see Annex A.

- b) The lubricity shall be as specified in Table 1.

NOTE A lubricity requirement has been included in this International Standard and is applicable to clear and bright distillate fuels with a sulfur content below 500 mg/kg (0,050 mass %). The lubricity limit is based on the existing requirements for high-speed automotive and heavy-duty industrial diesel engines.

6.3 Requirements for residual fuels

- a) Ignition characteristics, as determined by the Calculated Carbon Aromaticity Index (CCAI), shall be as specified in Table 2.

NOTE 1 CCAI, an indication of ignition performance, has been added in Table 2 in order to avoid fuels with uncharacteristic density-viscosity relationships. For a determination of CCAI, see Annex F.

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

NOTE 3 For RME 180 and RMK 380, when blending at or close to the maximum density, the CCAI limit can restrict the combination of density and viscosity.

- b) The sodium concentration shall be as specified in Table 2.

NOTE A limit for sodium content has been included due to concerns regarding the influences of metals in fuels on ash deposition and high-temperature corrosion. Information on the subject is given in Annex I.

7 Test methods

7.1 Density

When density is determined in accordance with ISO 3675, the hydrometer readings obtained at ambient temperature for distillate fuels, and at elevated temperatures of between 50 °C and 60 °C for fuels containing residual components, shall be converted to results at 15 °C using ISO 91-1:1992, Table 53B. When density is determined in accordance with ISO 12185, an appropriate correction for the glass expansion coefficient shall

be applied to readings obtained by a digital density analyser at any temperature other than 15 °C, before conversion and application of ISO 91-1:1992, Table 53B.

The reference test method shall be ISO 3675.

7.2 Sulfur content

The reference test method shall be ISO 8754.

In the event of a dispute concerning sulfur content, all parties shall agree, prior to testing, upon the same sulfur certified reference material.

NOTE See Annex C.

7.3 Flash point

The flash point for fuels in Table 1 shall be determined in accordance with ISO 2719:2002, Procedure A. If the flash point result of DMX is less than 40 °C, it shall be determined in accordance with ISO 3679.

The flash point of fuels in Table 2 shall be determined in accordance with ISO 2719:2002, Procedure B.

NOTE See Annex G.

7.4 Total sediment by hot filtration

If the appearance of DMB is assessed as not clear and bright (see 7.6), the total sediment shall be determined by the test method ISO 10307-1, typically called total sediment existent.

7.5 Total sediment — Aged

Either of the standard procedures for ageing in ISO 10307-2 can be used; Accelerated Total Sediment (TSA) or Potential Total Sediment test (TSP).

The reference test method shall be the Potential Total Sediment test.

7.6 Appearance

For distillate fuel, the appearance of a sample shall be assessed by visual inspection in good light, free from glare and shadow, at a temperature between 10 °C and 25 °C.

- DMX, DMA or DMZ 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 affords visual inspection and appears clear and bright, then testing for total sediment by hot filtration and for water is not required.

7.7 Vanadium

The reference test method shall be IP 501.

NOTE See Annex I.

7.8 Sodium

The reference test method shall be IP 501.

NOTE See Annex I.

7.9 Aluminium plus silicon

The reference test method shall be IP 501.

NOTE See Annex J.

7.10 Used lubricating oil (ULO)

A fuel shall be free from ULO.

In the context of this International Standard, a fuel shall be considered to contain ULO when combinations of calcium and zinc or calcium and phosphorus are above the specified levels; see Table 2.

The reference test method shall be IP 501.

NOTE See Annex K.

8 Precision and interpretation of test results

The test methods specified in Tables 1 and 2 all contain a statement of precision (repeatability and reproducibility). The determination of reproducibility for CCAI is contained in Annex F.

ISO 4259:2006, which covers the use of precision data in the interpretation of test results, shall be used in cases of dispute. Information about precision and interpretation of test results is also given in Annex L.

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Table 1 — Distillate marine fuels

Characteristics	Unit	Limit	Category ISO-F-				Test method reference
			DMX	DMA	DMZ	DMB	
Kinematic viscosity at 40 °C ^a	mm ² /s	max.	5,500	6,000	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	890,0	900,0	see 7.1 ISO 3675 or ISO 12185
Cetane index	—	min.	45	40	40	35	ISO 4264
Sulfur ^b	mass %	max.	1,00	1,50	1,50	2,00	see 7.2 ISO 8754 ISO 14596
Flash point	°C	min.	43,0	60,0	60,0	60,0	see 7.3 ISO 2719
Hydrogen sulfide ^c	mg/kg	max.	2,00	2,00	2,00	2,00	IP 570
Acid number	mg KOH/g	max.	0,5	0,5	0,5	0,5	ASTM D664
Total sediment by hot filtration	mass %	max.	—	—	—	0,10 ^e	see 7.4 ISO 10307-1
Oxidation stability	g/m ³	max.	25	25	25	25 ^f	ISO 12205
Carbon residue: micro method on the 10 % volume distillation residue	mass %	max.	0,30	0,30	0,30	—	ISO 10370
Carbon residue: micro method	mass %	max.	—	—	—	0,30	ISO 10370
Cloud point	°C	max.	-16	—	—	—	ISO 3015
Pour point (upper) ^d	winter quality	max.	-6	-6	-6	0	ISO 3016
	summer quality	max.	0	0	0	6	ISO 3016
Appearance	—	—	Clear and bright ^g				see 7.6
Water	volume %	max.	—	—	—	0,30 ^e	ISO 3733
Ash	mass %	max.	0,010	0,010	0,010	0,010	ISO 6245
Lubricity, corrected wear scar diameter (wsd 1,4) at 60 °C ^h	µm	max.	520	520	520	520 ^g	ISO 12156-1

Table 1 (continued)

Characteristics	Unit	Limit	Category ISO-F-				Test method reference
			DMX	DMA	DMZ	DMB	
a	1 mm ² /s = 1 cSt.						
b	Notwithstanding the limits given, the purchaser shall define the maximum sulfur content in accordance with relevant statutory limitations. See Annex C.						
c	Due to reasons stated in Annex D, the implementation date for compliance with the limit shall be 1 July 2012. Until such time, the specified value is given for guidance. For distillate fuels the precision data are currently being developed.						
d	Purchasers should ensure that this pour point is suitable for the equipment on board, especially if the ship operates in cold climates.						
e	if the sample is not clear and bright, the total sediment by hot filtration and water tests shall be required, see 7.4 and 7.6.						
f	if the sample is not clear and bright, the test cannot be undertaken and hence the oxidation stability limit shall not apply.						
g	if the sample is not clear and bright, the test cannot be undertaken and hence the lubricity limit shall not apply.						
h	This requirement is applicable to fuels with a sulfur content below 500 mg/kg (0,050 mass %).						
j	if the sample is dyed and not transparent, then the water limit and test method as given in 7.6 shall apply.						

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Table 2 — Residual marine fuels

Characteristic	Unit	Limit	Category ISO-F-												Test method reference
			RMA	RMB	RMD	RME	RMG			RMK					
			10 ^a	30	80	180	180	380	500	700	380	500	700		
Kinematic viscosity at 50 °C ^b	mm ² /s	max.	10,00	30,00	80,00	180,0	180,0	380,0	500,0	700,0	380,0	500,0	700,0	ISO 3104	
Density at 15 °C	kg/m ³	max.	920,0	960,0	975,0	991,0	991,0	991,0	991,0	991,0	991,0	991,0	991,0	see 7.1 ISO 3675 or ISO 12185	
CCAI	—	max.	850	860	860	860	860	870	870	870	870	870	870	see 6.3 a)	
Sulfur ^c	mass %	max.	Statutory requirements												see 7.2 ISO 8754 ISO 14596
Flash point	°C	min.	60,0	60,0	60,0	60,0	60,0	60,0	60,0	60,0	60,0	60,0	60,0	60,0	see 7.3 ISO 2719
Hydrogen sulfide ^d	mg/kg	max.	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	IP 570
Acid number ^e	mg KOH/g	max.	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	ASTM D664
Total sediment aged	mass %	max.	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	see 7.5 ISO 10307-2
Carbon residue: micro method	mass %	max.	2,50	10,00	14,00	15,00	18,00	18,00	18,00	18,00	18,00	18,00	18,00	20,00	ISO 10370
Pour point (upper) ^f	winter quality	max.	0	0	30	30	30	30	30	30	30	30	30	30	ISO 3016
	summer quality	max.	6	6	30	30	30	30	30	30	30	30	30	30	ISO 3016
Water	volume %	max.	0,30	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	ISO 3733
Ash	mass %	max.	0,040	0,070	0,070	0,070	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,150	ISO 6245
Vanadium	mg/kg	max.	50	150	150	150	350	350	350	350	350	350	350	450	see 7.7 IP 501, IP 470 or ISO 14597
Sodium	mg/kg	max.	50	100	100	50	100	100	100	100	100	100	100	100	see 7.8 IP 501 IP 470

Table 2 (continued)

Characteristic	Unit	Limit	Category ISO-F-										Test method reference		
			RMA	RMB	RMD	RME	RMG			RMK					
			10 ^a	30	80	180	180	380	500	700	380	500		700	
Aluminium plus silicon	mg/kg	max.	25	40	40	50	60	60	60	60	60	60	60	60	see 7.9 IP 501, IP 470 or ISO 10478
Used lubricating oils (ULO): calcium and zinc; or calcium and phosphorus	mg/kg	—	The fuel shall be free from ULO. A fuel shall be considered to contain ULO when either one of the following conditions is met: calcium > 30 and zinc > 15; or calcium > 30 and phosphorus > 15										see 7.10 IP 501 or IP 470 IP 500		

a This category is based on a previously defined distillate DMC category that was described in ISO 8217:2005, Table 1. ISO 8217:2005 has been withdrawn.

b 1 mm²/s = 1cSt.

c The purchaser shall define the maximum sulfur content in accordance with relevant statutory limitations. See 0.3 and Annex C.

d Due to reasons stated in Annex D, the implementation date for compliance with the limit shall be 1 July 2012. Until such time, the specified value is given for guidance.

e See Annex H.

f Purchasers shall ensure that this pour point is suitable for the equipment on board, especially if the ship operates in cold climates.

Annex A (informative)

Bio-derived products and Fatty Acid Methyl Esters (FAMES)

A.1 Bio-fuels and blends

Bio-derived fuels and blends of bio-derived fuels with petroleum products are included within the range of potential alternative energy sources being considered by some sections of marine industry since they are renewable and can result in reduced Green House Gases (GHGs) and SO_x emissions.

The bulk of bio-derived fuels currently available is the product of a transesterification process that removes the glyceride fraction to produce fatty acid methyl esters (FAMES), commonly referred to as bio-diesel. Bio-diesels can also contain fatty acid ethyl esters, FAEEs, for which test methods and specifications are being developed.

Bio-derived fuels can also be produced by other process methods; however, there is no general broad experience with regard to the application of any bio-derived fuels in marine systems and machinery. Hence, this International Standard does not address this issue but does outline some of the issues that have been encountered in other markets where bio-derived FAME fuels have been mandated.

NOTE FAME is defined in EN 14214 and ASTM D6751.

Notwithstanding that FAME has good ignition, lubricity properties and perceived environmental benefits, there are potentially specific complications with respect to storage and handling in a marine environment such as

- a tendency to oxidation and long-term storage issues;
- 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 different sourced FAME products each with its own particular characteristics that have implications with respect to storage, handling, treatment, engine operations and emissions.

In those instances 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 (such as oily-water separator systems) are compatible with such a product.

This International Standard specifically refers to petroleum-derived materials only, thereby excluding any bio-derived materials. However, the practice of blending FAME into automotive diesel and heating oils makes it almost inevitable, under current supply logistics, that some distillates supplied in the marine market can contain FAME. Even some residual fuels can contain FAME as a result of refinery processes or blending a distillate cutterstock containing FAME.

A.2 Precautionary approach

A.2.1 As there is no generalized experience with respect to storage, handling, treatment and service performance (including overboard discharges) within the broad spectrum of the marine environment, adoption of the precautionary principle to address any safety concerns in this area of using either blends of FAME/petroleum products or 100 % FAME is considered necessary. Furthermore, there are the issues as to the potential effects of FAME products on the range of marine engines and other equipment [i.e. oily-water

separators (OWS) or overboard discharge monitors (ODM)] currently in service. Therefore, this International Standard limits the FAME content to a “*de minimis*” level.

NOTE See 5.4.

A.2.2 To date, determining a *de minimis* level is not straightforward given that

- a wide range of types of FAME products from different sources is available in the market place;
- varying levels of contamination can be present due to the use of common equipment or pipelines in refineries, fuel terminals or other supply facilities;
- a wide range of different analytical techniques is used to detect these FAME products and associated by-products with no standardized approach;
- in most cases, sufficient data are not yet available with respect to the effects of FAME products on marine fuel systems.

A.2.3 For the purpose of this International Standard

- in the case of distillate fuels (DMX, DMA, DMZ and DMB when clear and bright), it is recommended that “*de minimis*” be taken as not exceeding approximately 0,1 volume % when determined in accordance with EN 14078.
- In the case of DMB when it is not clear and bright and all categories of residual fuels, “*de minimis*” cannot be expressed in numerical terms since no test method with formal precision statement is currently available. Thus, it should be treated as contamination from the supply chain system.

Fuel producers and suppliers should ensure that adequate controls are in place so that the resultant fuel, as delivered, is compliant with the requirements of Clause 5 of this International Standard.

Annex B (informative)

Deleterious materials

This International Standard precludes the incorporation of deleterious materials as stipulated in Clause 5. Such materials should not be present, mixed or blended in marine fuels.

Determining the harmful level of a material or substance is not straightforward given that

- a) each fuel is a unique, complex blend of hydrocarbon species;
- b) a wide range of materials from different sources can enter the marine supply chain from the production, handling and transport systems;
- c) varying levels of contamination can be present in the fuel due to the use of common equipment or pipelines in refineries, fuel terminals or other supply facilities;
- d) various analytical techniques are used to detect these contaminants and specific chemical species with no standardized approach;
- e) in most cases, sufficient data are not available with respect to the effects of any one specific contaminant, or combinations thereof, on the variety of marine machinery systems in service, personnel or upon the environment.

It is, therefore, not practical to require detailed chemical analysis for each delivery of fuels beyond the requirements listed in this International Standard. Instead, it is required that a refinery, fuel terminal or any other supply facility, including supply barges and truck deliveries, have in place adequate quality assurance and management of change procedures to ensure that the resultant fuel is compliant with the requirements of Clause 5 of this International Standard with regard to the exclusion of deleterious materials.

Annex C (informative)

Sulfur content

The fourth edition of this International Standard has retained the third edition's limits for sulfur for distillate fuels, but does not include limits for residual fuels. Previously, such limits were included since the sulfur content acts to reduce the specific energy value and, given the appropriate post-combustion temperature conditions, can result in corrosion of susceptible components.

Sulfur limits for distillate fuels in Table 1 were retained due to technical requirements to protect small, high-speed diesel engines.

Statutory requirements, i.e. the Revised MARPOL Annex VI, either specify a maximum sulfur content of the fuel being used or allow the adoption of technical solutions to ensure compliance with the emission regulations for sulfur oxides and particulate matter. Therefore, the sulfur content of both distillate and residual fuels is directly controlled by the statutory requirements.

Consequently, the purchaser's responsibility is to define the maximum sulfur content of the fuels in accordance with the ship's engine design, emission control equipment and the prevailing statutory limitations in the areas in which the fuel will be used.

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Annex D (informative)

Hydrogen sulfide

H₂S is a highly toxic gas and exposure to high vapour concentrations 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.

H₂S can be formed during the refining process and can evolve from the fuels in storage tanks, in product barges and customer tanks. H₂S can be present in both liquid and vapour phase and the degree and speed of partitioning between the liquid and vapour phase depend 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 H₂S vapours can occur when personnel are exposed to fuel vapours, such as when dipping tanks, opening tank hatch covers, entering empty tanks, from vent/vent pipes when tanks are being filled and/or heated, in purifier rooms, breaking into fuel lines and during filter changing operations.

The risks are highlighted in Material Safety Data Sheets (MSDSs) and the dangers presented to health and exposure guidelines are documented. A useful reference guidance is provided in Section 2.3.6 of ISGOTT^[11]. There are many other sources of information regarding H₂S but few are marine specific.

The liquid-phase limit stated in this fourth edition of this International Standard is designed to provide an improved margin of safety over the previous edition. This limit alone does not constitute a safe level or eliminate the risk of very high levels of H₂S vapour being evolved in enclosed spaces.

Reference is made to footnote c in Table 1 and footnote d in Table 2 that specify the date for the implementation of the limit of H₂S in liquid phase. The reasons for the implementation date not being in line with the publication of this International Standard are

- to provide adequate time
 - for the development of a precision statement for distillate fuels in IP 570, the completion of which is anticipated before the implementation date,
 - for the world-wide dissemination and application of the new test method IP 570,
 - for the industry to engineer, procure and construct facility modifications, where required, in order to comply with the limit;
- to avoid fuel supply disruption in the intervening period.

The inclusion in this International Standard of an H₂S in liquid phase limit of 2,00 mg/kg in the fuel directionally reduces the risk of H₂S vapour exposure. However, 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 H₂S vapour.

Annex E (informative)

Specific energy

E.1 Specific energy is not controlled in the manufacture of fuel except in a secondary manner by the specification of other properties.

E.2 For residual fuels, 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 Equations (E.1) and (E.2)^[6], respectively:

$$Q_{Rnp} = \left(46,704 - 8,802\rho_{15}^2 \cdot 10^{-6} + 3,167\rho_{15} \cdot 10^{-3} \right) \cdot \left[1 - 0,01(w_w + w_a + w_s) \right] + 0,094 2w_s - 0,024 49w_w \quad (E.1)$$

$$Q_{Rgv} = \left(52,190 - 8,802\rho_{15}^2 \cdot 10^{-6} \right) \cdot \left[1 - 0,01(w_w + w_a + w_s) \right] + 0,094 2w_s \quad (E.2)$$

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.

NOTE For the purpose of rapid estimation, the net specific energy of residual fuel can be conveniently read from Figure E.1, which has been derived from Equation (E.1). However, the values obtained from the graph are only approximate.

E.3 For distillate fuels, 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 Equations (E.3) and (E.4), respectively:

$$Q_{Dnp} = \left(46,423 - 8,792\rho_{15}^2 \cdot 10^{-6} + 3,170\rho_{15} \cdot 10^{-3} \right) \cdot \left[1 - 0,01(w_w + w_a + w_s) \right] + 0,094 2w_s - 0,024 49w_w \quad (E.3)$$

$$Q_{Dgv} = \left(51,916 - 8,792\rho_{15}^2 \cdot 10^{-6} \right) \cdot \left[1 - 0,01(w_w + w_a + w_s) \right] + 0,094 2w_s \quad (E.4)$$

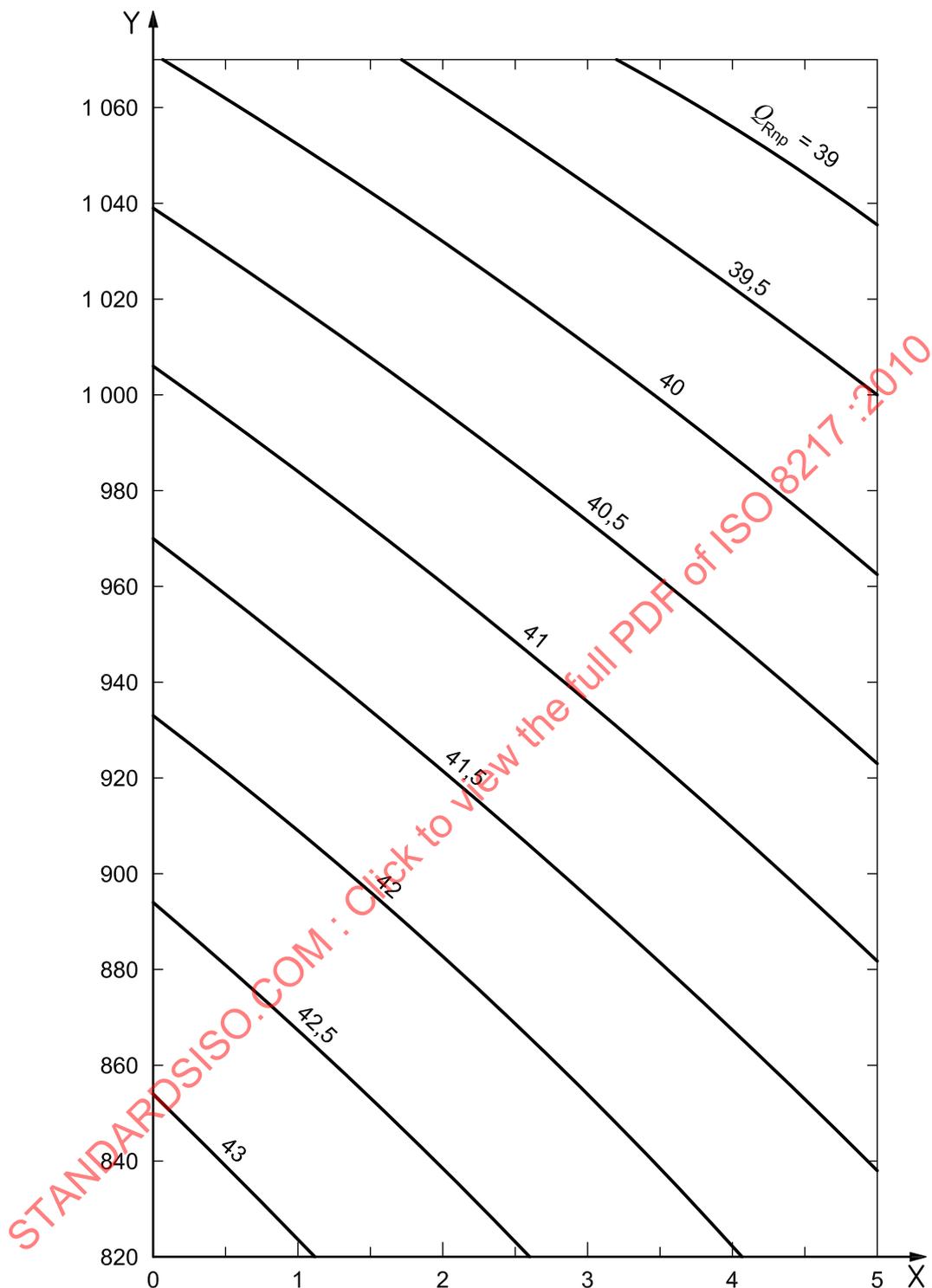
where

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.



Key

- X sulfur concentration, expressed in percent mass fraction
- Y density at 15 °C, expressed in kilograms per cubic metre

NOTE To correct for ash and water, subtract $0,01 Q_{Rnp}(w_a + w_w)$ from the net specific energy, Q_{Rnp} , read from this graph.

Figure E.1 — Net specific energy of residual fuel expressed in megajoules per kilogram

Annex F (informative)

Ignition characteristics of residual marine fuels

F.1 Application

The ignition and combustion characteristics of a residual fuel in a diesel engine is dependant on the particular type, design, operating and engine condition, load profile and the chemical properties of the fuel oil.

The Calculated Carbon Aromaticity Index (CCAI) is determined from the density and viscosity of a residual fuel and, whilst it does not provide information related to the combustion characteristics of residual fuel, it does provide an indication of the ignition delay. CCAI has been included in order to avoid residual fuel oils with uncharacteristic density viscosity relationships, which can lead to an extended ignition delay.

The CCAI value is calculated in accordance with Lewis, *et al.*, using Equation (F.1):

$$\text{CCAI} = \rho_{15} - 81 - 141 \cdot \lg[\lg(v + 0,85)] - 483 \cdot \lg \frac{T + 273}{323} \quad (\text{F.1})$$

where

- T is the temperature, expressed in degrees Celsius, at which the kinematic viscosity is determined;
- v is the kinematic viscosity at temperature T , expressed in square millimetres per second; ρ_{15} is the density at 15 °C, expressed in kilograms per cubic metre;
- \lg is the logarithm to base 10.

NOTE 1 In this International Standard, marine distillate categories DMX, DMA, DMZ and DMB (see Table 1) have a minimum specified cetane index; see ISO 4264. This provides a better approximation of ignition quality than the CCAI parameter, which was primarily developed for use with residual fuels of the type specified in Table 2.

NOTE 2 Work is continuing in a number of countries to identify alternative techniques to determine the overall combustion behaviour of residual fuels.

In an attempt to address both ignition and combustion characteristics of a residual fuel, a standard test method has been established using a constant volume combustion chamber (CVCC); see IP 541. Whilst it has been recognized that fuels with similar densities and viscosities (i.e. similar CCAI's), can have significantly different ignition and combustion properties, work continues to relate the characteristics derived from IP 541^[12] with both fuel quality and in-service experience.

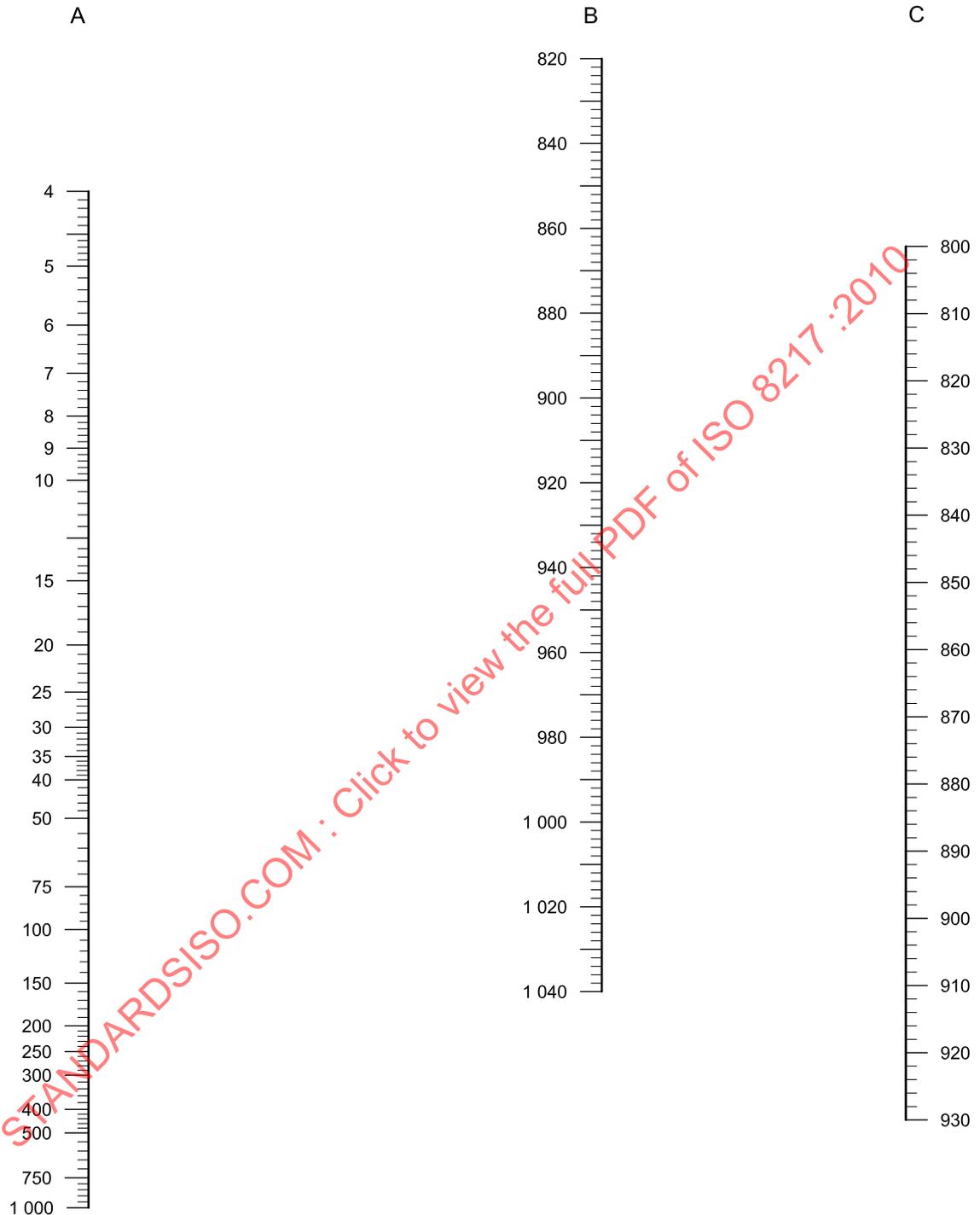
Most ships today are uni-fuel ships; hence, the engines with less tolerance towards ignition and combustion quality discrepancies should be taken into consideration when residual fuels are being ordered.

The International Council on Combustion Engines, CIMAC, is developing guidelines regarding ignition and combustion quality recommendations for diesel engines.

F.2 Use of the nomogram

For the purpose of a rapid estimation, the CCAI value of a residual fuel can be conveniently read from Figure F.1, which has been derived from Equation (F.1), by means of extending a straight line connecting the axes of viscosity, expressed in square millimetres per second, at 50 °C (see A in Figure F.1) and density,

expressed in kilograms per cubic metre, at 15 °C (see B in Figure F.1) to the CCAI axis (see C in Figure F.1). However, the values obtained from Figure F.1 are only approximate.



Key

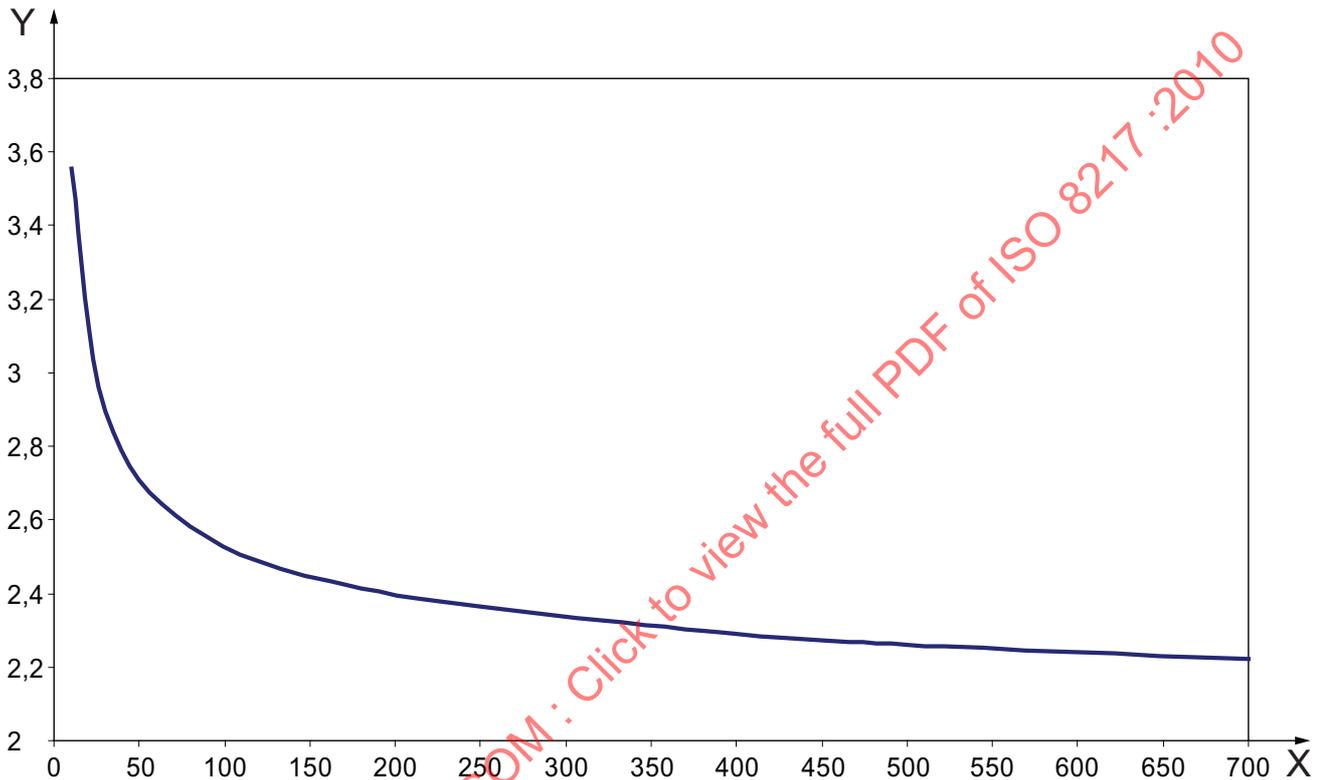
- A kinematic viscosity at 50 °C, expressed in square millimetres per second
- B density at 15°C, expressed in kilograms per cubic metre
- C CCAI

Figure F.1 — Nomogram for deriving CCAI

F.3 Calculation of CCAI precision

The reproducibility of the CCAI value of a particular residual fuel is dependant 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 Figure F.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. The application of the reproducibility is covered in Annex L.



Key

- X viscosity at 50 °C, expressed in square millimetres per second
- Y CCAI reproducibility

Figure F.2 — Plot of CCAI reproducibility against viscosity

Annex G (informative)

Flash point

The flash point value is not a physical constant but is dependent on the test method, the apparatus and the procedure used. In this International Standard, the test method described in ISO 2719 should be used for both distillate and residual fuels. Flash point is one of the valid indicators of the fire hazard posed by the fuel.

For residual fuels, available information shows that flash point on its own is not a reliable indicator of the flammability conditions that can exist within the headspaces of storage tanks. This means that residual fuels can have the potential to produce a flammable atmosphere in the tank headspace, even when stored at a temperature below the measured flash point. Consequently, residual fuels should be considered as potentially hazardous and capable of producing light hydrocarbons that can result in tank headspace atmospheres being near, or within, the flammable range. Appropriate precautions are necessary, therefore, to ensure the safety of people and property.

Further information is contained in ISO/TR 29662^[8] and CEN/TR 15138:2006^[9]. Additional advice on precautionary measures is given in *The Flammability Hazards*^[10] and in *International Safety Guide for Oil Tankers and Terminals*^[11].

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Annex H (informative)

Acidity

Fuels with high acid numbers 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, (formerly known as total acid number or TAN) by ASTM D664-09 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 the tables, are 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 supplier and the purchaser to agree on an acceptable acid number.

Acid number levels significantly higher than those stated above can indicate significant amounts of acidic compounds and, possibly, other contaminants. However, 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 no currently recognized correlation between acid number test results and the corrosive activity of a fuel.

A fuel in which a strong acid species is detected, even at a low level not detectable by the standard test method, SAN, as described in ASTM D664-09, is non-compliant with this International Standard, as there is a correlation between the presence of a strong acid and the corrosive activity of a fuel.