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

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Contents

Page

Foreword ... **iv**
Introduction ... **v**
1 Scope ... **1**
2 Normative references ... **1**
3 Terms and definitions ... **3**
4 Application and sampling ... **3**
5 General requirements ... **3**
6 Test methods ... **4**
6.1 Density ... 4
6.2 CCAI ... 4
6.3 Sulfur ... 4
6.4 Flash point ... 4
6.5 Hydrogen sulfide ... 5
6.6 Acid number ... 5
6.7 Oxidation stability ... 5
6.8 Total sediment by hot filtration ... 5
6.9 Total sediment — Aged ... 5
6.10 Fatty acid methyl ester(s) (FAME) ... 5
6.11 Pour point/cloud point/cold filter plugging point ... 5
6.12 Appearance/water ... 6
6.13 Lubricity ... 6
6.14 Vanadium ... 6
6.15 Sodium ... 6
6.16 Aluminium plus silicon ... 6
6.17 Used lubricating oil (ULO) ... 6
7 Specific energy ... **7**
8 Precision and interpretation of test results ... **7**
Annex A (informative) **Bio-derived products including fatty acid methyl esters** ... **12**
Annex B (informative) **Deleterious materials** ... **14**
Annex C (informative) **Ignition characteristics of residual marine fuels** ... **15**
Annex D (informative) **Hydrogen sulfide** ... **17**
Annex E (informative) **Acidity** ... **18**
Annex F (informative) **Ash** ... **19**
Annex G (informative) **Used lubricating oil** ... **20**
Annex H (informative) **Specific energy** ... **21**
Bibliography ... **22**

Foreword

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

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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

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

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 28, *Petroleum products and related products of synthetic or biological origin*, Subcommittee SC 4, *Classifications and specifications*.

This sixth edition cancels and replaces the fifth edition (ISO 8217:2012), which has been technically revised.

Introduction

General

This document was prepared in cooperation with ship owners, ship operators, shipping associations, national standards bodies, classification societies, fuel testing services, engine designers, 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 increasing demands of environmental legislation are leading to a transition in the nature of marine fuels supplied from traditional oil products derived from the processing of petroleum crude to the potential inclusion of oil products derived from renewable and/or alternative sources. This document takes into consideration the diverse nature of these fuels and incorporates a number of categories of distillate or residual fuels, even though not all categories may be available in every supply location.

Classification

The categories of fuel in this document have been classified in accordance with ISO 8216-1[1].

At the time of preparation of this document, a number of unconventional fuels have been offered to the market which do not conform exactly to this particular distillate/residual categorization. In these instances, it is recommended that the fuel characteristics or limits should be agreed between the purchaser and supplier and defined by both a category of fuel as given by this document together with any different or additional fuel characteristics or limits necessary to adequately define that fuel.

International statutory requirements

This document specifies allowable minimum flash point limits following the provisions given in the SOLAS Convention[2]. MARPOL Annex VI[3], which controls air pollution from ships, includes a requirement that either the fuel shall not exceed a specified maximum sulfur content or an approved equivalent alternative means be used. During the lifetime of this document, regional and/or national bodies may introduce their own local emission requirements, which can impact the allowable sulfur content, for example, the EU Sulphur Directive[4]. It is the purchaser's and the user's responsibility to establish which statutory requirements are to be met and specify on that basis the corresponding maximum fuel sulfur content to the supplier.

Changes with respect to ISO 8217:2012

This sixth edition reflects important and significant changes. These include substantial amendments to the scope (Clause 1) and to the general requirements (Clause 5).

Changes to the distillate fuels include the following:

— additional grades, DFA, DFZ and DFB have been added with a maximum fatty acid methyl ester(s) (FAME) content of 7,0 volume %;

— the sulfur content of DMA and DMZ has been reduced to a maximum of 1,00 mass %;

— the sulfur content of DMB has been reduced to a maximum of 1,50 mass %;

— requirements for the following characteristics have been added to winter grades of DMA and DMZ: cloud point and cold filter plugging point.

The following annexes, previously included, have been deleted, but the key information is included in the body of this document or is available in referenced industry publications:

— Sulfur content;

— Flash point;

— Catalyst fines;

— Precision and interpretation of test results.

All other annexes have been reviewed and updated.

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

WARNING — The handling and use of products specified in this document can be hazardous if suitable precautions are not observed. This document 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 document to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.

1 Scope

This document specifies the requirements for fuels for use in marine diesel engines and boilers, prior to conventional onboard treatment (settling, centrifuging, filtration) before use. The 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 six categories of residual fuels.

For the purposes of this document, the term "fuels" is currently used to include the following:

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

— hydrocarbons from synthetic or renewable sources, similar in composition to petroleum distillate fuels;

— blends of the above with a fatty acid methyl ester(s) (FAME) component where permitted.

NOTE 1 Appropriate guidance about fuel treatment systems for diesel engines is published by the International Council on Combustion Engines (CIMAC)[5].

NOTE 2 Requirements for gas turbine fuels used in marine applications are specified in ISO 4261[6].

NOTE 3 For the purposes of this document, the terms "mass %" and "volume %" are used to represent the mass and volume fractions respectively.

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 products — Determination of cloud point

ISO 3016, *Petroleum products — 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, *Petroleum products — Determination 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 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 and petroleum products — Determination of density — Oscillating U-tube method*

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 13739, *Petroleum products — Procedures for transfer of bunkers to vessels*

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*

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

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 D7963, *Standard Test Method for 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*

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

IP 309, *Diesel and domestic heating fuels — Determination of cold filter plugging point*

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

IP 612,*Diesel and domestic heating fuels — Determination of cold filter plugging point Linear cooling bath method — Linear cooling bath method*

3 Terms and definitions

No terms and definitions are listed in this document.

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

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

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

4 Application and sampling

This document 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.

The sampling of 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 as supplied shall be homogeneous and conform to the characteristics and limits given in Table 1 or Table 2, as appropriate, when tested in accordance with the methods specified.

The fuel composition shall consist predominantly of hydrocarbons primarily derived from petroleum sources while it may also contain hydrocarbons from the following:

— synthetic or renewable sources such as Hydrotreated Vegetable Oil (HVO), Gas to Liquid (GTL) or Biomass to Liquid (BTL);

— co-processing of renewable feedstock at refineries with petroleum feedstock.

The DF grades, as defined in ISO 8216, include up to 7,0 volume % FAME (see Table 1), where FAME at the time of blending shall be in accordance with the requirements of EN 14214 or ASTM D6751.

DMX shall be free of 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*" means an amount that does not render the fuel unacceptable for use in marine applications that are not designed or suited to handling fuels containing FAME.

NOTE See Annex A for more details on the level and impacts of FAME.

5.2 The fuel shall be free from any material at a concentration that causes the fuel to be unacceptable for use in accordance with Clause 1 (i.e. material not at a concentration that is harmful to personnel, jeopardizes the safety of the ship, or adversely affects the performance of the machinery).

NOTE See Annex B.

5.3 Subject to the requirements of 5.1 and 5.2, 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

Calculated carbon aromaticity index (CCAI) shall be as specified in Table 2.

The CCAI value is calculated in accordance with Lewis, et al.[7], using Formula (1):

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

where

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

lg is the logarithm to base 10;

v is the kinematic viscosity at temperature T, expressed in millimetres squared 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 according to the test methods specified in Table 2.

NOTE 1 CCAI was originally developed as an indicator of ignition performance, but is included in Table 2 in order to avoid fuels with uncharacteristic density-viscosity relationships (see Annex C).

NOTE 2 For engines and/or applications where the ignition quality is known to be particularly critical, Annex C 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 restricts the combination of density and viscosity.

6.3 Sulfur

Sulfur test precision for fuels containing FAME has not been established for the test methods ISO 8754 and ISO 14596 at the time of preparing this International Standard. The sulfur test precision for distillate fuels containing FAME has been established for test method ASTM D4294.

The reference test method shall be ISO 8754 for DM and RM grades and ASTM D4294 for DF grades.

In case of disagreement concerning sulfur content, all parties shall agree, prior to additional testing, upon the same sulfur certified reference material.

6.4 Flash point

The flash point for all fuels, except for DMX, is set at 60 °C minimum according to the International Convention for Safety of Life at Sea (SOLAS)[2].

Residual 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 [8] to[11].

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. The flash point of fuels in Table 2 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 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 could be exposed to H_2S; see Annex D.

6.6 Acid number

The fuel shall be free of inorganic acids. The fuel shall be tested in accordance with ASTM D664.

NOTE See Annex E.

6.7 Oxidation stability

The oxidation stability shall be as specified in Table 1.

NOTE 1 The oxidation stability limit takes into account that some refinery processes used to manufacture distillate fuels lead to products that have limited oxidation stability and that bio-derived products, e.g. FAME, can impact the oxidation stability of the fuel.

NOTE 2 See Annex A.

6.8 Total sediment by hot filtration

If the appearance of DMB or DFB is assessed as not clear and bright (see 6.12), the total sediment shall be determined by the test method ISO 10307-1, typically called existent total sediment.

6.9 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 in accordance with ISO 10307-2.

6.10 Fatty acid methyl ester(s) (FAME)

Test method IP 579 is not applicable to RM grades at the time of preparation of this document. Test method ASTM D7963 is applicable to all DM, DF and RM grades.

The reference test method shall be IP 579 for DM and DF grades.

NOTE See Annex A.

6.11 Pour point/cloud point/cold filter plugging point

The purchaser 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.

Issues with low temperature operability (i.e. deposition of solidified wax in fuel tanks, fuel lines, centrifuges and filters) can occur with distillate fuels. The pour point requirement as defined in Table 1

cannot guarantee operability for all ships in all climates. Therefore, for winter grades of DMA, DFA, DMZ and DFZ, the cloud point and cold filter plugging point shall be reported.

NOTE More information can be found in the CIMAC guideline for managing cold flow properties of marine fuels[12].

6.12 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 (0,020 mass %), 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 total sediment by hot filtration and for water is not required. If the appearance is not clear and bright, the water content shall be determined by ISO 3733.

6.13 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.

6.14 Vanadium

The reference test method shall be IP 501.

NOTE See Annex F.

6.15 Sodium

The reference test method shall be IP 501.

NOTE See Annex F.

6.16 Aluminium plus silicon

The aluminium plus silicon limits in Table 2 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][13].

The reference test method shall be IP 501.

6.17 Used lubricating oil (ULO)

The fuel shall be free of ULO. In the context of this document, 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 G.

7 Specific energy

The specific energy of marine fuels can be calculated as given in Annex H.

8 Precision and interpretation of test results

The test methods specified in Table 1 and Table 2 all contain a statement of precision (repeatability and reproducibility). The determination of reproducibility for CCAI shall be in accordance with Annex C.

ISO 4259, which covers the use of precision data in the interpretation of test results, shall be used in cases of dispute.

The precision data for the test methods ISO 6245 (ash) and ISO 12205 (oxidation stability) for diesel fuels containing 5,0 volume % FAME were determined by the experts of CEN/TC 19 to be the same as the reported precision data[14].

However, at the time of publication of this document, the precision data determined by the experts of CEN/TC 19 for diesel fuels containing 5,0 volume % FAME for the test method ISO 3104 were as follows:

Property	Test method	Unit	Precision for 5,0 volume % FAME blend
Viscosity at 40 °C	ISO 3104	mm^2/s	r = 0,001 1 X; R = 0,018 X

where r is repeatability and R is reproducibility (see ISO 4259), X is the mean of two results being compared.

It is the technical opinion of the experts of ISO/TC 28/SC 4 that the same precision data for 5,0 volume % FAME can be applied to distillate marine fuels containing up to 7,0 volume % FAME.

NOTE Since all fuel testing is subject to inherent variations, the assessment of fuels as supplied is governed by the provisions of ISO 4259. More information is provided in the CIMAC guideline on the interpretation of marine fuel oil analysis test results[15].

Table 1 — Distillate marine fuels

Characteristics		Unit	Limit	Category ISO-F-							Test method(s) and references
				DMX	DMA	DFA	DMZ	DFZ	DMB	DFB	
Kinematic viscosity at 40 °C		mm^2/s[a]	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		ISO 3675 or ISO 12185; see 6.1
Cetane index			Min	45	40		40		35		ISO 4264
Sulfur[b]		mass %	Max	1,00	1,00		1,00		1,50		ISO 8754 or ISO 14596, ASTM D4294; see 6.3
Flash point		°C	Min	43,0	60,0		60,0		60,0		ISO 2719; see 6.4
Hydrogen sulfide		mg/kg	Max	2,00	2,00		2,00		2,00		IP 570; see 6.5
Acid number		mg KOH/g	Max	0,5	0,5		0,5		0,5		ASTM D664; see 6.6
Total sediment by hot filtration		mass %	Max	—	—		—		0,10[c]		ISO 10307-1; see 6.8
Oxidation stability		g/m^3	Max	25	25		25		25[d]		ISO 12205
Fatty acid methyl ester (FAME)[e]		volume %	Max	—	—	7,0	—	7,0	—	7,0	ASTM D7963 or IP 579; see 6.10
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[f]	winter	°C	Max	–16	report		report		—		ISO 3015; see 6.11
	summer	°C	Max	–16	—		—		—		
Cold filter plugging point[f]	winter	°C	Max	—	report		report		—		IP 309 or IP 612; see 6.11
	summer	°C	Max	—	—		—		—		

[a] 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 Introduction.

[c] If the sample is not clear and bright, the total sediment by hot filtration and water tests shall be required. See 6.8 and 6.12.

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

[e] See 5.1 and Annex A.

[f] Pour point cannot guarantee operability for all ships in all climates. The purchaser 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 6.11.

[g] If the sample is dyed and not transparent, then the water limit and test method as given in 6.12 shall apply.

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

Table 1 *(continued)*

Characteristics		Unit	Limit	Category ISO-F-							Test method(s) and references
				DMX	DMA	DFA	DMZ	DFZ	DMB	DFB	
Pour point (upper)[f]	winter	°C	Max	—	−6		−6		0		ISO 3016; see 6.11
	summer	°C	Max	—	0		0		6		
Appearance				Clear & Bright[g]					[c]		see 6.12
Water		volume %	Max	—	—		—		0,30[c]		ISO 3733
Ash		mass %	Max	0,010	0,010		0,010		0,010		ISO 6245
Lubricity, corrected wear scar diameter (WSD) at 60 °C[h]		µm	Max	520	520		520		520[d]		ISO 12156-1

[a] 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 Introduction.

[c] If the sample is not clear and bright, the total sediment by hot filtration and water tests shall be required. See 6.8 and 6.12.

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

[e] See 5.1 and Annex A.

[f] Pour point cannot guarantee operability for all ships in all climates. The purchaser 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 6.11.

[g] If the sample is dyed and not transparent, then the water limit and test method as given in 6.12 shall apply.

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

Table 2 — Residual marine fuels

Characteristics		Unit	Limit	Category ISO-F-											Test method(s) and references
				RMA	RMB	RMD	RME	RMG				RMK			
				10	30	80	180	180	380	500	700	380	500	700	
Kinematic viscosity at 50 °C		mm^2/s[a]	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				1010,0			ISO 3675 or ISO 12185; see 6.1
CCAI			Max	850	860	860	860	870				870			See 6.2
Sulfur[b]		mass %	Max	Statutory requirements											ISO 8754 or ISO 14596 or ASTM D4294; see 6.3
Flash point		°C	Min	60,0	60,0	60,0	60,0	60,0				60,0			ISO 2719; see 6.4
Hydrogen sulfide		mg/kg	Max	2,00	2,00	2,00	2,00	2,00				2,00			IP 570; see 6.5
Acid number[c]		mg KOH/g	Max	2,5	2,5	2,5	2,5	2,5				2,5			ASTM D664; see 6.6
Total sediment – Aged		mass %	Max	0,10	0,10	0,10	0,10	0,10				0,10			ISO 10307-2; see 6.9
Carbon residue – Micro method		mass %	Max	2,50	10,00	14,00	15,00	18,00				20,00			ISO 10370
Pour point (upper)[d]	winter	°C	Max	0	0	30	30	30				30			ISO 3016
	summer	°C	Max	6	6	30	30	30				30			
Water		volume %	Max	0,30	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				0,150			ISO 6245
Vanadium		mg/kg	Max	50	150	150	150	350				450			IP 501, IP 470 or ISO 14597; see 6.14

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

[b] The purchaser shall define the maximum sulfur content in accordance with relevant statutory limitations. See Introduction.

[c] See Annex E.

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

Table 2 *(continued)*

Characteristics	Unit	Limit	Category ISO-F-											Test method(s) and references
			RMA	RMB	RMD	RME	RMG				RMK			
			10	30	80	180	180	380	500	700	380	500	700	
Sodium	mg/kg	Max	50	100	100	50	100				100			IP 501, IP 470; see 6.15
Aluminium plus silicon	mg/kg	Max	25	40	40	50	60				60			IP 501, IP 470 or ISO 10478; see 6.16
Used lubricating oil (ULO): 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 6.17

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

[b] The purchaser shall define the maximum sulfur content in accordance with relevant statutory limitations. See Introduction.

[c] See Annex E.

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

Annex A
(informative)

Bio-derived products including fatty acid methyl esters

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 greenhouse gases (GHGs) and sulphur emissions (SO_x).

The bulk of bio-derived fuels currently available are the products of a transesterification process that removes the glyceride fraction to produce fatty acid methyl ester(s) (FAME), also referred to as bio-diesel. Bio-diesels can also contain fatty acid ethyl ester(s) (FAEE), for which, at the time of preparing this document, test methods and specifications are being developed.

In 2010, due to limited experience with the use of FAME blends in the marine sector, ISO 8217 was modified to require marine fuels to contain no more than a "*de minimis*" level, which for distillate fuel was indicated at that time as approximately 0,1 volume % FAME. The practice of blending FAME into conventional diesel and heating oils makes it almost inevitable, under current supply logistics, that some distillate fuels supplied in the marine market can contain FAME. Even some residual fuels can contain FAME as a result of cross contamination or blending with a distillate cutter stock containing FAME.

Since 2010, additional information has become available on the use of biodiesel in conventional automotive diesel fuel as well as on the use of distillate fuels containing biodiesel on-board ships. In the light of this experience, this edition of this document retains the general "*de minimis*" level requirement, but with a wider tolerance as given below and also includes additional specifications (DF grades) for distillate marine fuels containing up to 7,0 volume % FAME. The FAME used for blending shall meet specification requirements of EN 14214 or ASTM D6751.

The increase in demand for marine fuels with sulfur content limited to no more than 0,10 mass % as a result of regulatory requirements, may partially be met by supplying distillate fuel which may contain up to 7,0 volume % FAME.

NOTE In some countries, legislation mandates that distillate fuels shall contain bio-derived products, which may result in FAME levels exceeding 7,0 volume %.

For the purpose of this document, DMX shall be free of FAME and, with exception of DF 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*" which is now taken to be a level of approximately 0,5 volume % FAME, and

— the fuel is compliant with the requirements of Clause 5.

To determine the FAME content of DM grades, test methods IP 579 or ASTM D7963 can be used, except IP 579 cannot be used for DMB when it is not clear and bright. For DMB (not clear and bright) and RM grades test method, ASTM D7963 should be used.

A.2 Storage and handling of DF grade marine fuels

The International Council on Combustion Engines (CIMAC) has developed guidelines on managing distillate marine fuels containing up to 7,0 volume % FAME[16].

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

— a tendency to oxidation and long-term storage issues,

— an affinity to water and risk of microbial growth,

— degraded low-temperature flow properties, and

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

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

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 in terms of materials and operational performance compatible with such a product. Contact of materials such as bronze, brass, copper, lead, tin and zinc with FAME should be avoided as these may oxidize FAME thereby creating sediments.

Annex B
(informative)

Deleterious materials

This document precludes the incorporation of any material at a concentration that causes the fuel to be unacceptable for use as stipulated in Clause 5.

Identifying and determining the concentration of a material that causes the fuel to be unacceptable for use can be difficult 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) various analytical techniques are used to detect specific chemical species with no standardized approach, and

d) in most cases, sufficient data are not available with respect to the effects of any one specific material, or combinations thereof, on the variety of marine machinery systems in service, on personnel or on the environment.

It is therefore not practical to require detailed chemical analysis for each delivery of fuels beyond the requirements listed in Table 1 or Table 2. Instead, a refinery, fuel terminal or any other supply facility, including supply barges and truck deliveries, should 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.

NOTE The marine industry continues to build on its understanding of the impact of specific chemical species and the respective critical concentrations at which detrimental effects are observed on the operational characteristics of marine fuels in use.

Annex C
(informative)

Ignition characteristics of residual marine fuels

C.1 Application

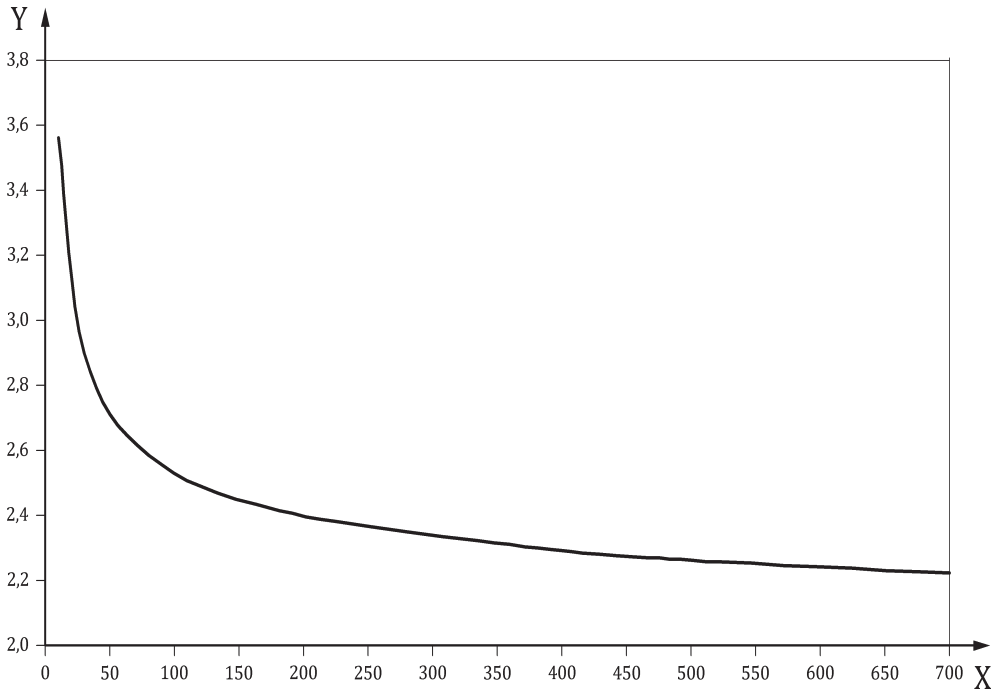
A diesel engine's sensitivity to a fuel's ignition characteristics depends not only on the fuel's chemical composition but also the particular engine type and design together with its maintenance and operating conditions. Where the same fuel is to be used for both main and auxiliary engines, the requirements 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 residual fuels and is determined from the density and viscosity values. CCAI is primarily included in Table 2 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 Figure C.1. 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 millimetres squared per second

Y CCAI reproducibility

Figure C.1 — Plot of CCAI reproducibility against viscosity

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-100FCA, 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 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.

H_2S can be formed during the refining process and may evolve from the fuels in storage tanks, in product barges and customer 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 material safety data sheets (MSDSs) and the dangers presented to health and exposure guidelines are documented. A useful reference guidance is provided in ISGOTT, section 2.3.6[8]. There are many other sources of information regarding H_2S, but few are marine specific.

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 reduces 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 being present in enclosed spaces and 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 could 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)

Acidity

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; formerly known as total acid number or TAN) by 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 Table 1 or Table 2, 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 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 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 species [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)

Ash

All residual fuels contain some metallic species, 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. It is for this reason that 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 International Council on Combustion Engines (CIMAC) has produced a detailed document “recommendations regarding fuel quality for diesel engines (21/2003)”[20], Annex 7 of which provides an in-depth review of this subject.

Annex G
(informative)

Used lubricating oil

The addition of 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, ULO is quite a variable material, but it is comprised predominantly of used vehicle crankcase oils which contain significant amounts of detergent and anti-wear additives. 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 ULO if either of the two groups of elements, calcium and zinc or calcium and phosphorus, are above the limits specified in Table 2.

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 free from ULO and the reproducibility of the test methods. It is, therefore, not possible to set a zero upper limit on these “fingerprint” elements.

On the basis of extensive statistical reports, the combination of these elements given in this document would not trigger the incorrect identification of ULO.

The limits on zinc, phosphorus and calcium given in Table 2 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 ULO is necessarily unsuitable for use.

Annex H
(informative)

Specific energy

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

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 Formulae (H.1) and (H.2)[21], respectively:

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

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

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 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 Formulae (H.3) and (H.4), respectively:

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

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

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.

Bibliography

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

[2] International Maritime Organization (IMO). *International Convention for Safety of Life at Sea* (SOLAS), 1974, as amended, Chapter II- 2, Part B, Regulation 4, Section 2.1

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

[4] Directive (EU) 2016/802 of the European Parliament and of the Council of 11 May 2016 relating to a reduction in the sulphur content of certain liquid fuels (codificatiion)

[5] International Council on Combustion Engines (CIMAC). Recommendation No. 25, *Recommendations concerning the design of heavy fuel treatment plants for diesel engines*. (May 2006)

[6] ISO 4261, *Petroleum products — Fuels (class F) — Specifications of gas turbine fuels for industrial and marine applications*

[7] 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[1)]

[8] *International Safety Guide for Oil Tankers and Terminals* (ISGOTT), 5th edition, ISBN 978-1-85609-291-3

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

[10] CEN/TR 15138, *Petroleum products and other liquids — Guide to flash point testing*

[11] Oil Companies International Marine Forum. (OCIMF). *The Flammability Hazards Associated with the Handling, Storage and Carriage of Residual Fuel Oils*, December 1989

[12] International Council on Combustion Engines (CIMAC) — CIMAC *Guideline. Cold flow properties of marine fuels (01/2015)*

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

[14] CEN/TR 15160, *Petroleum and related products — Applicability of diesel fuel test methods for Fatty Acid Methyl Esters (FAME) — Information and results on round robin tests*

[15] International Council on Combustion Engines (CIMAC) — CIMAC *Guideline. The interpretation of marine fuel analysis test results (02/2016)*

[16] International Council on Combustion Engines (CIMAC) — *Guideline for ship owners and operators on managing distillate fuels up to 7,0 % v/v FAME (biodiesel)(2013)*

[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] International Council on Combustion Engines (CIMAC) — *Recommendations regarding fuel quality for diesel engines (21/2003)*

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

[21] ISO/TR 18455[2)], *Petroleum products — Calculation of specific energy of residual fuels from physical and compositional properties — Basic data*

2) Withdrawn.

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