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

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



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Contents

Page

Foreword	iv
Introduction	v
1 Scope	1
2 Normative references	1
3 Application	2
4 Sampling	2
5 General requirements	3
6 Other properties of fuels	3
7 Test methods	3
7.1 Density	3
7.2 Flash point.....	3
7.3 Sulfur content.....	4
7.4 Appearance	4
7.5 Total sediment existent.....	4
7.6 Total sediment potential	4
7.7 Used lubricating oil (ULO)	4
7.8 Vanadium.....	4
7.9 Aluminium plus silicon	4
8 Precision and interpretation of test results	4
Annex A (informative) Specific energy	8
Annex B (informative) Ignition quality	10
Annex C (informative) Viscosity conversions	12
Annex D (informative) Catalyst fines	13
Annex E (informative) Flash point — Residual fuel oils	14
Annex F (informative) Examples of precision and interpretation of test results	15
Annex G (informative) Sodium and vanadium in marine fuels	17
Annex H (informative) Used lubricating oils in marine fuels	19
Annex I (informative) Acidity in marine fuels	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.

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 third edition cancels and replaces the second edition (ISO 8217:1996), in which the Introduction and Table 1 and Table 2 have been revised.

Introduction

0.1 General

The specifications in this International Standard were prepared in co-operation with the marine and petroleum industries to meet the requirements for marine fuels supplied on a world-wide basis for consumption on board ships. Crude oil supplies, refining methods, ships' machinery 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 might be relatively few categories. Several of the residual fuels are unique in origin to one country or area, but nevertheless are included in the specification because of their importance in the international marine fuel market.

0.2 Classification

The categories of fuel in this International Standard have been classified in accordance with ISO 8216-1^[3]. The sub categories (M) and (H) of ISO-F-D categories, as described in ISO 8216-99^[4], have not been used in this International Standard since the distillate categories described can fall into either or both of these sub categories.

0.3 International statutory requirements

This International Standard takes account of the international requirements for flash point, as given by the International Maritime Organization (IMO)^[6] and of the international requirements for the sulfur content given by the IMO in a protocol adopted in September 1997 and in force since May 2005^[7]. Additionally, regional and/or national bodies may introduce their own local requirements for the sulfur content of marine fuels during the lifetime of this International Standard, for example by the European Communities^[8]. These might be more stringent than those prescribed by the IMO Protocol, and it is the users' responsibility to establish the existence of any such requirements, their applicability and compliance with them.

0.4 Informative annexes

Important information to support this International Standard is given in the informative Annexes A to I. The subjects covered are specific energy, ignition quality, viscosity conversions, catalyst fines, limitations of flash point, precision and interpretation of test results, sodium and vanadium, used lubricating oil and acidity.

0.5 Changes from previous editions of this International Standard

This is the third edition of this International Standard. It reflects several important changes, particularly in the viscosity classification of residual fuels, in the number of categories of residual fuels, which are now reduced to ten, and in the alignment of limits on sulfur to those currently being ratified by the International Maritime Organization as mentioned above. For the residual fuel categories, the maximum water content is reduced to 0,5 % (V/V) and density limits for the lower viscosity categories have been lowered. The reference temperature for viscosity limits for all residual fuel grades have been changed from 100 °C to 50 °C. While measurement at 100 °C gives better precision, it is at variance with the reality of the bunker market. Previous editions of this International Standard have used a reference temperature of 100 °C, but most of the bunker market has in practice continued to refer to kinematic viscosity measured at 50 °C for commercial transactions. The reference temperature has, therefore, been changed in this edition to 50 °C in recognition of commercial practice. It also has to be recognized that viscosity is not a very critical parameter as far as the shipboard technical requirement is concerned and that the better precision of 100 °C is of no meaningful consequence in this respect. The inclusion of used lubricating oil is now controlled by limits on levels of zinc, phosphorus and calcium in all the residual fuel categories and in distillate category DMC.

NOTE For the purposes of this International Standard, the terms “% (m/m)” and “% (V/V)” are used to represent the mass and volume fractions, respectively.

0.6 Further changes

This International Standard will be kept continually under review.

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

WARNING — The handling and use of products as specified in this International Standard may be hazardous, if suitable precautions are not observed. This International Standard does not purport to address all of the safety problems 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.

This International Standard specifies four categories of distillate fuel, one of which is for diesel engines for emergency purposes. It also specifies ten 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) (see Reference [9]).

NOTE 3 Requirements for gas turbine fuels used in marine applications are specified in ISO 4261^[1].

The specifications for marine residual fuels in this International Standard can also be applicable to stationary diesel engines of the same or similar make and type as those used for marine purposes.

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 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 4259:1992, *Petroleum products — Determination and application of precision data in relation to methods of test*

ISO 4264:1995, *Petroleum products — Calculation of cetane index of middle-distillate fuels by the four-variable equation*

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

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

ISO 10307-1:1993, *Petroleum products — Total sediment in residual fuel oils — Part 1: Determination by hot filtration*

ISO 10307-2:1993, *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 12185:1996, *Crude petroleum and petroleum products — Determination of density — Oscillating U-tube method*

ISO/TR 13739:1998, *Petroleum products — Methods for specifying practical procedures for the transfer of bunker fuels to ships*

ISO 14596:1998, *Petroleum products — Determination of sulfur content — Wavelength-dispersive X-ray fluorescence spectrometry*

ISO 14597:1997, *Petroleum products — Determination of vanadium and nickel content — Wavelength-dispersive X-ray fluorescence spectrometry*

IP 470/03, *Determination of aluminium, silicon, vanadium, nickel, iron, calcium, zinc and sodium in residual fuel oil by ashing, fusion and atomic absorption spectrometry*

IP 500/03, *Determination of the phosphorus content of residual fuels by ultra-violet spectrometry*

IP 501/03, *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*

3 Application

When used in connection with commercial transactions, this International Standard specifies the required properties for marine fuels at the time and place of custody transfer. Samples for quality verification can be taken in any location agreed between the parties.

4 Sampling

The sampling of petroleum fuels for analysis, for the purposes of this International Standard, shall be carried out in accordance with the procedures given in ISO/TR 13739:1998, Clause 10, or an equivalent National Standard.

5 General requirements

5.1 The fuels shall be homogeneous blends of hydrocarbons derived from petroleum refining. This shall not preclude the incorporation of small amounts of additives intended to improve some aspects of performance. The fuels shall be free from inorganic acids and from used lubricating oils.

The fuel should not include any added substance or chemical waste which

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

5.2 Fuels shall comply with the requirements in Tables 1 and 2 when tested by the methods referred to therein.

6 Other properties of fuels

6.1 It has not been possible to reach agreement on a direct method of handling ignition quality for residual fuels in a way that would enable this parameter to be included in the mandatory part of this International Standard. It is nevertheless recognized that a measure of ignition quality control already exists via the density and viscosity requirements within the mandatory part of this International Standard. For engines and/or applications where ignition quality is known to be particularly critical, Annex B provides a basis for suppliers and purchasers of marine residual fuels to agree on acceptable ignition quality characteristics.

6.2 While it is not considered necessary to include specification limits in this International Standard for additional metal elements, such as sodium, concerns about the influences of metals in marine fuels upon ash deposition and high temperature corrosion are well recognized. Information on the subject is given, therefore, in Annex G. Similarly, this International Standard does not include any limits for acids in fuels, information on which 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 on distillate fuels, and at elevated temperatures of between 50 °C and 60 °C on fuels containing residual components, shall be converted to results at 15 °C using Table 53B of ISO 91-1:1992. When density is determined in accordance with ISO 12185, an appropriate correction for glass expansion coefficient shall be applied to readings, obtained by digital density analyser at any temperature other than 15 °C, before conversion and application of Table 53B of ISO 91-1:1992.

The reference method shall be ISO 3675.

7.2 Flash point

The flash point for all categories of fuels in Table 1 shall be determined in accordance with ISO 2719, Procedure A. If the flash point of a category DMX sample is less than 40 °C, it shall be determined in accordance with ISO 3679.

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

7.3 Sulfur content

The reference method for compliance with this International Standard shall be ISO 8754. In some geographical areas, other methods may be specified by national authorities for environmental control purposes.

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

7.4 Appearance

For categories DMX, DMA and DMB, the appearance of samples shall be assessed by visual inspection in good light, free from glare and shadow, at a temperature between 10 °C and 25 °C.

- DMX and DMA categories samples shall appear clear and bright.
- If the clarity of DMB category samples affords visual inspection, and if they appear free from visible sediment and water, testing for total sediment existent and for water is not required.

7.5 Total sediment existent

The total sediment existent shall be determined in accordance with ISO 10307-1 for all DMB category samples that fail the visual inspection prescribed in 7.4.

7.6 Total sediment potential

The method given in ISO 10307-2 for determination of potential sediment (Procedure A) shall be the reference method.

7.7 Used lubricating oil (ULO)

The reference test method for compliance with this International Standard shall be IP 501.

7.8 Vanadium

The reference test method for compliance with this International Standard shall be ISO 14597.

7.9 Aluminium plus silicon

The reference test method for compliance with this International Standard shall be ISO 10478.

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). Attention is drawn to ISO 4259:1992, Clause 9 and Clause 10, which cover the use of precision data in the interpretation of test results; this method shall be used in cases of dispute. Information about precision and interpretation of test results is also given in Annex F.

Table 1 — Requirements for marine distillate fuels

Characteristic	Unit	Limit	Category ISO-F-				Test method reference
			DMX	DMA	DMB	DMC ^a	
Density at 15 °C	kg/m ³	max.	—	890,0	900,0	920,0	ISO 3675 or ISO 12185 (see also 7.1)
Viscosity at 40 °C	mm ² /s ^b	min. max.	1,40 5,50	1,50 6,00	— 11,0	— 14,0	ISO 3104 ISO 3104
Flash point	°C	min. min.	— 43	60 —	60 —	60 —	ISO 2719 (see also 7.2)
Pour point (upper) ^c — winter quality — summer quality	°C	max. max.	— —	- 6 0	0 6	0 6	ISO 3016 ISO 3016
Cloud point	°C	max.	-16 ^d	—	—	—	ISO 3015
Sulfur	% (m/m)	max.	1,00	1,50	2,00 ^e	2,00 ^e	ISO 8754 or ISO 14596 (see also 7.3)
Cetane index	—	min.	45	40	35	—	ISO 4264
Carbon residue on 10 % (V/V) distillation bottoms	% (m/m)	max.	0,30	0,30	—	—	ISO 10370
Carbon residue	% (m/m)	max.	—	—	0,30	2,50	ISO 10370
Ash	% (m/m)	max.	0,01	0,01	0,01	0,05	ISO 6245
Appearance ^f	—	—	Clear and bright		^f	—	See 7.4 and 7.5
Total sediment, existent	% (m/m)	max.	—	—	0,10 ^f	0,10	ISO 10307-1 (see 7.5)
Water	% (V/V)	max.	—	—	0,3 ^f	0,3	ISO 3733
Vanadium	mg/kg	max.	—	—	—	100	ISO 14597 or IP 501 or IP 470 (see 7.8)
Aluminium plus silicon	mg/kg	max.	—	—	—	25	ISO 10478 or IP 501 or IP 470 (see 7.9)
<u>Used lubricating oil (ULO)</u>							
- Zinc	mg/kg	max.	—	—	—	The fuel shall be free of ULO ^g 15 15 30	IP 501 or IP 470 IP 501 or IP 500 IP 501 or IP 470 (see 7.7)
- Phosphorus	mg/kg	max.	—	—	—		
- Calcium	mg/kg	max.	—	—	—		

^a Note that although predominantly consisting of distillate fuel, the residual oil proportion can be significant.

^b 1 mm²/s = 1 cSt

^c Purchasers should ensure that this pour point is suitable for the equipment on board, especially if the vessel operates in both the northern and southern hemispheres.

^d This fuel is suitable for use without heating at ambient temperatures down to – 16 °C.

^e A sulfur limit of 1,5 % (m/m) will apply in SO_x emission control areas designated by the International Maritime Organization, when its relevant protocol enters into force. There may be local variations, for example the EU requires that sulphur content of certain distillate grades be limited to 0,2 % (m/m) in certain applications. See 0.3 and reference [7].

^f If the sample is clear and with no visible sediment or water, the total sediment existent and water tests shall not be required. See 7.4 and 7.5.

^g A fuel shall be considered to be free of used lubricating oils (ULOs) if one or more of the elements zinc, phosphorus and calcium are below or at the specified limits. All three elements shall exceed the same limits before a fuel shall be deemed to contain ULOs.

Table 2 — Requirements for marine residual fuels

Characteristic	Unit	Limit	Category ISO-F-										Test method reference	
			RMA 30	RMB 30	RMD 80	RME 180	RMF 180	RMG 380	RMH 380	RMK 380	RMH 700	RMK 700		
Density at 15 °C	kg/m ³	max.	960,0	975,0	980,0	991,0	991,0	991,0	991,0	1010,0	991,0	1010,0	ISO 3675 or ISO 12185 (see also 7.1)	
Kinematic viscosity at 50 °C	mm ² /s ^a	max.	30,0		80,0	180,0			380,0		700,0		ISO 3104	
Flash point	°C	min.	60		60	60			60			60	ISO 2719 (see also 7.2)	
Pour point (upper) ^b - winter quality - summer quality	°C	max. max.	0 6	24 24	30 30	30 30			30 30			30 30	ISO 3016 ISO 3016	
Carbon residue	% (m/m)	max.	10		14	15	20	18		22		22	ISO 10370	
Ash	% (m/m)	max.	0,10		0,10	0,10	0,15		0,15			0,15	ISO 6245	
Water	% (V/V)	max.	0,5		0,5	0,5			0,5			0,5	ISO 3733	
Sulfur ^c	% (m/m)	max.	3,50		4,00	4,50			4,50			4,50	ISO 8754 or ISO 14596 (see also 7.3)	
Vanadium	mg/kg	max.	150		350	200	500	300		600		600	ISO 14597 or IP 501 or IP 470 (see 7.8)	
Total sediment potential	% (m/m)	max.	0,10		0,10	0,10			0,10			0,10	ISO 10307-2 (see 7.6)	
Aluminium plus silicon	mg/kg	max.	80		80	80			80			80	ISO 10478 or IP 501 or IP 470 (see 7.9)	

Table 2 (continued)

Characteristic	Unit	Limit	Category ISO-F-										Test method reference
			RMA 30	RMB 30	RMD 80	RME 180	RMF 180	RMG 380	RMH 380	RMK 380	RMH 700	RMK 700	
Used lubricating oil (ULO) - Zinc - Phosphorus - Calcium	mg/kg	max. max. max.	The fuel shall be free of ULO ^d 15 15 30										IP 501 or IP 470 (see 7.7) IP 501 or IP 500 (see 7.7) IP 501 or IP 470 (see 7.7)
<p>^a Annex C gives a brief viscosity/temperature table, for information purposes only. 1 mm²/s = 1 cSt</p> <p>^b Purchasers should ensure that this pour point is suitable for the equipment on board, especially if the vessel operates in both the northern and southern hemispheres.</p> <p>^c A sulfur limit of 1,5 % (<i>m/m</i>) will apply in SO_x emission control areas designated by the International Maritime Organization, when its relevant protocol comes into force. There may be local variations.</p> <p>^d A fuel shall be considered to be free of ULO if one or more of the elements zinc, phosphorus and calcium are below or at the specified limits. All three elements shall exceed the same limits before a fuel shall be deemed to contain ULO.</p>													

Annex A (informative)

Specific energy

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

A.2 For residual fuels, net specific energy, N_a , and gross specific energy, G , both in megajoules per kilogram, can be calculated with a degree of accuracy acceptable for normal purposes from the equations given below (see also Reference [5]).

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

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

where

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

w_w is the water content, expressed as a mass fraction;

w_a is the ash content, expressed as a mass fraction;

w_s is the sulfur content, expressed as a mass fraction.

A.3 Alternatively, for the purposes of rapid estimation, the net specific energy of marine residual fuels can be conveniently read off from Figure A.1, which has been derived from Equation (A.1). However, the value obtained are only approximate.

A.4 For marine distillate fuels, net specific energy, N_a , in megajoules per kilogram, can be calculated with a degree of accuracy acceptable for normal purposes from Equation (A.3) (see also Reference [10]):

$$N_a = \left(46,423 - 8,792\rho_{15}^2 10^{-6} + 3,15\rho_{15} 10^{-3}\right) \times \left[1 - 0,01(w_w + w_a + w_s)\right] + 0,094 2 w_s - 0,024 w_w \quad (\text{A.3})$$

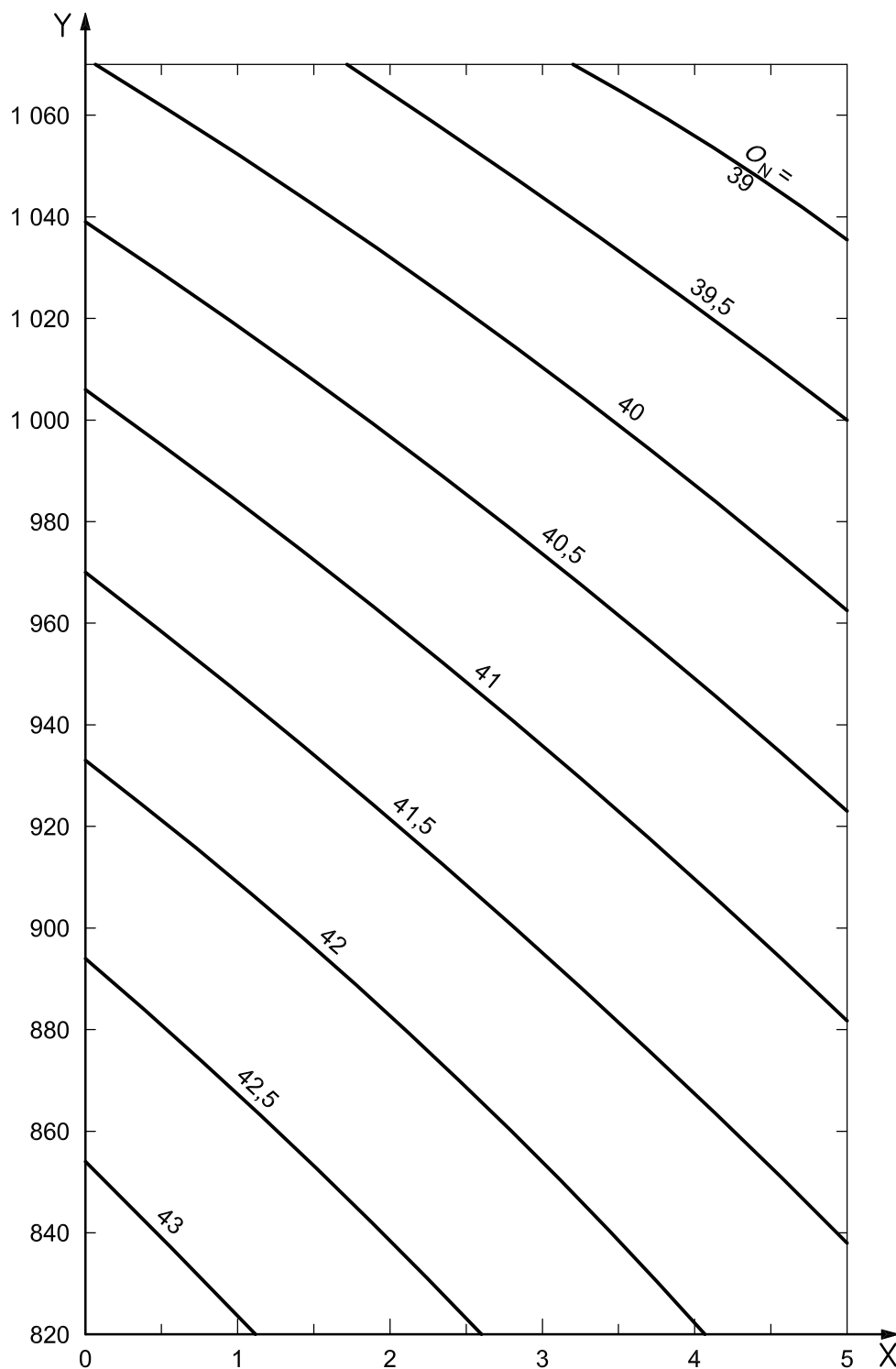
where

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

w_w is the water content, expressed as a mass fraction

w_a is the ash content, expressed as a mass fraction

w_s is the sulfur content, expressed as a mass fraction

**Key**X w_s , sulfur content, % (m/m)Y ρ_{15} , density at 15 °C, in kilograms per cubic metre

NOTE 1 To correct for ash and water, subtract 0,01 Q_N (% ash + % water) from net specific energy (Q_N) read from this graph.

NOTE 2 Values read from this figure might not agree exactly with the calculated values (see A.2), and are considered as approximate.

Figure A.1 — Net specific energy, in megajoules per kilogram, of marine fuels

Annex B (informative)

Ignition quality

B.1 Application

Ignition performance requirements of residual fuels in marine diesel engines are primarily determined by engine type and, more significantly, by engine operating conditions. Fuel factors influence ignition characteristics to a much lesser extent. For this reason, no general limits for ignition quality can be applied, since a value which can be problematical to one engine under adverse conditions can perform quite satisfactorily in many other instances. If required, further guidance on acceptable ignition quality values should be obtained from the engine manufacturer.

B.2 Use of nomogram

The extension of a straight line connecting the viscosity and the density of a fuel oil can be used to give its calculated carbon aromaticity index (CCAI, see Reference [11]) value, which allow ranking of its ignition performance. These values can also be calculated using Equation (B.1):

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

where

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

v is the kinematic viscosity, in square millimetres per second;

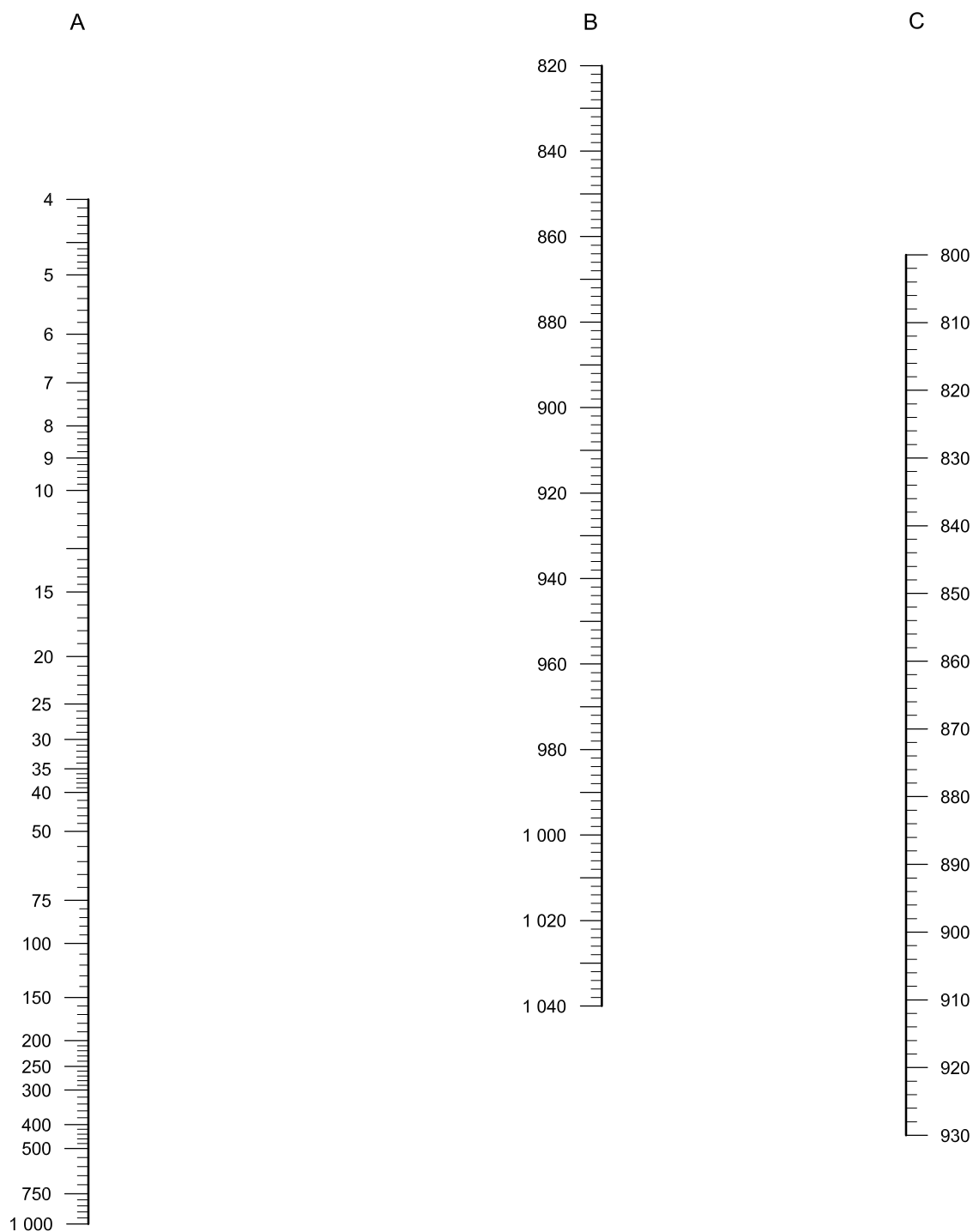
ρ is the density at 15 °C, in kilograms per cubic metre.

NOTE 1 An alternative to CCAI for ranking ignition performance of residual fuels is the calculated ignition index CII. See Reference [12].

NOTE 2 In this International Standard, marine distillate categories DMX, DMA 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 to be used for residual fuels of the type specified in Table 2.

NOTE 3 Work is continuing in a number of countries to identify alternative techniques to determine the overall combustion behaviour of residual fuels.

NOTE 4 \lg is the logarithm to base 10.

**Key**

- A Kinematic viscosity, square millimetres per second.
- B Density at 15 °C, in kilograms per cubic metre.
- C CCAI

Figure B.1 — Nomogram for deriving CCAI

Annex C (informative)

Viscosity conversions

This International Standard specifies limiting values of kinematic viscosity at 50 °C for the fuel categories contained in Table 2. In some cases, kinematic viscosity may be measured or quoted at other temperatures, and Table C.1 below gives approximate relationships. The data should be used with caution because the variability of composition of residual fuels can cause variations in viscosity-temperature relationships.

Table C.1 — Viscosities estimated from those measured at 50 °C

Kinematic viscosity mm ² /s ^a				
Measured at 50 °C	Approximate estimations at			
	40 °C	100 °C	125 °C	150 °C
30	45	7	4	3
80	135	13	7	4
180	330	22	11	7
380	750	35	16	9
700	1500	50	22	11
^a 1 mm ² /s = 1 cSt				

Annex D

(informative)

Catalyst fines

The main source of potentially abrasive particulates in bunker fuels is catalyst fines. The selected control parameter, aluminium plus silicon, with limit values for all fuels in Table 2 and category DMC in Table 1, is intended to limit catalyst fines contamination to a level that will ensure minimal risk of abrasive wear, given that adequate fuel pre-treatment is achieved.

There are significant variations from refinery to refinery in the proportions of the aluminium and the silicon compounds that comprise catalyst fines. The combined aluminium and silicon limit value of 80 mg/kg is intended, therefore, to reflect such variations.

The lower limit for aluminium plus silicon applied to category DMC (25 mg/kg) is based on the proportion of residual fuel that may be expected to be part of this product.

Annex E (informative)

Flash point — Residual fuel oils

Whilst flash point is a valid indicator of the fire hazard posed by residual fuel oil, information is available which shows that it is not a reliable indicator of the flammability conditions that can exist within the headspaces of tanks containing such fuel oils. This means that residual fuel oil 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 fuel oils should be considered to be potentially hazardous and capable of producing light hydrocarbons, which could result in tank headspace atmospheres being near to, or within, the flammable range. Appropriate precautions are necessary therefore to ensure the safety of people and property. Further information and advice on precautionary measures are given in References [13] and [14].

Annex F (informative)

Examples of precision and interpretation of test results

F.1 Introduction

Marine fuel quality complaints can be categorized generally as either those where a problem has occurred on board or where there is a dispute over the acceptability of the product prior to its use. Whichever the case, the fuel must be tested to ascertain its nature.

F.2 Use of ISO 4259

Table 1 and Table 2 of this International Standard, specify maximum and minimum limits to the *true value* of a given property. *True value*, as defined by ISO 4259, represents the average of an infinite number of single results obtained by an infinite number of laboratories. Therefore this true value can never be established exactly. A fuel test, run a number of times at the same laboratory, by the same person, on the same sample, under the same conditions, will rarely yield exactly the same answer for each test run. Occasional human mistakes or omissions will introduce a random error, which can be quantified for each test method as *Repeatability* (r). When two different laboratories test the same sample using the same method, the random error is called *Reproducibility* (R).

Clause 8 of this International Standard states:

‘The test methods specified in Table 1 and Table 2 all contain a statement of precision (repeatability and reproducibility). Attention is drawn to ISO 4259:1992, Clause 9 and Clause 10, which cover the use of precision data in the interpretation of test results: it is this method that shall be used in cases of dispute.’ (Emphasis added).

ISO 4259:1992, Clause 9, provides information to allow the supplier or the recipient of fuels to judge the quality of a product with regard to the specification when a single result is available.

F.3 Recipient with a single test result

A recipient who has no other information on the true value of a characteristic, other than a single test result, can consider that the product fails the specification limit, with 95 % confidence, only if the test result is such that:

- a) in the case of a maximum specification limit
 - test result $>$ specification limit $+ 0,59 \times R$;
- b) or in the case of a minimum specification limit
 - test result $<$ specification limit $- 0,59 \times R$.

EXAMPLE Recipient has ordered fuel to ISO-F-RMG 380 specification in which the limit on viscosity is 380 mm²/s at 50 °C max.

For the test method, ISO 3104, when the viscosity is measured at 50 °C, R is 0,074 times, (or 7,4 % of) the test value.

Therefore, at 380 mm²/s at 50 °C, $R = 0,074 \times 380 = 28,12$ mm²/s at 50 °C.

Consequently, if the single test result is $> 380 + (0,59 \times 28,12)$, i.e. $> 396,59$, then the recipient can consider the sample to fail the specification with 95 % confidence.

F.4 Supplier with a single test result

Similarly, a supplier who has no other source of information than a single result shall consider that the fuel meets the specification limit, with 95 % confidence, only if the test result is such that

- a) in the case of a maximum specification limit:
 - test result \leq specification limit $- 0,59 \times R$;
- b) or in the case of a minimum specification limit
 - test result \geq specification limit $+ 0,59 \times R$.

EXAMPLE Supplier has delivered fuel to the RMG 380 specification in which the limit on viscosity is 380 mm²/s at 50 °C max.

For the test method ISO 3104, when the viscosity is measured at 50 °C, R is 0,074 times (or 7,4 % of) the test value.

Therefore, at 380 mm²/s at 50 °C, $R = 0,074 \times 380 = 28,12$ mm²/s at 50 °C

Consequently, if a single test result is $\leq 380 - (0,59 \times 28,12)$, i.e. $\leq 363,41$, then the supplier can consider the sample to meet the specification with 95 % confidence.

F.5 Resolving disputes

If the supplier and recipient cannot reach agreement about the quality of a fuel, ISO 4259:1992, Clause 10, gives the appropriate procedures to be followed. The reader should refer to the full text of ISO 4259:1992, Clause 10 for the definitive procedures, but should note that the procedures only cover the situation where each laboratory is analysing fuel samples that are subdivisions from one representative sample.

Annex G (informative)

Sodium and vanadium in marine fuels

G.1 Introduction

All residual fuels contain some metallic species, either those that are naturally present [such as vanadium (V)], or those introduced from external sources [sodium (Na) from sea water, aluminium and silicon (Al & Si) from catalyst fines and iron (Fe) from rust]. When a fuel is burned some of these metals are converted into solid particles of oxides, sulfates, or more complex compounds, collectively known as ash. At some temperature these solid ash particles will 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 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 which are rich in V and/or Na. It is for this reason that particular attention is paid to the amounts of these metals in fuels.

G.2 Ash melting points

Melting points of ashes vary greatly depending on ash constituents. For example sodium vanadyl vanadate, as an uncontaminated compound, has an ash melting temperature of 535 °C. However this can be depressed further by solution of other metal oxides derived from corroding surfaces. For this reason ash melting temperatures well below 400 °C are theoretically possible. A sodium/vanadium ratio of 1:3 is frequently claimed to yield the lowest ash melting temperature. This is correct for a simple two component ($\text{Na}_2\text{SO}_4/\text{V}_2\text{O}_5$) ash complex. Ashes derived from combustion of real fuel oils are, however, complex mixtures of compounds which will also incorporate compounds of calcium, nickel, silicon and aluminium, together with many other metals at lower concentrations. All of these additional metals will tend to influence ash melting temperatures, in some cases exerting a beneficial effect by making the ash less prone to adhering to surfaces, while in other cases having the opposite effect.

The critical 1:3 Na/ V ratio assumes increasing importance as the vanadium content of the fuel oil rises because the ash will become increasingly vanadium rich. (While vanadium levels in a residual fuel can be several hundred milligrams per kilogram, other metals do not usually reach such levels; therefore their influence on "stiction" temperatures is reduced.) Also, at high vanadium levels the total ash burden will be greater, thus exacerbating any problems which may arise due to ash deposition.

It is not uncommon to find that some ship-owners' specifications limit the maximum sodium level to one-third of the actual vanadium level. It will be obvious from the above that such a generalized limit is not well founded scientifically and is unnecessarily restrictive, particularly at lower vanadium levels (say < 150 mg/kg).

G.3 Vanadium and sodium levels

As noted in the introduction, vanadium is a natural component of fuel oil. It is present not as the neat metal, but as complex chemical molecules containing both vanadium and other elements; such molecules are effectively dissolved within the fuel. There are no practical methods by which vanadium can be removed from fuel oil on board ship. Therefore, the only practical way to restrict vanadium is by limiting its content in the fuel purchasing arrangements. What constitutes a realistic limit will be dependent primarily on operational experience and the known sensitivity of the particular engine or boiler to ash related problems, as well as on the availability and price of the preferred fuel oil quality at ports to which the vessel trades.

The level of sodium that can be present in bunker fuel is not directly controlled in this International Standard. The reason for this is that the usual source of sodium is seawater contamination. Each mass fraction unit of sea water, on average, adds about 100 mg/kg to the sodium content of a fuel, while fuels that are essentially water-free will normally have sodium contents between about 10 mg/kg and 50 mg/kg, rarely significantly higher.

Unlike vanadium, sodium is not usually present in the fuel in an oil-soluble form. In most cases, high sodium levels are associated with seawater contamination, hence the amount of sodium removed will be directly related to the amount of water that can be removed in settling tanks and by centrifugal treatment. Very occasionally, sodium hydroxide used in the refining process can be the source of the contaminant. Some of the sodium can be present in an oil soluble form that cannot be removed on board ship.

G.4 Engineering solutions to the problem

The engineering solution to the control of hot corrosion is primarily achieved by a combination of control of metal surface temperature and selection of alloys that have the optimum combination of physical properties and hot corrosion resistance. Nimonic 80A and Nimonic 81¹⁾ alloys are regarded by many to represent the "industry standard" materials for best, all round, performance of exhaust valves.

There have also been significant advances in engine design in recent years which have aimed to prevent the ash adhering to the critical components in the first place. Examples of this are more efficient cooling of valve seats and faces, and the use of valve rotators to even out the thermal load on valves. As a result of all the advances, modern engine designs are much more tolerant of vanadium and/or sodium than earlier designs. Manufacturers recommendations for acceptable vanadium levels span a wide range which can be up to 600 mg/kg of vanadium for more modern designs.

1) Nimonic 80A and Nimonic 81 are examples of suitable products available commercially. This information is given for the convenience of users of ISO 8217 and does not constitute an endorsement by ISO of these products.

Annex H (informative)

Used lubricating oils in marine fuels

Used lubricating oils (ULOs), predominantly spent motor vehicle crankcase oils, have been added to bunker fuels in some parts of the world for over 25 years. The acceptability of this practice has become a highly contentious issue, even in areas where it is officially encouraged and where strict environmental rules exist.

Although the proportion of fuels containing ULO varies, best estimates are that its presence has varied up to 3 % of fuel samples tested.

The technical and commercial opinion on the subject is very strongly divided.

The arguments presented for allowing used lubricating oil (ULO) in bunker fuels include the following.

- There is no firm or conclusive evidence of any harmful effects of ULO, at least at “low” levels (although the definition of “low” is imprecise).
- Many ship-owners adopt the practice of disposing of a ship’s own used crankcase oils to the ship’s fuel, and therefore the disposal of ULO from land-based sources is thought to be equally acceptable.
- Field studies of the efficiency of shipboard fuel treatment have not shown any significant adverse effect when ULO is present.

The arguments presented for opposing the practice include the following.

- Various laboratory studies^[15] of centrifuge performance have been carried out, and some of these (but not all) indicate that ULO can have an adverse effect on centrifuge performance.
- ULO addition can lead to engine problems such as accelerated turbocharger fouling (due to increased ash loading), or fuel pump damage (due to increased abrasives and/or cavitation damage due to water).
- The addition of ULO as a fuel blend component collected from inland sources with no or inadequate environmental regulations may provide a route for other waste materials (e.g. industrial solvents) to enter the bunker fuel oil pool.

In addition to these technical considerations, there is also a commercial view; users and purchasers are unhappy at paying fuel oil prices for what they perceive to be someone else’s waste products.

As a consequence, many purchasers now include a clause specifying that the fuel “shall contain no ULO”. However, such a clause is too loosely defined to enable monitoring of the requirement. For this reason, this International Standard now contains limits on appropriate “fingerprint” elements of ULOs. These limits are designed to prevent, as far as possible, any addition of ULO to marine fuels, as explained below.

Potentially, ULO is quite a variable material but, as noted above, is comprised predominantly of used vehicle crankcase oils. Such oils contain significant amounts of detergent and anti-wear additives. Detergent additives are based mainly on calcium, while anti-wear additives are usually zinc-phosphorus compounds. However, it is not possible to set a zero upper limit on these “fingerprint” elements because the same elements can originate from natural sources. The levels are usually only a few milligrams per kilogram, but for fuel oil derived from some crude oils, the levels can be very much higher.

The principle used in setting limits for this standard is that if ULO is present then all three of the “fingerprint” elements will be present also in significant amounts. Natural sources of the elements, on the other hand, are expected to show a high concentration for only one of the elements. 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 fuels free of ULO and the reproducibility of the test methods.

The limits on zinc, phosphorus and calcium given in Table 1 and 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. As with all specification parameters, the appropriate action in the event of a deviation from specification should take into account the specific circumstances of the case.

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Annex I

(informative)

Acidity in marine fuels

Fuels with high acid numbers arising from acidic compounds occasionally have caused accelerated damage to marine diesel engines. Such damage has been found primarily within the fuel injectors and associated pumps. These failures have resulted shortly after commencement of use of the bunker-fuel supplies.

Testing fuels for acid number (AN, but formerly known as total acid number or TAN) by use of ISO 6619 (see Reference [2]) can give indications as to the likely presence of acidic compounds. Although many fuels have a measurable acid number, these are generally (but not always) less than 3 mg KOH/g, and AN levels significantly higher than this might indicate significant amounts of acidic compounds and, possibly, other contaminants. However, an AN below 3 mg KOH/g does not guarantee that the fuel is free from problems associated with the presence of acidic compounds. Further, there is no currently recognized correlation between AN test results and the corrosive activity of a fuel.

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2) To be published. (Revision of ISO 8216-1:1996)

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