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CIMAC Guideline

The Interpretation of Marine Fuel Analysis Test Results

By CIMAC WG7 Fuels

The first edition of this CIMAC Guideline was approved by the members of the CIMAC WG7 ‘Fuels’ in February 2016.

Content

Appendices:

1 Introduction

This guideline follows on from the CIMAC WG7 guideline No 09:2014 [1] which set out the differences between the ISO 4259 approach and that adopted under MARPOL Annex VI in respect of fuel sulphur content test results. However, it is important to understand that this ISO 4259 approach is also applied generally to the interpretation of all marine fuel analysis test results.

Therefore this guideline has been developed in order to provide information on how to apply the ISO 4259 approach to the interpretation of the analysis test results in respect of those marine fuel characteristics given in ISO 8217 from both the recipient and the supplier perspectives.

2 Background and Assumptions

In the marine market, fuel is typically ordered and supplied against ISO 8217 *Petroleum Products – Specifications of marine fuels* [2].

As part of the production and supply chain processes, fuel will usually be analysed to ensure that the product supplied meets the required specification. In addition, at the time of delivery some ships either request an additional sample to be provided to the ship from the witnessed supplier's sample, or take their own independent sample of the fuel supplied, for dispatch to an analytical laboratory. Hence there will often be a 'supplier's' and 'recipient's' set of test results.

There is an assumption that the fuel supplied is homogeneous and that all samples drawn from a fuel supply are identical. Whilst testing samples drawn from the same sampling location reduces differences, in many cases (in the marine market), testing is carried out on samples drawn from different locations which, while it does not preclude them being considered 'identical', can introduce further uncertainties.

Irrespective of how the samples are drawn, there will inevitably be variability in test results provided by the supplier and those obtained by the recipient, due to the inherent variability of test results from different laboratories. This can occur even when testing samples, which have been verified as being identical, e.g. through "fingerprint parameter testing". Whenever referring to ´identical samples´, this document makes the assumption that these samples are representative of the same bunker fuel.

This guideline takes the primary approach that each party has a single test result; albeit in practice there may have been subsequent duplicate tests undertaken to validate the initial finding. Multiple test results act to reduce inter-test variability, but do not eradicate the inherent differences. In this review, the term 'recipient' is generally used to describe whoever the responsible party is for receiving the fuel.

3 The Measurement of Fuel Characteristics

Measurement is not an exact science, whether applied to fuel testing or to any other measurement activity. Consequently, there are factors, and combinations of factors, which influence a particular test result. A declared value for a tested property may be the outcome of a single test or a series of tests, obtained in a single laboratory or from a number of different laboratories. Therefore, in order to provide a controlled framework within which fuel testing is undertaken, analysis should always be performed using standard test methods in laboratories with robust quality assurance systems such as accredited laboratories. The accreditation of a laboratory within a national or

international laboratory scheme covers its general competence, impartiality and performance capability. Typically, this assessment will be against the requirements of ISO 17025 [3] or equivalent national / international standard and will cover the principal test methods performed by the laboratory in question.

Standard test methods have been developed for a wide range of fuel characteristics and the majority of the test methods usually exist within both the ISO system and national equivalents. These methods cover aspects such as the test equipment, reference materials, consumables and procedures used, together with the relevant result reporting convention.

As part of the development of a test method, repeatability and reproducibility values will be determined and both will be stated in the test method. It is important to note that when a test method is revised, as indicated by the associated issue date, the repeatability and reproducibility values may also change.

Repeatability – expressed as 'r'

Is the closeness of agreement, usually found, between independent results obtained in the normal and correct operation of the same method on identical test material, in a short interval of time, and under the same test conditions (same operator, same apparatus, same calibration standard and same laboratory).

Reproducibility – expressed as 'R'

Is the closeness of agreement, usually found, between individual results obtained in the normal and correct operation of the same method on identical test material but under different test conditions (different operators, different apparatus, different calibration standards and different laboratories).

For a number of characteristics given in ISO 8217 more than one test method is specified and where this occurs a reference test method, for use in case of disputes, is defined. The 'r' and 'R' values are dependent on the test method used.

4 Test Result Assessment in Accordance with ISO 4259

Given that there will be variability between test results, even from identical samples tested in the same laboratory, this raises the issue of when does an individual test result indicate that a fuel has, or has not, met a particular specification requirement. In the case of marine fuel oils, ISO 8217 employs the well-established, statistically based, ISO 4259 *Petroleum Products – Determination and Application of Precision Data in Relation to Methods of Test* [4] for the interpretation of test results. A summary of the relevant requirements is given as Annex L in ISO 8217 [2].

It is necessary that any analysis result specifies the test method used, so that an accurate assessment can be made, in accordance with ISO 4259, as to whether a fuel has, or has not, met a particular specification requirement. Laboratories satisfying the requirements of ISO 17025 will report the test results the interpretation of the results in accordance with this standard (Appendix I).

If a fuel has a 'true value' that is equal to the specification limit then, due to the natural variability in testing, when tested multiple times, there will be as many test results above that limit as there are below that limit.

On the basis of the inherent level of test variability, establishing the 'true value' of a specification characteristic is not achievable in practice. Instead the usual approach adopted is in terms of 95% confidence that a single (or multiple) test result(s) either satisfies or does not satisfy a specification limit. For commercial marine fuel transactions, the 95% confidence testing boundary is given by ISO 4259 as 0.59 times the reproducibility value (R); hereafter expressed as 0.59R. Where, as in the usual case, there is a single test result the value of R is that which is stated in the relevant test method. However, where multiple tests have been undertaken or where more than one laboratory has been involved in the testing this given R value is modified by the relevant equations as given in ISO 4259.

It is to be noted that the confidence testing boundary for a characteristic is not an error margin; it is the direct result of the inherent reproducibility of the fuel test method.

4.1 Interpreting the Test Result in Accordance with ISO 4259

An important distinction in the application of the testing boundary is that there are different approaches for the supplier and for the recipient as to whether a specification limit has been met.

For the supplier, with a single test result, the approach is:

> *In the case of a maximum specification limit, the specification limit has been met, with 95% confidence, if the test result is less than or equal to the specification limit minus 0.59R.*

However, it is further given that *this is for the guidance of the supplier, not an obligation,* and that *a value between the specification limit and the limit minus 0.59R is not proof of non-compliance* (i.e. not proof that the specification has not been met).

In contrast, for the recipient with a single test result, the approach is:

> *In the case of a maximum specification limit, the specification limit has not been met, with 95% confidence, if the test result is greater than the specification limit plus 0.59R.*

The reverse applies in the case of minimum specification limits.

4.2 The Implications of ISO 4259

The implications of these ISO 4259 requirements are that:-

- The supplier, intending to meet a particular maximum specification limit, should target a value at or below the specification limit. Any test result obtained by the supplier which exceeds the limit indicates that the product has not met the specification.

- The recipient with a single test result above the specification limit but below the 'limit plus 0.59R' cannot claim that the specification has not been met and consequently has to accept that the product has met the specification and there is no requirement to carry out additional testing. The recipient can only consider that a maximum specification limit value has been exceeded if their test result exceeds the limit plus 0.59R.

These limits are set out in Appendix II for the range of standard tests specified in ISO 8217. The limits are based on the principles of ISO 4259, using the relevant R value multiplied by 0.59. The look up tables provided clearly indicate whether or not a recipient can claim that the fuel has failed to meet the specification, based on both single and two results obtained in a single laboratory. The duplicate testing results in all cases indicate no, or at most marginal reduction in the confidence boundary that is achieved when more than one test is carried out by a laboratory.

A point to note is that 95% confidence is a defined statistical process and is not 100% confidence – in fact, it is not statistically possible to achieve a confidence level of 100%. Therefore, despite all the care taken in the application of the relevant test method, there remains a slight chance that the result will be outside the 0.59R boundary. In such cases, the supplier has to accept the risk that a characteristic, which from their initial testing was shown to not exceed the specification limit, on retesting does exceed that limit. Equally, from the recipient's side, there is the same chance that a result which indicated that the limit plus 0.59R had been exceeded is not supported by subsequent analysis. Such is the reality of fuel testing. However, this risk can be minimised by carrying out repeat checks in a laboratory (using the same sample and test method) before reporting the result.

If resolution between recipient and supplier cannot be achieved following the practice summarised in this document, then ISO 4259 provides a comprehensive dispute procedure.

5 Compliance with the Specification

Market fuel analysis data confirms that the majority of the fuels supplied comply with the ordered specification. However, on the rare occasion that the analysis results confirm that the fuel does not comply with the specification, it does not necessarily follow that the fuel cannot successfully be used [5]. For a number of the characteristics covered by ISO 8217; with the knowledge of the actual fuel quality, combined with a competent crew and robust on board operation, many fuels that are determined to have failed to meet the specification, can be successfully handled and used on board the ship.

6 References

1 CIMAC WG7 Guideline No. 09:2014 “The Interpretation of Marine Fuel Oil Analysis Test Results with Particular Reference to Sulphur Content”

2 ISO 8217:2012 Petroleum products - Fuels (class F) - Specifications of marine fuels.

3 ISO 17025:2005 General requirements for the competence of testing and calibration laboratories.

4 ISO 4259:2006 Petroleum products - Determination and application of precision data in relation to methods of test.

5 Wilson T., FOBAS’s view on marine fuel quality trends, Bunkerworld ‘Bunker Bulletin’ June 2014.

7 CIMAC WG7 Fuels Working Group Membership

A.P. Moller Maersk
Alfa Laval
ANP
Bollfilter
BP Marine Ltd
Bureau Veritas Marine Fuel Services
CEPSA
Chevron
Chevron Oronite
CMA-CGM
DNV-GL
Exxon Mobil
GEA
IMarEST
Infineum
Innospec Fuel Specialties
Intertek Lintec Shipcare Service
Lemag Lehmann & Michels
Lloyd's Register FOBAS
Maersk Maritime Technology
MAN Diesel and Turbo
Mitsubishi Machinery & Engine Group
Mitsui O.S.K. Lines
Nippon Yuka Kogyo C / NYK Line
Petrobras
Shell
Total, France
VISWA Lab Corporation
Wartsila
Win GD
World Fuel Services

Appendix I

Application of ISO 17025 - Reporting the Results

This appendix contains an abridged version of the requirements for the reporting the results of analytical testing under the ISO 17025 *"General requirements for the competence of testing and calibration laboratories requirement".* For some laboratories the requirements outlined below may not be explicitly stated on the Test Report but will be available in the public domain.

For laboratories that operate under ISO 17025 the standard specifies that each test report or calibration certificate shall include at least the following information, unless the laboratory has valid reasons for not doing so:

a) a title (e.g. "Test Report" or "Calibration Certificate");
b) the name and address of the laboratory, and the location where the tests and/or calibrations were carried out, if different from the address of the laboratory;
c) unique identification of the test report or calibration certificate (such as the serial number), and on each page an identification in order to ensure that the page is recognized as a part of the test report or calibration certificate, and a clear identification of the end of the test report or calibration certificate;
d) the name and address of the customer;
e) identification of the method used;
f) a description of, the condition of, and unambiguous identification of the item(s) tested or calibrated;
g) the date of receipt of the test or calibration item(s) where this is critical to the validity and application of the results, and the date(s) of performance of the test or calibration;
h) reference to the sampling plan and procedures used by the laboratory or other bodies where these are relevant to the validity or application of the results;
i) the test or calibration results with, where appropriate, the units of measurement;
j) the name(s), function(s) and signature(s) or equivalent identification of person(s) authorizing the test report or calibration certificate; and
k) where relevant, a statement to the effect that the results relate only to the items tested or calibrated.

NOTE 1 Hard copies of test reports and calibration certificates should also include the page number and total number of pages.
NOTE 2 It is recommended that laboratories include a statement specifying that the test report or calibration certificate shall not be reproduced except in full, without written approval of the laboratory.

In addition to the requirements listed in a) to k) above the test reports shall, where necessary for the interpretation of the test results, include the following:

l) deviations from, additions to, or exclusions from the test method, and information on specific test conditions, such as environmental conditions;
m) where relevant, a statement of compliance/non-compliance with requirements and/or specifications;
n) where applicable, a statement on the estimated uncertainty of measurement; information on uncertainty is needed in test reports when it is relevant to the validity or application of the test results, when a customer's instruction so requires, or when the uncertainty affects compliance to a specification limit;
o) where appropriate and needed, opinions and interpretations (see below); and
p) additional information which may be required by specific methods, customers or groups of customers.

When opinions and interpretations are included, the laboratory shall document the basis upon which the opinions and interpretations have been made. Opinions and interpretations shall be clearly marked as such in a test report.

NOTE 3 Opinions and interpretations should not be confused with inspections and product certifications as intended in ISO/IEC 17020 and ISO/IEC Guide 65.

NOTE 4 Opinions and interpretations included in a test report may comprise, but not be limited to, the following:

- an opinion on the statement of compliance/noncompliance of the results with requirements;
- fulfilment of contractual requirements;
- recommendations on how to use the results;
- guidance to be used for improvements.

NOTE 5 In many cases it might be appropriate to communicate the opinions and interpretations by direct dialogue with the customer. Such dialogue should be written down.

Appendix II

Commercial Practice: Application of ISO 4259 to ISO 8217 Specification Limits

The following tables set out the appropriate limits in accordance with ISO 4259 for the characteristics set out in the ISO 8217 specification. The values provided for each property are based on the published precision for each test method at the time of publication of this Guideline.

For a maximum result:-

Recipient

If the Recipient has a single result that is less than or equal to Y, then the Recipient cannot claim that the specification limit has not been met and consequently has to accept that the fuel, as supplied, met the specification limit.

If the Recipient has a single result that is greater than Y, then the Recipient can claim that the specification limit has not been met and consequently the fuel, as supplied, failed to meet the limit and the Supplier is required to test their retained sample.

Note. The tables also contain the values for Y when the laboratory has determined two valid test results and provided the Recipient with the average of these results. In this situation, the Reproducibility is modified to R1, in accordance with the relevant equation given in ISO 4259.

Supplier

To claim that the fuel has met the specification limit (X) – the 'Supplier's Limit', a Supplier has to determine a single test result at or below that limit. If the single test result is above the specification limit, the Supplier cannot claim with any level of confidence that the fuel supplied has met that limit and therefore has to accept that the fuel has failed to meet the specification limit.

For a minimum result:-

Recipient

If the Recipient has a single result that is greater than or equal to Y, then the Recipient cannot claim that the specification limit has not been met and consequently has to accept that the fuel, as supplied, met that limit.

If the Recipient has a single result that is less than Y, then the Recipient can claim that the specification limit has not been met and consequently the fuel, as supplied, failed to meet the limit and the Supplier is required to test their retained sample.

Note. The tables also contain the values for Y when the laboratory has determined two valid test results and provided the Recipient with the average of these results. In this situation the Reproducibility is modified to R1, in accordance with the relevant equation given in ISO 4259.

Supplier

To claim that the fuel has met the specification limit (X) – the 'Supplier's Limit', a Supplier has to determine a single test result at or above that limit. If the single test result is below the specification limit, the Supplier cannot claim with any level of confidence that the fuel supplied has met the limit and therefore has to accept that the fuel has failed to meet the specification limit.

In accordance with ISO 4259, the purchaser's requirement establishes the 'Specification Limit', which in turn generates a 'Recipient's Limit' - dependent on the number of test results, as shown in the following tables:

Kinematic Viscosity

Viscosity (cSt) at 50 ºC using ISO 3104:1994		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R_1** (Recipient's Limit) (Average of two test results)
10.0	10.44	10.43
30.0	31.31	31.30
80.0	83.49	83.46
180.0	187.9	187.8
380.0	396.6	396.4
500.0	521.8	521.6
700.0	730.6	730.2

Viscosity (cSt) at 40 ºC (maximum) using ISO 3104:1994		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R_1** (Recipient's Limit) (Average of two test results)
5.500	5.531	5.529
6.000	6.034	6.031
11.00	11.06	11.05
14.00	14.07	14.07

Viscosity (cSt) at 40 ºC (minimum) using ISO 3104:1994		
X = Specification Limit (Supplier's Limit)	**Y = X - 0.59R** (Recipient's Limit) (Single test result)	**Y = X - 0.59R_1** (Recipient's Limit) (Average of two test results)
1.400	1.388	1.389
1.500	1.488	1.489
2.000	1.985	1.987
3.000	2.981	2.982

Density

Density (kg/m^3) at 15 ºC using ISO 3675:1998 (Opaque)		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R$_1$** (Recipient's Limit) (Average of two test results)
890.0	890.9	890.8
900.0	900.9	900.8
920.0	920.9	920.8
960.0	960.9	960.8
975.0	975.9	975.8
980.0	980.9	980.8
991.0	991.9	991.8
1010.0	1010.9	1010.8

Density (kg/m^3) at 15 ºC using ISO 3675:1998 (Transparent low viscosity)		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R$_1$** (Recipient's Limit) (Average of two test results)
890.0	890.7	890.7
900.0	900.7	900.7

Density (kg/m^3) at 15 ºC using ISO 12185:1996 (Crude oils and other petroleum products)		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R$_1$** (Recipient's Limit) (Average of two test results)
900.0	900.9	900.9
920.0	920.9	920.9
960.0	960.9	960.9
975.0	975.9	975.9
980.0	980.9	980.9
991.0	991.9	991.9
1010.0	1010.9	1010.9

Density (kg/m^3) at 15 ºC using ISO 12185:1996 (Transparent middle distillates)		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R$_1$** (Recipient's Limit) (Average of two test results)
890.0	890.3	890.3
900.0	900.3	900.3

CCAI

The Calculated Carbon Aromaticity Index (CCAI) is a calculated value based on density and viscosity. ISO 8217:2012 contains a figure for the determination of Reproducibility.

Cetane Index

The Cetane Index is a calculated value based on density and distillation recovery temperature determinations. The Reproducibility of these determinations is stated in the test methods ISO 3675, ISO12185 and ISO 3405.

Sulphur

Sulphur (mass %) using ISO 8754:2003		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R_1** (Recipient's Limit) (Average of two test results)
0.10	0.11	0.11
0.50	0.53	0.53
1.00	1.06	1.05
1.50	1.58	1.58
2.00	2.10	2.10
3.50	3.67	3.67
4.50	4.72	4.72

Sulphur (mass %) using ISO 14596:2007		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R_1** (Recipient's Limit) (Average of two test results)
0.10	0.11	0.11
0.50	0.51	0.51
1.00	1.02	1.02
1.50	1.52	1.52
>2.50	Test out of scope	Test out of scope

Flash Point

Flash Point (^oC) (minimum) using ISO 2719:2002 Distillate Fuel (Procedure A) Note: Results reported rounded to nearest 0.5^oC		
X = Specification Limit (Supplier's Limit)	**Y = X - 0.59R** (Recipient's Limit) (Single test result)	**Y = X - 0.59R_1** (Recipient's Limit) (Average of two test results)
43	41.0	41.5
60	57.5	57.5

Flash Point (^oC) (minimum) using ISO 2719:2002 Residual Fuel (Procedure B) Note: Results reported rounded to nearest 0.5 ^oC		
X = Specification Limit (Supplier's Limit)	**Y = X - 0.59R** (Recipient's Limit) (Single test result)	**Y = X - 0.59R_1** (Recipient's Limit) (Average of two test results)
60	56.5	56.5

Hydrogen Sulphide

Hydrogen Sulphide (mg/kg) using IP 570:2014 (Procedure A)		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R_1** (Recipient's Limit) (Average of two test results)
2.00	2.39	2.33

Acid Number

Acid Number (mg KOH/g) using ASTM D664-11a		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R$_1$** (Recipient's Limit) (Average of two test results)
0.5	0.6	0.6
2.5	2.8	2.8

Total Sediment - Aged

Total Sediment – Aged (mass %) for residual fuel using ISO 10307-2:2009 (accelerated or potential)		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R$_1$** (Recipient's Limit) (Average of two test results)
0.10	0.15	0.15

Total Sediment by Hot Filtration

Total Sediment by Hot Filtration (mass %) distillate fuels containing residual components using ISO 10307-1:2009		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R$_1$** (Recipient's Limit) (Average of two test results)
0.10	0.13	0.13

Carbon Residue – Micro Method

Carbon Residue (mass %) – Micro Method on 10% volume distillation residue using ISO 10370:2014		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R$_1$** (Recipient's Limit) (Average of two test results)
0.30	0.37	0.36

Carbon Residue (mass %) – Micro Method using ISO 10370:2014		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R$_1$** (Recipient's Limit) (Average of two test results)
0.30	0.36	0.36
2.50	2.77	2.76
10.00	10.67	10.65
14.00	14.84	14.82
15.00	15.88	15.86
18.00	18.99	18.97
20.00	21.07	21.04
22.00	23.14	23.11

Pour Point

Pour Point (°C) (upper) using ISO 3016:1994		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R$_1$** (Recipient's Limit) (Average of two test results)
-6	-2	-2
0	4	4
6	10	10
24	28	28
30	34	34

Water

Water (volume %) using ISO 3733:1999		
X = Specification Limit* (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R$_1$** (Recipient's Limit) (Average of two test results)
0.30	0.42	0.41
0.50	0.62	0.61
1.00	1.12	1.11

* The 3 Supplier limits given take into consideration ISO 8217: 1996, 2005 and 2012 water limits

Water (mass %) using ISO 12937:2000		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R$_1$** (Recipient's Limit) (Average of two test results)
0.020	0.026	0.026

Note: 0.020 mass % = 200 mg/kg

Ash

Ash (mass %) using ISO 6245:2001		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R$_1$** (Recipient's Limit) (Average of two test results)
0.010	0.013	0.013
0.040	0.043	0.043
0.070	0.073	0.073
0.100	0.114	0.114
0.150	0.164	0.164

Vanadium

Vanadium (mg/kg) using IP 501:2005		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R_1** (Recipient's Limit) (Average of two test results)
50	60	60
100	116	115
150	170	169
200	224	223
350	383	382
450	489	487
500	541	540
600	646	644

Vanadium (mg/kg) using IP 470:2005		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R_1** (Recipient's Limit) (Average of two test results)
50	64	63
100	119	119
150	174	173
200	227	227
350	386	386
450	491	490
500	543	542
600	647	646

Vanadium (mg/kg) using ISO 14597:1997		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R_1** (Recipient's Limit) (Average of two test results)
50	56	56
100	106	106
>100	Test out of scope	Test out of scope

Sodium

Sodium (mg/kg) using IP 501:2005		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R_1** (Recipient's Limit) (Average of two test results)
50	55	55
100	108	107

Sodium (mg/kg) using IP 470:2005 (Atomic absorption spectrometry)		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R_1** (Recipient's Limit) (Average of two test results)
50	58	58
100	112	112

Aluminium plus Silicon

For simplification, either the Aluminium or Silicon Reproducibility has been used depending on which yields the lowest Recipient's Limit. Where a precise interpretation is required, the actual reproducibility values should be applied, determined from the individual measured values.

Aluminium plus Silicon (mg/kg) using IP 501:2005 (ICP) based on Silicon Reproducibility		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R_1** (Recipient's Limit) (Average of two test results)
25	30	30
40	48	48
50	60	60
60	72	72
80	96	96

Aluminium plus Silicon (mg/kg) using IP 470:2005 (Atomic Adsorption) based on Aluminium Reproducibility		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R_1** (Recipient's Limit) (Average of two test results)
25	29	29
40	46	45
50	56	56
60	67	67
80	89	88

Aluminium plus Silicon (mg/kg) using ISO 10478:1994 (ICP) based on Silicon Reproducibility		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R_1** (Recipient's Limit) (Average of two test results)
25	30	30
40	48	48
50	60	60
60	72	72
80	96	96

Used Lubricating Oil

Calcium, Zinc, Phosphorus (mg/kg) IP 501:2005 (Inductively Coupled Plasma)			
	X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**$Y = X + 0.59R_1$** (Recipient's Limit) (Average of two test results)
Calcium	30	33	33
Zinc	15	17	17
Phosphorus	15	18	18

Calcium, Zinc (mg/kg) IP 470:2005 (Atomic Adsorption)			
	X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**$Y = X + 0.59R_1$** (Recipient's Limit) (Average of two test results)
Calcium	30	34	34
Zinc	15	18	17

Phosphorus (mg/kg) IP 500:2003 (Ultra–Violet Spectrometry)			
	X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**$Y = X + 0.59R_1$** (Recipient's Limit) (Average of two test results)
Phosphorus	15	17	17

Oxidation Stability

Insolubles (g/m^3) ISO 12205:1995		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R$_1$** (Recipient's Limit) (Average of two test results)
25	33	32

Fatty Acid Methyl Ester (FAME)

FAME (volume %) IP 579:2014		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R$_1$** (Recipient's Limit) (Average of two test results)
7.0	7.3	7.3

Cloud Point

Cloud point (^{o}C) ISO 3015:1992		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R$_1$** (Recipient's Limit) (Average of two test results)
-16	-14	-14

Lubricity

Corrected wear scar diameter (µm) ISO 12156-1:2006		
X = Specification Limit (Supplier's Limit)	**Y = X + 0.59R** (Recipient's Limit) (Single test result)	**Y = X + 0.59R$_1$** (Recipient's Limit) (Average of two test results)
520	580	574

Imprint

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