Most bunker fuel orders specify a fuel quality defined by ISO 8217 and many of Chevron’s customers have their bunker fuel deliveries analyzed by an independent laboratory to comply with ISO 8217.

It is Chevron’s policy to supply bunker fuels that comply with the specifications agreed upon when the order is accepted and confirmed. Our terms of sale state that only retain samples provided by/on behalf of Chevron at the time of bunkering are considered valid samples. However, a test analyzed by a customer’s chosen lab on the customer's retain sample may fail a specification limit, while Chevron’s retain sample analysis shows the product to meet specifications. How is this possible?

If the samples were properly taken and closely represent the quality of the fuel delivered, the answer is found in the ISO 8217 reference to the individual test methods to be used, and in the ISO 4259:2006 standard on the “determination and application of precision data in relation to methods of test.” If the prescribed test method defined in ISO 8217 was not used by one of the two parties, that party should obtain the result using the prescribed test method before initiating any discussion.

The following question and answer format describes how to interpret a test method’s precision and specification limit. Please see ISO 4259:2006 for additional information about the interpretation of test results.

**Is every single test result the “true value?”**

No, every single test result is only an approximation of the true value. The intrinsic limitations of the test result are determined by the precision of the test method. True value is the average of an infinite number of single test results obtained by an infinite number of laboratories and, therefore, cannot be exactly established.

**What defines the precision of a test method?**

For each test method “repeatability” and “reproducibility” values are defined and listed. Repeatability is the difference between consecutive test results obtained by the same operator using the same apparatus under constant operating conditions on identical test material. It is only relevant for the individual testing laboratory.

Reproducibility is the closeness of agreement between individual results obtained in the normal and correct operation of the same method on identical test material (different operator, different apparatus, and different laboratories).

**How is test reproducibility used to judge the acceptability of two test results?**

If the difference between two single test results (obtained with the same method in two different laboratories, for example, a supplier’s test result and a customer’s test result) is less than or equal to the reproducibility “R” of the test method, then both test results are considered acceptable. Their average value is considered the estimated value of the tested property.
**Example 1: RMG 380 test — density determination**

Lab 1: Density at 15°C, ISO 12185:1996: 991.4 kg/m³
Lab 2: Density at 15°C, ISO 12185:1996: 990.2 kg/m³
Listed reproducibility "R" of method ISO 12185:1996: R = 1.5 kg/m³

The difference between the two single test results, 991.4 kg/m³ – 990.2 kg/m³ = 1.2 kg/m³, is less than R. Hence, the average value of the two test results is considered the estimated value of the density:

\[
\frac{991.4 \text{ kg/m}^3 + 990.2 \text{ kg/m}^3}{2} = 990.8 \text{ kg/m}^3
\]

If the two results differ by more than R, both results are considered to be suspect and, in theory, each lab will then apply the procedures outlined in ISO 4259:2006. In practice, both parties will generally agree to accept the result obtained by a mutually selected third laboratory on a valid retain sample. In this case, it is important to ascertain that the third laboratory is using the prescribed test method and has accepted quality certificates.

**Is it correct to say that a test result meets a specification requirement if it exceeds the specification limit by a value less than R?**
No. Reproducibility is only applicable on two analysis results, not on an analysis result and a specification limit.

**Is it possible to estimate the product’s compliance to a specification limit when only one single result is available?**
Yes. ISO 4259:2006 includes supplier and customer guidelines to evaluate a product against a specification limit, using the customer’s single test result. It is assumed that:

- The sample used for the analysis is a valid retain sample.
- The laboratory has performed the test under the conditions fully prescribed by the test method.

**How can a supplier make an evaluation of maximum specification limit when there is only a single test result which is smaller than the specification limit?**
The supplier can consider, with 95% confidence, that his or her product meets a maximum specification limit (A1) if the test result X ≤ A1 – 0.59R, where R is the reproducibility of the test method (see Example 2). If the supplier’s single test result X’ is such that A1 – 0.59R < X’ ≤ A1, then there is a calculated risk that the product would fail the specification limit during multiple testing.

**Example 2: Supplier with a single test result for density**

**Case 1**
Density specification limit (A1): 991.0 kg/m³ @ 15°C
R (test method ISO 12185:1996): 1.5 kg/m³
Single test result X available on a representative sample for delivery: 990.0 kg/m³ @ 15°C
It is 95% likely that this product will meet the specification limit upon multiple testing, because the condition X ≤ A1 – 0.59R is fulfilled.

\[
(990.0 < 991.0 - 0.59 \times 1.5) \text{ or } 990.0 < 991.0 - 0.9 \text{ or } 990.0 < 990.1)
\]

**Case 2**
Density specification limit (A1): 991.0 kg/m³ @ 15°C
R (test method ISO 12185:1996): 1.5 kg/m³
Single test result X’ available on a representative sample for delivery: 990.5 kg/m³ @ 15°C
It is likely that this product would fail the specification limit during multiple testing because the condition X’ ≤ A1 – 0.59R is not fulfilled.

\[
(990.5 \text{ exceeds } A1 - 0.59R \text{ or } 990.5 > 991.0 - 0.9 \text{ or } 990.5 > 990.0)
\]

**How can a customer make an evaluation about a maximum specification limit when there is only one single test result which exceeds the specification limit?**
The customer can consider, with 95% confidence, that a product will fail the maximum specification limit requirement upon multiple testing if the single test result X > A1 + 0.59R (where A1 is the maximum limit and R is the reproducibility of the test method). If a customer’s single test result X’ meets the condition A1 < X’ ≤ A1 + 0.59R, there is a statistical chance that multiple testing would still show the product to be on spec.

**Example 3: Customer with a single test result for density**

**Case 1**
Density specification limit (A1): 991.0 kg/m³ @ 15°C.
R (test method ISO 12185:1996): 1.5 kg/m³
Single test result X available: 992.2 kg/m³ @ 15°C
It is 95% likely that the product will fail the specification limit upon multiple testing, because X > A1 + 0.59R.

\[
(992.2 > 991.0 + 0.59 \times 1.5 \text{ or } 992.2 > 991.0 + 0.9 \text{ or } 992.2 > 991.9)
\]
Case 2
Density specification limit (A1): 991.0 kg/m³ @ 15°C.
R (test method ISO 12185:1996): 1.5 kg/m³
Single test result X available: 991.4 kg/m³ @ 15°C.
The single test result exceeds the specification limit A1; however, because it is lower than A1 + 0.59R, multiple testing may still result in finding the density on spec (A1 + 0.59R ≥ X’ > A1).

(991.0 + 0.59 × 1.5 > 991.4 > 991.0 or 991.0 + 0.9 > 991.4 > 991.0 or 991.9 > 991.4 > 991.0)

For the evaluation of one single test result X with a minimum specification A2, the conditions applied by the supplier and customer are, respectively, X ≥ A2 + 0.59R and X < A2 − 0.59R.

Summary:
Test results deviate from the “true value”; this is inherent to all test methods. The precision statements are an integral part of every official test method and listed in the method. For more information, please see Appendix: Reproducibility of ISO 8217 or Equivalent IP/ASTM Test Methods.

Appendix: Reproducibility of ISO 8217 or Equivalent IP/ASTM Test Methods*

Density at 15°C, kg/m³
1. ISO 3675
   For transparent, nonviscous products:
   \[ R = 1.2 \text{ kg/m}³ \text{ or } 0.0012 \text{ kg/l} \]
   For opaque products:
   \[ R = 1.5 \text{ kg/m}³ \text{ or } 0.0015 \text{ kg/l} \]
2. ISO 12185
   For transparent middle distillates:
   \[ R = 0.5 \text{ kg/m}³ \]
   or 0.0005 kg/l
   For crude oils and other petroleum products:
   \[ R = 1.5 \text{ kg/m}³ \text{ or } 0.0015 \text{ kg/l} \]

Kinematic viscosity, mm²/s
ISO 3104
Distillate fuels at 40°C:
\[ R = 0.0082 (x + 1) \]
   Where x is the average of the results being compared
Heavy fuels at 50°C:
\[ R = 0.074x \]
   Where x is the average of the results being compared

Flash point, P.M., closed tester
ISO 2719
Procedure A (distillate fuels):
\[ 0.071x \]
   Where x is the average of the results (°C) being compared
Procedure B (residual fuel oils):
6°C

Pour Point, °C
ISO 3016
R = 6.59°C

Cloud Point, °C
ISO 3015
For distillate fractions:
\[ R = 4°C \]

For sulphur content in the range 0.10–0.99 m/m %:
1. ISO 8754
   For values > 0.05% (m/m) and ≤ 5.00% (m/m):
   \[ R = 0.0812 (x + 0.15) \]
   Where x is the average of the results being compared
   For values ≥ 0.03% (m/m) and ≤ 0.05% (m/m):
   \[ R = 0.1781 (x + 0.05) \]
   Where x is the average of the results being compared
   For sulphur content in the range 1.00–2.50 m/m %:
   \[ R = 0.04 \]

H₂S, mg/kg
IP 570
For residual fuel oils:
\[ R = 0.5232x^{0.6} \]
   Where x is the average of the results being compared

Cetane index (4 variable equation)
ISO 4264
Precision depends on:
• The precision of the original density
• The distillation recovery temperature determinations that enter into the calculation

Oxidation stability, g/m³
ISO 12205
\[ R = 10.6 (x/10)^{0.25} \]
   Where x is the average of the results being compared

Micro carbon residue, % (m/m)
ISO 10370
\[ R = X^{2/3} × 0.2451 \]
   Where X is the average of the results being compared

Ash, % (m/m)
ISO 6245
For ash content between 0.001 and 0.079 wt%:
\[ R = 0.005 \]
For ash content between 0.080 and 0.180 wt%:
\[ R = 0.024 \]

Lubricity, corrected wear scar diameter, µm
ISO 12156-1
\[ R = 102 \mu m \]

CCAI (Calculated Carbon Aromaticity Index)
Precision (R) depends on the precision (R) of the density and viscosity of the residual fuel oil that enter into the calculation

Total existent sediment, % (m/m)
ISO 10307-1
Heavy fuels:
\[ R = 0.294 \sqrt{x} \]
Distillate fuels containing heavy components:
\[ R = 0.174 \sqrt{x} \]
Where x is the average of the test results in % (m/m)

Total sediment potential ageing, % (m/m)
ISO 10307-2
Heavy fuels:
\[ R = 0.294 \sqrt{x} \]
Distillate fuels containing heavy components:
\[ R = 0.174 \sqrt{x} \]
Where x is the average of the test results in % (m/m)

Water, % (v/v)
ISO 3733
Water collected between 0.0 and 1.0 ml:
\[ R = 0.2 \text{ ml} \]
Water collected between 1.1 and 25 ml:
\[ R = 0.2 \text{ ml or 10\% of mean, whichever is greater} \]

Acid number, mg KOH/g
ASTM D664
\[ R \text{ (used oils buffer endpoint)} = 0.44x \]
Where x is the average of the results being compared

Vanadium, mg/kg
1. ISO 14597
Applicable to products having V content in the range of 5 to 1,000 mg/kg, although reproducibility data have only been determined up to 100 mg/kg for V
For V content between 5 - 30 mg/kg:
\[ R = 5 \text{ mg/kg} \]
For V content between 31 - 100 mg/kg:
\[ R = 10 \text{ mg/kg} \]

2. IP 501
\[ R = 1.6799 x^{0.6} \]
Where x is the average of the results (mg/kg) being compared

3. IP 470
\[ R = 3.26 x^{0.5} \]
Where x is the average of the results (mg/kg) being compared

Cat fines Al + Si, mg/kg
1. ISO 10478, IP 501
ICP detection:
Al: \[ R = 0.337x \]
Si: \[ R = 0.332x \]

2. IP 470
AAS detection:
Al: \[ R = 0.789x^{0.67} \]
Si: \[ R = 1.388x^{0.67} \]
Where x is the average of the results (mg/kg) being compared

Ca, Zn, P, mg/kg
1. Ca
IP 501 (ICP) \[ R = 0.6440x^{0.65} \]
IP 470 (AAS) \[ R = 1.139x^{0.8} \]

2. Zn
IP 501 (ICP) \[ R = 0.5082x^{0.7} \]
IP 470 (AAS) \[ R = 0.580x^{0.75} \]

3. P
IP 501 (ICP) \[ R = 1.2765x^{0.55} \]
IP 500 (UV) \[ R = 1.2103x^{0.4} \]
Where x is the average of the results (mg/kg) being compared

Sodium, mg/kg
1. IP 501 (ICP)
\[ R = 1.0667x^{0.55} \]

2. IP 470 (AAS)
\[ R = 1.303x^{0.6} \]
Where x is the average of the results being compared