
**Petroleum liquids — Automatic pipeline
sampling — Statistical assessment of
performance of automatic samplers
determining the water content in
hydrocarbon liquids**

*Produits pétroliers liquides — Échantillonnage automatique en oléoduc —
Estimation statistique des performances d'échantillonneurs automatiques
pour déterminer la teneur en eau dans les hydrocarbures liquides*



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Foreword

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

The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report for one of the following types :

- type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;
- type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;
- type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard (« state of the art », for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 9494, which is a Technical Report of type 3, was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, Subcommittee SC 3, *Static petroleum measurement*.

In publishing this text, the committee was aware that the terminology used in this Technical Report in connection with measurement uncertainty, and the methods used to evaluate and express measurement uncertainty, are not consistent with the *Guide to the Expression of Uncertainty in Measurement*. Nevertheless it is believed that it will still serve as a helpful aid to those who have to implement ISO 3171, in particular clause 16.

It is envisaged that at the first revision of this Technical Report the opportunity will be taken to align it with the *Guide to the Expression of Uncertainty in Measurement*.

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Petroleum liquids — Automatic pipeline sampling — Statistical assessment of performance of automatic samplers determining the water content in hydrocarbon liquids

1 Scope

This Technical Report describes a mathematical method for assessing the overall uncertainty of automatic sampling systems for determining the water content in oil being transferred through pipelines.

The model estimates the overall uncertainty (tolerance) by combining statistically the individual systematic and random uncertainties of a number of individual component variables defined in an automatic 'grab' type sampling system.

The tolerances on water content determination as a function of the number of sampling grabs, the water content, and the number of water analyses performed are summarized in graphics form (see figures 6-11).

It serves as technical support for clause 16 of ISO 3171.

2 Normative references

The following standards contain provisions, which, through reference in this text, constitute provisions of this Technical Report. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Technical Report are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 3171: 1988 Petroleum liquid - Automatic pipeline sampling

RENYI. Calculation of probabilities. Dunod, 1966

3 Definitions of symbols

w, w subscripted	= Water content in the pipeline, in percent volume/volume (v/v)
P_i, q_i, S', w', w''	= Water content in the various parts of the sampler and of the analysis
$T_j, T;$	= Estimates of water content
V, V_i	= Volume of fluid passing through the system in the interval between two consecutive grabs

v_i	= Total volume of fluid passing through the straight section from the beginning of sampling up to t_i
W	= Total volume of fluid passing through the straight section
e_i	= Volume of grab
D	= Combined uncertainty of the random uncertainties and systematic uncertainties in "w" - half-width of a symmetrical bilateral confidence interval (with a 95 % confidence level)
n	= Number of analyses
N	= Number of grabs
S, R, L and P	= Derived parameters
$a_s, b_s, \dots, g_s$	= Relative systematic uncertainty on the factors influencing the measurement "w"
$a_r, b_r, \dots, g_r$	= Relative random uncertainty on the factors influencing the measurement "w"

NOTE - The relative uncertainty on x is = $\frac{\text{Uncertainty of } x}{\text{value of } x}$

Where the relative systematic uncertainties and the relative random uncertainties are the following:

- Degree of non-homogeneity of water content, as described in clause 5 and annex A of ISO 3171: 1988 (e.g. poor dispersion)

a_s relative systematic uncertainty

a_r relative random uncertainty

- Distortion of the water content by the sampling system as described in clause 8 of ISO 3171: 1988 (e.g. non-isokinetic)

b_s relative systematic uncertainty

b_r relative random uncertainty

- Uncertainties on the volume of each grap

d_s relative systematic uncertainty (not used but see clause 9)

d_r relative random uncertainty

- Flowmeter (degree of non-proportionality), as described in clause 10 of ISO 3171: 1988 (e.g. variations in the k-factor of correction of the turbine meter)

c_s relative systematic uncertainty (not used but see clause 9)

c_r relative random uncertainty

- Distortion of water content during sampling, as described in clause 11 of ISO 3171: 1988 (e.g. by emulsification or evaporation)

h_s relative systematic uncertainty

h_r relative random uncertainty

- Distortion of water content due to sample handling and mixing, as described in clause 12 of ISO 3171: 1988 (e.g. poor homogenization in the laboratory)

f_s relative systematic uncertainty

f_r relative random uncertainty

- Distortion of water content due to transfer to laboratory glassware and analysis (e.g. tube graduation error)

g_s relative systematic uncertainty

g_r relative random uncertainty

The derived parameters are obtained from the following equations:

Sampling

$$S = a_s + b_s + h_s \quad \text{(relative systematic uncertainty)}$$

$$R = \frac{1}{4}(a_r^2 + b_r^2 + c_r^2 + d_r^2)$$

(relative random uncertainty)

Laboratory

$$L = f_s + g_s$$

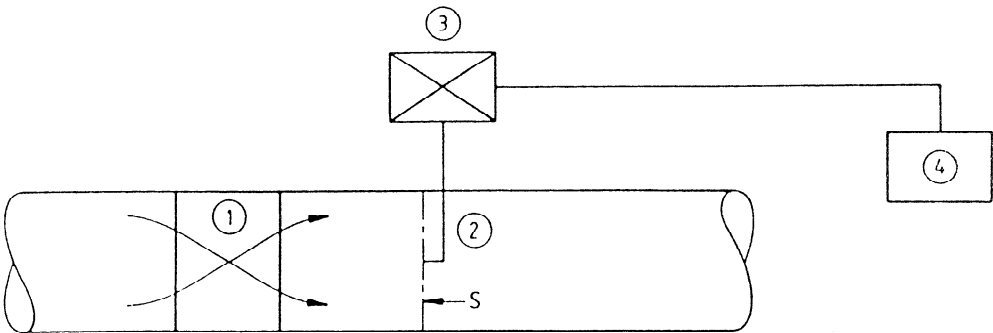
(relative systematic uncertainty)

$$P = \frac{1}{4}(f_r^2 + \frac{g^2}{n})$$

(relative random uncertainty)

4 General

The water content w of volume W fluid flowing in a pipeline is estimated by taking N samples (grabs) automatically from a section of the pipeline as illustrated in figure 1.



- 1- Mixer
- 2- Probe
- 3- Sampling system
- 4- Container (R_1)

Figure 1 - Sampling system

The probe of the sampling system is located in a section downstream from the mixer. The sampling moments are controlled by a flowmeter so that the volume of fluid passing through the section between two sampling operations is equal to V , i.e. sampling is proportional to flow.

The N samples (grabs) are collected in the same container (R_1).

The volume, v , of the fluid passing through the section is taken as a variable and $w(v)$, the water content in the section in question, is noted.

In view of the random effects on the flowmeter, the N samples are separated by intervals of fluid volume V_i with $i = 1$ to $N - 1$ (as shown in figure 2).

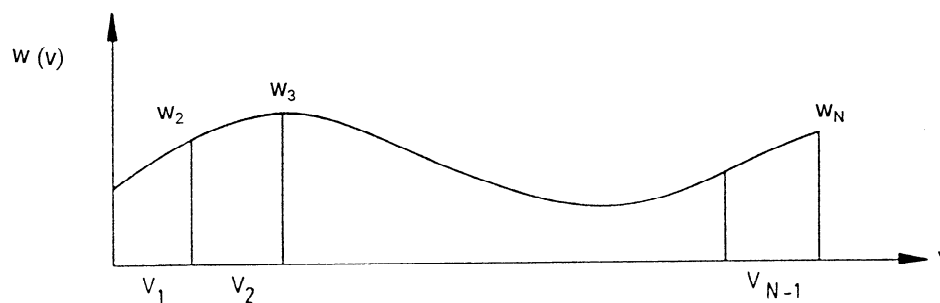


Figure 2 - Grab sequences

Thus:

$$W = \sum_{i=1}^{N-1} V_i \quad (1)$$

taking

$$v_0 = 0 \text{ and for } i \geq 1, v_i = \sum_{j=1}^i V_j$$

$$w_i = w(v_{i-1}) \text{ for } i = 1 \text{ to } N$$

At each sampling interval sample (grab) of volume c_i is taken. Taking into account the defects of the mixer, the water content at the sampling point (probe) at this grab is P_i .

The sampling system (with or without loop) leads to the sample not being truly representative. The water content of the material in the container is therefore not fully representative of the sample material which enters the container. The water content in the i th sample when it falls into the container (R_i) is designated q_i and the water content into container (R_i) is designated w^1 .

During sampling, retention of the collected volume is not perfect. The water content of the container is therefore distorted. The water content in the container (R_i) at the end of sampling is designated w^1 .

The contents of (R_i) are mixed and a volume is sampled and transferred into an intermediate container (R_2).

The contents of (R_2) are mixed and n sub-samples are taken and analyzed.

A note is made of S' as the water content in (R_2), S_j as the water content in the j th sub-sample and T_j as the result of the j th analysis with $j = 1$ to n .

The quantity

$$T' = \frac{1}{n} \sum_{j=1}^n T_j \quad (2)$$

is taken as the estimation of the water content w of the consignment.

An order of magnitude, D , for the standard deviation between T' and w as a function of N , n and various statistical parameters is allowed, i.e. a number such that:

$$Prob [| T' - w | < D] \geq 0,95 \quad (3)$$

The interval $[T' - D, T' + D]$ constitutes a 95 % confidence interval

5 Statistical models

5.1 General conventions

P is taken as the true value of a physical magnitude that is to be measured by a certain method.

a) The systematic error or systematic uncertainty, S_1 , represents the difference between the true value, P, and the mean of measurements, S_o , has a probability at least equal to or less than

$$S_1 = S_o - P \quad (4)$$

S_1 permits the **accuracy of the measurements to be measured**.

S_s is used to denote the absolute value of the systematic error and is sometimes referred to as the systematic deviation.

NOTE 1 - S_1 is often unknown in sign and magnitude. An upper bound of the absolute value of S_1 is therefore taken for S_s .

b) The random uncertainty, S_r , represents a number such that the absolute value of the deviation between a measurement, S' , and the mean of the measurements, S_o , has a probability at least equal to or less than S_r , i.e.

$$Prob [| S' - S_o | < S_r] \geq a \quad (5)$$

If "a" is not specified, assume that it is 95 %, the value which is used below. S_r permits the **precision of the measurements to be measured**.

NOTE 2 - The characteristics of a measurement system can be defined by the repeatability, standard deviation or variance. These magnitudes are linked to the random uncertainty by the following equations.

repeatability = $\sqrt{2}$ x random uncertainty

random uncertainty = 2 x standard deviation

random uncertainty = 2 x $\sqrt{\text{variance}}$

The variance, S_3 , is noted and the random uncertainty is therefore given by the following equation.

$$S_r = 2 \sqrt{S_3} \quad (6)$$

A note is made of S_5 , the number such that the deviation between a measurement, S' , and the true value, P , has a probability of at least 95 % of being less than S_5 , i.e.

$$\text{Prob} [| S' - P | < S_5] \geq 0,95 \quad (7)$$

Although S_5 has no standard designation, it is hereinafter referred to as the uncertainty on P . Thus

$$S_5 = | S_1 | + 2 \sqrt{S_3} \leq S_s + S_r = S_s + 2 \sqrt{S_3} \quad (8)$$

With S' denoting a random measurement of the physical magnitude P , the notation used for the following calculation of probability is as follows.

$$E(S') = S_o = \text{mean of } S'$$

$$\text{var}(S') = S_3 = \text{variance of } S'$$

It is often convenient to write S' in the form

$$S' = S_o + S_2 = P + S_1 + S_2 \quad (9)$$

where S_2 represents the random uncertainty. Thus

$$E(S') = S_o; E(S_2) = 0; \text{var}(S') = \text{var}(S_2) = S_3$$

For many physical phenomena, the mean, S_o , and the random uncertainty, S_r , are proportional to the value of the physical magnitude P , i.e. it can be written

$$E(S') = P \times s_o; S_r = P \times s_r \quad (10)$$

s_o and s_r are called the relative mean of the measurements and the relative random uncertainty.

Similarly, the relative systematic uncertainty can be defined by the equation $s_1 = s_0 - 1$

Thus:

$$S_1 = P \times s_1 \text{ and} \quad (11)$$

a) The absolute value for the relative systematic uncertainty

$$s_s = |s_1| \quad (12)$$

b) The relative variance $s_3 = s_r^2/4$ (13)

c) The relative tolerance s_5 which is such that

$$Prob \left[\left| \frac{S' - P}{P} \right| < s_5 \right] \geq 95 \% \quad (14)$$

Thus

$$s_5 = |s_1| + 2\sqrt{s_3} \leq s_s + s_r = s_s + 2\sqrt{s_3} \quad (15)$$

NOTE 3 - The term 'relative' is not standard. However, these are the values often supplied in the technical specifications for equipment (e.g. flowmeter).

With S' denoting a random measurement of the physical magnitude P , S' may be expressed in the form

$$S' = P (1 + s_1 + s_2) \quad (16)$$

with

$$E(S') = P(1+s_1); E(s_2) = 0; \text{var } S' = P^2 \text{var } s_2 = P^2 \times s_3 \quad (17)$$

s_2 is referred to as the centred relative measurement uncertainty.

In view of the experimental results obtained, all the random measurements appearing in the remainder of this study are linked to their true value by an equation similar to equation (16).

If a letter (a, b, c, etc.) is chosen to represent a random effect on measurement, the indices 0, 1, 2, 3, r, 5 and s are used systematically to denote the relative mean for the measurements, the relative systematic uncertainty, the centred relative measurement uncertainty, the relative variance, the relative random uncertainty, the relative tolerance and the relative systematic deviation, respectively.

5.2 Parameters having an effect on obtaining the sample

Taking the above conventions, the following may be written using the notation from clause 4:

a) that for $i = 1$ to N

$$P_i = w_i (1 + a_i + a_{2i}) \quad (18)$$

(non-homogeneity)

where

a_i is the relative systematic uncertainty and

$E(a_{2i} = 0; \text{var } a_{2i} = a_3 = \text{relative variance})$.

b) that for $i = 1$ to N

$$q_i = P_i (1 + b_i + b_{2i}) \quad (19)$$

(distortion due to the sampling system)

where

b_i is the relative systematic uncertainty and

$E(b_{2i} = 0; \text{var } b_{2i} = b_3 = \text{relative variance})$.

c) that for $i = 1$ to $N - 1$

$$V_i = V (1 + c_{1i} + c_{2i}) \quad (20)$$

(flowmeter fault)