INTERNATIONAL STANDARD

ISO 7278-3

Second edition
1998-02-15

Liquid hydrocarbons — Dynamic measurement — Proving systems for volumetric meters —

Part 3:
Pulse interpolation techniques

Hydrocarbures liquides — Mesurage dynamique — Systèmes d'étalonnage pour compteurs volumétriques —

Partie 3: Techniques d'interpolation des impulsions

Reference number
ISO 7278-3:1998(E)

Contents

Page

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet central@iso.ch
X.400 c=ch; a=400net; p=iso; o=isocs; s=central

Printed in Switzerland

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.

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.

International Standard ISO 7278-3 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, Subcommittee SC 2, *Dynamic petroleum measurement*.

This second edition cancels and replaces the first edition (ISO 7278-3:1986), which has been technically revised, in particular with addition of annex A and annex B.

ISO 7278 consists of the following parts, under the general title *Liquid hydrocarbons – Dynamic measurement – Proving systems for volumetric meters:*

— *Part 1: General principles*

— *Part 2: Pipe provers*

— *Part 3: Pulse interpolation techniques*

— *Part 4: Guide for operators of pipe provers*

— *Part 5: Small volume/compact provers*

Annex A forms an integral part of this part of ISO 7278. Annex B is for information only.

Introduction

The use of pipe provers to prove meters with pulsed outputs requires that a minimum number of pulses be collected during the proving period. The number of pulses which a meter can produce during a proving run is often limited to significantly less than 10 000 pulses. Therefore, in many applications some means of increasing the meter's resolution has to be found.

One way of overcoming this problem is to process the signal from the meter in such a way that the resolution of the meter is increased. This technique is known as pulse interpolation.

This part of ISO 7278 applies primarily to pipe provers, but it is not intended to restrict in any way the future development of different methods of pulse interpolation to this and other applications.

Liquid hydrocarbons — Dynamic measurement — Proving systems for volumetric meters —

Part 3:
Pulse interpolation techniques

1 Scope

This part of ISO 7278 gives guidance on the procedures and conditions of use to be observed if pulse interpolation is used in conjunction with a pipe or small volume prover and a turbine or displacement meter to improve the discrimination of proving.

This part of ISO 7278 describes the three methods of pulse interpolation most commonly used and their conditions of use. It also describes the equipment and test procedures for checking that the pulse interpolation system is operating satisfactorily and it describes some methods of measuring the irregularity of pulse spacing for a meter.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this part of ISO 7278. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this part of ISO 7278 are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 6551:1982, *Petroleum liquids and gases – Fidelity and security of dynamic measurement – Cabled transmission of electric and/or electronic pulse data*.

3 Definitions

For the purposes of this part of ISO 7278, the following definitions apply.

3.1 clock: Device for generating a stable frequency, the period of which is used as a standard reference for time measurements.

3.2 detector signal: Contact closure or voltage change that starts or stops the indicating device.

3.3 intra-rotational linearity: Quantitative measure of the degree of regularity of spacing between the pulses, produced by a rotating meter at constant flowrate, generally expressed as the standard deviation of pulse spacing about the mean pulse spacing. This measure will include cyclic and non-cyclic measurements introduced by the meter mechanism. The pulse spacing is the time between the leading or lagging edges of consecutive pulses.

NOTE — Intra-rotational linearity is the regularity measurement which repeats in a periodic or cyclic manner attributed to the rotation of the meter.

3.4 leading/lagging edge: Rising or falling voltage of a pulse used to trigger or gate a counter.

3.5 phase detector: Electronic circuit which detects a phase difference between two pulse frequencies.

3.6 ramp generator: Electronic circuit whose output voltage varies linearly with time.

NOTE — Non-linear ramp generators are not used.

3.7 repeatability (of measurement instrument)**:** Closeness of the agreement between the results of successive measurements of the same measurand carried out under the same conditions of measurement [VIM].

NOTE — The defined conditions of use are usually as follows:

- repetition over a short period of time;
- use at the same location under constant ambient conditions;
- reduction to a minimum of the variations due to the observer.

3.8 resolution: Quantitative expression of the ability of an indicating device to distinguish meaningfully between closely adjacent values of the quantity indicated [VIM].

3.9 rotating meter: Meter, the measuring element of which has one or more rotating parts driven by the flowing fluid (e.g. turbine meters and displacement meters).

NOTE — For the purposes of this part of ISO 7278, the output from the meter should be in the form of electrical pulses, the mean frequency of which is a function of the flowrate.

4 Principles

4.1 General

The following points are applicable when using any of the three techniques of pulse interpolation described in this part of ISO 7278.

a) The use of pulse interpolation is based on the assumption that there is no significant variation in the frequency of the pulses. Any variations in frequency caused by flowrate (see 5.1c)), or especially by intra-rotational non-linearity (see clause 6) will degrade the accuracy.

b) The interpolated number of pulses n' as described in 4.2, 4.3 and 4.4, will not generally be a whole number.

Multiple pulses from a flowmeter may be generated during a revolution of the meter, or to reduce intra-rotational non-linearity a single pulse per revolution may be used.

4.2 Double-timing method

See figure 1.

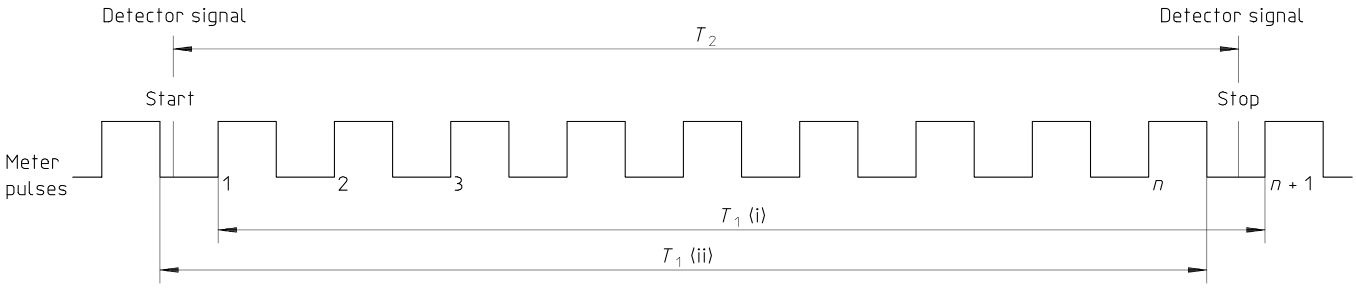
The principle of operation of this method is shown in figure 1. It consists of collecting, in a counter, the total number of complete meter pulses, n, generated during a proving run, and measuring two time-intervals, T_1 and T_2.

a) T_1 is the time-interval between the first meter pulse following the first detector signal and the first meter pulse following the last detector signal;

b) T_2 is the time-interval between the first and last detector signals.

The interpolated number of pulses is then given by

$$n' = n \frac{T_2}{T_1}$$



Interpolated number of pulses, $n' = n \dfrac{T_2}{T_1\text{(i)}}$ or $n' = n \dfrac{T_2}{T_1\text{(ii)}}$

Figure 1 — Double-timing method

4.3 Quadruple-timing method

See figure 2.

The principle of operation of this method is shown in figure 2. It consists of collecting, in a counter, the total integral number of pulses, *n*, generated during a proving run and measuring four time-intervals, t_1 to t_4.

a) t_1 is the time-interval between the first detector signal and the first meter pulse following that signal;

b) t_2 is the time-interval between the last meter pulse before the first detector signal and the first meter pulse after it;

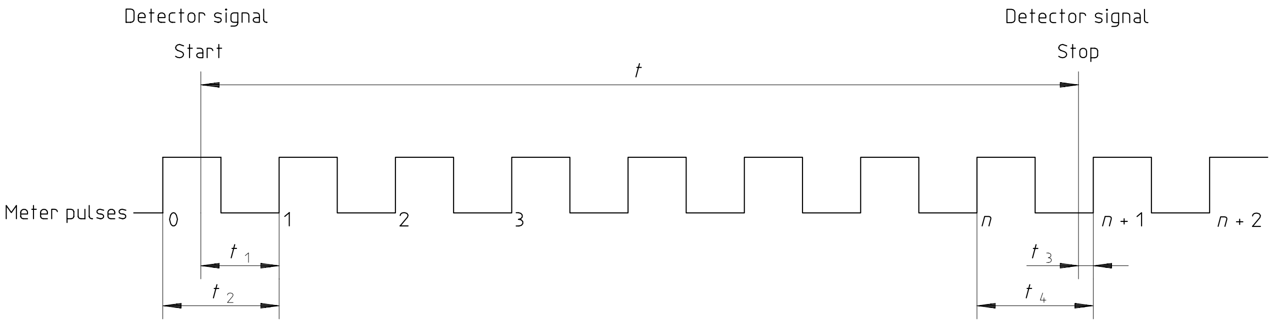
c) t_3 is the time-interval between the second detector signal and the first meter pulse following that signal;

d) t_4 is the time-interval between the last meter pulse before the second detector signal and the first meter pulse after it.

The number of complete pulses, *n*, in the main pulse count is counted in the normal way by a counter gated by the detector signals.

The interpolated number of pulses, n', between the detector signals is then

$$n' = n + \frac{t_1}{t_2} - \frac{t_3}{t_4}$$



Interpolated number of pulses, $n' = n + \dfrac{t_1}{t_2} - \dfrac{t_3}{t_4}$

Figure 2 — Quadruple-timing method

4.4 Phase-locked-loop method

See figure 3.

The principle of operation of this method is shown in figure 3. The pulses from the meter are introduced to input 1 of the phase comparator and the output signal is passed to the voltage controlled oscillator (VCO). This device generates pulses with a higher frequency proportional to its input voltage. This frequency is chosen to be higher than the meter frequency.

The output signal of the VCO is also fed back, through a frequency divider, to input 2 of the phase comparator. The frequency of the multiplied pulses is reduced by the divisor, *R*. The output voltage of the phase comparator is proportional to the difference in phase or frequency between its two inputs, so that the output frequency of the VCO is continually being servo-controlled to ensure that the frequency and phase of the two inputs are identical. The selection of frequency divisor, *R*, thus determines the pulse interpolation divisor.

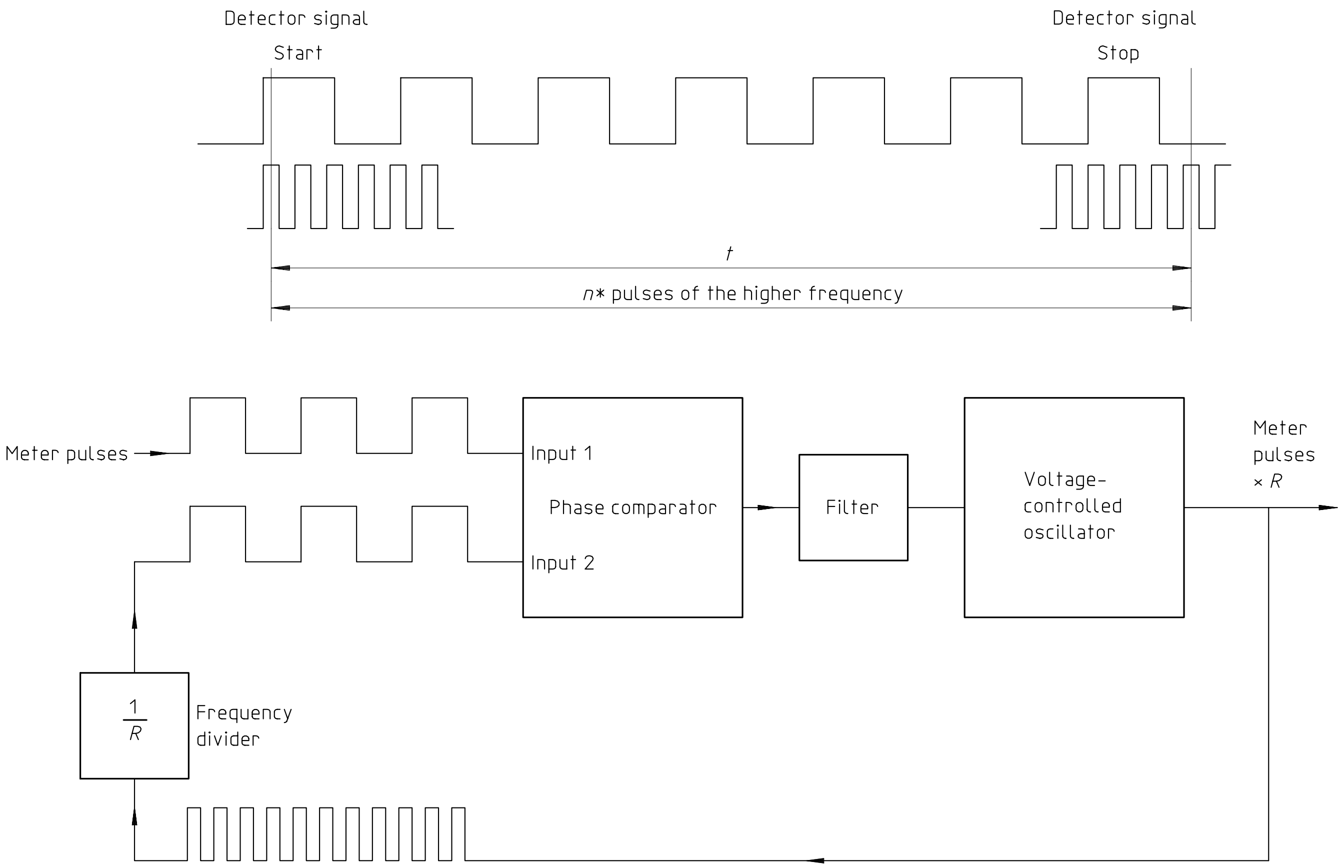
The interpolated number of pulses collected during the proving run is normally expressed as

$$n' = \frac{n^*}{R}$$

where

n^* is the number of multiplied pulses collected from the multiphase output;

R is the selected divisor (or multiplication factor).



Interpolated number of pulses, $n' = \frac{n^*}{R}$

Figure 3 — Phase-locked-loop method

To achieve precise control, it is necessary to filter the output of the phase comparator to avoid sudden VCO changes. This filter, normally of the simple RC type, has the property of momentarily retaining the voltage required by the VCO to keep generating *R* times the meter frequency between each phase comparison. Selection of the filter's time constant should be chosen to provide stability but not mask changes in input pulse frequency due to flowrate fluctuation.

5 Conditions of use

5.1 General

The following conditions shall apply generally to all the pulse interpolation methods described in this part of ISO 7278.

a) Resolution

The resolution of the indication device attached to the system shall in all instances be better than 1 in 10 000.

b) Number of significant digits for n'

As stated in 4.1 b), the number n' will not necessarily be a whole number. For the timing methods which yield a fractional result, there will be a practical limit on the number of decimal places which are used for n'. In practice the improvement by pulse interpolation is not unlimited, as n' shall be rounded to five significant digits, not more and not less.

c) Stability of flowrate

The pulse interpolation methods are based on the assumption that the flow is stable during the period of the proving. To maintain the stability of the flow, the fluctuations in the flowrate during a pass of the prover displacer, shall be less than ± 2 % of the mean flowrate.

NOTES

1 The pulse interpolation equipment is tested under conditions of simulated flowrate variation (see 7.3) to show satisfactory operation with such fluctuations.

2 The stability of the meter frequency will be the parameter normally used to assess flow stability.

d) Immunity from electrical interference

The equipment used shall be immune from electrical interference (see 7.4). In particular, the signal-to-noise ratio shall be adequately high.

e) Detector switch signal

The switching edge from the detector shall be well-defined and repeatable (some mechanical switches produce signals with non-repeatable lagging edges due to switch bounce). It is, however, necessary to use the same edge in each case.

f) Clock stability

Any clock used for timing shall have a stability commensurate with the required resolution.

5.2 Double-timing method

5.2.1 Resolution

To obtain a resolution better than ± 0,01 %, the period of the test, i.e. the time T_2 (see figure 1), shall be at least 20 000 times greater than the reference period t_c of the clock (i.e. the reciprocal of the clock frequency) used to measure the time-intervals.

That is

$$T_2 \geqslant 20\,000 t_c$$

that is

$$\frac{n}{f_m} \geqslant \frac{20\,000}{f_c}$$

therefore

$$f_c \geqslant \frac{20\,000}{n} f_m$$

where

f_m is the maximum meter test frequency;

f_c is the clock frequency;

n is the number of pulses collected during the proving run.

5.3 Quadruple-timing method

5.3.1 Resolution

To obtain a resolution better than ± 0,01 % the period of the test, i.e. the time T_2 (see figure 2), shall be at least 40 000 times greater than the reference period t_c of the clock (i.e. the reciprocal of the clock frequency) used to measure the time-intervals.

$$f_c \geqslant \frac{40\,000}{n} f_m$$

where f_c, f_m and n are as defined in 5.2.1.

5.4 Phase-locked-loop method

5.4.1 Frequency (locking) range

The operating frequency range shall always be greater than and encompass that of the meter under test.

NOTE — A minimum frequency rangeability of 100 to 1 is recommended for a pulse interpolation system.

5.4.2 Pulse interpolation divisor

The pulse interpolation divisor(s) shall be preset by the manufacturer and access to the preset value(s) shall be protected by a seal or other security device.

5.4.3 Resolution

To obtain a resolution better than ± 0,01 % the count n^* shall be equal to or greater than 10 000 pulses.

6 Meter requirements

The meter which is being proved and is providing the pulses for the pulse interpolation system shall meet the requirements laid down in this clause so that the proving uncertainty is not more than 1 in 10 000.

In an ideal meter, when operating at a constant flowrate, the emitted pulses are separated by exactly equal intervals of time. In practice, the spacing of pulses may be somewhat irregular, owing to intra-rotational linearity in rotating meters and other random fluctuations.

Such irregularities will reduce the accuracy of a pulse interpolation system. Some systems of pulse interpolation are more seriously affected by irregularities in pulse spacing than others but none is immune from it. The greater the degree of irregularity, the more pulses it is necessary to collect during a proving run if serious errors are to be avoided. At present, not enough is known about the effect to lay down mandatory rules, but if the guidelines given below are followed then the errors resulting from pulse spacing irregularities are considered unlikely to be very significant.

Two conditions are recognised as governing the estimation of the number of pulses required to give an acceptable calibration with a spread of results within ± 0,02 %.

If the pulse intervals scatter in a random manner, the following equation gives an estimate of the minimum number of pulses required.

$$n_m = 500(\sigma_1)^2$$

where

n_m is the recommended minimum of pulses;

σ_1 is the standard deviation of the pulse time intervals expressed as a percentage of the mean pulse interval.

The constant 500 was derived from theoretical and field experience.

Where large degrees of cyclic intra-rotational non-linearity are present, this equation may underestimate or, what is more likely, overestimate by a significant amount the number of pulses required. In this case, the repeatability is a complex function of the standard deviation, the number of pulses in the repeating cycle and the pulses collected in the proving run.

In all cases more than 100 pulses shall be collected and calibration shall be with more than one meter rotation or intra-rotational cycle. Some practical results can show acceptable calibrations with fewer pulses than recommended; others require more.

These instructions are based on practical and theoretical experience. In each particular application where poor calibration repeatability is found, poor meter repeatability or effects from pulse interpolation errors may be the cause. The use of multiple prover passes to increase the number of collected pulses is not considered here but may be an acceptable technique. Methods of estimation pulse stability are given in annex A. In some applications no repeatable calibration can be achieved and other calibration methods may be required.

7 Tests for pulse interpolation system

7.1 General

The pulse interpolation system shall be tested and a report submitted in accordance with clause 8 before it is used in proving operations. The verification given in the following subclauses shall be applied to whichever of the three previously described techniques is to be used. The tests are intended to check the validity of the pulse interpolation equipment with respect to its response to a given frequency range and to the rate of change of frequency. The verification shall include a series of environmental tests in which the ambient temperature and humidity are varied over a range likely to be encountered in practice; tests in which the supply voltage is varied should also be carried out.

The equipment tests can be carried out using the pulses generated by one or several meters at different flowrates and the signals from the detectors of the pipe prover or by other suitable simulation methods.

7.2 Test circuit

See figure 4.

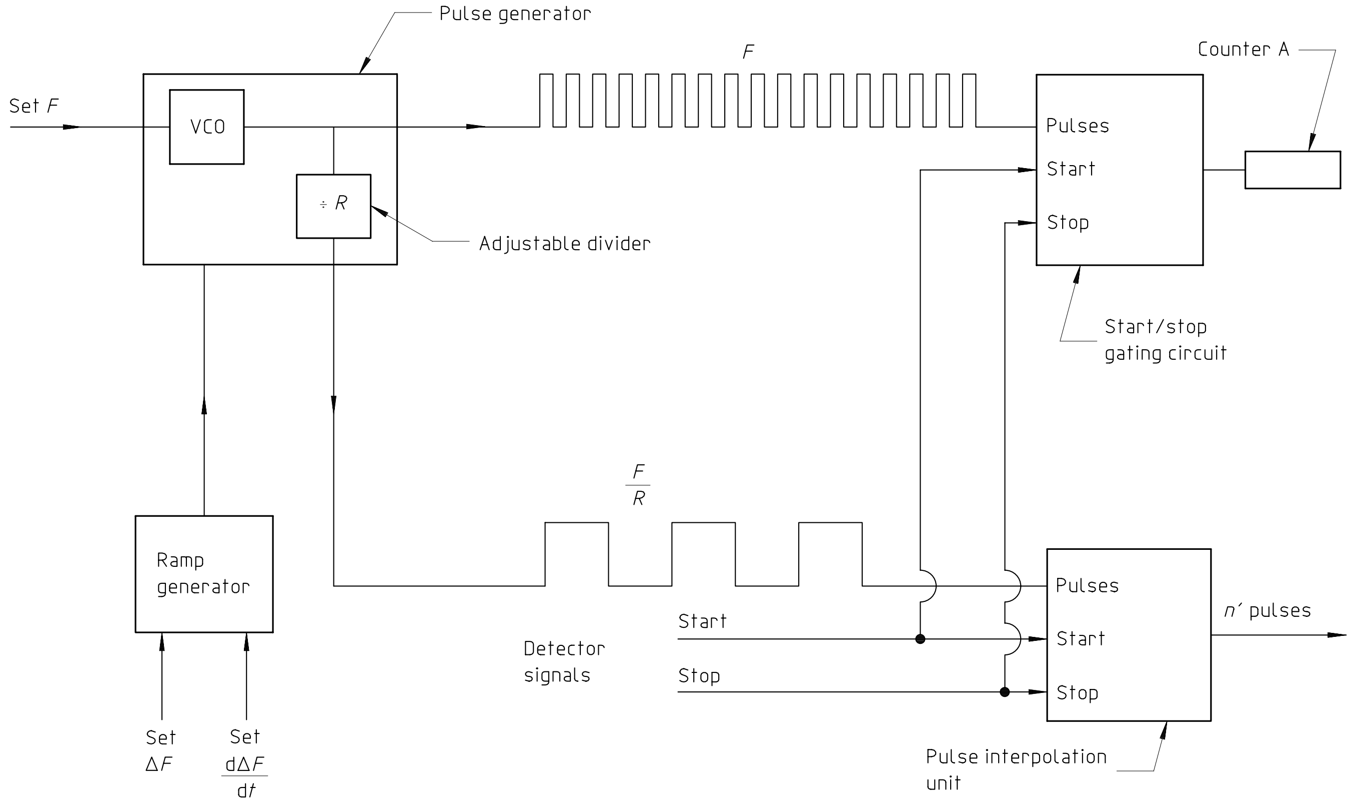


Figure 4 — Block diagram for equipment verification tests

A block diagram of the test circuit is shown in figure 4. A pulse generator, whose frequency is determined by a voltage-controlled oscillator (VCO), provides two outputs, the frequencies of which differ by a factor set into an adjustable divider.

One pulse stream, of frequency F, drives a reference counter A, which is controlled by a start/stop gating circuit. The other pulse stream, of frequency F/R, drives the pulse interpolation unit under test, which is also controlled by the detector start/stop signals. Both counter A and the interpolation unit may be set to zero by a common reset command.

The pulse generator's VCO allows the frequency F to be set. The ramp generator provides means for changing the frequency by ΔF and causing F to change with time at the rate dF/dt.

After the systems have been reset to zero, the detector start/stop signals shall be operated with a timer interval sufficient to accumulate at least 10 000 pulses in counter A. The readings of counter A and those of the interpolation unit shall agree to within 0,01 % for the phase-locked-loop method. In the case of the timing methods, counter A shall agree with (n' x R) to within 0,01 %.

7.3 Test schedule

The test shall be carried out at a minimum of three points over the required frequency range – within 5 % of the lower limit, within 10 % of the middle of the frequency range and within 5 % of the upper limit. When a range of pulse interpolation divisors is available, as in the phase-locked-loop technique, the smallest and the largest shall be tested as well as a divisor in the middle of the available range. These tests shall be carried out over a period of time, for example, at the beginning and the end of the endurance test (see below).

Additional tests shall be carried out to check the response of the pulse interpolation system to changes in frequency (or flowrate). For this a ramp generator, shown in figure 4, shall be used to provide changes of frequency over a given time interval. The ramp generator rate of change of frequency shall be variable and tests shall be carried out using frequency variations of up to 15 % above and below the mean frequency. These frequency variations should be checked at low, mid-range and high values of the mean frequency. The minimum period of the frequency variations shall be 0,5 s.

An endurance test shall be carried out under steady conditions around the middle of the frequency range. This endurance test shall last at least 72 h.

7.4 Immunity from electrical noise

The immunity of the pulse interpolation system from electrical interference shall be verified by the test procedures specified in ISO 6551. These tests shall be carried out at the same time as the equipment tests described above.

8 Test report and markings

When all equipment tests have been completed satisfactorily and their results are within the specified limits, a report shall be prepared containing the following information:

a) a reference to this part of ISO 7278;

b) the method of pulse interpolation used;

c) the frequency range;

d) the range of pulse interpolation divisors (if applicable);

e) the maximum frequency variation tested dF/dt.

The equipment may also be marked with the above information.

Annex A
(normative)

Measurement techniques for determining pulse intervals

A.1 General

As explained in clause 6, the variation in pulse interval time is a major limitation to the use of pulse interpolation systems. To use the advisory equation, the standard deviation of the pulse intervals shall be calculated. To assess the magnitude of any intra-rotational non-linearity, the pattern produced by the pulse times shall be examined. No commercial equipment is available to carry out these measurements directly, so either a special timer/counter can be designed and built, or other instruments used as a compromise.

To illustrate what is required of a general instrument system to carry out the measurement of pulse time intervals on all common flowmeters, a general specification is given in table A.1. This specification can be modified to suit the user’s requirements. The table is produced in two parts since a personal computer can usually carry out the calculation and display functions as long as it has suitable communications to the measurement system.

Table A.1 — Outline specification

Input requirements	10 mV to 30 V isolated input to avoid interference. A.C. and D.C. coupling
Trigger levels	5 mV to 10 V variable
Frequency levels	1 Hz to 10 kHz
Resolution	1 µs
Capacity	1 000 pulses
Calculations	Mean, variance, standard deviation, distribution, extra capacity for pattern recognition when developed
Display/Output	Screen graphics, dump to plotter and printer

A.2 Instruments

Three types of commercial instrument have been used to measure pulse times.

A.2.1 Electronic timers

Electronic timers can be used to measure the time interval between two pulses. They have suitable resolution and many have adaptable input characteristics. They are not suitable for measuring every consecutive pulse owing to the time taken to read the measured time. Connecting the counter to a computer can allow every second or third pulse to be timed; however, care should be taken to avoid synchronization with meter revolutions. The use of two or three counters connected to read time pulses sequentially with a computer recording the results is possible but difficult to control.

Calculation and display of the results shall be carried out by a calculator or computer.

A.2.2 Oscilloscopes

Older storage oscilloscopes, with screen storage, can show an image of the pulses if switched to 'store' and 'free run'. This provides a very rough guide to the spread of pulse intervals.

Modern digital storage oscilloscopes can store the incoming pulse signal and play it back on to the screen or download it to a computer. As this information is the pulse voltage and the time from a start point, extracting the time between pulses can be difficult. The capabilities of individual instruments would have to be examined to assess their ability to give the required performance.

Possible use of computers programmed to simulate an oscilloscope can also be considered.

A.2.3 Logic analysers

To test the operation of complex electronic systems, logic analysers are used to time the events occurring throughout the system. Most analysers have multiple channels, only one of which is required for interval timing. Each channel has the capability of timing many hundreds of events, either in real time or relative to the last event. The collected data can be displayed on the instrument's screen or in many cases transmitted to a computer or printer for calculation and display.

Usually signal processing will be required, as analysers are designed to operate at normal electronic logic levels of 5 V or 12 V with square edged pulses.

Annex B
(informative)

Bibliography

[1] ISO 2714:1980, *Liquid hydrocarbons — Volumetric measurement by displacement meter systems other than dispensing pumps.*

[2] ISO 2715:1981, *Liquid hydrocarbons — Volumetric measurement by turbine meter systems.*

[3] ISO 4267-2:1988, *Petroleum and liquid petroleum products — Calculation of oil quantities — Part 2: Dynamic measurement.*

[4] ISO 7278-2:1988, *Liquid hydrocarbons — Dynamic measurement — Proving systems for volumetric meters — Part 2: Pipe provers.*

[5] *VIM, International Vocabulary of Basic and General Terms in Metrology* — International Organization for Standardization, 1993.

ICS 75.180.30

Descriptors: petroleum products, hydrocarbons, liquid flow, flow measurement, flowmeters, calibration.

Price based on 12 pages