International Standard 7278/3

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

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

First edition — 1986-06-15

UDC 665.7 : 681.121 : 53.089.68 **Ref. No. ISO 7278/3-1986 (E)**

Descriptors : petroleum products, hydrocarbons, liquid flow, flowmeters, tests, dynamic tests, flow measurement.

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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 7278/3 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants.*

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

Liquid hydrocarbons — Dynamic measurement — Proving systems for volumetric meters — Part 3 : Pulse interpolation techniques

0 Introduction

The use of pipe provers to prove meters with pulsed outputs requires that a minimum number of pulses is collected during the proving period. The number of pulses which a meter can produce per unit of volume of throughput is often limited; this means that in many applications some means of increasing the meter's discrimination has to be found.

One way of overcoming this problem is to treat the signal from the meter in such a way that the discrimination of the meter is increased. This technique of increasing the meter's discrimination 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.

1 Scope and field of application

This part of ISO 7278 specifies the procedures and conditions of use to be observed if pulse interpolation is used in conjunction with a pipe prover and a turbine meter or displacement meter of good intra-rotational linearity to improve the discrimination of proving. It does not apply to other types of prover or other types of meter, to which these or other techniques of pulse interpolation may apply. It does not necessarily apply to meters fitted with accessories which superimpose a cyclic variation on the output of the meter such as temperature compensators or calibrators.

This part of ISO 7278 describes the three methods 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.

2 References

ISO 2714, *Liquid hydrocarbons — Volumetric measurement by displacement meter systems other than dispensing pumps.*

ISO 2715, *Liquid hydrocarbons — Volumetric measurement by turbine meter systems.*

ISO 4267/2, *Petroleum and liquid petroleum products — Dynamic measurement — Part 2 : Calculation of oil quantities.*[1)]

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

ISO 7278/1, *Liquid hydrocarbons — Proving systems for meters used in dynamic measurement — Part 1 : General principles.*[1)]

ISO 7278/2, *Liquid hydrocarbons — Dynamic measurement — Proving systems for volumetric meters — Part 2 : Pipe provers.*[1)]

3 Definitions

For the purpose of this International Standard, the following definitions apply.

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

3.2 detector signal : A contact closure or voltage that starts or stops the indicating device.

3.3 discrimination : The quality which characterizes the ability of a measuring instrument to react to small changes of the quantity measured.

3.4 lagging edge : The positive to negative transition of a pulse signal.

3.5 leading edge : The negative to positive transition of a pulse signal.

3.6 meter, non-rotating : A meter, the measuring element of which has no rotating parts. Such meters are, for example, vortex, ultrasonic or electromagnetic meters. Their output signal is derived from some characteristic which is proportional to flowrate.

1) At present at the stage of draft.

3.7 meter, rotating : A meter, the measuring element of which has one or more rotating parts. Such meters are, for example, turbine meters and displacement meters. Their output signal is derived from the continuous displacement of a mechanism which is driven by the flowing liquid.

3.8 phase detector : An electronic circuit which detects a phase difference between two pulsing or analog voltages.

3.9 ramp generator : An electronic circuit whose output voltage varies linearly with time.

3.10 repeatability (of a measuring instrument) **:** The ability of a measuring instrument to give, under defined conditions of use, closely similar responses for repeated applications of the same stimulus.

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.

4 Principles

4.1 General

The following points are applicable when using any of the three methods described in this International Standard.

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 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 necessarily be a whole number.

4.2 Double-timing method

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

a) T_1, (i) the time-interval between the first meter pulse following the first detector signal and the first meter pulse following the last detector signal, or alternatively (ii) the time-interval between the first meter pulse prior to the first detector signal and the first meter pulse prior to the last detector signal.

b) T_2, the time-interval between the first and last detector signals. Either the leading or lagging edges of these signals can be used. It is, however, necessary to use the same edge in each case. The interpolated number of pulses is then given by

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

4.3 Quadruple-timing method

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

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

b) t_2, (i) the time-interval between the first meter pulse and the second meter pulse after the first detector signal, or alternatively (ii) the time-interval between the last meter pulse before the first detector signal and the first meter pulse after it.

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

d) t_4, (i) the time-interval between the meter pulse immediately following the second detector signal and the next meter pulse, or alternatively (ii) the time-interval between the last meter pulse before the second detector signal and the first meter pulse after it.

[If alternative (i) is used in b), then it shall also be used in d), and if alternative (ii) is used in b), then it must also be used in d).]

The number of complete pulses, n, in the main pulse count are counted in the normal way by a counter gated by the detector signals. Either the leading or the lagging edges of these signals can be used to gate additional timers in order to determine the periods t_1, t_2, t_3, and t_4. It is, however, necessary to use always the same edge of the pulse for the measurement.

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

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

4.4 Phase-locked-loop method

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

The output signal of the VCO is also fed back to input 2 of the phase comparator, through a frequency divider where 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 number of multiplied pulses, n^*, collected in time T during a proving run is divided by the divisor R to obtain the interpolated number of pulses, n', i.e.

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

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.

5 Conditions of use

5.1 General

The following conditions shall apply generally to all the pulse interpolation methods described in this International Standard.

a) Resolution

The resolution of the system shall in all instances be better than 0,000 1 n.

b) Number of significant digits for n'

As stated in 4.1 b), the number n' will not necessarily be a whole number. However, 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', since the improvement by pulse interpolation is not unlimited. In practice n' shall be rounded to five significant digits, not more and not less.

c) Response to flowrate changes

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 short period fluctuations in the flowrate during the proving operation shall be less than ± 10 % of the mean flowrate.

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

d) Immunity from electrical interference

To avoid counting any spurious pulses during the proving period, the equipment used shall be immune from electrical interference (see 7.4). In particular, the signal-to-noise ratio shall be adequately high.

5.2 Double-timing method

5.2.1 Discrimination

To obtain a discrimination 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 Discrimination

To achieve the required discrimination of better than ± 0,01 %, the time between the start and stop detector signals shall be at least 40 000 times greater than the reference period of the clock used to measure the four time intervals. Thus

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

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. A minimum frequency rangeability of 100 : 1 is recommended for the 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 Discrimination

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

6 Meter requirements

6.1 General

The meter which is being proved and is thus providing the pulses for the pulse interpolation system shall meet the requirements laid down in this clause if the overall system uncertainty is not to be exceeded.

In an ideal meter, when operating at a constant flowrate, the emitted pulses will be separated by exactly equal intervals of time. In practice, however, the spacing of pulses may be somewhat irregular, on account of intra-rotational non-linearity in rotating meters and random fluctuations in fluidic and vortex-shedding meters.

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 concerning it, but it is considered that if the guidelines given below are followed, then the errors resulting from pulse spacing irregularities are unlikely to be very significant.

Extent of irregularity of pulse spacing %	Desirable minimum number of pulses to be collected during a proving run
± 1	100
± 2	200
± 5	500
± 10	1 000
± 20	2 000
± 30	3 000

6.2 Signal conditioning

The size and shape of the signal generated by the meter shall be suitable for presentation to the pulse interpolation system. If the signal is not in a suitable form for the particular system, it shall be amplified and/or shaped before entering the pulse interpolation system.

7 Equipment tests

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 sub-clauses 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 the pulse interpolation divisor, its response to a given frequency (or flowrate) range and to the rate of change of frequency (or flowrate). 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.

7.2 Test circuit

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 ΔF to change with time at the rate $\mathrm{d}\Delta F/\mathrm{d}t$.

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 within 0,01 % for the phase-locked-loop method. In the case of the timing methods, Counter A shall agree with $(n' \times R)$ 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 shall 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 should be carried out at the same time as the equipment tests described above.

8 Markings

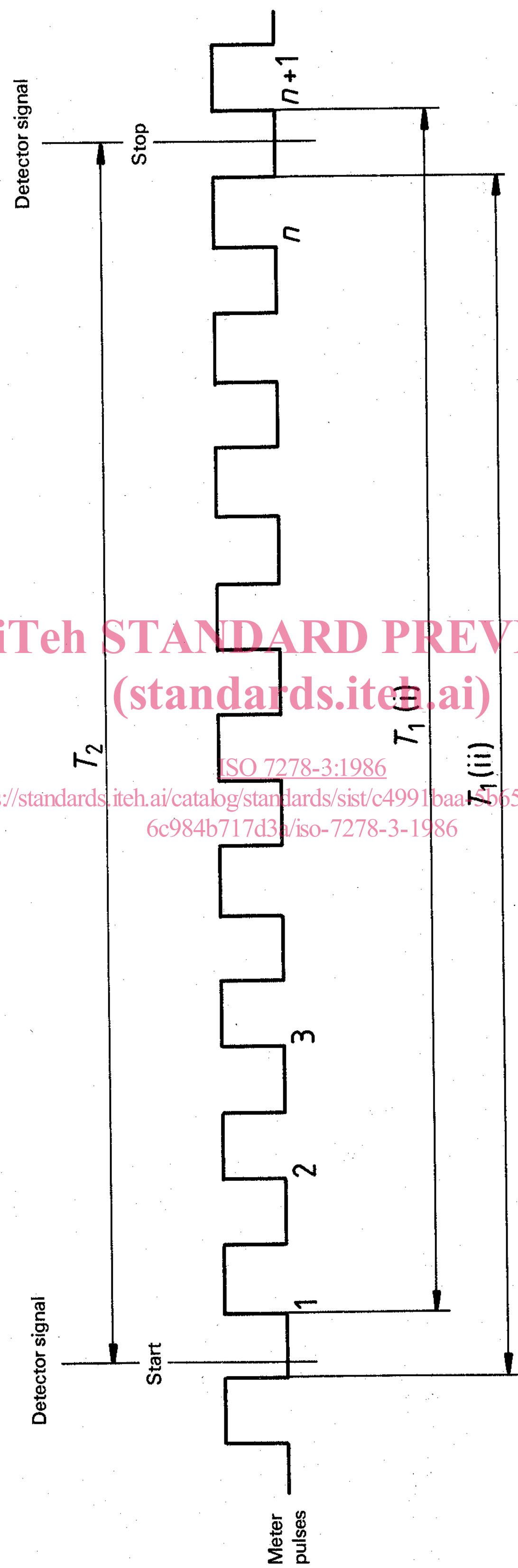
When all equipment tests have been completed satisfactorily, and their results are within the specified limits, a report shall be prepared setting out the following information :

a) the number of this International Standard;

b) the method of pulse interpolation used;

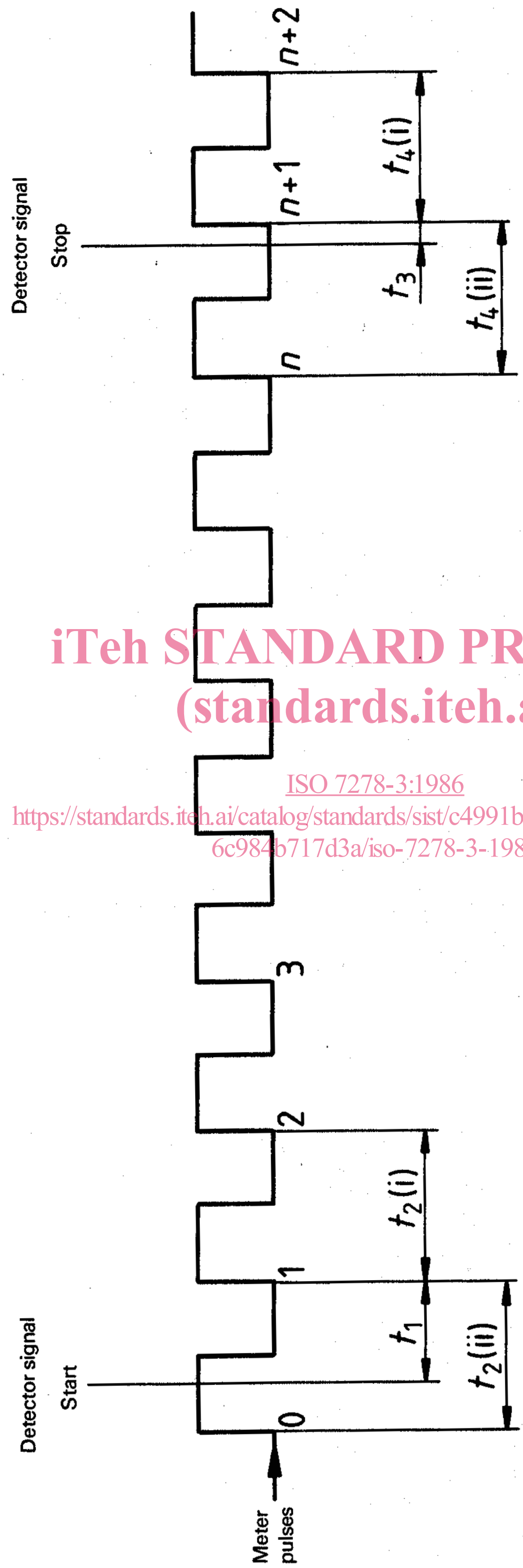
c) the operating frequency range;

d) the range of pulse interpolation divisors (where applicable).



Interpolated number of pulses, $n' = n \frac{T_2}{T_{1\,(i)}}$ or $n' = n \frac{T_2}{T_{1\,(ii)}}$

Figure 1 — Double-timing method



Interpolated number of pulses, $n' = n + \frac{t_1}{t_2\,(\mathrm{i})} - \frac{t_3}{t_4\,(\mathrm{i})}$ or $n' = n + \frac{t_1}{t_2\,(\mathrm{ii})} - \frac{t_3}{t_4\,(\mathrm{ii})}$

Figure 2 — Quadruple-timing method

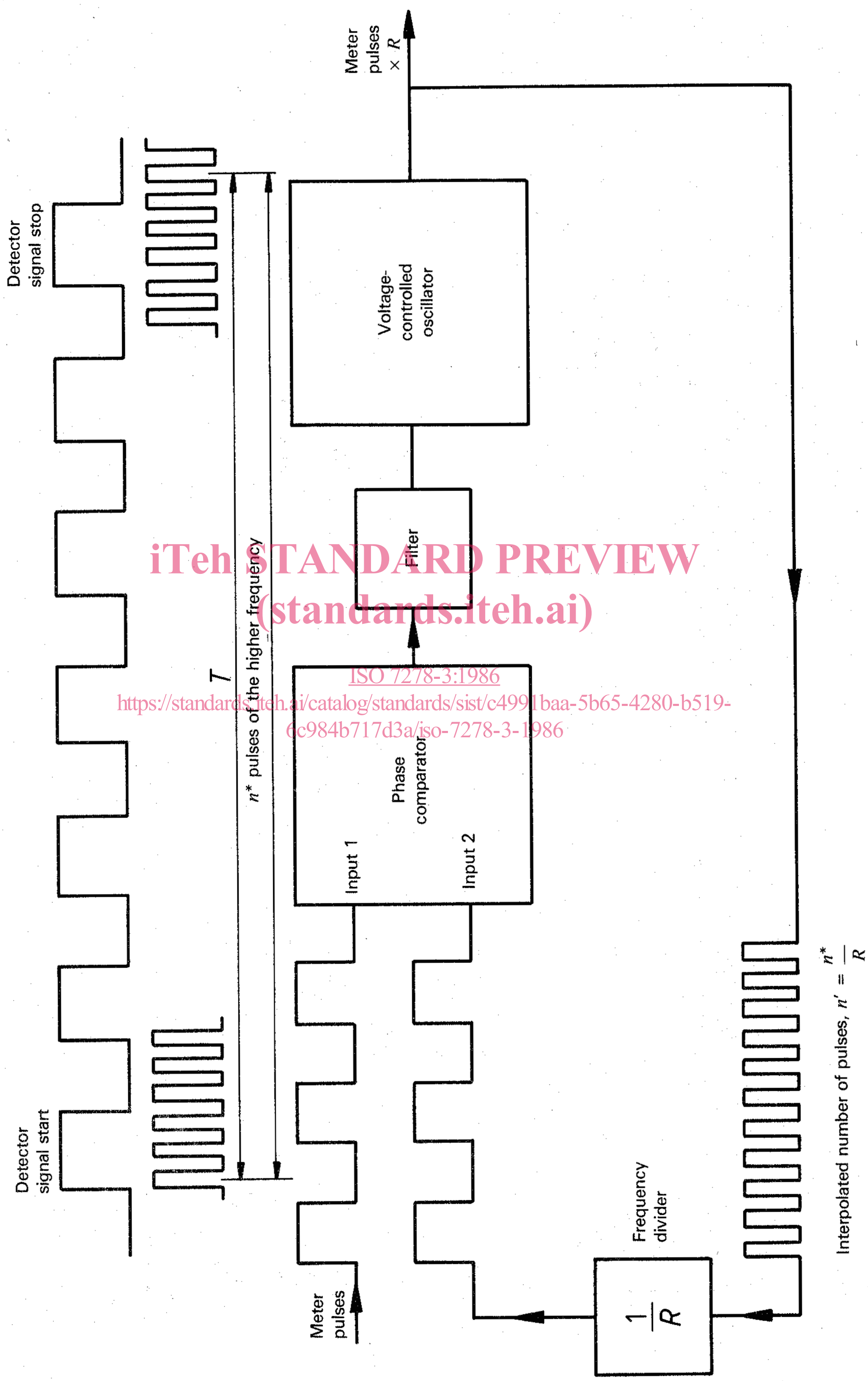


Figure 3 — Phase-locked-loop method