INTERNATIONAL STANDARD ISO 3846

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

Liquid flow measurement in open channels by weirs and flumes — Free overfall weirs of finite crest width (rectangular broad-crested weirs)

Mesure de débit des liquides dans les canaux découverts au moyen de déversoirs et de canaux jaugeurs — Déversoirs à largeur de crête finie et à déversement dénoyé (déversoirs rectangulaires à seuil épais)

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FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up 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.

International Standard ISO 3846 was developed by Technical Committee ISO/TC 113, *Measurement of liquid flow in open channels*, and was circulated to the member bodies in July 1975.

It has been approved by the member bodies of the following countries :

Australia	India	South Africa, Rep. of
Austria	Italy	Switzerland
Belgium	Japan	Turkey
Canada	Mexico	United Kingdom
Czechoslovakia	Netherlands	U.S.A.
France	Norway	U.S.S.R.
Germany	Romania	Yugoslavia

No member body expressed disapproval of the document.

Liquid flow measurement in open channels by weirs and flumes — Free overfall weirs of finite crest width (rectangular broad-crested weirs)

1 SCOPE AND FIELD OF APPLICATION

This International Standard lays down requirements for the use of full-width rectangular free overfall weirs of finite crest width for the measurement of flow of clear water in open channels.

The advantages and disadvantages of this type and other types of weirs and flumes, as well as the relative accuracies of each of these devices, are given in the annex.

2 REFERENCES

ISO 748, *Liquid flow measurement in open channels — Velocity-area methods.*

ISO 772, *Liquid flow measurement in open channels — Vocabulary and symbols.*

3 DEFINITIONS

For the purposes of this International Standard, the definitions given in ISO 772 apply.

4 UNITS OF MEASUREMENT

The units of measurement used in this International Standard are seconds and metres.

5 INSTALLATION

Conditions regarding preliminary survey, selection of site, installation, the approach channel, maintenance, measurement of head, stilling or float wells which are generally necessary for flow measurement are given in the following sub-clauses. The particular requirements for the finite crest-width weir are given separately in clause 8.

5.1 Selection of site

A preliminary survey shall be made of the physical and hydraulic features of the proposed site, to check that it conforms (or may be made to conform) to the requirements necessary for measurement by weir.

Particular attention shall be paid to the following features in selecting the site upstream of the weir :

a) availability of an adequate length of channel of regular cross-section;

b) the existing velocity distribution;

c) the avoidance of a steep channel, if possible;

d) the consequential effects of any increased upstream water level due to the measuring structure;

e) the consequential conditions downstream, including such influences as tides, confluences with other streams, sluice gates, mill dams and other controlling features which might cause drowning;

f) the impermeability of the ground on which the structure is to be founded, and the necessity for piling, grouting or other sealing-in river installations;

g) the necessity for flood banks to confine the maximum discharge to the channel;

h) the stability of the banks, and the necessity for trimming and/or revetment in natural channels;

j) the clearance of rocks or boulders from the bed of the approach channel;

k) the effects of wind; wind can have a considerable effect on the flow in a river, or over a weir, especially when these are wide and the head is small and when the prevailing wind is in a transverse direction.

If the site does not possess the characteristics necessary for satisfactory measuring, the site shall be rejected unless suitable improvements are practicable.

If a survey of the stream shows that the existing velocity distribution is regular, then it may be assumed that the velocity distribution will remain satisfactory after the construction of the weir.

If the existing velocity distribution is irregular and no other site for a gauge is feasible, due consideration shall be given to checking the distribution after the installation of the weir and to improving it, if necessary.

Several methods are available for obtaining a more precise indication of irregular velocity distribution : velocity rods, floats or concentrations of dye can be used in small channels, the latter being useful in checking conditions at the bottom of the channel. A complete and quantitative assessment of velocity distribution may be made by means of a current meter. More information about the use of current meters is given in ISO 748.

5.2 Installation conditions

5.2.1 *General*

The complete measuring installation consists of an approach channel, a measuring structure and a downstream channel. The conditions of each of these three components affect the overall accuracy of the measurements.

Installation requirements include such features as weir finish, cross-sectional shape of channel, channel roughness, influence of control devices upstream or downstream of the gauging structure.

The distribution and direction of velocity have an important influence on the performance of a weir, these factors being determined by the features mentioned above.

Once an installation has been designed, the user shall prevent any changes which could affect the discharge characteristics.

5.2.2 *The approach channel*

On all installations the flow in the approach channel must be smooth, free from disturbance and have a velocity distribution as normal as possible over the cross-sectional area. This can usually be verified by inspection or measurement. In the case of natural streams or rivers this can only be attained by having a long straight approach channel free from projections either at the side or on the bottom. Unless otherwise specified in the appropriate clauses the approach channel shall comply with the following general requirements.

The altered flow conditions due to the construction of the weir might have the effect of building up shoals of debris upstream of the structure, which in time might affect the flow conditions. The likely consequential changes in the water level should be taken into account in the design of gauging stations.

In an artificial channel the cross-section should be uniform and the channel should be straight for a length equal to at least 10 times its width.

In a natural stream or river the cross-section should be reasonably uniform and the channel should be straight for such a length as to ensure a regular velocity distribution.

If the entry to the approach channel is through a bend or if the flow is discharged into the channel through a conduit or smaller cross-section, or at an angle, then a longer length of straight approach channel may be required to achieve a regular velocity distribution.

No baffle shall be nearer to the points of measurement than 10 times the maximum head to be measured.

Under certain conditions, a standing wave may occur upstream of the gauging device, for example if the approach channel is steep. Provided this wave is at a distance of not less than 30 times the maximum head upstream, flow measurement is feasible, subject to confirmation that a regular velocity distribution exists at the gauging station.

If a standing wave occurs within this distance the approach conditions and/or gauging device must be modified.

5.2.3 *The measuring structure*

The structure must be rigid and water tight and capable of withstanding flood flow conditions without distortion or fracture. It shall be at right angles to the direction of flow and conform to the dimensions given in the relevant clauses.

5.2.4 *Downstream of the structure*

The channel downstream of the structure is usually of no importance as such provided that the weir has been so designed that it cannot become drowned under the operating conditions.

The altered flow conditions due to the construction of the weir might have the effect of building up shoals of debris immediately downstream of the structure, which in time might raise the water level sufficiently to drown the weir. Any accumulation of debris downstream of the structure shall therefore be removed.

6 MAINTENANCE – GENERAL REQUIREMENTS

Maintenance of the measuring structure and the approach channel is important to secure accurate continuous measurements.

It is essential that the approach channel to weirs be kept clean and free from silt and vegetation as far as practicable for at least the distance specified in 5.2.2. The float well and the entry from the approach channel must also be kept clean and free from deposits.

The weir must be kept clean and free from clinging debris and care shall be taken in the process of cleaning to avoid damage to the weir crest.

7 MEASUREMENT OF HEAD

7.1 General

The head upstream of the measuring structure may be measured by a hook gauge, point gauge or staff gauge where spot measurements are required or by a float-operated recording gauge where a continuous record is required, and in many cases it is preferable to measure heads in a separate stilling well to reduce the effects of surface irregularities. Other head measuring methods (e.g. bubble tubes) may be used, provided sufficient accuracy is obtainable.

The discharges given by the working equation are volumetric figures, and the liquid density does not affect the volumetric discharge for a given head, provided the operative head is gauged in liquid of identical density. If the gauging is carried out in a separate well, a correction for the difference in density may be necessary if the temperature in the well is significantly different from that of the flowing liquid. However, it is assumed herein that the densities are equal.

It shall, however, be ensured that the gauge is not located in a pocket or still pool, but measures the piezometric head.

7.2 Stilling or float well

Where provided, the stilling well shall be vertical and have a margin of 0,6 m over the maximum water level estimated to be recorded in the well.

It shall be connected to the approach channel by an inlet pipe or slot, large enough to permit the water in the well to follow the rise and fall of head without significant delay.

The connecting pipe or slot shall, however, be as small as possible consistent with ease of maintenance, or alternatively be fitted with a constriction, to damp out oscillations due to short amplitude waves. This will be necessary, for example, if the chart of the recorder cannot be read to within ± 6 mm.

The well and the connecting pipe or slot shall be watertight. Where provided for the accommodation of the float of a level recorder, the well shall be of adequate diameter and depth to accommodate the float.

The well shall also be deep enough to accommodate any sediment which may enter without the float grounding. The float well arrangement may include an intermediate chamber between the stilling well and the approach channel of similar proportions to the stilling well to enable sediment to settle down.

7.3 Zero setting

A means of checking the zero setting of the head-measuring device shall be provided, consisting of a pointer with its points set exactly level with the sill of the weir and fixed permanently in the approach channel or alternatively in the stilling or float well, where provided.

A zero check based on the level of the water when the flow ceases is liable to serious errors from surface tension effects and must not be used.

As the size of the weir and the head on it reduces, small errors in construction and in the zero setting and reading of the head-measuring device become of greater importance.

8 FINITE CREST-WIDTH WEIRS

8.1 Specification for the standard weir

The crest of the standard weir shall be a smooth, horizontal, rectangular plane surface (in these specifications a "smooth" surface shall be equivalent in surface finish to that of rolled sheet metal). The width of the crest perpendicular to the direction of flow shall be equal to the width of the channel in which the weir is located. The upstream and downstream end faces of the weir shall be smooth, vertical plane surfaces, and they shall be perpendicular to the sides and the bottom of the channel in which the weir is located. The upstream face, in particular, shall form a sharp, right-angle corner at its intersection with the plane of the crest.

A typical sketch of the weir is shown in figure 1.

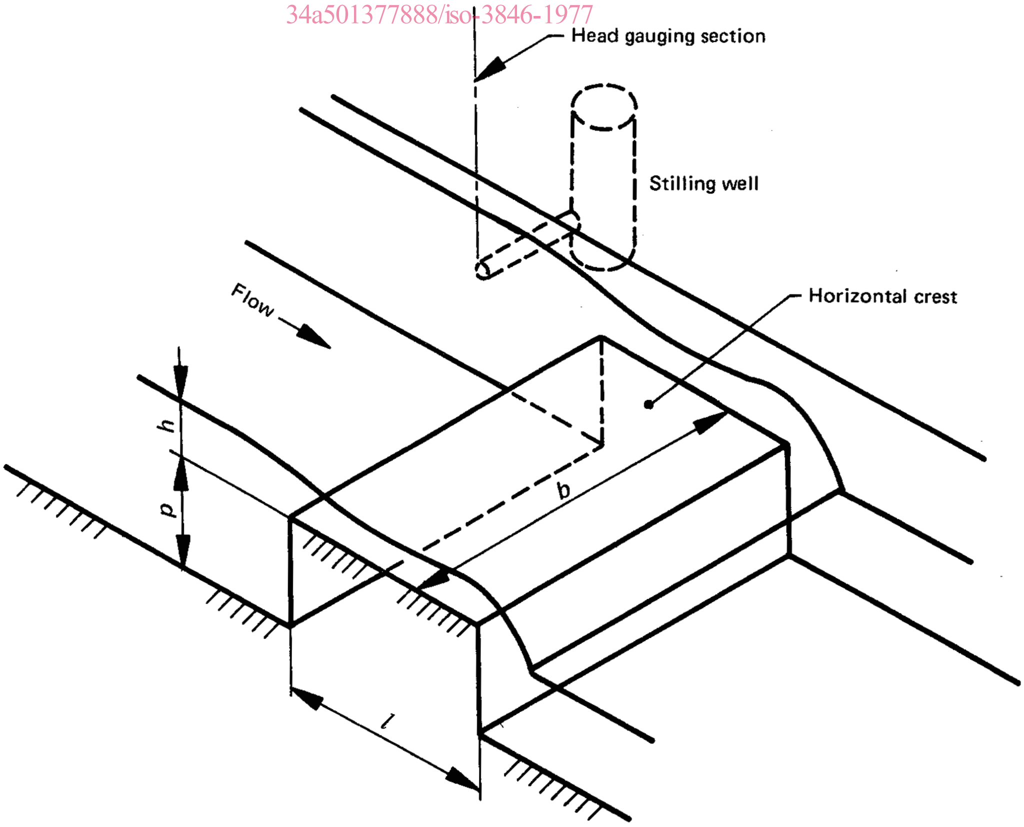


FIGURE 1 — **Rectangular-profile weir**

8.2 Location of the head gauge section

Piezometers or a point-gauge station for the measurement of head on the weir shall be located at sufficient distance upstream from the weir to avoid the region of surface drawdown. They shall, however, be close enough to the weir for the energy loss between the section of the measurement and the control section on the weir to be negligible. For these standards it is recommended that the head-measurement section be located at a distance equal to from three to four times the maximum head (3 to 4 h max.) upstream from the upstream face of the weir.

8.3 Provision for ventilated, free flow

Provision for ventilation of the discharging jet should ensure that the pressure on the upper and lower nappe surfaces is atmospheric. The tail water level should be low enough for it not to interfere with the ventilation or free discharge of the jet.

9 DISCHARGE EQUATION

9.1 Equation

The discharge equation is given below :

$$Q = (2/3)^{3/2}\, C \sqrt{g}\, b\, h^{3/2} \qquad \ldots (1)$$

where

Q is the discharge;

C is the non-dimensional coefficient of discharge;

g is the acceleration due to gravity;

b is the width of weir perpendicular to the direction of flow;

h is the measured head.

9.2 Coefficient of discharge

The coefficient C is constant, viz. 0,864, in the range

$$0{,}1 \leqslant \frac{h}{l} \leqslant 0{,}4$$

$$0{,}15 \leqslant \frac{h}{p} \leqslant 0{,}6$$

where

l is the width of the weir in the direction of flow;

p is the height of the weir with respect to the bottom of the approach channel.

For $\frac{h}{l}$ ranging from 0,4 to 1,6, C varies linearly with $\frac{h}{l}$, provided $\frac{h}{p} < 0{,}6$, and is given by the equation

$$C = 0{,}191 \frac{h}{l} + 0{,}782$$

For $\frac{h}{p}$ greater than 0,6, provided $\frac{h}{l} < 0{,}85$, the above values of C shall be multiplied by a numerical factor as shown in the table, before use in equation (1).

TABLE – **Correction factors for C**

Value of $\frac{h}{p}$	Correction factor
0,6	1,011
0,7	1,023
0,8	1,038
0,9	1,054
1,0	1,064
1,25	1,092
1,5	1,123

Intermediate values may be interpolated linearly.

NOTE – Based on the variation of C in the range of $0{,}1 \leqslant \frac{h}{l} \leqslant 0{,}4$, and $0{,}4 \leqslant \frac{h}{l} \leqslant 1{,}6$, the weir may be called broad-crested and narrow-crested respectively. In the broad-crested range, the flow across the weir is parallel to the crest for a certain portion. In the narrow-crested range, the flow is totally curvilinear. (See figure 2.)

9.3 Limitations

The following general limitations are recommended :

$$h \geqslant 0{,}06 \text{ m};$$

$$b \geqslant 0{,}3 \text{ m};$$

$$p \geqslant 0{,}15 \text{ m};$$

$$0{,}15 \leqslant \frac{p}{l} \leqslant 4;$$

$$0{,}1 \leqslant \frac{h}{l} \leqslant 1{,}6 \text{ (with } \frac{h}{p} \leqslant 0{,}85 \text{ for } \frac{h}{l} > 0{,}85\text{)};$$

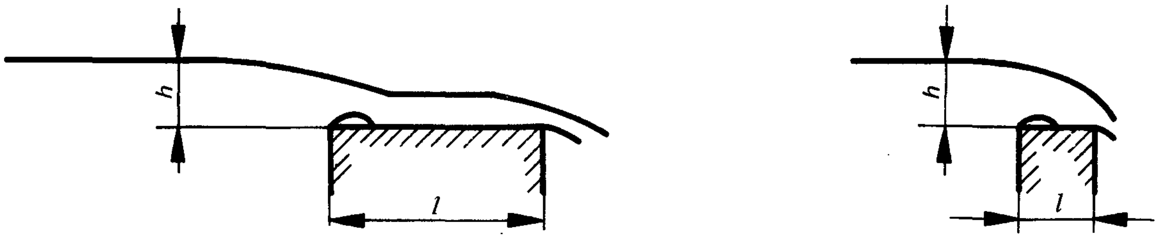
$$0{,}15 \leqslant \frac{h}{p} \leqslant 1{,}5 \text{ (with } \frac{h}{l} \leqslant 0{,}85 \text{ for } \frac{h}{p} > 0{,}85\text{)}.$$

9.4 Uncertainty of measurement

The overall uncertainty of flow measurements made with these weirs depends on the uncertainties of the head measurement, of the measurement of the dimensions of weir and of the coefficients as they apply to the weir in use.

With reasonable care and skill in the construction and installation of these weirs, the maximum uncertainty in the coefficient of discharge may be of the order of ± 3 %.

The method by which the uncertainty in the coefficients shall be combined with other sources of uncertainty is given in clause 10. In general, calibration experiments have been carried out on model structures of small dimensions and when transferred to larger structures there may be small changes in the discharge coefficient due to scale effect.



a) Broad-crested weir

$0,1 \leqslant \frac{h}{l} \leqslant 0,4$

b) Narrow-crested weir

$0,4 \leqslant \frac{h}{l} \leqslant 1,6$

FIGURE 2 — **Flow patterns over weirs of finite crest-width**

10 UNCERTAINTIES IN FLOW MEASUREMENT

10.1 General

10.1.1 The total uncertainty of any flow measurement can be estimated if the uncertainties from various sources are combined. In general, these contributions to the total uncertainty may be assessed and will indicate whether the discharge can be measured with sufficient accuracy for the purpose in hand.

This clause is intended to provide sufficient information for the user of this International Standard to estimate the uncertainty in a measurement of discharge.

10.1.2 The error may be defined as the difference between the actual rate of flow and that calculated in accordance with the equation for the weir, which is assumed to be constructed and installed in accordance with this International Standard.

The term uncertainty will be used to denote the deviation from the true rate of flow within which the measurement is expected to lie some nineteen times out of twenty (the 95 % confidence limits).

The uncertainty shall be calculated according to the method in this clause and quoted under this reference term whenever a measurement is claimed to be in conformity with this International Standard.

10.2 Sources of error

10.2.1 The sources of error in the discharge measurement may be identified by considering a generalized form of discharge equation for weirs :

$$Q = \left(\frac{2}{3}\right)^{3/2} C \sqrt{g}\, b\, h^{3/2}$$

where

$\left(\frac{2}{3}\right)^{3/2}$ is a numerical constant not subject to error;

g, the acceleration due to gravity, varies from place to place, but in general the variation is small enough to be neglected in flow measurement.

10.2.2 The only sources of error which need to be considered further are :

a) the discharge coefficient C (numerical estimates of uncertainty in C are given in 9.4);

b) the dimensional measurement of the structure, for example the width of the weir, b;

c) the measured head h.

10.2.3 The uncertainty in b and h must be estimated by the user. The uncertainty in dimension will depend upon the accuracy to which the device as constructed can be measured; in practice this uncertainty may prove to be insignificant in comparison with other uncertainties. The uncertainty in the head will depend upon the accuracy of the head-measuring device, the determination of the gauge zero, and upon the technique used. This uncertainty may be small if a vernier or micrometer instrument is used, with a zero determination of comparable precision.

10.3 Kinds of error

10.3.1 Errors may be classified as random or systematic, the former affecting the reproducibility (precision) of measurement and the latter affecting its true accuracy.

10.3.2 The standard deviation of a set of measurements under steady conditions may be estimated from the equation :

$$S_y = \left[\frac{\sum_{i=1}^{n} (y_i - \bar{y})}{n-1}\right]^{1/2}$$

where $\bar{y}$ is the arithmetic mean of n measurements.

The standard deviation of the mean is then given by :

$$S_{\bar{y}} = \frac{S_y}{\sqrt{n}}$$

and the uncertainty of the mean is twice $S_{\bar{y}}$ (for 95 % probability)[1]. This uncertainty is the contribution of random errors in any series of experimental measurements to the total uncertainty.

1) This factor of two assumes that n is large. For $n = 6$ the factor should be 2,6; $n = 8$ requires 2,4; $n = 10$ requires 2,3; $n = 15$ requires 2,1.

10.3.3 A measurement may also be subject to systematic error; the mean of very many measured values would thus still differ from the true value of the quantity being measured. An error in setting the zero of a water level gauge to crest level, for example, produces a systematic difference between the true mean measured head and the actual value. As repetition of the measurement does not eliminate systematic errors, the actual value could only be determined by an independent measurement known to be more accurate.

10.4 Uncertainties in coefficient values

10.4.1 All errors in this category are systematic.

10.4.2 The value of the discharge coefficient C quoted in this International Standard is based on an appraisal of experiments, which may be presumed to have been carefully carried out, with sufficient repetition of the readings to ensure adequate precision. However, when measurements are made on other similar installations, systematic discrepancies between coefficients of discharge may well occur, which may be attributed to variations in the surface finish of the device, its installation, the approach conditions, the scale effect between model and site structures, etc.

10.4.3 The uncertainty in the coefficients quoted in the preceding clauses of this International Standard are based on a consideration of the deviation of experimental data from various sources from the equations given. The suggested uncertainty values thus represent the accumulation of evidence and experience available.

10.5 Uncertainties in measurements made by the user

10.5.1 Both random and systematic errors will occur in measurements made by the user.

10.5.2 Since neither the methods of measurement nor the way in which they are to be made are specified, no numerical values for uncertainties in this category can be given; they must be estimated by the user. For example, consideration of the method of measuring the weir should permit the user to determine the uncertainty in this quantity.

10.5.3 The uncertainty of the gauged head shall be determined from an assessment of the individual sources of error, for example the zero error, the gauge sensitivity, backlash in the indication mechanism, the residual random uncertainty in the mean of a series of measurements, etc. The uncertainty on the gauge head is the square root of the sum of the squares of the individual uncertainties.

10.6 Combination of uncertainties to give total uncertainty on discharge

10.6.1 The total uncertainty is the resultant of several contributory uncertainties, which may themselves be composite uncertainties (see 10.5.3). When partial uncertainties, the combination of which gives the total uncertainty, are independent of one another, are small and numerous, and have a Gaussian distribution, there is a probability of 0,95 that the true error is less than the total uncertainty.

10.6.2 The uncertainty on the rate of flow shall be calculated from the following equation :

$$X = \pm \sqrt{(X_C^2 + X_b^2 + 1{,}5^2\, X_h^2)}$$

where

X_C is the percentage uncertainty in C;

X_b is the percentage uncertainty in b;

X_h is the percentage uncertainty in h.

In the above,

$$X_b = \pm\, 100 \times \frac{\epsilon_b}{b}$$

and

$$X_h = \pm \frac{100\,({}_1\epsilon_h^2 + {}_2\epsilon_h^2 + \ldots + 4\,S_{\bar{h}}^2)^{1/2}}{\bar{h}}$$

where

ϵ_b is the uncertainty in width measurement;

${}_1\epsilon_h$, ${}_2\epsilon_h$ etc. are uncertainties in head measurement (see 10.5.3);

$2S_{\bar{h}}$ is the uncertainty of the mean if a series of readings of the head measurement are taken (see 10.3.2 including foot-note).

10.6.3 It should be realized that the uncertainty X is not single-valued for a given device, but will vary with discharge. It may, therefore, be necessary to consider the uncertainty at several discharges covering the required range of measurement.

10.6.4 *Example*

The following is an example of the application of the formula to a single measurement with a rectangular weir at a crest height above the bed of the approach channel, p, of 0,30 m and operating at a gauged head of 0,40 m with a width of weir crest, b and width of approach channel B of 10 m. A digital head-measuring device is used, operating at 1 mm intervals but with an actual accuracy of ± 3 mm with zero set to within ± 5 mm.

X_c is taken as ± 3 % for the specific case.

$$X_h = \pm 100 \times \frac{(0{,}003^2 + 0{,}005^2)^{1/2}}{0{,}40}$$

$$= \pm 1{,}46\ \%$$

If the width of the weir, b, was measured on site to 0,02 m in a total width 10 m :

$$X_b = \pm 100 \times \frac{0{,}02}{10} = \pm 0{,}20\ \%$$

Thus

$$X = \pm [3^2 + 0{,}20^2 + (1{,}5^2 \times 1{,}46^2)]^{1/2}$$

$$= \pm 3{,}7\ \%$$