# INTERNATIONAL STANDARD ISO 1438

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# Liquid flow measurement in open channels using thin-plate weirs and venturi flumes

*Mesure de débit des liquides dans les canaux découverts au moyen de déversoirs en mince paroi et de canaux venturi*

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## FOREWORD

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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 1438 was drawn up by Technical Committee ISO/TC 113, *Measurement of liquid flow in open channels*, and circulated to the Member Bodies in June 1968.



It has been approved by the Member Bodies of the following countries :



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# Liquid flow measurement in open channels using thin-plate weirs and venturi flumes

## 1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies methods for the measurement of liquid flow in open channels using rectangular thin-plate weirs, triangular thin-plate weirs (V-notch) and venturi flumes. The flow conditions considered are limited to steady flows which are uniquely dependent on the upstream head. Thus, submerged flows, which depend on downstream as well as upstream water levels, are not considered herein.

## 2 REFERENCES

ISO/R 541, *Measurement of fluid flow by means of orifice plates and nozzles.*

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 (feet).

## 5 PRINCIPLE OF THE METHOD OF MEASUREMENT

### 5.1 Thin-plate weirs

The discharge is measured by interposing a thin-plate weir with an opening and observing the head over the weir and employing a known unique functional relationship between the rate of flow and the head over the weir.

The original basic discharge equation is attributable to Poleni and may be expressed in the form :

$$Q = Cbh^{3/2}$$

where

$Q$ is the discharge;

$C$ is the coefficient of discharge;

$b$ is the width of the opening;

$h$ is the measured head over the weir.

In the case of triangular thin-plate weirs, for the sake of convenience $b$ is replaced in terms of $h$ and the tangent of the angle of the apex.

### 5.2 Standing-wave or Free-flowing venturi flumes

The discharge is measured by building a streamlined structure to form a contraction and observing only the upstream head and then employing a functional relationship between the rate of flow and the upstream head, since under the conditions in which critical flow occurs at the throat, the discharge depends only on the upstream head.



## 6 INSTALLATION

### 6.1 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 weirs or flumes.

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

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 effects of any increased upstream water levels due to the measuring structure;

e) the 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;

i) the clearance of rocks or boulders from the bed of the approach channels;

j) effect of wind, which can have a considerable effect on the flow over a river, weir or flume, 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 measurement, the site shall be rejected unless suitable improvements are practicable.

If an inspection of the stream shows that the existing velocity distribution is regular (see figure 1 for typical regular open-channel velocity distribution), then it may be assumed that the velocity distribution will remain satisfactory after the construction of the weir or flume.

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 or flume, 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. Complete information about the use of current-meters is given in ISO 748.

### 6.2 Installation conditions

#### 6.2.1 *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.

Velocity profile obtained in 360 cm (12 ft) wide channel
Actual width = 358,75 cm (11 ft 11 1/2 in)
Depth of water = 74 cm (29.6 in)



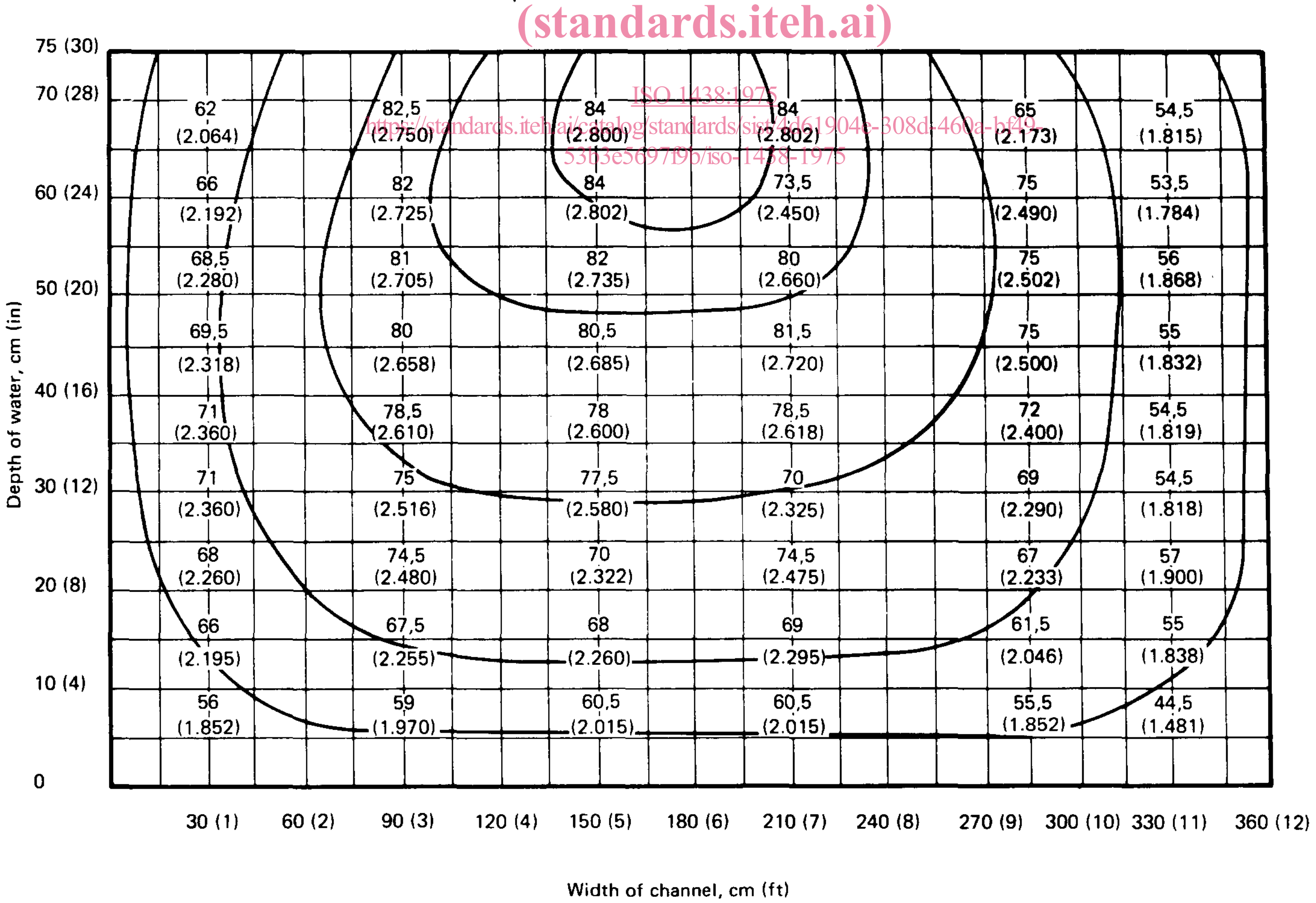


FIGURE 1 — **Example of a regular velocity profile in the approach channel**

Installation requirements include such features as finish of the weir or flume, 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 or flume, these being determined by the features mentioned above.

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

**6.2.2** *Approach channel*

On all installations the flow in the approach channel shall be smooth and free from disturbance and shall 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 following general requirements shall be complied with.

The altered flow-conditions due to the construction of the weir or flume 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 shall be taken into account in the design of the gauging stations.



In an artificial channel the cross-section shall be uniform and the channel shall be straight for a length equal to at least 10 times its width, if the width of the weir or flume throat is equal to or greater than half the width of the channel. The length of the channel can be reduced if the width of the weir or flume throat is less than half the width of the channel.

In a natural stream or river the cross-section shall be reasonably uniform and the channel shall be straight for a length as required for an artificial channel.

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 an even velocity distribution.

In an artificial channel where there is no debris or matter carried in suspension, suitable flow conditions can often be provided by suitably placed baffles formed by vertical laths, but there shall be no baffle nearer to the point 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 will be feasible, subject to confirmation that a regular velocity distribution exists at the gauging station. (See 11.1.4 e) for exception in case of venturi flumes.)

If a standing wave occurs within this distance, the approach conditions and/or gauging device shall be modified if measurement errors are to be avoided.

**6.2.3** *Measuring structure*

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

NOTE — In the case of a thin-plate weir, the wall on which it is built shall be free from projections, and its upstream face shall not protrude beyond the face of the weir. On the downstream side, the structure shall be such that it does not interfere with the aeration of the nappe.

**6.2.4** *Downstream of the structure*

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

The altered flow conditions due to the construction of the weir or flume 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 or flume. Any accumulation of debris downstream of the structure shall therefore be removed.

## 7 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 channels to both weirs and flumes be kept clean and free from silt and vegetation as far as practicable for at least the distance specified in 6.2.2. The float-well, and the entry from the approach channel shall also be kept clean and free from deposits.

The throat and the curved entry to a flume shall be kept clean and free from algal growths.

The weir structure shall 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. Thin-plate weirs shall be examined periodically for damage.

## 8 MEASUREMENT OF HEAD

### 8.1 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. The location of the head measurement station is dealt with in 9.3, 10.3 and 11.1.5, and in many cases it is preferable to measure heads in a separate stilling-well to reduce the effects of surface irregularities.

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.

### 8.2 Stilling-well or float-well

Where provided, the stilling-well shall be vertical and have a minimum margin of 60 cm (2 ft) over the maximum water level estimated to be recorded in the well.

It shall be connected to the river 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 shall alternatively be fitted with a constriction, to damp out oscillations due to short amplitude wave. This will be necessary for example, if the chart of the recorder canot be read to within ± 6 mm (0.02ft).

The well and the connecting pipe or slot shall be watertight. Where provided for the accomodation 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 silt 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 silt and other solids to settle out.

### 8.3 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 or the invert of the flume throat and fixed permanently in the approach channel or alternatively in the stilling-well 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 shall not be used.

As the size of the weir or flume 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.

## 9 TRIANGULAR THIN-PLATE WEIRS (V-NOTCHES)

### 9.1 Specifications for the standard weir

Within the range of conditions for which the available experimental data are competent, the triangular thin-plate weir (V-notch) is one of the most precise flow-measuring devices. It is inexpensive and simple to construct and install. A standard triangular thin-plate weir (V-notch) is shown in figure 2.



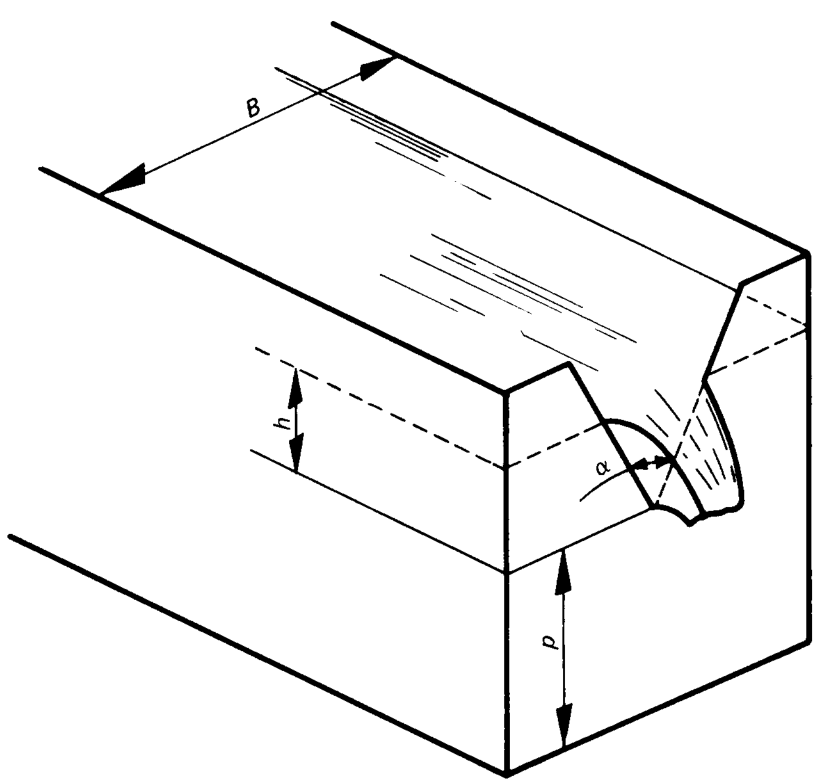


FIGURE 2 — **Triangular thin-plate weir, V-notch**

The standard weir shall consist of a symmetrical, V-shaped notch in a vertical, thin-plate. The line which bisects the angle of the notch shall be vertical and equidistant from the sides of the approach channel. The weir plate shall be smooth and plane, especially on the upstream side, and it shall be perpendicular to the sides as well as the bottom of the channel.

NOTE – In this International Standard a "smooth" surface shall be equivalent in surface finish to that of rolled sheet metal.

The crest surfaces shall be plane surfaces of width (measured perpendicular to the upstream face of the plate) between 1 and 2 mm (0.04 and 0.08 in), which shall form a sharp right-angled edge at their intersection with the upstream face of the weir plate. These surfaces shall be machined (or filed) perpendicular to the upstream face; the edges shall be free from burrs and scratches, and untouched by abrasive cloth or paper. The downstream edges of the weir shall be chamfered if the weir plate is thicker than the allowable crest width. The surface of the chamfer shall make an angle of not less than 45° with the crest surface. The weir plate is usually made of metal, preferably of that kind of metal which can resist erosion and corrosion.

### 9.2 Specifications for the installation

In addition to the requirements specified in clause 6, the following conditions shall be satisfied :

The weir shall be located in a straight, smooth, horizontal (level-bottomed), rectangular channel. As an exception, when the effective opening of the weir is so small in comparison with the upstream channel that the approach velocity is negligible, the shape of the channel is not of significance. The channel upstream from the weir, described hereinafter as the standard approach channel, shall be of sufficient length to develop the normal (uniform flow) velocity distribution for all discharges, or it shall be so arranged and equipped with baffles and screens as to simulate the normal velocity distribution and normal turbulence in the approach channel (see 6.2.2).

### 9.3 Location of the head-gauge section

Piezometers or a point-gauge station for the measurement of the head on the weir shall be located a sufficient distance upstream from the weir to avoid the region of surface draw-down. On the other hand, they shall be close enough to the weir for the energy loss between the section of measurement and the weir to be negligible. It is recommended that the head-measurement section be located at a distance equal to three to four times the maximum head ($3h_{max}$ to $4h_{max}$) upstream from the weir.

### 9.4 Provision for ventilated, free flow

Provisions for ventilation of the discharging jet shall ensure that the pressure on the nappe surface is atmospheric. The tailwater level shall be low enough not to interfere with the ventilation or free discharge of the jet.

NOTE – Free (unsubmerged) flow is defined here as flow which is independent of variations in tailwater level. It is recommended that the tailwater level should be at least 0,1 m (0.3 ft) below the lowest point of the notch.

### 9.5 Basic discharge equation (Kindsvater-Shen)

The basic equation of discharge for the triangular thin-plate weir, (V-notch) is the equation of Kindsvater-Shen.

$$Q = C_e \frac{8}{15} \sqrt{2g} \operatorname{tg} \frac{\alpha}{2} h_e^{5/2} \qquad \ldots (1)$$

where

$Q$ is the discharge volume rate in cubic metres per second (cubic feet per second);

$C_e$ is the coefficient of discharge (non-dimensional);

$g$ is the acceleration of free fall in metres per second squared (feet per second squared);

$\alpha$ is the angle included between the sides of the notch (radians or degrees);

$h_e$ is the effective piezometric head referred to the vertex of the notch in metres (feet).



For water at ordinary temperatures, i.e. 5 to 30 °C (40 to 85 °F) the coefficient of discharge, $C_e$, has been determined by experiment as a function of three variables,

$$C_e = f\left(\frac{h}{p}, \frac{p}{B}, \alpha\right) \qquad \ldots (2)$$

where

$h$ is the measured head in metres (feet);

$p$ is the apex height in metres (feet);

$B$ is the width of the upstream channel in metres (feet).

The effective head, $b_e$ in equation (1), is defined by the equation

$$h_e = h + k_h \qquad \ldots (3)$$

where $k_h$ is an experimentally determined quantity in metres (feet) which compensates for the influence of surface tension and viscosity.

#### 9.5.1 *Evaluation of $C_e$ and $k_h$*

Experimentally determined values of the coefficients required to describe the flow of water over a full practical range of values of $h/p$ and $p/B$ are available for only one value of $\alpha$ i.e. 90°.

It is recommended that a constant value of $k_h$ = 0,85 mm (0.002 8 ft) be used with the values of $C_e$ shown in figure 3.

Triangular thin-plate weirs (V-notches) covering a range of values of $\alpha$ from 10° to 120° have been studied by a large number of investigators. However, the range of values of $p/B$ and $h/p$ covered by the available data is quite limited. The conditions covered by virtually all of the experimental data available for triangular thin-plate weirs (V-notches) covering a range of values of $\alpha$ from 10° to 120° (except those for $\alpha = 90°$) are within limits in which $C_e$ is a function of $\alpha$ alone. For such weirs, which can be described as "fully contracted", the available experimental data give the values of $C_e$ shown in figure 4. The corresponding values of $k_h$ are shown in figure 5. In both figures, the curves are shown with dashed lines for values of $\alpha$ less than 20° or greater than 100°. Within the range $\alpha$ = 20° to 100°, coefficients are recommended for standard flow measurements. Outside this range the coefficients are not well defined.

**9.5.2** *Practical limitations on h/p, p/B, h and p*

Practical limitations on $h/p$ and $p/B$ are related to the observation that head-measurement difficulties and errors result from surges and waves which occur in the approach channel when the velocity of approach is large in comparison with the depth of flow. The available experimental data are not adequate to establish the limiting values of $h/p$ and $p/B$ which are associated with this condition. The range of values of $h/p$ and $p/B$ represented by the curves in figure 3 (for $\alpha = 90°$ only) is a full, practical range.

NOTE — Limitations on $h/p$ corresponding to smaller values of $p/B$ have not been established, but it is assumed that the maximum permissible value of $h/p$ increases as $p/B$ decreases. Limitations on $h/p$ shall be determined on the basis of the flow characteristics and related conditions which influence the accuracy of head measurement.

Practical limitations on the magnitude of $h$ are related to the "clinging nappe" phenomenon which characterizes low heads. To ensure a freely discharging stable nappe, a minimum value of $h$ = 0,06 m (0.2 ft) is recommended for notch angles between 20° to 100°. It is recommended that $p$ be limited to values greater than 0,1 m (0.3 ft).

**9.6 Effect of velocity distribution in the approach channel**

The specifications for the standard installation include the requirement that the velocity in the channel upstream from the weir be such as to simulate the normal velocity distribution in a smooth, horizontal, rectangular channel. When the velocity distribution in the approach channel differs considerably from the normal, the discharge characteristics are altered. Consequently, flow measurements made with non-standard weir installations are subject to error.

In the range of conditions represented by figure 4, the influence of approach channel velocity distribution may be considered to be negligible.

**9.7 Accuracy of measurement**

The relative accuracy of flow measurements made with a standard triangular thin-plate weir (V-notch) depends on the accuracy of the head measurement, the notch-angle measurement, and on the accuracy of the coefficients as they apply to the weir in use.

With reasonable care and skill in the construction and installation of a standard weir, the error in the coefficient of discharge can be expected to be of the order of 1,0 %.

The method by which the error in the coefficients is to be combined with other sources of error is explained in clause 13 which deals with the estimation of errors.



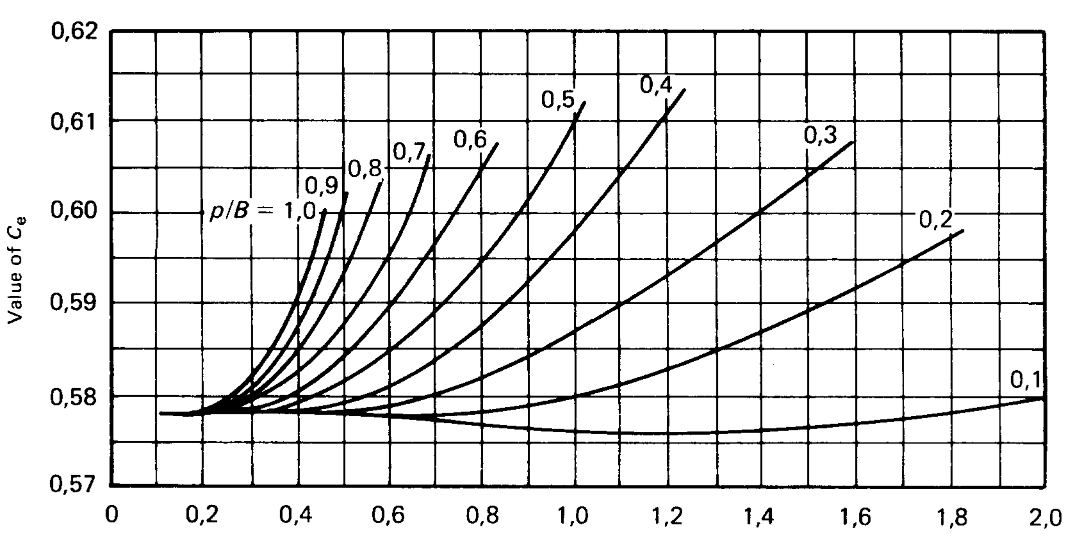


FIGURE 3 — **Coefficient of discharge $C_e$** ($\alpha$ = 90°)

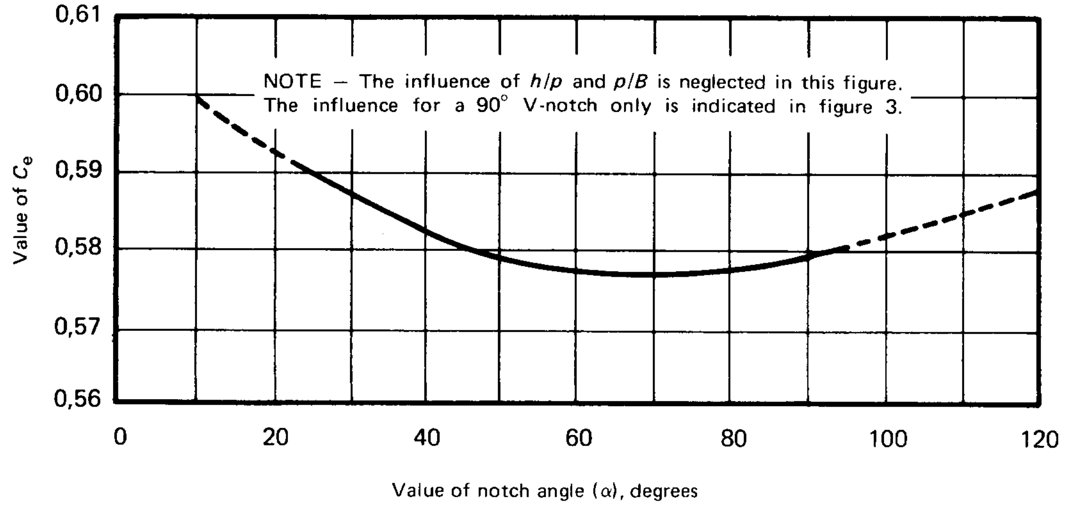


FIGURE 4 – **Coefficient of discharge $C_e$ related to notch angle**



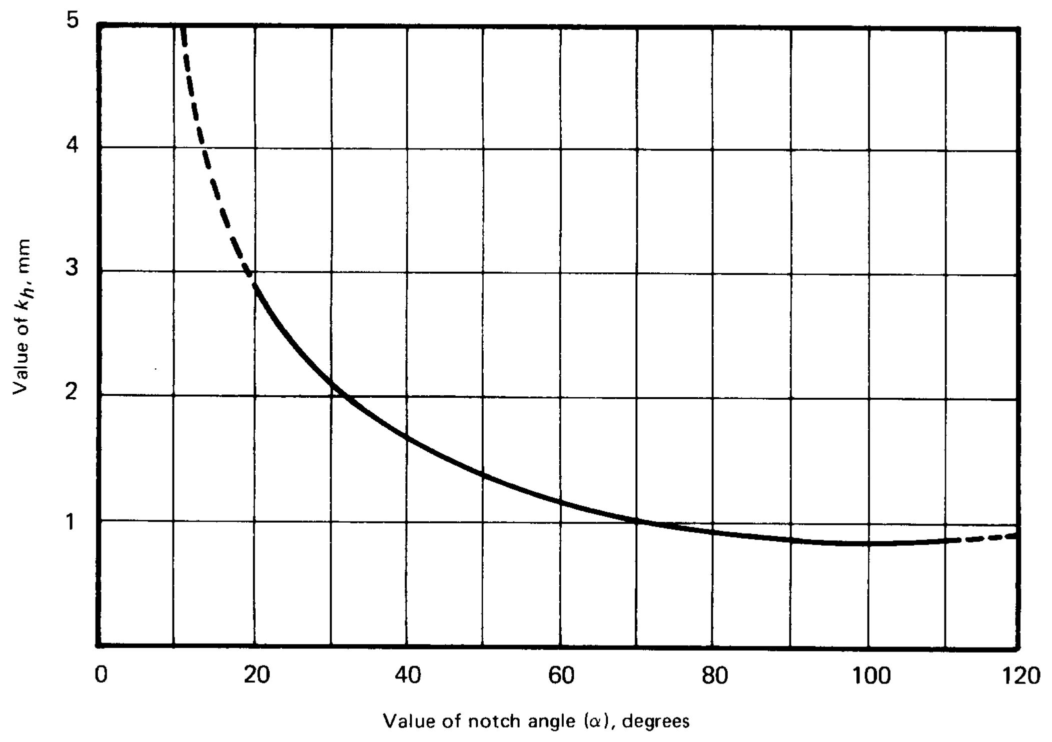


FIGURE 5 – **Value of $k_h$ related to notch angle**