INTERNATIONAL STANDARD 3455

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Liquid flow measurement in open channels — Calibration of rotating-element current-meters in straight open tanks

Mesure de débit des liquides dans les canaux découverts — Étalonnage des moulinets à élément rotatif en bassins découverts rectilignes

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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 3455 was drawn up by Technical Committee ISO/TC 113, *Measurement of liquid flow in open channels*, and circulated to the Member Bodies in February 1974.

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

Australia	Germany	South Africa, Rep. of
Belgium	India	Spain
Bulgaria	Netherlands	Switzerland
Chile	New Zealand	Turkey
Czechoslovakia	Norway	United Kingdom
France	Romania	

No Member Body expressed disapproval of the document.

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Liquid flow measurement in open channels — Calibration of rotating-element current-meters in straight open tanks

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies the procedure to be used for the calibration of current-meters, i.e. for the experimental determination of the relationship between liquid velocity and rate of revolution of the rotating element. It also specifies the type of tank and equipment to be used and the method of presenting the results.

The procedure does not take into account any possible difference existing between the behaviour of a current-meter moving in motionless water and that of a fixed current-meter in turbulent flow.

2 DEFINITIONS

For the purpose of this International Standard, the definitions given in ISO 772, *Liquid flow measurement in open channels — Vocabulary and symbols*, shall apply.

3 PRINCIPLE OF CALIBRATION PROCEDURE

The current-meter is drawn through still water contained in a straight tank of uniform cross-section at a number of steady velocities. Measurements are made of the speed of the towing carriage and of the rate of revolution of the rotor of the meter. The two sets of values are related by one or more equations of which the limits of application are stated.

4 DESIGN CRITERIA FOR CALIBRATION STATIONS

4.1 Dimensions of calibration tank

The dimensions of the tank and the number and relative position of current-meters in the tank cross-section may affect the test results.

4.1.1 *Length*

The length of a calibration tank may be considered as comprising accelerating, stabilizing, measuring and braking sections.

The length of the accelerating and braking sections depends on the design of the carriage and on the maximum speed at which it is to be towed along the tank. The length required for the braking section must take account of safety requirements.

The length of the measuring section shall be such that the calibration error, which is composed of inaccuracies in the measurement of time, distance covered and rate of revolution, does not exceed the desired tolerance at any velocity. The required length will, therefore, depend on the type of current-meter being calibrated, the way the signals are produced and transmitted and the method of calibration.

For example, if measured times both for distance covered by the carriage and for the revolutions counted are accurate to 0,01 s in order to limit the error in time measurement to 0,1 % at the 95 % confidence level, the duration of the test shall be at least 10 s at maximum speed. If the maximum speed is 6 m/s, then the measuring section of the tank would be 60 m long. The total length of the tank would be about 100 m of which about 20 m would be for acceleration and stabilizing and 20 m for braking.

4.1.2 *Depth and width*

The depth of the tank may have an influence on the test results which cannot be regarded as negligible, more particularly when the towing speed coincides with the velocity of propogation of the surface wave. The dependence of this critical velocity v_c on tank depth is given by the equation.

$$v_c = \sqrt{gd}$$

where

g is the acceleration due to gravity;

d is the depth of water.

The wave crest produced by the current-meter and its means of suspension, which moves forward with the instrument, causes an increase in the height of the wetted cross-section and thus, in accordance with the continuity equation, a reduction of the relative velocity. This phenomenon, known as the Epper effect, may cause an error in calibration within a narrow band in the velocity range from 0,5 v_c to 1,5 v_c. The magnitude of the Epper effect depends on the size of the current-meter(s) and suspension equipment, relative to the cross-sectional area of the tank. It may be negligible when a very small current-meter is calibrated.

The depth of the tank must therefore be chosen to suit the maximum velocity limits of the instruments to be calibrated. Care shall be taken to ensure either that the highest calibration velocities are attained before the interference or that they exceed it sufficiently for the critical zone to be bridged without extrapolation.

The width of the tank is of importance because the Epper effect is more pronounced in a narrower tank. The width also limits the number of instruments that can be calibrated simultaneously and has an effect on the stilling characteristics (time taken for the water to become reasonably still).

For example, when a field-type current-meter on rod suspension is calibrated in a tank 1,83 m wide in which the depth of water is 1,83 m, the Epper effect is greatest at a speed of about 4 m/s ($\sqrt{9,81 \times 1,83}$) and amounts to about 0,3 %. The size of the effect dies away on either side of the critical velocity, but is detectable at velocities between 3 and 5 m/s.

Details of some of the rating tanks in use are given in the annex.

4.2 Rating carriage

In order to move the current-meter through the water at known and accurate speeds, the current-meter is suspended from a carriage which may run on rails (or a track) which must be accurately aligned with both the length of the tank and the surface of the water in the tank. If two rails are used, they must be parallel.

It is essential that the rails are straight and that the rails and the wheels of the carriage are free of irregularities, otherwise the carriage will move with irregular motion and cause vibrations which may be transmitted to the current-meters and disturb the rating.

Two types of carriage are in common usage, namely :

a) the towed carriage which is moved along the rails by a cable driven from a constant-speed motor standing apart from the moving carriage.

The towed carriage may be lightly constructed with the consequent advantage of high acceleration and quick braking, but the elasticity of the towing cable can cause irregularities in the running of the carriage.

b) the self-propelled carriage which is moved along the rails by an internally mounted motor.

The self-propelled carriage will be heavier in construction as it has to carry the driving motors. This results in greater inertia of the carriage and assists in smoothing out the running irregularities of the carriage.

4.3 Measuring equipment

The calibration of a current-meter calls for the simultaneous measurement of the following three quantities :

a) the distance covered by the carriage;

b) the number of pulses delivered by the current-meter;

c) the time.

The towing speed is calculated from the simultaneous measurements of distance and time and the rate of rotation is obtained by simultaneous measurement of the number of pulses and time.

4.3.1 *Distance*

The measurement of distance shall be accurate to within 0,1 % at the 95 % confidence level. A variety of methods is available by which this can be achieved. Two of the most common methods are as follows :

a) the establishment of markers at regular intervals along the length of the calibration tank which actuate mechanical or optical pulse transmitters fitted to the carriage;

b) the use of measuring wheels with mechanical or photo-electric pulse transmitters which are drawn along the track by the carriage.

4.3.2 *Time*

The measurement of time shall be accurate to within 0,1 % at the 95 % confidence level. A variety of methods is available by which this can be achieved. Two of the most common methods in use are :

a) a clock giving a contact pulse after one or several seconds. These time pulses are usually recorded on a graph or magnetic tape together with the pulses of the current-meter and distances. The time corresponding to an integral number of pulses from the meter is usually determined by interpolation of the time pulse;

b) electronic clocks, capable of measuring fractions of a second, which time and display a preset number of distance intervals and a corresponding number of pulses from the current-meter.

4.3.3 *Current-meter pulses*

The measurement of current-meter revolutions shall be accurate to within 0,1 % at the 95 % confidence level. The pulses from the current-meter may be counted or recorded. In measuring the number of current-meter revolutions in a given time, it is important to measure between identical points on the current-meter pulse.

When a recording is made, the speed of the recording media shall be adjustable so that the separation of the current-meter pulse may be compatible with the speed of the carriage and the required accuracy of the measurement.

4.4 Ancillary equipment

In order to increase the efficiency of a current-meter calibration station, several items of ancillary equipment shall be provided.

a) Filtering, dosing and scum-removing equipment for the cleansing of the water and for keeping it free from algal growth.

b) Spending beaches, stilling devices or other similar devices to reduce the reflection of disturbance in the water by the end walls of the tank. Alternatively, transverse curtains can be installed at intervals along the tank and lowered to the bottom of the tank before the start of each run.

c) Means for checking that a cable-suspended meter is properly aligned at the start of a run and that the meter is not swinging when measurements are started should be available when the installation is operated from a control room. Closed-circuit television is useful for this purpose and also for observing the behaviour of current-meters at speeds close to their minimum speed of response.

d) A thermometer to indicate the temperature of the water in the tank.

5 CALIBRATION PROCEDURE

5.1 Instructions for calibration

The instructions for calibration shall include :

a) the limits of calibration speeds. When fixing a maximum limit, care shall be taken to ensure that the last measuring points are situated clearly outside the zone where the Epper effect is felt;

b) details of the means of suspension; for example, rod profile and dimensions, fixing method of electric cables, type of suspension cable, type and mass of ballast weight, position of current-meter with respect to support, etc.;

c) for meters with oil-filled contact systems, the oil used in the measurements or its complete specification must be sent in with the instruments;

d) information concerning the desired calibration documents, such as equations, calibration diagrams or tables, units in which the results are to be expressed, etc.;

e) any particular requirements, such as whether the current-meter is to be calibrated at delivery and again after any repair.

5.2 Suspension of the current-meter

Attention shall be paid to the following points :

5.2.1 Before the meter is immersed in water, it shall be checked for cleanliness, lubrication and for its mechanical and electrical functioning.

5.2.2 The suspension of the meter shall be as specified. This will usually be the same as that used during field measurement. For example, if during measurements the meter is attached near the lower end of the rod when used in the field, it must be mounted in the same position for calibration. Should this not be the case, the meter must be mounted far enough from the end of the rod to ensure that any influence from this quarter is eliminated.

If the signal cable is laid outside the rod during field measurements, a similar cable, attached in the same way, shall be used for the calibration. It should be noted that loose signal cables can influence the calibration result.

5.2.3 The meter must be placed at such a depth below the surface of the liquid that the surface influence is negligible. For an axial flow meter, a depth (liquid level to rotary axis) twice the diameter of the rotary element is generally sufficient. A cup-type meter shall be immersed to a depth of at least 0,3 m or one and a half times the height of the rotor, whichever is greater.

At higher towing speeds there may be separation of flow behind certain rod profiles, causing a decrease in the angular velocity as if a thicker rod were used. This disturbance can often be eliminated by increasing the immersion depth, or by providing the rod with a flairing at the water surface.

5.2.4 If several current-meters are calibrated at the same time, care shall be taken to ensure that there is no mutual interference, or that the mounting is exactly reproduced in order that interferences between current-meters are the same during calibration and during measurement.

5.2.5 A rod-supported meter shall be rigidly attached to the rod so that it is aligned parallel to the direction of travel. A cable-suspended meter shall be aligned with the direction of travel at the start of each run.

5.2.6 If the meter is of the type which is capable of swivelling in a vertical plane, its balance must be checked and, if necessary, adjusted before calibration tests are started.

5.2.7 Care shall be taken to ensure that the carriage vibrations (especially noticeable at lower speeds) and the rod vibrations (especially noticeable at higher speeds) are low enough not to influence the speed of revolution of the current-meter.

5.3 Performance of calibration

5.3.1 *Minimum response speed*

The minimum response speed is determined by gradually increasing the carriage velocity from zero until the rotating element revolves at a constant angular velocity.

5.3.2 *Number of calibration points*

Measurements shall be carried out from the minimum response speed at a sufficient number of towing velocities to enable the calibration of the current-meter to be defined accurately. It will generally be necessary to carry out tests at closer velocity intervals at the lower end of the range because the largest errors expressed as percentages usually occur in this range. For example 0,10 m/s intervals should be provided at the lower end of the range, 0,25 m/s intervals in the middle of the range and 0,5 m/s at the upper end of the range.

In accordance with current practice in a number of calibration stations, the total number of measuring points would be about :

10 to 12 for calibration up to 2 m/s

12 to 16 for calibration up to 5 m/s

16 to 20 for calibration up to 8 m/s

5.3.3 *Stilling time*

The water in the tank shall be relatively still before each test run and the waiting period shall be chosen so that residual velocities are negligible compared with the following test velocity. The time needed for the water to still depends on the dimensions of the tank, the use of damping devices, the previous test velocity, the size and shape of the meters and of the suspension equipment immersed in the water.

The following mean values may be given for guidance :

Velocity	Stilling time
m/s	min
0,5	10
2	15
5	25
8	30

5.4 Evaluation and presentation of results

5.4.1 *Determination of translation and rotation speeds*

If an electronic counter as described in 4.3.2 b) is used, the velocity v of the carriage and the rotation rate n of the current-meter can be calculated by dividing the distance and the number of revolutions by the time.

If a graph recording as described in 4.3.2 a) is used, the evaluation of v and n can be made in two ways :

a) lengths corresponding to a certain number of pulses relating to the current-meter, to the distance and time are measured along the recording strip, in millimetres as shown in figure 1.

If t is the number of seconds represented on the chart by a trace of length l_1, if the distance l between an integral number of distance markers at the side of the tank is represented by a trace of length l_2 and if an integral number of revolutions r is represented by a trace of length l_3, the average velocity of the carriage, v (m/s), and the average rate of revolution of the rotor, n (rev/s), can be calculated from the following formulae :

$$v = \frac{l \times l_1}{t \times l_2} \text{ (m/s)}$$

$$n = \frac{r \times l_1}{t \times l_3} \text{ (rev/s)}$$

b) the beginning and the end of the recording segments corresponding to a given number of pulses relating to the current-meter on the one hand and to the distance on the other hand are projected onto the time-recording line as shown in figure 2. The interpolation between two time-signals allows the exact duration corresponding to the number of rotor turns and to the distance chosen to be determined. This method is particularly suitable with long recording-strips.

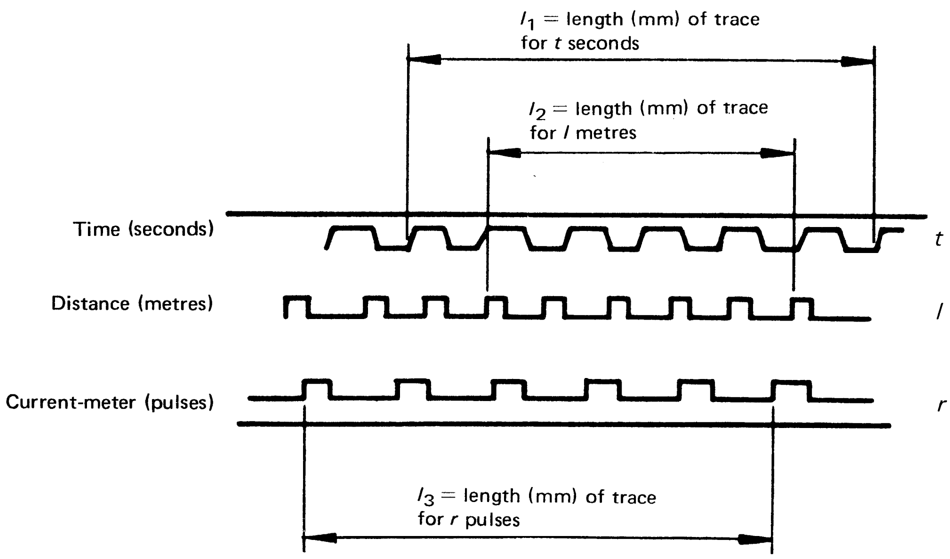

FIGURE 1

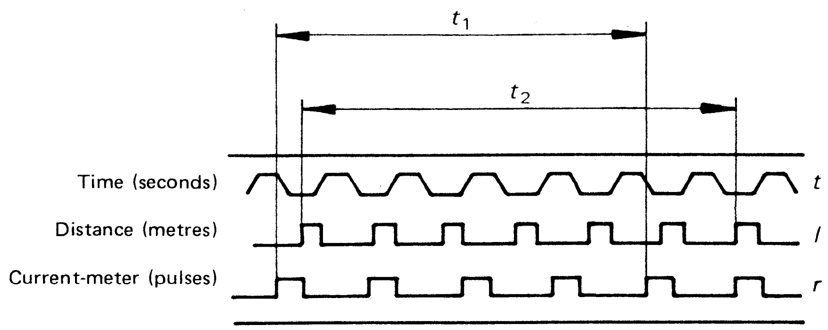

FIGURE 2

If t_1 is the time (number of complete intervals and fractional intervals of time multiplied by the duration of one interval) corresponding to N revolutions of the current-meter rotor, and if t_2 is the time (calculated in the same way) corresponding to a travel of length l, we obtain :

— average rate of revolution of current meter :

$$n = \frac{N}{t_1} \text{ (rev/s)}$$

— average velocity of carriage :

$$v = \frac{l}{t_2} \text{ (m/s)}$$

5.4.2 *Calibration diagrams* (Figure 3)

The calibration points are normally entered in a graphic system with the velocity v as the ordinate and the rate of rotation of the rotor n as the abscissa. In order to raise the accuracy of the graphic entries to the highest possible level without having to choose too large a scale, a theoretical rotor pitch is selected which lies close to the calibration curve and only the deviations $\Delta v = v - kn$ from this auxiliary straight line are entered on the large scale. The curve of Δv as a function of n can be replaced with adequate accuracy by the straight lines A, B and C whose equations are easy to calculate.

5.4.3 *Calibration equations*

Apart from the above diagram, the calibration form shall indicate the equations of the straight lines with which the calibration curve roughly coincides, specifying for each value of n the interval to which it is applicable.

These equations are generally given in the following form :

$$v = a + bn$$

where

v is the velocity, in metres per second;

n is the revolution of the rotor per second;

a and b are constants determined for each equation in figure 3.

The equations can also be given in the form :

$$v = a + b\frac{N}{t}$$

when it is convenient to show the time t corresponding to N rotor turns.

5.4.4 *Calibration tables*

Computer programmes can be written into which are fed constants of the calibration equations and their limits of application. The programmes can be arranged to produce tables in forms suitable to the gauging techniques used. The velocity can be given for every 0,01 rev/s or for integral numbers of revolutions in a predetermined time-interval or corresponding to a predetermined number of revolutions.

Calibration tables can also be prepared by a computer directly from the experimental values of v and n. This method is only justifiable if the form of the relation between v and n is well established or if the assumption of fixed limits of application of each is justified.

The advantage gained by using a computer may be lost, for example if a spurious experimental value of v or n for one test, which would normally be detected during the derivation of equations and which would be repeated or rejected, is passed to the computer unnoticed. Such spurious values may be identified and eliminated by inserting in the computer programme the limiting values for the deviations of individual points from the rating curve.

5.4.5 *Calibration documents*

In addition to the elements mentioned in 5.4.2, 5.4.3 and 5.4.4, the calibration form shall include the following information :

a) the name and address of the rating station;

b) the date of calibration;

c) the calibration number;

d) the make and type of current-meter;

e) the serial number of the meter and of each rotor;

f) details of the suspension used;

g) the position of the current-meter in the cross-section of the tank;

h) a statement of the minimum speed of response;

i) the limits of calibration;

j) any remarks, for example, statements of any modifications made to the meter such as the fitting of spare parts;

k) the water temperature during calibration;

l) the viscosity of the bearing oil;

m) a statement concerning the accuracy of the rating equation, which shall include an assessment of the accuracy of the basic calibration technique;

n) the signature of a responsible member of the staff at the calibration station.

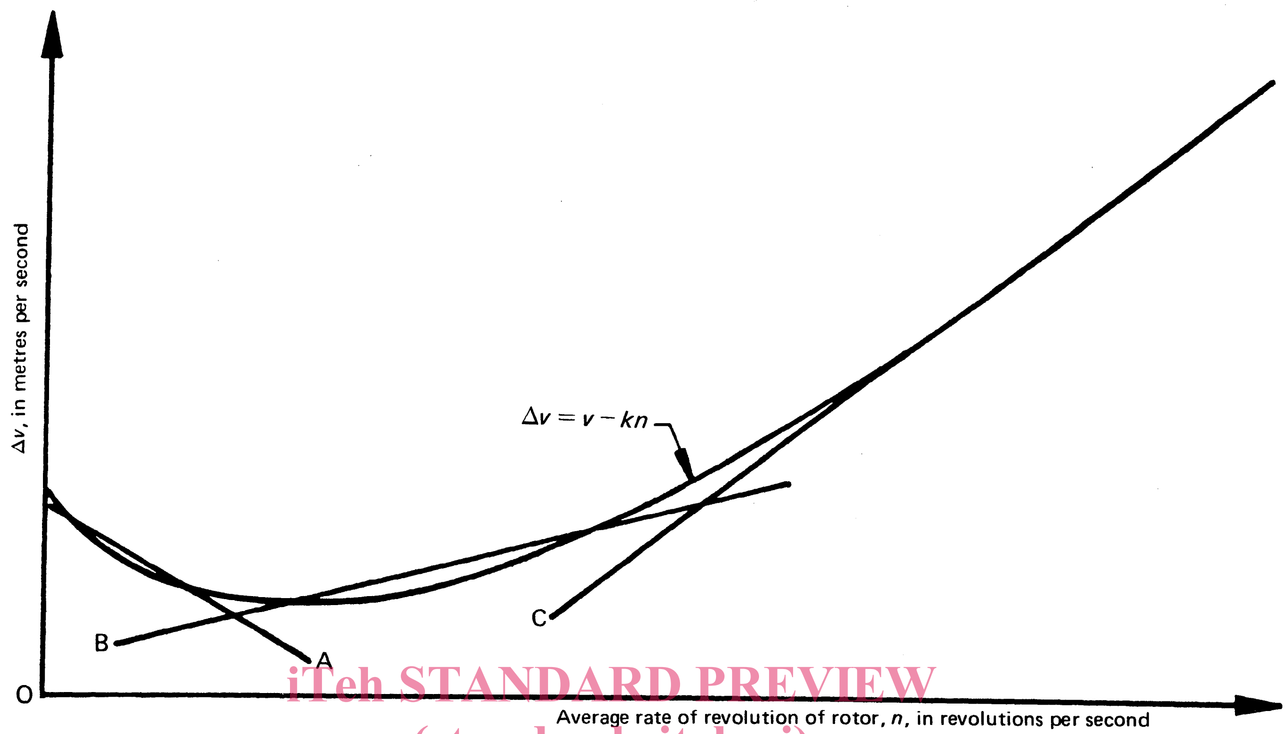

FIGURE 3 A

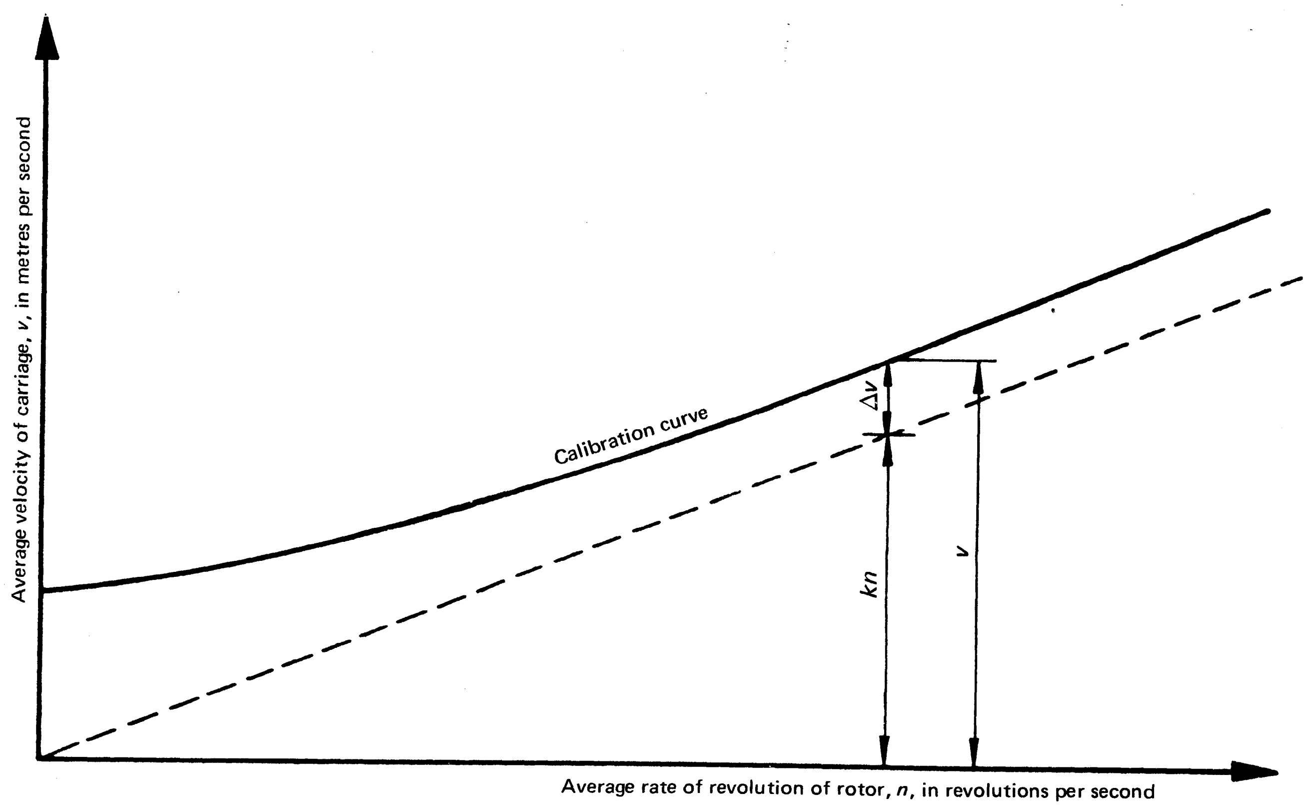

FIGURE 3 B