9.4 Flow from horizontal pipes

9.4.1 Description

Flow from a horizontal pipe can be estimated by using either the California pipe method* developed by Van Leer (1922) or the trajectory method developed at Purdue University by Greeve (1928). The California pipe method applies only to pipes flowing less than half full, whereas the more general trajectory method applies equally well to both partially and completely filled pipes. The California pipe method consists of measuring the end depth at the pipe outlet and is valid if $y_e = D_p - Y \leqslant 0.56\ D_p$ (see Figure 9.9).

The Purdue trajectory method consists of measuring two coordinates of the upper surface of the jet as shown in Figure 9.10. If the pipe is flowing with a depth of less

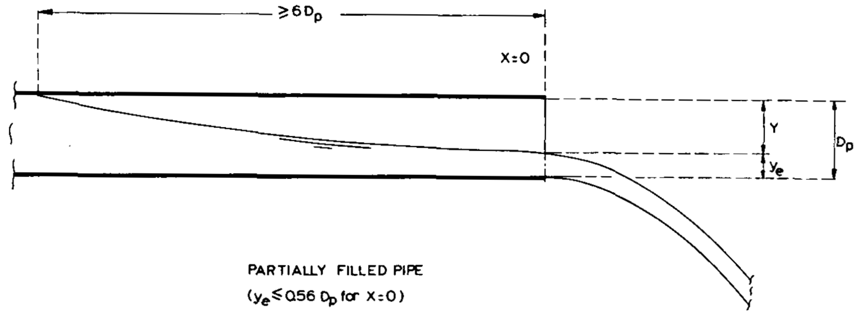


Figure 9.9 Dimension sketch partially filled pipe

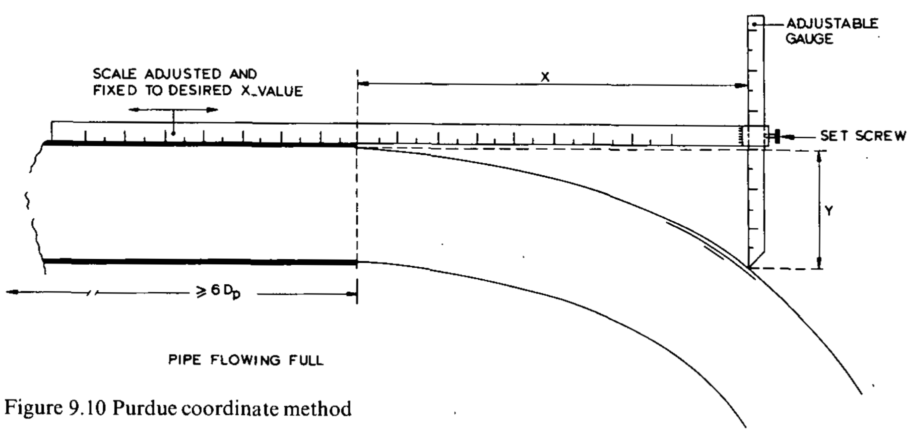


Figure 9.10 Purdue coordinate method

* The California pipe method is identical to the brink depth method for circular canals.

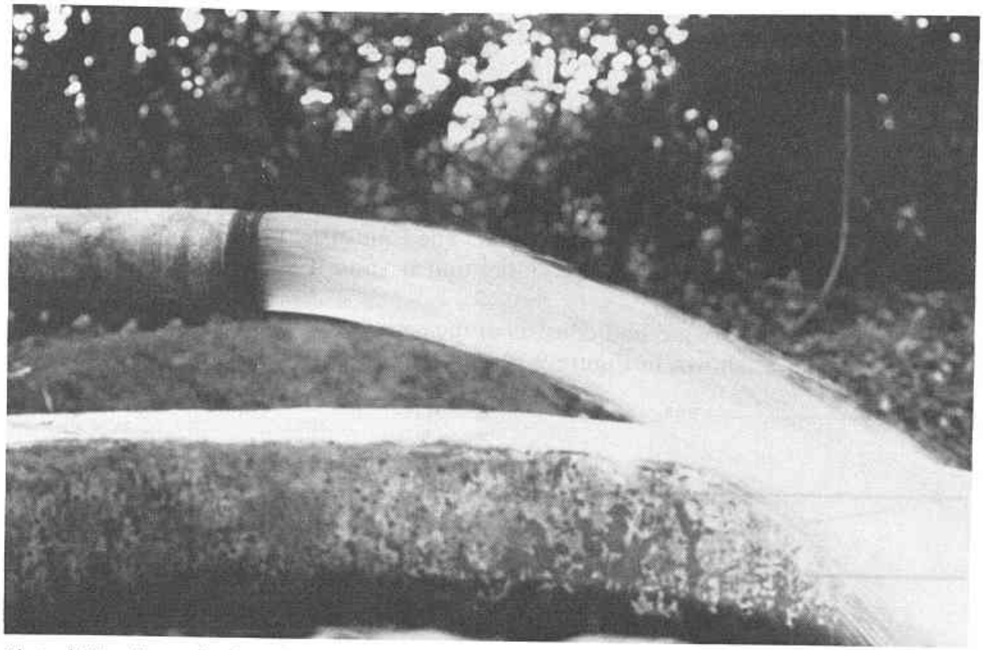


Photo 3 Flow from a horizontal pipe

than 0.56 D_p at the outlet, the vertical distance from the upper inside surface of the pipe to the surface of the flowing water, Y, can be measured at the outlet of the pipe where X = 0. For higher discharges, Y can be measured at horizontal distances X from the pipe outlet of 0.15, 0.305 or 0.46 metre.

9.4.2 Evaluation of discharge

California pipe method (X = 0)

The California pipe method is based on the unique relationship between the depth, y_e, of flow at the pipe outlet and the pipe discharge, Q. A dimensionless plot of this relationship is shown in Figure 9.11.

Provided that $y_e \leq 0.56\ D_p$ the pipe discharge can be calculated from this figure for any diameter D_p. Discharge values in $m^3/s \times 10^{-3}$ for 2- to 6-inch diameter (0.05 to 0.15 m) standard pipes are shown in Figure 9.13A as a function of $Y = D_p - y_e$.

The user will experience difficulty in making the measurement Y exactly at the brink. Since the upper nappe surface is curved, any small error in the location of the gauge will cause large errors in Y. Actually, the only method by which Y can be measured accurately is by installing a point gauge at the center line of the pipe exactly above the brink (see also Figure 9.10). Since the upper nappe surface at the brink is instable, the accuracy of the Y-value can be greatly improved by repeating its measurement and taking the average value.

The error in the discharge value as derived from Figure 9.11 for partially filled pipes may be expected to be less than 3 per cent. The method by which the various errors have to be combined with other sources of error is shown in Annex 2.

Purdue trajectory method

The shape of the jet from a horizontal pipe can be interpreted by the principle of a projectile (Figure 9.12). According to this principle, it is assumed that the horizontal velocity component of the flow is constant and that the only force acting on the jet is gravity. In time t, a particle on the upper surface of the jet will travel a horizontal distance X from the outlet of the pipe equal to

$$X = v_0 t \tag{9-9}$$

where v_0 is the velocity at the point where $X = 0$. In the same time t, the particle will fall a vertical distance Y equal to

$$Y = \tfrac{1}{2} g t^2 \tag{9-10}$$

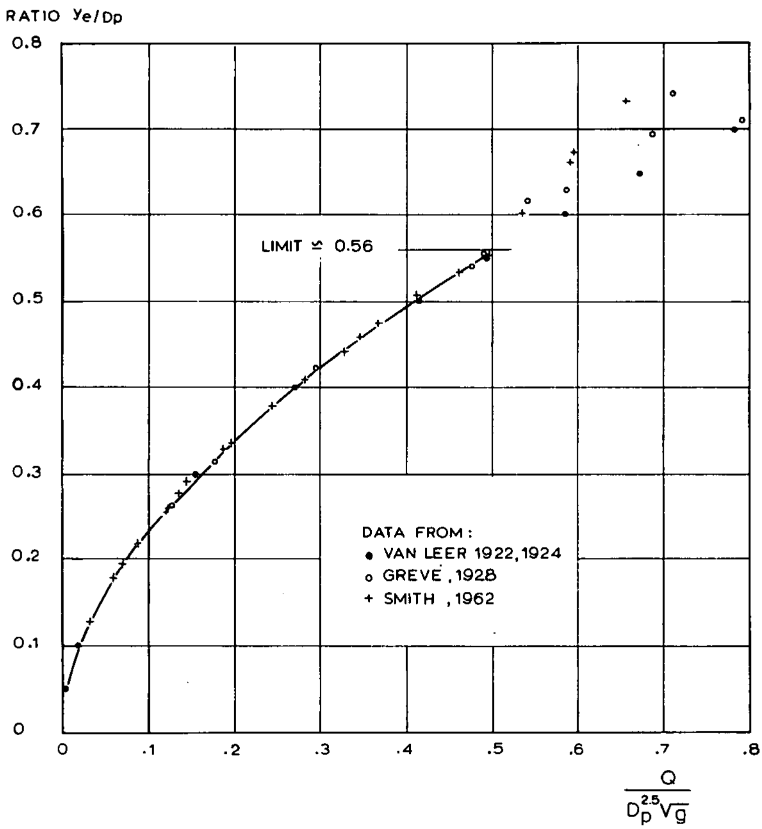


Figure 9.11 Flow from horizontal pipes by California pipe method or brink depth method

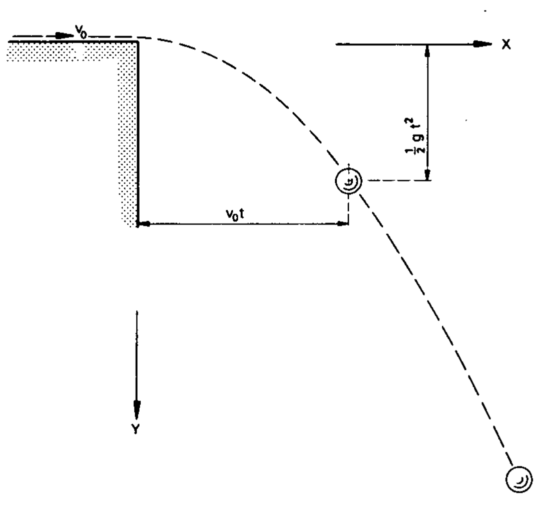


Figure 9.12 Derivation of jet profile by the principle of projectile

Eliminating t from the above two equations and multiplying each term by the inside pipe area $\frac{1}{4}\pi D_p^2$ and a discharge coefficient ($C_d \simeq 1.10$) leads to

$$Q = C_d \frac{1}{4} \pi D_p^2 \sqrt{g \frac{X^2}{2Y}} \qquad (9\text{-}11)$$

Discharge values in $m^3/s \times 10^{-3}$ (l/s) for 2- to 6-inch diameter (0.05 to 0.15 m) standard pipes are shown in graphs in Figure 9.13B to D.

Due to the difficulty of making the vertical measurement Y in the Purdue trajectory method ($y_e > 0.56\ D_p$ or pipe flowing full), the error in flow measurement found

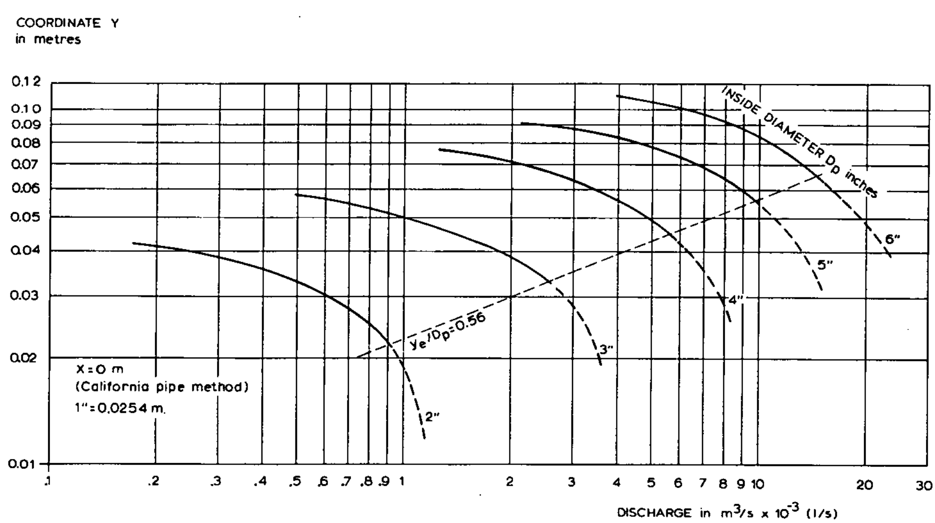


Figure 9.13A Flow from horizontal pipes by either Purdue trajectory method or by California pipe method

by using Figure 9.13 may be expected to be about 10 to 15 per cent. If this error is not to be exceeded, the pipe should be truly horizontal and straight for at least 6 times D_p from the outlet. If it slopes downward, the discharge taken from Figure 9.13 will be too low. If it slopes upward, the discharge will be too high.

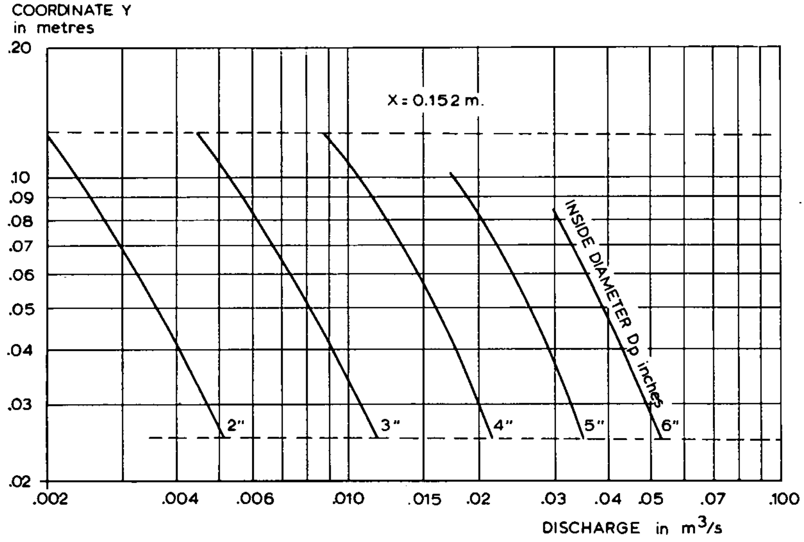


Figure 9.13B (cont.)

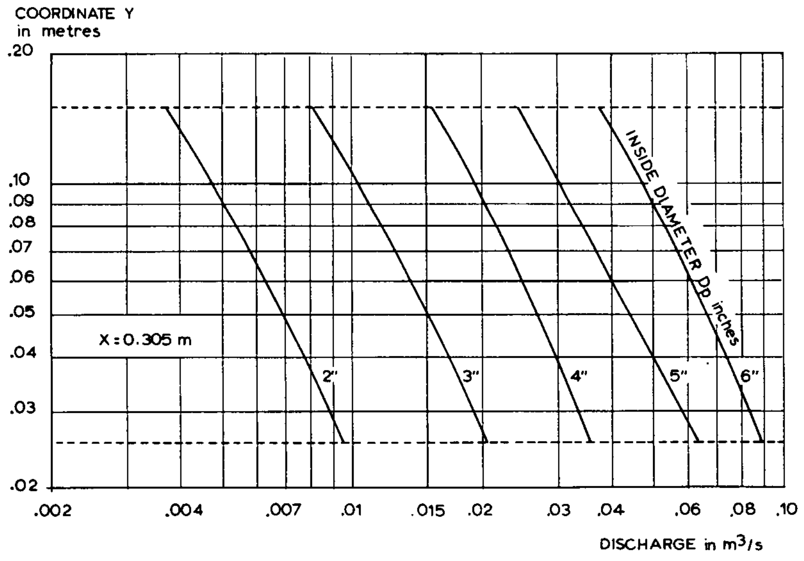


Figure 9.13C (cont.)

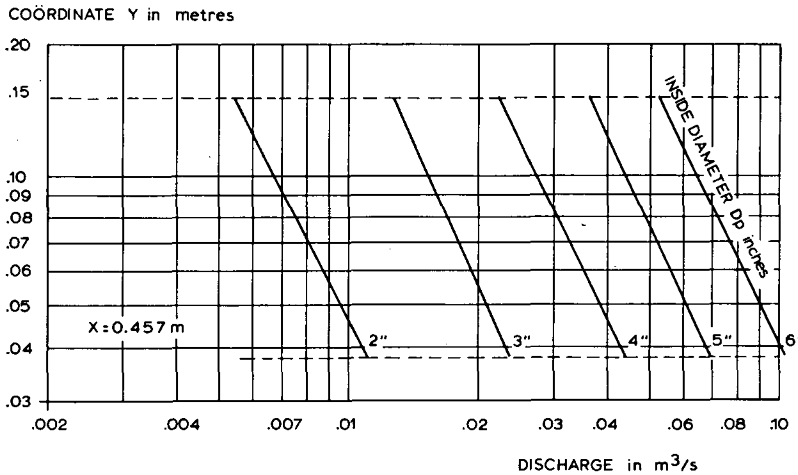


Figure 9.13D (cont.)

9.4.3 Limits of application

The limits of application that enable a reasonably accurate estimate of the discharge from a horizontal pipe are:

a. Pipes should have clear cut edges and a constant diameter over at least a length of 6 D_p from the outlet;
b. Pipes should be straight and truly horizontal over at least a length of 6 D_p from the outlet;
c. Pipes must discharge freely into the air.

9.5 Brink depth method for rectangular canals

9.5.1 Description

When the bottom of a low gradient canal drops suddenly, a free overfall is formed which, since flow changes to supercritical, may be used as a discharge measurement device. In principle, any canal cross section can be used for flow measurement provided that the free overfall is calibrated.

Sufficiently accurate experimental data, however, are only available for rectangular and circular cross sections. Since the circular section was treated in Section 9.4, we will confine our remarks here to the brink depth method for rectangular canals.

The simplest case of a free overfall is that of a rectangular canal with sidewalls continuing downstream on either side of the free nappe over a distance of at least 0.3 H_{1max}, so that at the brink the atmosphere has access only to the upper and lower side of the nappe. This is a two-dimensional case with a 'confined nappe', and is the only form of the problem for which serious attempts have been made to find a solution.

Some experiments, however, have been made on a free overfall with 'unconfined nappe', i.e. where the side walls end at the sudden drop.

In the situation shown in Figure 9.14, flow takes place over a confined drop which is sharp enough (usually 90 degrees) to guarantee complete separation of the nappe. The bottom of the tailwater channel should be sufficiently remote so as not to influence the streamline curvature at the brink section. To ensure that this does not happen, the drop distance should be greater than 0.6 y_c.

The user will experience difficulty in making the measurement y_e exactly at the brink. Since the upper nappe surface is curved, any small error in the location of the gauge will cause large errors in y_e. Actually, the only method by which y_e can be measured accurately is by installing a point gauge in the middle of the canal exactly above the brink. Since a point gauge is vulnerable to damage, however, a staff gauge, with its face flush with the side wall, will be found more practical. The location of the brink should be marked on the gauge face to enable y_e readings to be made. The brink depth as measured at the side wall will be higher than that in the middle of the canal, because of side wall effects. To limit the effect of roughness on the brink depth as measured with a staff gauge, the side walls as well as the bottom of the canal should be smooth. If the brink depth is measured with a point gauge, no significant influence of roughness is found, as is illustrated for three values of the equivalent sand roughness, k, in Figure 9.15.

9.5.2 Evaluation of discharge

If we assume that the streamlines in the rectangular canal are straight and parallel, we may, according to Equation 1-26, write the specific energy in the canal as

$$H_o = y + \alpha \frac{q^2}{2gy^2} \tag{9-12}$$

Differentiation of H_o to y, while q remains constant leads to

$$\frac{dH_o}{dy} = 1 - \alpha \frac{q^2}{gy^3} \tag{9-13}$$

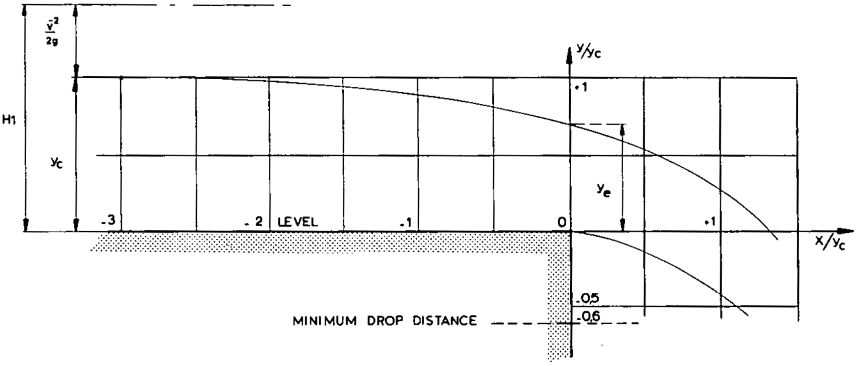


Figure 9.14 Flow profile at the free overfall

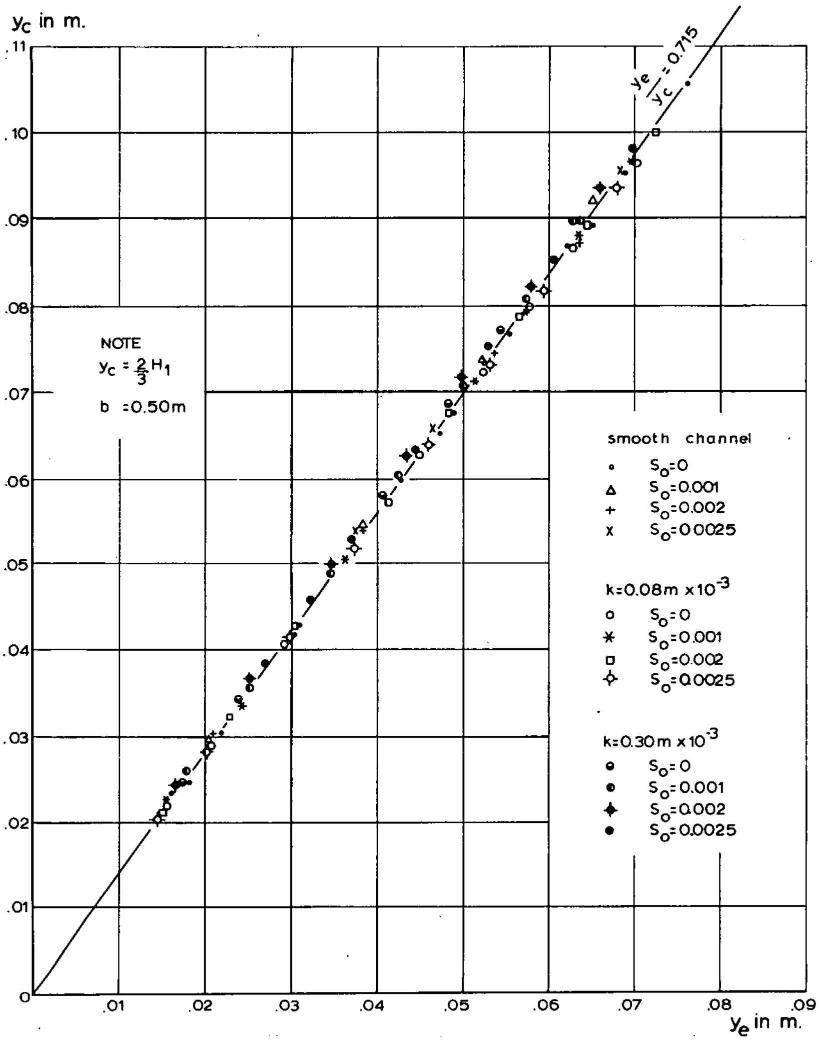


Figure 9.15 Relation between y_e and y_c (after Kraijenhoff van de Leur and Dommerholt 1972)

If the depth of flow is critical ($y = y_c$), dH_o/dy equals zero, and we may write

$$y_c = \sqrt[3]{\frac{\alpha q^2}{g}} \tag{9-14}$$

Assuming $\alpha = 1$ and substituting $Q = b_c q$ leads to

$$Q = b_c \sqrt{g}\, y_c^{3/2} \tag{9-15}$$

The experiments of Rouse (1936), and further experiments by various authors, showed that for a confined nappe the brink section has a flow depth equal to

$$y_e = 0.715\, y_c \qquad (9\text{-}16)$$

resulting in the discharge equation

$$Q = b_c\sqrt{g}\left(\frac{y_e}{0.715}\right)^{3/2} = 5.18\, b_c y_e^{3/2} \qquad (9\text{-}17)$$

As shown in Figure 9.15, slight variations in the roughness of the canal boundaries and in the canal bottom slope are of little significance on the ratio y_e/y_c. If the free overfall has an unconfined nappe, however, the ratio y_e/y_c is somewhat less than in the two-dimensional case, being equal to 0.705.

For a free overfall which is constructed and maintained with reasonable care and skill, the coefficients 0.715 and 0.705 can be expected to have an error of the order of 2% and 3% respectively, provided y_e is measured in the middle of the channel. If y_e is measured at the side walls an additional error in y_e occurs due to boundary roughness (see Section 9.4.2 for other possible errors). The method by which these errors are to be combined with other sources of error is shown in Annex 2.

9.5.3 Limits of application

The limits of application of the brink depth method for rectangular canals are:

a. Perpendicular to the flow, the brink should be truly horizontal and the side walls of the rectangular approach canal should be parallel from end to end;
b. To obtain a uniform velocity distribution, the length of the approach channel should not be less than 12 y_e;
c. The longitudinal slope of this approach channel should preferably be zero but not more than $s = 0.0025$;
d. The practical lower limit of y_e is related to the magnitude of the influence of fluid properties and the accuracy with which y_e can be measured. The recommended lower limit is 0.03 m;
e. The y_e-value should be measured in the middle of the canal, preferably by means of a point gauge;
f. The width of the canal should not be less than 3 $y_{e\,max}$ nor less than 0.30 m;
g. To obtain free flow, the drop height should not be less than 0.6 $y_{c\,max}$.

9.6 Dethridge meter

9.6.1 Description

The Dethridge meter is a rather commonly used device for measuring the volume of irrigation water supplied to farms from main and lateral canals in Australia. The meter was designed by J.S. Dethridge of the State Rivers and Water Supply Commission, Victoria, in 1910. This Commission provided the present information on the standard device, of which today about 40000 are in operation in irrigation areas throughout Australia. The meter consists of an undershot water wheel turned by the discharging water passing through its emplacement, which is a short concrete outlet specially formed to provide only the minimum practicable clearance of the lower half of the wheel at its sides and round the lowest 70 degrees of its circumference. Two standard sizes of the meter are used: the 1.524 m (5 ft) diameter 'large' meter which is suitable for discharges from 0.040 m^3/s to 0.140 m^3/s, and the 'small', 1.219 m (4 ft) diameter meter for discharges from 0.015 m^3/s to 0.070 m^3/s. The main dimensions of both meters, which are similar in general form, are shown in Figure 9.16.

The wheel is made up of a cylinder of 2 mm thick mild steel sheet, bearing eight external vanes of the same material, each welded against the surface of the cylinder on a widely distended 'V', with the root of the 'V' leading in the direction of the wheel's rotation. At the root of each vane is a small air vent so that compartments between the vanes can fill completely with water while being submerged by rotation of the wheel. The outer corners of the vanes are chamferred.

The internal bracing used to consist of three crossed pairs of timber spokes ($\pm$ 0.10 $\times$ 0.05 m) placed at the middle and both ends of the cylinder. Today they have given way to ∅ 16 mm steel rods in parallel pairs, welded on either side of the 25 mm internal diameter pipe-axle of the wheel (see Figure 9.17).

The concrete structure in which the wheel has been placed has upstream of the wheel a simple rectangular section, with level floor in the vicinity of the wheel. At the wheel the walls remain plane and parallel but the floor is intended to accomodate an arc of about 70 degrees of the wheel's circumference. Immediately downstream of the wheel the walls are flared outward and the floor is sloped up to a lip of sufficient

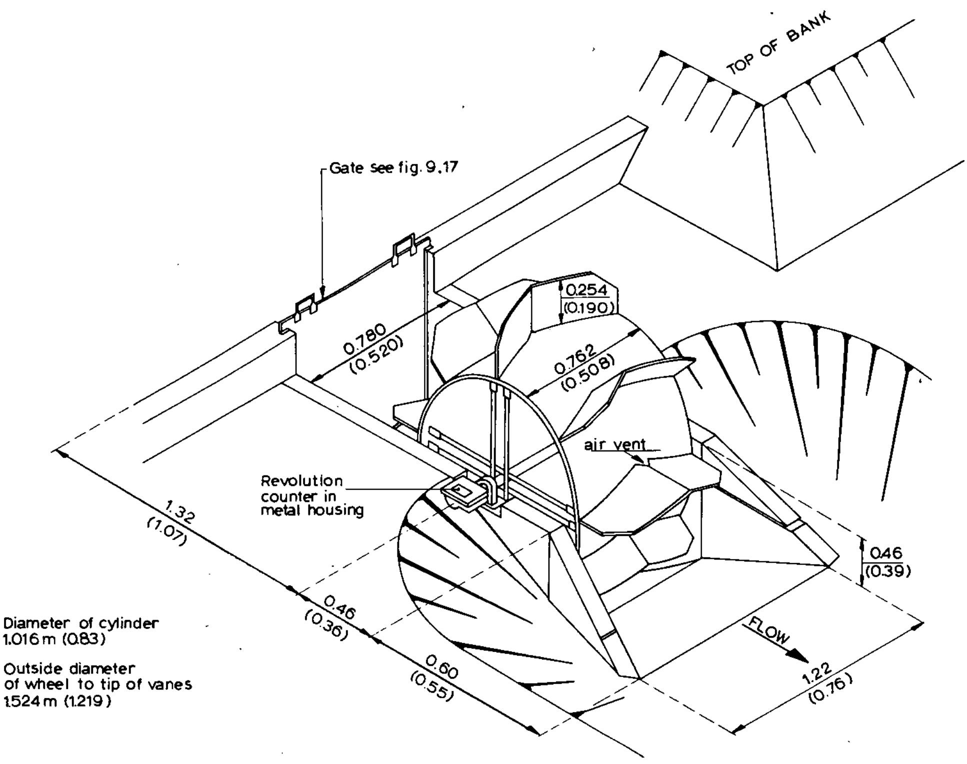


Figure 9.16 Dethridge meter

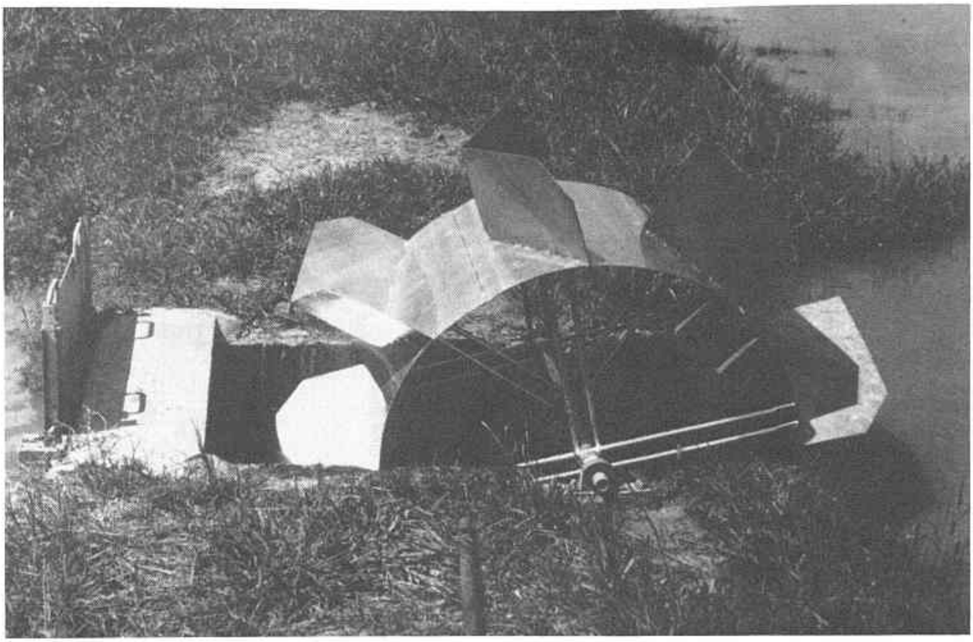


Photo 4 One of the vanes was painted red to check the revolutions counter and required gate openings

height (see Figure 9.17) to ensure submergence of the passage swept by the vanes under the wheel.

Most Dethridge meters are equipped with cheap wooden bearing blocks, usually seasoned Red Gum or other durable hardwood, dressed to dimensions shown in Figure 9.18. A disadvantage of these blocks is that they wear and are not always replaced in time so that the wheel may scrape on the concrete. A variety of more permanent type bearings was tested under the supervision of the above mentioned Commission and it appeared that the best installation would be a non-corrosive ball bearing which does not require any maintenance. Details of the type adapted as standard by the State Rivers and Water Supply Commission, Victoria, are shown in Figure 9.18.

The operational life of revolution counters mounted to the wheel axle is quite irregular due to their fragile construction, the wire connection to the axle, and the jerky motion of the wheel. None of the counters in use can be considered satisfactory but (since 1966) tests showed that a pendulum actuated revolution counter fitted in a sealed casing inside the drum of the wheel may be satisfactory (see Figure 9.17 and Photo 4).

It is important that the Dethridge meter be installed at the correct level in relation to full supply level in the undivided irrigation canal, so as to make the best use of the generally limited head available. The standard setting of the large meter is to have the floor of the concrete structure, at entry, 0.38 m below design supply level to the meter, being full supply level at the next check downstream of the meter. For the small meter this depth is 0.30 m. If excess head over the meter is available the depth may be increased up to 0.90 m, with the necessity of course, of correspondingly increasing the height of the sluice gate and head wall (see also Figure 9.19).

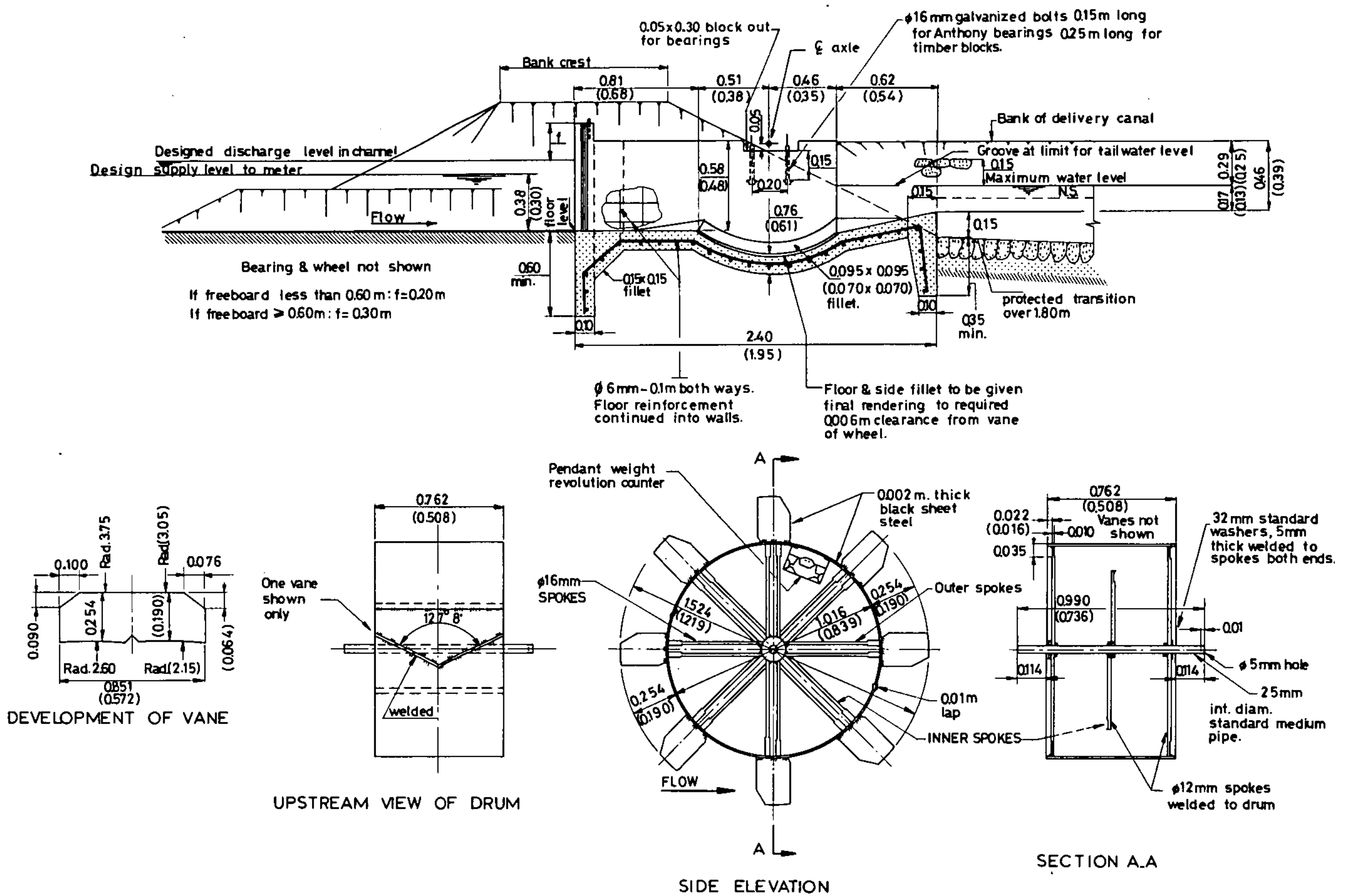
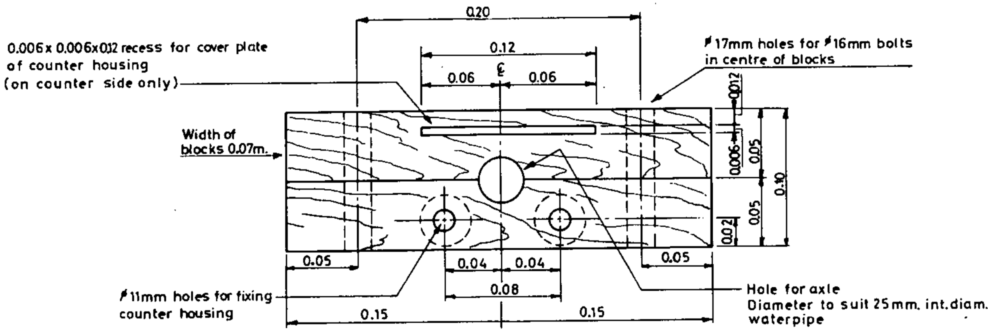
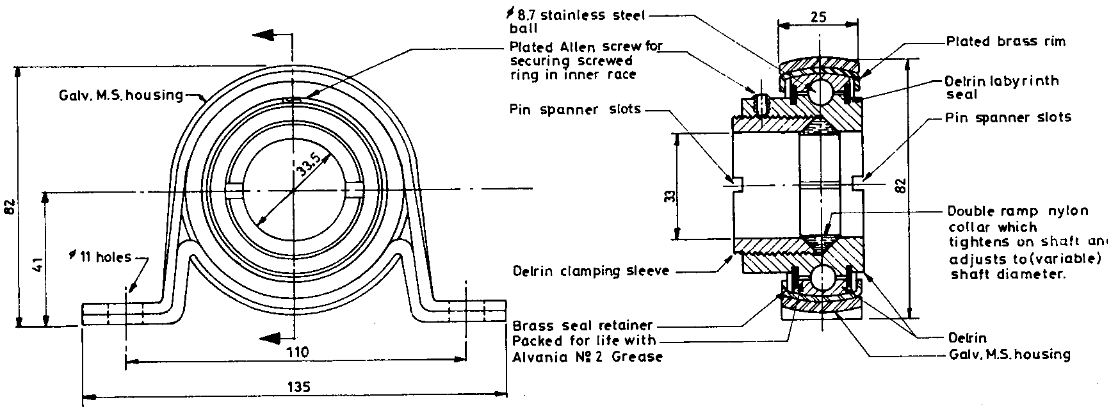


Figure 9.17 Dethridge meter dimensions (small meter dimensions shown between brackets, if different from large meter)



TIMBER AXLE BLOCK (dimensions in mm)



ANTHONY BEARING DETAILS (dimensions in mm)

Figure 9.18 Alternative wheel bearing arrangements

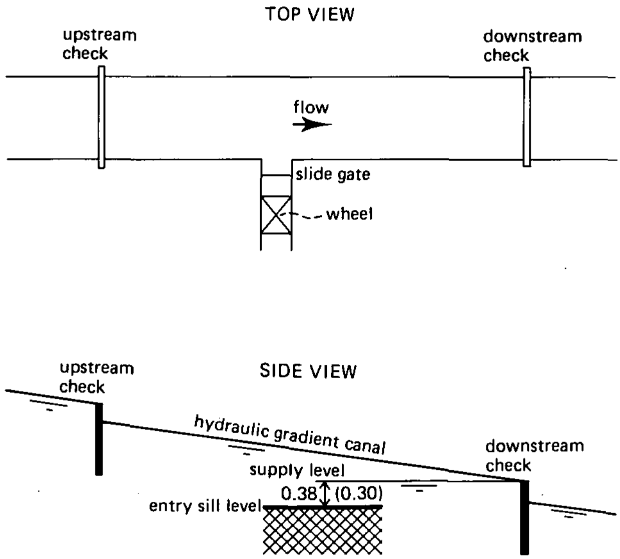


Figure 9.19 Setting of meter in relation to supply canal

Supply level should not exceed 0.90 m above the meter sill at entry to avoid the jet below the sluice gate from driving the wheel. This 'Pelton' wheel effect reduces the volume of water supplied per revolution. Discharge regulations are usually effectuated by adjusting a sluice gate immediately upstream of the wheel. Provided that supply level does not exceed 0.90 m above the meter sill at entry, the gate may be hand-operated. Gates may be locked in place as shown in Figure 9.20.

The main advantage of the Dethridge meter is that it registers a volume of supplied water; it is simple and robust in construction, operates with small headloss, and it will pass ordinary floating debris without damage to or stoppage of the wheel.

9.6.2 Evaluation of flow quantity

If there were no clearances between the wheel and the concrete structure, the meter would give an exact measurement of the water passing through it, as each revolution of the wheel would pass an invariable quantity. With the provision for the necessary clearances, however, leakage occurs through the clearance space at a rate dependent not only on the rotation of the wheel, but dependent also on other factors such as the difference in water levels immediately upstream and downstream of the wheel, and the depth of submergence. For free flow over the end sill, rating curves for both wheels are given in Figure 9.21.

As shown, the quantity of water passed per revolution of the wheel varies to some extent with the running speed of the wheel. For the conversion of revolutions to water quantity supplied, constant ratios are assumed, being 0.82 m^3/rev for the large wheel and 0.35 m³/rev for the small wheel. Leakage around the wheel increases, and thus more water is supplied than registered, if there are large bottom clearances, large side clearances, high tailwater levels, and if the wheel is rotating at less than about three revolutions per minute.

The positive error resulting from excessive side clearances is smaller than that from bottom clearances. Increase in supply level has only a small effect on the rating.

A Dethridge meter which has been constructed and installed with reasonable care

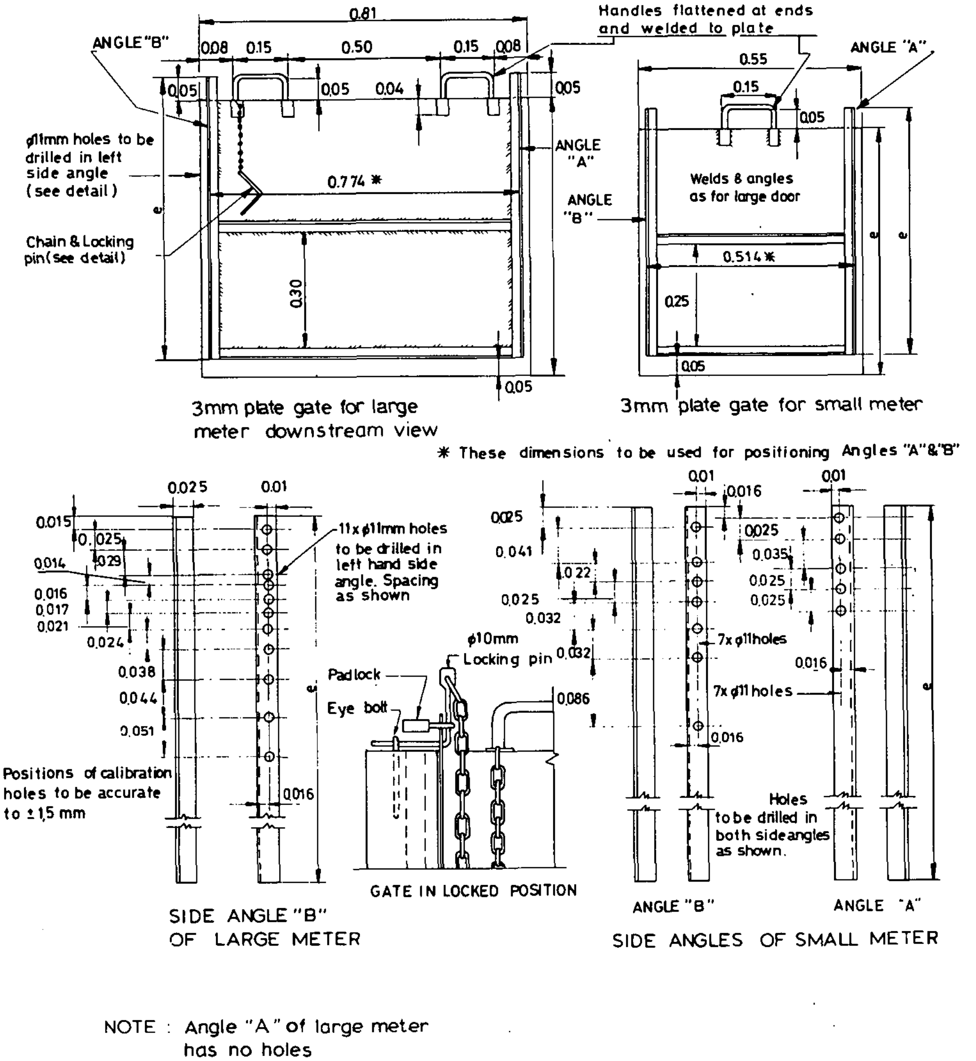


Figure 9.20 Gate dimensions

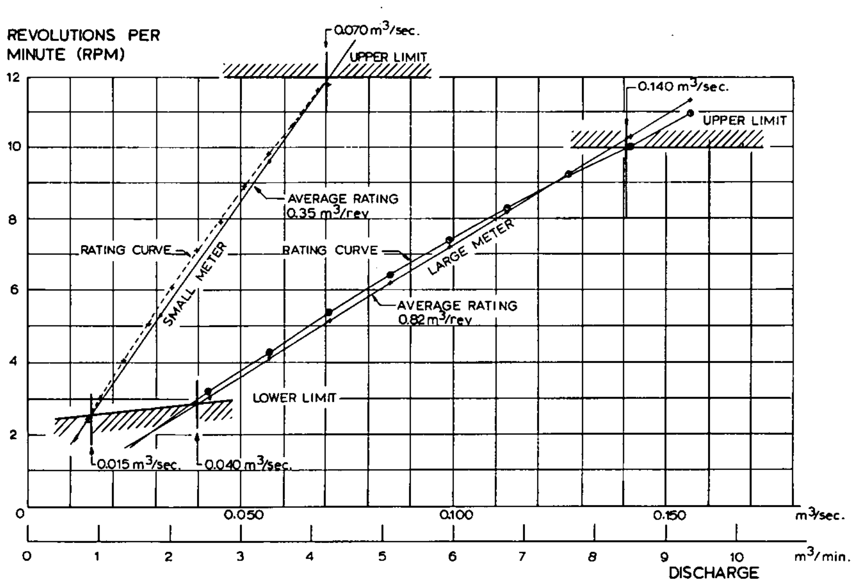


Figure 9.21 Rating curves for free flow over end sill for large and small meter

and skill may be expected to measure the total quantity of water passsing through it with an error of less than 5%. It is obvious that this quite reasonable degree of accuracy for the measurement of irrigation deliveries can only be achieved if adequate and regular maintenance is provided.

9.6.3 Regulation of discharge

As mentioned in Section 9.6.1, the discharge through the Dethridge meter is regulated by a sluice gate. Provided that flow over the end sill is modular, meter discharge can be set by adjusting the gate opening according to Figure 9.22.

If the meter is submerged, the most convenient method of setting a flow rate is to adjust the sliding gate so that the wheel makes the required revolutions per minute to pass this flow. Figure 9.21 may be used for this purpose, provided that tailwater levels remain less than 0.17 m over the end sill to avoid excessive leakage through the clearances of the large wheel. For the small wheel this value is 0.13 m. Approximate limits of tailwater level to obtain modular flow through the Dethridge meter are shown in Figure 9.23 for both meters.

9.6.4 Limits of application

The limits of application of the Dethridge meter are:

a. The practical lower limit for the supply level over the entry sill is 0.38 m for the large meter and 0.30 m for the small meter. The upper limit for this supply level is 0.90 m for both meters;

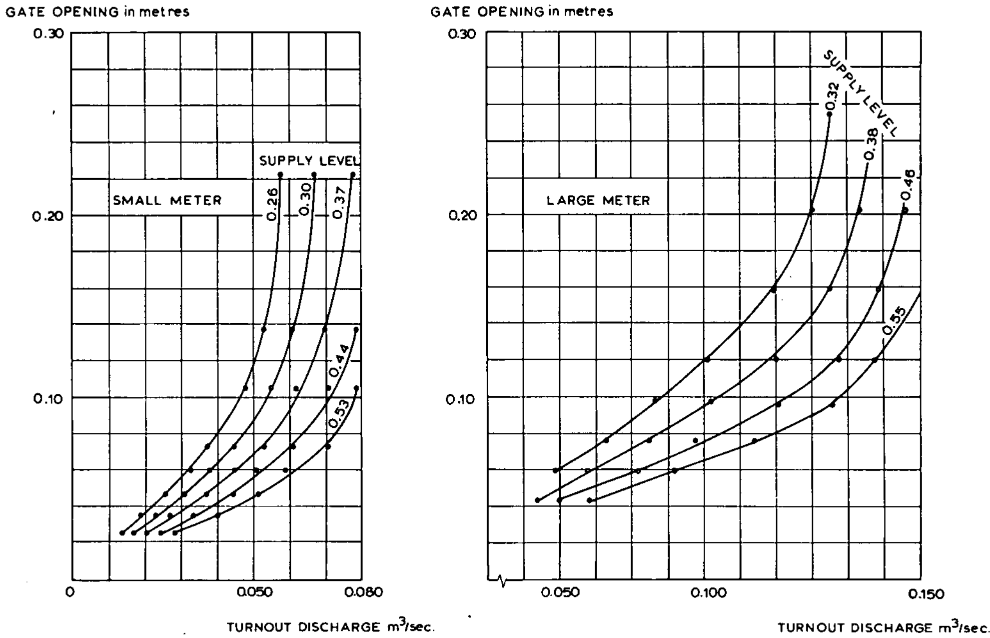


Figure 9.22 Gate calibration curves for Dethridge meters

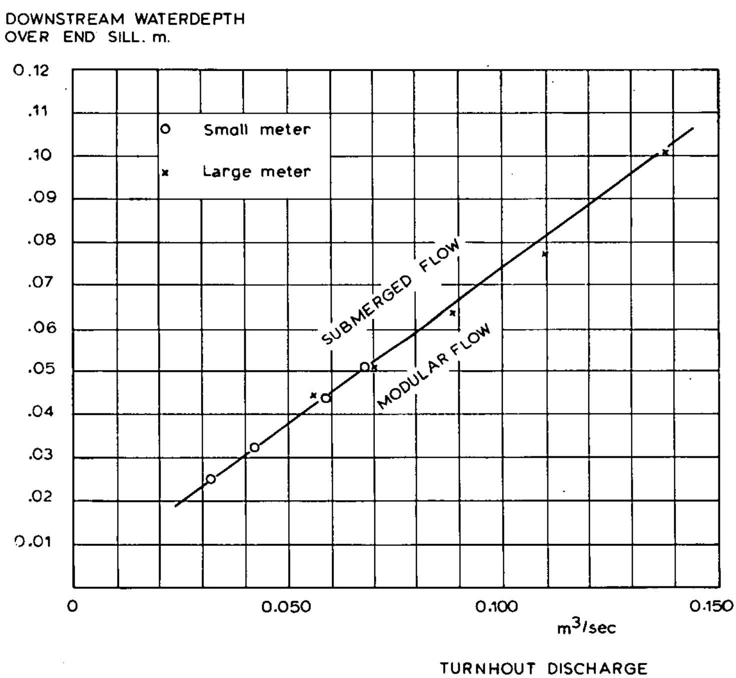


Figure 9.23 Approximate limits of tailwater for modular flow over downstream lip

b. Tailwater level should not be more than 0.17 m over the end sill of the large meter. This value is 0.13 m for the small meter;
c. The wheel should neither make less than about 3 r.p.m. nor more than about 10 to 12 r.p.m. Consequently, the discharge capacity ranges between 0.040 m^3/s and 0.140 m^3/s for the large meter and between 0.015 m^3/s and 0.070 m^3/s for the small meter (see also Figure 9.21);
d. Clearance between the floor and side fillets of the structure and the wheel should not exceed 0.006 m for both meters. Clearance between the side walls and the wheel should not exceed 0.009 m for the large meter and 0.006 m for the small meter.

9.7 Propeller meters

9.7.1 Description*

Propeller meters are commercial flow measuring devices used near the end of pipes or conduits flowing full, or as 'in-line' meters in pressurized pipe systems. The meters have been in use since about 1913 and are of many shapes, kinds, and sizes. The material presented in this section applies to all makes and models of meters, in general, and serves to provide a better understanding of propeller operation.

Propeller meters utilize a multibladed propeller (two to six blades) made of metal, plastic, or rubber, rotating in a vertical plane and geared to a totalizer in such a manner that a numerical counter can totalize the flow in cubic feet, cubic metres, or any other desired volumetric unit. A separate indicator can show the instantaneous discharge in any desired unit. The propellers are designed and calibrated for operation in pipes and closed conduits and should always be fully submerged. The propeller diameter is always a fraction of the pipe diameter, usually varying between 0.5 to 0.8 D_p. The

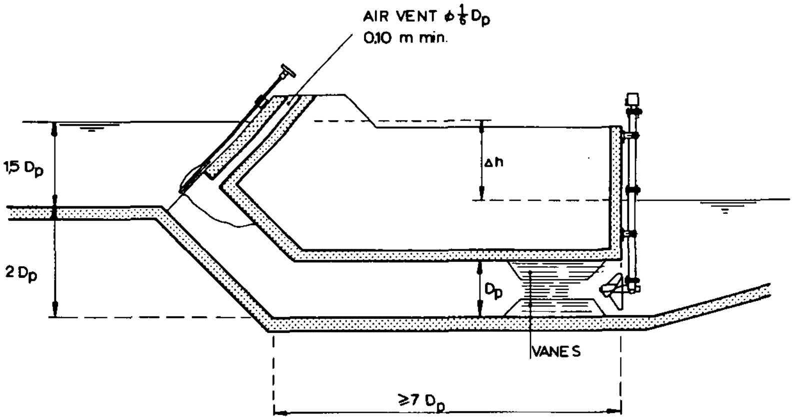


Figure 9.24 Typical propeller meter installation

* The information presented in this section is for the major part an abstract from an excellent review on propeller meters by Schuster and USBR (1970 and 1967)

measurement range of the meter is usually about 1 to 10; that is the ratio $\gamma = Q_{max}/Q_{min} \simeq 10$. The meter is ordinarily designed for use in water flowing at 0.15 to 5.0 m/s although inaccurate registration may occur for the lower velocities in the 0.15 to 0.45 m/s range. Meters are available for a range of pipe sizes from 0.05 to 1.82 m in diameter.

The principle involved in measuring discharges is not a displacement principle as in the Dethridge meter described earlier, but a simple counting of the revolutions of the propeller as the water passes it and causes it to rotate. Anything that changes the pattern of flow approaching the meter, or changes the frictional resistance of the propeller and drive gears and shafts, affects the accuracy of the meter registration.

9.7.2 Factors affecting propeller rotation

Spiral flow

Spiral flow caused by poor entrance conditions from the canal to the measuring culvert is a primary cause of discharge determination errors. Depending on the direction in which the propeller rotates, the meter will over or under register. Flow straightening vanes inserted in the pipe upstream from the propeller will help to eliminate errors resulting from this cause. Meter manufacturers usually specify that vanes be several pipe diameters in length and that they be located in a straight, horizontal piece of pipe just upstream from the propeller. The horizontal pipe length should not be less

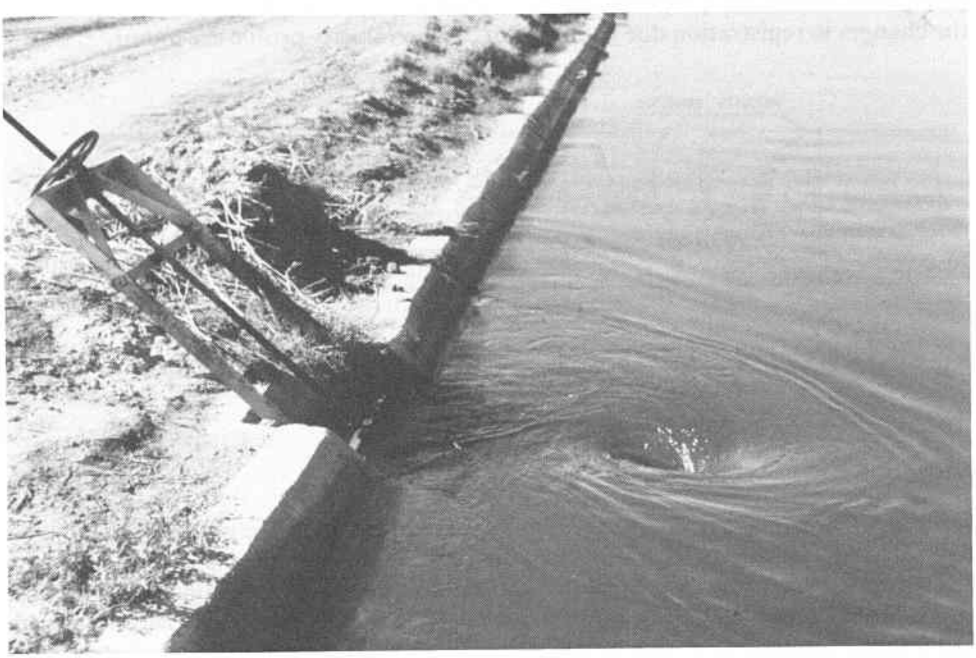


Photo 5 To avoid such a vortex the gate opening must be sufficiently deep below the upstream water level

than 7 D_p. Vanes are usually made in the shape of a plus sign to divide the pipe into equal quarters. Because the area taken up by the vanes near the centre of the pipe tends to reduce the velocity at the centre of the propeller such a vane type has a negative influence on the registered discharge (about 2%) and some manufacturers suggest using vanes that do not meet in the middle. One or two diameters of clear pipe, however, between the downstream end of the vanes and the propeller will nullify any adverse effects caused by either type of vane.

If straightening vanes are not used, a long length of straight horizontal pipe (30 or more diameters long) may be required to reduce registration errors.

Velocity profiles

Changes in velocity distribution, or velocity profile, also influence registration. If the distance between the intake and the propeller is only 7 or so diameters long, the flow does not have time to reach its normal velocity distribution, and a blunt, rather evenly distributed velocity pattern results as shown in Figure 9.25, Case A. On the other hand, if the conduit length is 20 to 30 diameters or longer, the typical fully developed velocity profile as shown in Figure 9.25, Case B, occurs.

Here, the velocity of flow near the centre of the pipe is high compared with the velocity near the walls. A meter whose propeller diameter is only one-half the pipe diameter would read 3 to 4 per cent higher than it would in the flat velocity profile. A larger propeller could therefore be expected to produce a more accurate meter because it is driven by more of the total flow in the line. Laboratory tests show this to be true. When the propeller diameter exceeds 75 per cent of the pipe diameter, the changes in registration due to variations of the velocity profile are minor.

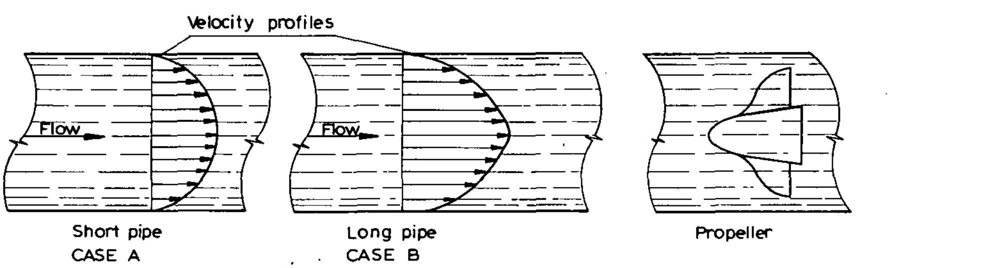


Figure 9.25 Velocity profiles (after Schuster 1970)

Propeller motion

Since the meter, in effect, counts the number of revolutions of the propeller to indicate the discharge, any factor that influences the rate of propeller turning affects the meter registration. Practically all propeller effects reduce the number of propeller revolution which would otherwise occur, and thus result in under-registration. Propeller shafts are usually designed to rotate in one or more bearings. The bearing is contained in a hub and is protected from direct contact with objects in the flow. However, water often can and does enter the bearing. Some hubs trap sediment, silt, or other foreign particles, and after these work into the bearing a definite added resistance to turning becomes apparent. Some propellers are therefore designed for flow through cleaning action so that particles do not permanently lodge in the bearings. Care should be taken in lubricating meter bearings. Use of the wrong lubricant (perhaps none should be used) can increase the resistance to propeller motion, particularly in cold water. It should also be established that the lubricant is reaching the desired bearing or other surfaces after it is injected. For some meters, the manufacturers do not recommend lubrication of the bearings.

Floating moss or weeds can foul a propeller unless it is protected by screens. Heavy objects can break the propeller. With larger amounts, or certain kinds, of foreign material in the water, even screens may not solve the problem.

The propeller meter will require continuous maintenance. Experience has shown that maintenance costs can be reduced by establishing a regular maintenance programme, which includes lubrication and repair of meters, screen cleaning, replacement about every 2 years, and general maintenance of the turnout and its approaches. In a regular programme many low-cost preventive measures can be made routine and thereby reduce the number of higher cost curative measures to be faced at a later time. Maintenance costs may be excessive if meters are used in sediment-laden water.

Effect of meter setting

Unless the meter is carefully positioned in the turnout, sizeable errors may result. For example, a meter with an 0.30 m propeller in an 0.60 m diameter-pipe discharging 0.22 m^3/s, set with the hub centre 0.025 m off the centre of the pipe, showed an error of 1.2 per cent. When the meter was rotated 11.5° in a horizontal plane (8 mm measured on the surface of the 76 mm-diameter vertical meter shaft housing), the error was 4 per cent; for 23°, the error was 16 per cent (under-registration).

Effect of outlet box design

The geometry of the outlet box downstream from the flow meter may also affect meter accuracy. If the outlet is so narrow as to cause turbulence, boils, and/or white water, the meter registration may be affected.

Figure 9.26 shows two designs of outlet boxes (to scale). Design B is believed to be the smallest outlet box that can be built without significantly affecting the meter calibration. The vertical step is as close to the meter as is desirable. Larger outlet structures – those providing more clearance between the meter and vertical step – would probably have less effect on the registration. More rapidly diverging walls than shown in Figure 9.26 should be avoided since they tend to produce eddies over the meter and/or surging flow through the meter and/or surging flow through the turnout. This has been observed as a continuously swinging indicator which follows the changing discharge through the meter. The surging may often be heard as well as seen. Large registration errors can occur when rapidly or continually changing discharges are being measured.

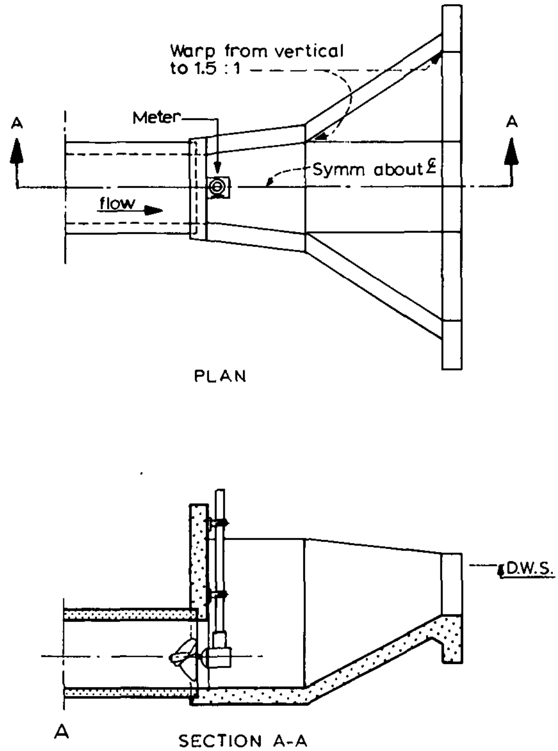


Figure 9.26 Outlet box design (after Schuster 1970)

9.7.3 Head losses

Head losses across a propeller meter are usually regarded as being negligible, although there is evidence that losses may run as high as two velocity heads. In many cases turnout losses including losses through the pipe entrance, screens, sand trap, pipe, etc., are large enough to make the losses at the meter seem negligible. Some allowance for meter losses should be made during turnout design, however, and the meter manufacturer can usually supply the necessary information. Table 9.1 may serve to give an impression of the head losses that occur over a typical propeller meter installation as shown in Figure 9.24, and in which the horizontal pipe length is 7 D_p.

Table 9.1 Head losses over propeller meter installation (after USBR 1967)

Q, m^3/s	D_p, m	Δh, m
0.085	0.30	0.50
0.140	0.36	0.54
0.280	0.46	0.66

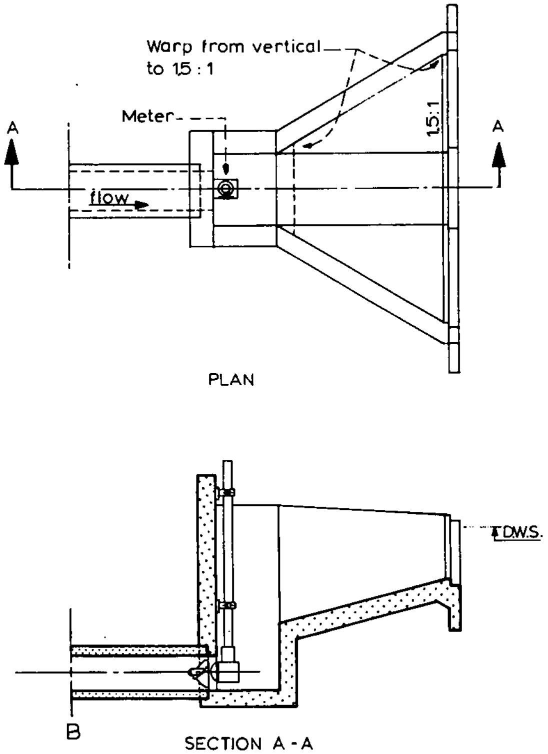


Figure 9.26 (cont.)

9.7.4 Meter accuracy

The accuracy of most propeller meters, stated in broad terms, is within 5 per cent of the actual flow. Greater accuracy is sometimes claimed for certain meters and this may at times be justified, although it is difficult to repeat calibration tests, even under controlled conditions in a laboratory, to within 2 per cent. A change in lubricating practice or lubricant, along with a change in water temperature, can cause errors of this magnitude. A change in line pressure (the head on the turnout entrance) can cause errors of from 1 to 2 per cent.

9.7.5 Limits of application

The limits of application of the propeller meter for reasonable accuracy are:

a. The propeller should be installed under the conditions it was calibrated for;
b. To reduce errors due to always existing differences in velocity profiles between calibration and field structure, the propeller diameter should be as large as practicable. For a circular pipe a propeller diameter of 0.75 D_p or more is recommended;

c. The minimum length of the straight and horizontal conduit upstream from the propeller is 7 D_p, provided flow straightening vanes are used;
d. If no flow straightening vanes are used, a straight horizontal pipe without any flow disturbances and with a minimum length of 30 D_p should be used upstream from the propeller;
e. The flow velocity in the pipe should be above 0.45 m/s for best performance. In sediment-laden water the velocity should be even higher to minimize the added friction effect produced by worn bearings.

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