International Standard 1100/1

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Liquid flow measurement in open channels — Part 1 : Establishment and operation of a gauging station

Mesure de débit des liquides dans les canaux découverts — Partie 1 : Établissement et exploitation d'une station de jaugeage

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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 1100/1 was developed by Technical Committee ISO/TC 113, *Measurement of liquid flow in open channels*, and was circulated to the member bodies in November 1979.

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

Canada	Norway	Switzerland
France	Philippines	United Kingdom
Germany, F. R.	Romania	USA
India	South Africa, Rep. of	
Netherlands	Spain	

The member body of the following country expressed disapproval of the document on technical grounds :

Australia

This second edition cancels and replaces the first edition (i.e. ISO 1100-1973).

Liquid flow measurement in open channels — Part 1 : Establishment and operation of a gauging station

1 Scope and field of application

1.1 This International Standard deals with the establishment and operation of a gauging station on a lake, reservoir, river or artificial open channel for the measurement of stage or discharge or both. It is generally applicable to the measurement methods described in the International Standards which are noted in clause 2 and it covers only such additional requirements as are necessitated by its wider scope.

1.2 The requirements for a stage measuring station are set out in clause 5. The requirements for a discharge measuring station are classified under two headings :

a) Individual measurements.

These include methods suitable for a single measurement of discharge or a limited number of measurements often used to calibrate a station.

b) Regular measurements.

These include methods suitable for relatively frequent measurements often made over many years.

2 References

ISO 31, *Quantities, units and symbols.*

ISO 555/1, *Liquid flow measurement in open channels — Dilution methods for measurement of steady flow — Part 1 : Constant rate injection method.*

ISO 555/2, *Liquid flow measurement in open channels — Dilution methods for measurement of steady flow — Part 2 : Integration (sudden injection) method.*

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

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

ISO 1000, *SI units and recommendations for the use of their multiples and of certain other units.*

ISO 1070, *Liquid flow meausrement in open channels — Slope-area method.*

ISO 1088, *Liquid flow measurement in open channels — Velocity area methods — Collection of data for determination of errors in measurement.*

ISO 1100/2, *Liquid flow measurement in open channels — Part 2 : Determination of the stage-discharge relation.*[1)]

ISO 1438/1, *Water flow measurement in open channels using weirs and venturi flumes — Part 1 : Thin-plate weirs.*

ISO 2425, *Measurement of flow in tidal channels.*

ISO 2537, *Liquid flow measurement in open channels — Cup-type and propeller-type current meters.*

ISO 3454, *Liquid flow measurement in open channels — Sounding and suspension equipment.*

ISO 3455, *Liquid flow measurement in open channels — Calibration of rotating element current meters in straight open tanks.*

ISO 3716, *Liquid flow measurement in open channels — Functional requirements and characteristics of suspended load samplers.*

ISO 3846, *Liquid flow measurement in open channels by weirs and flumes — Free overfall weirs of finite crest width (rectangular broad-crested weirs).*

1) At present at the stage of draft.

ISO 3847, *Liquid flow measurement in open channels by weirs and flumes — End-depth method for estimation of flow in rectangular channels with a free overfall.*

ISO 4359, *Liquid flow measurement in open channels using flumes.* [1]

ISO 4360, *Liquid flow measurement in open channels by weirs and flumes — Triangular profile weirs.*

ISO 4363, *Liquid flow measurement in open channels — Methods of measurement of suspended sediment.*

ISO 4364, *Liquid flow measurement in open channels — Bed material sampling.*

ISO 4366, *Echo sounders for water depth measurements.*

ISO 4369, *Measurement of liquid flow in open channels — Moving-boat method.*

ISO 4373, *Measurement of liquid flow in open channels — Water level measuring devices.*

ISO 4375, *Measurement of liquid flow in open channels — Cableway system for stream gauging.*

ISO 4377, *Measurement of liquid flow in open channels — Flat-V weirs.* [1]

ISO 5168, *Measurement of fluid flow — Estimation of uncertainty of a flow-rate measurement.*

ISO/TR 7178, *Measurement of liquid flow in open channels — Investigation of the total error in measurement of flow by velocity area methods.* [1]

WMO *(World Meteorological Organisation)* — No. 168, *Guide to Hydrometeorological Practices.*

WMO *(World Meteorological Organisation)* — No. 49, *Technical Regulations.*

3 Definitions

For the purpose of this International Standard, the definitions and symbols given in ISO 772 apply.

4 Units of measurement

The units of measurement used in this International Standard are SI Units in accordance with ISO 31 and ISO 1000.

5 Water level (stage) gauging station

5.1 Principle

5.1.1 The stage of a stream or lake is the height of the water surface above an established datum plane. Water levels of rivers, lakes and reservoirs are used directly in hydrological forecasting, in delineating flood hazard areas, and in the design of structures in, or near, water bodies. When correlated with discharge of streams, or with the volume of storage in reservoirs and lakes, water levels are used as the basis for computation of records of discharge, or changes in storage. Records of water level are obtained by systematic observations on a reference gauge, or from a water level recorder.

5.2 Preliminary survey

5.2.1 A preliminary survey should be made of the physical and hydraulic features of the proposed site to ensure that it conforms to the requirements necessary for the measurement of water level as specified in ISO 4373.

5.3 Selection of site

5.3.1 The site selected for observation of stage should be governed by the purpose for which the records are collected, the accessibility of the site, and the availability of an observer if the gauge is non-recording. Gauges on lakes and reservoirs are normally located near the outlet, but upstream from the zone where an increase in velocity causes a drawdown in water level. Gauges on large bodies of water should also be located so as to reduce the fetch of strong winds which may cause damage or misleading data. Hydraulic conditions are an important factor in site selection on channels, particularly where water levels are used to compute discharge records.

5.3.2 Gauging stations should conform to the requirements of the relevant sections of ISO 4373 which includes recommendations for the design of the reference gauge, recorder, and stilling well.

5.4 Design and construction

5.4.1 A water level gauging station shall consist essentially of a reference gauge or gauges. Where a continuous record of stage is not required see 7.1.7.2. It is usual however for a continuous record of stage to be required and for this purpose a water level recorder is installed in addition to the reference gauge (see 7.1.7.3).

1) At present at the stage of draft.

5.4.2 Reference gauge (see ISO 4373)

Reference gauges may be either the direct or the indirect type, with measuring instruments of the fixed or movable type, such as vertical and inclined gauges, needle gauges, float gauges, and wire weight gauges classified as direct reading instruments. The signifiant feature of this group of water-level indicators is that the reading may be made directly in units of length, without any intervening influences. Indirect water-level indication devices include those gauging systems which convert a pressure or electrical signal to an output which is proportional to the water level. Of the indirect devices available, those in most common usage are the pressure type, such as the servo-manometer and the servo-beam balance.

5.4.2.1 Vertical and inclined gauges

Such gauges comprise a scale marked on or attached to a suitable surface.

5.4.2.1.1 Functional requirements

These gauges should meet the following functional requirements :

a) they should be accurate and clearly marked;

b) they should be durable and easy to maintain;

c) they should be simple to install and use.

5.4.2.1.2 Material

The material of which a gauge is constructed should be durable, particularly in alternating wet and dry conditions and also in respect to the resistance to wear or fading of the markings. The material should have a low coefficient of expansion with respect to temperature or wetting effects.

5.4.2.1.3 Graduation

a) The graduations of a vertical gauge must be clearly and permanently marked directly on a smooth surface or on a gauge board. The numerals shall be distinct and placed so that the lower edge of the numeral is close to the graduation to which it refers.

b) The graduations of an inclined gauge may be directly marked on a smooth surface or on a gauge board as described in a) above, or may be carried on manufactured gauge plates designed to be set for particular slopes. Except where use is made of manufactured gauge plates designed to be set to a specified slope, an inclined gauge should be calibrated in-situ by precise levelling from the station bench mark.

c) Gauge plates should be manufactured in suitable lengths with the face of the scale not less than 50 mm in width.

d) The marking on the gauge should be made to read in multiples of millimetres.

The smallest graduation shall depend on the accuracy required, but may normally be 10 mm.

e) The markings of the subdivisions shall be accurate to ± 0,5 mm, and the cumulative error in length shall not exceed 0,1 % or 0,5 mm, whichever is greater.

5.4.2.1.4 Installation and use

5.4.2.1.4.1 General

The gauge should preferably be placed near the bank so that a direct reading of water level may be made. If this is impracticable because of excessive turbulence, wind effect, or inaccessibility, the measurement may be made in a suitable permanent stilling bay or stilling well in which the wave actions are damped and the level of the water surface closely follows the fluctuations of the water level in the channel. To ensure this, intakes to stilling wells should be properly designed and located.

The gauge should be located as closely as possible to the measuring section without affecting the flow conditions at this point. It should not be placed where the water is disturbed by turbulence, or there is danger of damage by drift. Bridge abutments or piers are generally unsuitable locations. Wherever the gauge is situated, it must be readily and conveniently accessible so that an observer may take readings as nearly as possible at eyelevel. Where necessary, the construction of a flight of steps to give convenient access is reccommended. The gauge board or plate should be securely fixed to the backing but provision must be made for removing the gauge board or plate for maintenance or adjustment. The edges of the gauge board should be protected.

5.4.2.1.4.2 Vertical gauges

A suitable backing for a vertical gauge is provided by the surface of a wall having a vertical or nearly vertical face parallel to the direction of flow. The gauge board or backing plate should be attached to the surface so as to present a truly vertical face to receive the graduations. The gauge board and backing plate should be securely fastened to the wall. Gauges may be fixed to piles, either driven firmly into the bed or banks, or set in concrete so as to be free from sinking, tilting, or being washed away. In either case the anchorage should extend below the ground surface to a level free of disturbance by frost. In order to avoid velocity effects which may hinder accurate reading, a pile may be shaped to be streamlined upstream and downstream, or the gauge may be situated in a bay where it will not be exposed to the force of the current. Where the range of water levels exceeds the capacity of a single vertical gauge, additional sections may be installed on the line of the cross section normal to the direction of flow. The scales on such a series of stepped gauges should have adequate overlap. These stepped gauges should be installed at such intervals as to ensure the measurement of water level at all stages of flow.

5.4.2.1.4.3 Inclined gauges

An inclined gauge should be installed in such a manner as to closely follow the contour of the river bank. The profile of the bank may be such that a gauge of a single slope may be installed; frequently however, it may be necessary to construct the gauge in several sections, each with a different slope. The general installation requirements given in 5.4.2.1 apply.

5.4.2.2 Needle gauges

5.4.2.2.1 General

A needle water-level gauge consists of a point and some means of determining its exact vertical position relative to a datum. It is mainly used for checking or calibrating other gauges or recorders. The two types of needle gauges are :

a) the point gauge whose tip approaches the free surface from above, and

b) the hook gauge which is hook-shaped, and whose tip is immersed and approaches the free surface from below.

The vertical position may be determined by a graduated scale, a tape with some vernier arrangement, or a digital indicator. The scale is movable and graduated to read downward from top to bottom. Application of needle gauges consists of positioning the needle of the gauge near the water surface and detecting the moment the tip just touches the free surface, apparently trying to pierce its skin. Setting a point exactly at the water surface may be facilitated by electrical means.

The advantage of water-level needle gauges is their high measuring accuracy, whereas their disadvantage is their small measuring range, usually about 1 m. However, this disadvantage can be overcome by installing a series of datum plates at different levels.

5.4.2.2.2 Functional requirements

a) A needle gauge installation should permit measurement of stage to be made at all levels from below the lowest to above the highest level anticipated.

b) There must be good illumination of the place where the tip meets the free liquid surface.

c) The hook or point should be made of metal sufficiently strong to resist deformation in transport and under field conditions of use. The tip should be tapered to a point having an included angle of approximately 60° and the point shall be rounded to a radius of approximately 0,25 mm.

5.4.2.2.3 Material

A hook or point gauge and auxiliary parts should be made throughout with durable corrosion-resistant materials.

5.4.2.2.4 Graduation

The graduations of a hook or point gauge shall be in millimetres and shall be clearly and accurately marked. A vernier or micrometer head may be provided which allows reading to 0,1 mm, however, such a reading accuracy is normally only required for laboratory measurements.

5.4.2.2.5 Installation and use

a) A hook or point gauge may be mounted over an open water surface at the edge of a channel if conditions permit. If this is not practicable because of turbulence, wind effect, or inaccessibility, a suitable permanent stilling bay or stilling well should be installed.

b) The location of the hook or point gauge should be as close as possible to the measuring section and should be conveniently accessible to the observer.

c) The gauging point shall not be installed in a location where the water surface is disturbed by turbulence, wind effect, or afflux. The vicinity of bridge abutments or piers is generally unsuitable.

d) Where more than one datum plate or bracket is provided at different levels, it is preferable that all should lie on the line of a single cross section normal to the direction of flow in the channel; if this is not practicable and it is necessary to stagger the points, all should lie within a distance of 1 m on either side of the cross-section line.

e) Datum plates and brackets should be mounted on a secure foundation which extends below the frost line.

f) The elevation of the datum plates, with reference to which the level of the free surface is determined, should be established with great care. This elevation should be checked from the station bench mark (see 5.5.4) at least annually. The uncertainty on the transfer of level from the station bench mark to each datum plate shall not exceed ± 1,0 mm.

5.4.2.3 Float gauge

5.4.2.3.1 General

The float gauge is used chiefly as an inside reference gauge in water stage measurements. The typical float gauge consists of a float operating in a stilling well, a graduated steel tape, a counterweight, a pulley, and a pointer. The float pulley is grooved on the circumference to accommodate the tape, and mounted on a support. The tape is fastened to the upper side of the float and runs slip-free over the pulley in the gauge shed above the well. The tape is kept tight by a counterweight at the free end or by a spring. In this way stage fluctuations are sensed by the float which positions the tape with respect to the pointer.

5.4.2.3.2 Functional requirements

a) A float gauge installation should permit measurement of stage to be made at all levels from below the lowest to above the highest level anticipated.

b) Float and counterweight dimensions and the quality of the elements of the mechanical device for remote indication should be selected so that there is a sufficiently high indication accuracy and working reliability.

c) The float should be made of durable corrosion-resistant and antifouling material. It should be leak-proof and function in a truly vertical direction. Its density should not change significantly.

d) The float should float properly and the tape or wire should be free of twists or kinks.

5.4.2.3.3 Graduation

The graduations of the float gauge shall be in millimetres and shall be clearly and accurately marked.

5.4.2.4 Wire-weight gauge

5.4.2.4.1 General

A typical wire-weight gauge consists of a drum wound with a single layer of cable, a weight attached to the end of the cable, a graduated disc, and a counter, all housed within a cast-aluminium box. The disc is graduated and is permanently connected to the counter and the shaft of the drum. The cable is guided to its position on the drum by a threading sheave. The reel is equipped with a pawl and ratchet for holding the weight at any desired elevation. The gauge is set so that when the bottom of the weight is at the water surface, the gauge height is indicated by the combined readings of the counter and the graduated disc.

5.4.2.4.2 Functional requirements

a) A wire-weight gauge installation should permit measurement of stage to be made at all levels from below the lowest to above the highest level anticipated.

b) The tape or wire should be free of twists or kinks.

c) The weight should be made of durable corrosion-resistant material.

d) The installation should be provided with a horizontal checking bar for checking the calibration datum of the graduated disc or counter.

5.4.2.4.3 Installation and use

a) The wire-weight gauge is used as an outside reference gauge where other outside gauges are difficult to maintain. The wire-weight gauge is normally mounted where there is a bridge, deck, or other structure over the water.

b) The gauging point should not be installed in a location where the water surface is disturbed by turbulence, wind effects, or afflux. The vicinity of bridge abutments or piers is generally unsuitable.

c) The check bar elevation of the wire-weight gauge should be read frequently to ensure reliability of correct base elevation.

5.4.2.5 Crest stage gauge

The crest stage gauge is used to obtain a record of the peak level reached during a flood when other methods of recording levels cannot be used. Peak discharges may be calculated from the water levels at two gauges installed some distance apart in a stretch of channel, provided that the time lag between measurements is negligible. These gauges do not meet the accuracy requirements of 5.6.

These gauges are locally made to different designs. Basically they may be a tube of about 50 mm internal diameter down the centre of which runs a rod. The tube is perforated to permit rising water to enter, the perforations being located to prevent drawdown or velocity head from affecting the static water level. The top of the tube must be closed to prevent the entry of rain, but it should have an air vent to permit water to rise up the tube without significant delay. Powdered cork in the bottom of the tube floats on the surface of the floodwater being deposited on the centre rod as the water recedes. Alternatively the centre rod is coated with a paint whose colour is permanently affected by water.

5.4.2.6 Pressure gauges

Pressure gauges are frequently used at sites where it would be too expensive to install stilling wells. They are also used on sand-channel streams because the intake line can be extended to follow a stream channel that shifts its location, and if the gas-purge technique is used, the gas flow tends to keep the orifice from becoming plugged with sand.

5.4.2.6.1 General

One widely-used method of measuring water level is to measure the height of a column of water with respect to some datum plane. This can be accomplished indirectly by sensing the water pressure at a fixed point below the water surface, and then utilizing the hydrostatic principle that the pressure of a liquid is proportional to the depth.

5.4.2.6.2 Functional requirements

The range of the instrument must be adequate to accommodate any anticipated ranges in water level and the response must be sufficiently rapid to follow any expected rate of change in water level.

The method of transmitting pressure from the water column to the sensor may be direct or indirect. When the sensor is located below the point in the water column at which the pressure is to be measured, the water pressure may be transmitted directly to the sensor. However, if the sensor is located above the water column, the direct method is usually not satisfactory because gases entrained in the water can create air locks in the line. Also, if the water is highly corrosive, it is undesirable to bring it into direct contact with the sensor.

5.4.2.6.3 Gas-purge (bubbler) technique

The most successful and widely used method of transmitting pressure is the gas-purge technique. This technique may be used regardless of the elevation of the pressure device with respect to the water column; and because the water does not come into direct contact with the pressure sensor, it is suitable for use in highly corrosive waters.

In the gas-purge technique, a small discharge of non-corrosive gas or compressed air is allowed to bleed into a tube, the free end of which has been lowered into the water and fixed at an elevation below the water column to be measured. For example, dry nitrogen is frequently used. The sensor, which is located at the opposite end, detects the pressure of the gas required to displace the liquid in the tube, this pressure is directly proportional to the head of liquid above the orifice.

When using the gas-purge technique there are certain installation and operation requirements that should be observed. The principal ones are listed below.

a) An adequate supply of gas or compressed air must be provided. A continuous flow of gas to the tube is necessary to prevent the liquid from entering it when the water level is rising. A particular rate of gas supplied will cause the pressure in the system to rise at the same rate as the head. If gas is supplied at a lower rate, liquid will enter the tube; and conversely, a higher rate will provide a continuous discharge of gas from the opening in the bottom of the tube. The gas is usually supplied from a cylinder or by an air compressor. In either case, the supply must have a delivery pressure in excess of the range to be measured.

b) A pressure reducing valve must be provided so that a pressure safely in excess of that of the maximum range can be set. A flow control valve and some form of visual flow-rate indicator is necessary, so that the discharge of gas supplied to the system can be properly adjusted. The pressure should be set to prevent water from entering the tube, even under the most rapid rates of change expected.

c) Incorrect readings due to the friction of the gas moving through the tube should be minimised. Long lengths of tube or very small diameter tubing aggravate the friction problem. This problem is frequently solved by running two tubes to a junction very near to the orifice with one tube serving as a gas-supply line and the other as a pressure-detection line. Under this arrangement the movement of gas in the pressure detection line is kept to a minimum, thereby reducing the friction to a minimum.

d) The tubing should be installed with a continuous down slope to the orifice.

5.4.2.6.4 Pressure bulb system

Where there is no gas supply available, a pressure bulb system is sometimes used to transmit pressure to the sensor. This device, frequently referred to as an elastic pressure bulb, is usually made of casting in the form of a short hollow cylinder with one open end. The open end is sealed with a slack, highly flexible diaphragm, and the cylinder is connected by means of tubing to the pressure sensor. The whole unit forms a closed gas system with pressure initially equal to atmospheric pressure. The cylinder is lowered into the water and fixed at an elevation below the water column to be measured. The slack diaphragm permits water pressure to compress the gas in the cylinder until the pressure within the system is proportional to the height of the water column above. One of the major disadvantages of this device is that ultimately an excessive amount of gas will escape from the system with a resultant stretching of the diaphragm. When this occurs the pressure within the system will no longer be equal to the pressure head. This disadvantage can be overcome by periodic renewal of the gas in the system by opening and re-sealing under atmospheric pressure and checking the calibration. It is difficult to maintain the accuracy stipulated under 5.6 with this device.

5.4.2.6.5 Servo-manometer and servo-beam balance

Both the servo-manometer and the servo-beam balance are pressure sensors that convert the pressure detected to a rotational shaft position proportional to the height of the column of water. The shaft rotation is used for driving a recorder and a water-level indicator. As the name implies, the servo-manometer is essentially a manometer with a servo-system detecting and following the liquid differential within the manometer. The servo-beam balance is a beam balance with a pressure balance on one side of the beam and a weight on the other. Here the servo-system positions the weight so that the beam is in balance and detects this position.

5.4.2.6.6 Water density compensation

Since the density of the water in which the sensor operates will vary with temperature and also with chemical and silt content, either automatic or manual means of compensating for these changes should be provided.

5.4.2.6.7 Changes in gas weight

If one of the gas techniques is used to transmit pressure, provisions should be made for compensating for changes in the density of the gas, as all gases vary in volume with temperature and pressure changes.

5.4.2.6.8 Miscellaneous pressure sensors

There are numerous pressure sensors available commercially operating on numerous principles. Most of these have an electrical output which is proportional to the pressure sensed. They are occasionally used for the detection of water level. The proper selection is dependent upon the particular application involved.

Their application is generally restricted to limited ranges because the accuracy requirements set out in 5.6 are difficult to meet over extended ranges.

5.4.3 Stilling well

5.4.3.1 Functional requirements of stilling well

5.4.3.1.1 General

The function of the stilling well is :

a) to accommodate the instrument and protect the float system;

b) to provide within the well an accurate representation of the water level in the channel;

c) to damp out oscillations of the water surface.

5.4.3.1.2 Specific

a) The well may be circular, oval, square or rectangular in plan and may be made of any suitable material.

b) The well may be placed in the bank of a channel or directly in the stream when attached to a bridge pier or abutment. It should not, however, be located directly in the channel where flow conditions would lead to separation and stagnation effects. When placed in the bank, the well shall be connected to the channel by intake pipe(s). When placed directly in the channel, the intakes may take the form of holes or slots cut in the well itself.

c) The well shall not interfere with the flow pattern in the approach channel and if set in relation to a control, it shall be located far enough upstream to be outside the area affected by the control.

d) The well shall be firmly founded when placed in the bank and firmly anchored when standing in the stream so that it shall remain stable at all times.

e) The well and all construction joints of well and intake pipes shall be watertight so that water can enter or leave only by the intake itself.

f) The well shall be vertical within acceptable limits and have sufficient height and depth to allow the float to travel freely the full range of water levels.

g) The dimensions of the well shall be such as to allow unrestricted operation of all equipment installed in it. Clearance between walls and float shall be at least 75 mm and where two or more floats are used within the well, clearance between them shall be at least 150 mm. In silt laden rivers, it is an advantage to have the well large enough to be entered and cleaned.

h) When placed in the bank of the stream the stilling well shall have a sealed bottom to prevent seepage into or leakage out of the chamber.

j) In wells with sealed bottoms the bottom of the well shall be at least 300 mm below the invert of the lowest intake to provide space for sediment storage and to avoid the danger of the float grounding at times of low flow.

5.4.3.2 Functional requirements of intakes

5.4.3.2.1 General

The function of the intakes to the stilling well is :

a) to allow water to enter or leave the stilling well so that the water in the well is maintained at the same elevation as that in the stream under all conditions of flow;

b) to permit some form of control to limit lag and oscillating effects within the well.

5.4.3.2.2 Specific

a) Intakes may take the form of one or more pipes connecting the well to the river when the well is set back into the bank or a series of holes or slots cut into the well itself when it is set directly into the river. In rivers with a permanent high silt content, a well set in the stream may have a hopper-shaped bottom to serve as an intake and also as a means of self-cleansing.

b) The dimensions of the intakes shall be large enough to allow the water level in the well to follow the rise and fall of river stage without appreciable delay.

c) The dimensions of the intakes shall be small enough to damp oscillations caused by wave action or surges.

d) Two or more intakes may be installed, one vertically above the other, to ensure operation of the system if the lowest pipe becomes blocked.

e) For a pipe well set into a bank the lowest intake shall be at least 150 mm below the lowest anticipated stage and shall enter the pipe well at least 300 mm above the well bottom.

f) Intake pipes shall be laid at a constant gradient on a suitable foundation which will not subside.

g) The intake shall be so oriented in the stream that it will sense the true water level. When velocities in the stream at the point of measurement are sufficiently large, that the dynamic pressure is of sensible magnitude, the intake shall incorporate a static pressure sensing device (wall piezometer, piezometer in a plate, surface parallel to flow, static tubes etc.).

h) It is desirable that intake pipes more than 20 m in length shall be provided with an intermediate manhole fitted with internal baffles to act as a silt trap and provide access for cleaning.

j) Means of cleaning the intakes shall be provided, either by a flushing system where water under head can be applied to the stilling well end of the intake, by pumping water through the intake or by hand cleaning with collapsible draining rods.

k) Where velocity past the river end of the intake is high, drawdown of the water level in the well may occur. This can be reduced by attaching a capped and perforated static tube to the river end of the intake.

5.4.3.3 Protection under ice conditions

For precautions to be taken under ice conditions see clause 9.

5.4.4 Water level recorders (see ISO 4373)

5.4.4.1 Mechanical recorders

Mechanical recorders can be classified as either analog or digital, depending upon the mode used in recording the rotational position of the input shaft. The analog recorder produces a graphic record of the rise and fall of parameter values with respect to time, while the digital recorder punches coded parameter values on paper tape at preselected time intervals. Anolog recorders can further be classified into two types, those which record continuously or at intervals for a fixed period of time (daily, weekly, monthly, etc).

5.4.4.2 Pressure-actuated recorders

Pressure-actuated recorders are simple in design and relatively rugged in construction. They are, however, susceptible to errors and, consequently, are not frequently used in recording water level.

They usually consist of a pressure-sensing element, a stylus linked to the pressure element by a lever arrangement, and a chart driven by a clock.

5.4.4.3 Electronic recorders

The electronic recorder consists of a case, an operating mechanism, a stylus, and a chart transport mechanism. The function of the operating mechanism is to position the stylus at the proper location on the chart in response to a signal. Although there is an extremely wide assortment of electronic recorders available, there are basically only two types, those with a direct-acting operating mechanism and those with a servo-operated mechanism. The low torque and relatively limited output motion of a direct acting mechanism will position only a light, low friction stylus over a limited range, whereas the sturdy servo-operated mechanism has ample power and a much wider motion capability.

The operating mechanism is the heart of the electronic recorder. Its quality and the techniques employed in its design determine the characteristics of the entire recorder.

5.4.4.4 *Regardless of the type of recorder used it should* satisfy the requirements enumerated in ISO 4373.

5.5 Gauge datum

5.5.1 The datum of the gauge may be a recognised datum, such as mean sea level, or an arbitrary datum plane selected for the convenience of using gauge readings of relatively low numbers. It is generally desirable to avoid negative values for these readings, therefore, the datum selected for operating purposes should be below the elevation of zero flow on the control. At sites that are subject to severe scour care must be taken to select a datum that is sufficiently low.

5.5.2 If an arbitrary datum plane is used, it should be referred to a bench mark of known elevation by accurate levelling so that the arbitrary datum may be recovered if the gauge and reference marks are destroyed. A permanent datum must be maintained so that only one datum for the stage record is used for the life of the station.

5.5.3 Gauge zero

The zero of the gauge should be correlated with a national datum through a station bench mark. The relation between the gauge zero and the station bench mark shall be checked at least annually. The relation between the gauge zero and other gauge sections shall be checked from time to time. As far as possible the gauge zero shall be kept the same. The uncertainty in the *transfer of the level from the station bench mark to the gauge* shall not exceed ± 1,0 mm.

5.5.4 Station bench mark

The station bench mark shall be set in a position offering maximum security against disturbance. It should be securely fixed in a concrete block or similar mounting that extends below the ground surface to a level free from disturbance, such as frost. It should be correlated with a national survey datum by accurate levelling. To facilitate accurate levelling between the station bench mark and the gauge zero, the bench mark should be located in a position such that the transfer of the level may be carried out by reciprocal levelling or with equally balanced foresights and backsights on the setting of the level. Where it is not feasible to correlate the bench mark with the national survey datum more than one (preferably three) station bench marks shall be established in significantly different locations.

5.6 Accuracy

For the measurement of stage, in certain installations an uncertainty of ± 10 mm may be satisfactory; in others an uncertainty of ± 3 mm or better may be required; however, in no case should be uncertainty be worse than ± 10 mm or ± 0,1 % of the range, whichever is greater.

6 Station for the measurement of discharge : individual measurements

The methods which follow are most suitable for a single measurement, a limited number of measurements or infrequent measurements of discharge.

6.1 Velocity area method

6.1.1 Principle of method of measurement

The principle of the method is to measure the velocity and area of cross section of flow in an open channel, the product of which is the discharge. The recommendations which follow restrict the application of the method to the case in which velocity is measured using current meters or floats.

6.1.2 Preliminary survey

A preliminary survey should be made to ensure that the physical and hydraulic features of the proposed site conform to the requirements of ISO 748. Several such surveys under different flow conditions may be required to ensure that the site is not subject to, for example, standing waves at high flow, weed conditions, adverse ice conditions, and so forth.

6.1.3 Selection of site

6.1.3.1 The site selected should be such that it is possible to measure the whole range and all types of flow which may be encountered or which it is required to measure.

6.1.3.2 Particular attention should be paid to the following features :

a) sites where weed growth is prevalent should be avoided, if possible;

b) there should be no vortices, dead water or other abnormalities of flow;

c) sites where poor ice conditions are prevalent should be avoided, if possible;

d) access to the site should be feasible under most conditions.

6.1.4 Survey for a permanent gauging station

6.1.4.1 After a preliminary survey, a topographical survey should be made when selecting a permanent site for a suitable measuring section. This should include a plan of the site indicating the width of the water surface at a stated stage, the edges of the natural banks of the channel(s), the line of any definite discontinuity of the slope of these banks and the toe and crest of any artificial flood bank.

6.1.4.2 The detailed survey of the reach should be extended through the floodway to an elevation well above the highest anticipated flood level. The spacing of levels or soundings should be close enough to reveal any abrupt change in the contour of the channel.

6.1.4.3 The bed of the reach should be examined carefully for the presence of rocks or boulders, particularly in the vicinity of the measuring section.

6.1.4.4 Where velocities are to be measured by current meter, exploratory measurements of velocities should be made in the proposed measuring section and in the cross-section immediately upstream and downstream. When possible, the method of velocity distribution described in ISO 748 should be used for these measurements to determine the feasibility of using reduced point methods.

6.1.4.5 When floats are to be used for velocity measurements trial runs of floats should be closely spread across the width of the channel.

6.1.5 Design and construction

6.1.5.1 The positions of each cross-section should be defined on the banks of the river by clearly visible and readily identifiable permanent markers, and a station bench mark shall be established to conform to 5.5.4.

6.1.5.2 The design of the station should be based on the features disclosed by the survey described in 6.1.4.

6.1.5.3 A water level gauge should be installed for checking changes in the water level which may occur during a gauging. The gauge should be located as closely as possible to the measuring reach, unless floats are used to measure velocities in which case the gauge should be located near the mid-point of the measuring reach.

6.1.5.4 Where the main requirements necessary for a suitable gauging site as specified, are not present, conditions may be improved as described below :

a) The loss of water from the main channel by spillage can often be avoided by constructing flood banks to confine the flow in a defined floodway.

b) Minor irregularities in the bank or bed causing local eddies may be eliminated by trimming the bank to a regular line and a stable slope and by removing from the bed any large stones or boulders.

c) Unstable banks should be protected wherever possible. Such protection should extend upstream and downstream of a measuring section for a distance equal to at least one quarter of the bankfull width of the channel in each direction. In the case of float gauging the whole of the measuring reach should be protected.

6.1.5.5 Where in the normal measuring section there is insufficient depth to comply with the requirements of ISO 748, or where there is excessively low velocity at low stages, these discharges may often be measured in the same reach of the channel at another section which is more suitable under these conditions but which may not be satisfactory for higher flows.

6.1.5.6 Trees obstructing the clear view of the measuring section or measuring reach should be trimmed or removed. The field of view of a measuring section should extend sufficiently upstrean to enable floating debris, which might damage any measuring instrument, to be seen in sufficient time to permit the removal of the instrument from the stream.

6.1.5.7 Where not already existing, a suitable access to the site should be constructed, where possible, to provide safe passage at all stages of flow and in all weathers for personnel and for any vehicles used for the conveyance of instruments and equipment.

6.1.5.8 All key points at the site should be permanently marked on the ground by markers sunk to such a depth below the surface as will secure them against movement. Cross-section markers should be set on the line of the cross-section to facilitate the repetition of levels or soundings when the section is checked.

6.1.5.9 Reference gauge

The reference gauge shall conform to 5.4.2 and to ISO 4373.

6.1.5.10 Station bench mark

A station bench mark shall be established to conform to 5.5.4.

6.1.5.11 Stilling well

The stilling well shall conform to 5.4.3 and to ISO 4373.

6.1.5.12 Water level recorder

The water level recorder shall conform to 5.4.4 and to ISO 4373.

6.1.5.13 Cableway and suspension

Cableways and methods of suspension of the current meter shall conform to ISO 4375 and ISO 3454.

6.1.6 Definitive survey

6.1.6.1 After the gauging station has been constructed, a definitive survey should be made.

6.1.6.2 For current meter stations, a standard profile on the measuring cross-section should be drawn, indicating the position of the cross-section markers. On this standard drawing the positions selected for the measuring verticals may be recorded (see ISO 748). The bed levels of the cross-section should be frequently checked and the profile revised if necessary.

A copy of the standard profile (most recent revision) should be kept in the instrument house at all times.

6.1.6.3 For float-gauging stations a standard plan should be prepared on which the lines of the selected float runs and the release points for floats should be indicated. A copy of this plan should be kept in the instrument house at all times.

6.1.6.4 The definitive survey, repeated as required at not less than annual intervals, should include the accurate determination of the elevations and the relative positions of all the station installations and any other key point or significant feature of the site. It is desirable to correlate the elevations with the National Survey datum through the station bench mark.

6.1.6.5 The distance between cross-section markers should be carefully determined.

6.1.6.6 Where the width of the channel permits or where the surface is covered by ice, the width should be measured by a steel tape, by a suitably marked wire or by other direct means, care being taken to apply the necessary corrections (see ISO 748).

6.1.6.7 Where direct measurement is not possible the width may be determined by tacheometry, by electronic distance measuring, or by any other suitable surveying method.

6.1.6.8 The estimated uncertainty in the measurement of width shall not exceed 0,5 % of the true value.

6.1.6.9 The distance between successive cross-sections used for the measurement of velocity by floats shall be determined by methods similar to those described above and to a similar degree of accuracy.

6.1.6.10 The bed profile of the channel shall be carefully determined along the line of each cross-section preferably when the flow is at low stage (see ISO 748 and ISO 3454).

6.1.6.11 At least two level readings, or soundings by rod or line, shall be taken at each point and the mean value adopted, unless the differences between the two values is more than 5 % (by reference to the lower of the two) or 10 mm (whichever is the greater) in which case a third reading shall be taken.

6.1.6.12 Where an echo sounder is used, it should be regularly and frequently calibrated under the same conditions of water salinity and temperature as those in which it is employed. The bed profile should be determined from the mean of two traverses. Individual depths may be taken from a single reading of the instrument (see ISO 4366).

6.1.6.13 When depths are determined by soundings referred to the water surface, frequent readings of water level should be made on the reference gauge to ensure that all measurements may be corrected to the same plane.

6.1.6.14 Inaccuracies in soundings are most likely to occur due to the conditions below.

a) The departure from the vertical of the sounding rod or line, particularly in deep water. A sounding line may deviate from the vertical owing to the force exerted by the stream on the line itself and on the sounding weight. The amount of deviation (drift) may be minimised by using a fine wire line (2,5 mm diameter or less) and a streamlined weight.

Corrections to the indicated depth should be applied to compensate for such deviation (drift) in accordance with the provisions of ISO 748.

b) The penetration of the bed by the sounding weight or rod. This difficulty may be alleviated by fitting a base plate.

c) The presence of boulders or large stones. The influence of these may be reduced by taking a number of soundings as described above.

d) When a echo sounder is used, the presence of soft deposits may give rise to a double echo. The upper echo will normally give the effective depth but further investigations would be required to determine the cause. This difficulty may be eliminated by using an echo sounder whose operating frequency is 200 kHz or higher.

6.1.6.15 The profile should be determined in accordance with the foregoing to ensure an accuracy within ± 2,5 % throughout the range of depths. An assessment of accuracy should be made at the time of measurement.

6.1.7 Measurement by stationary meter

6.1.7.1 A current meter is used to measure the speed of flow in the channel. The meter is held stationary in the desired position in any vertical by means of a wading rod in the case of shallow channels, or by suspending it from a cable or rod from a bridge, stationary trolley on a cable way, or stationary boat in the case of larger channels. (See ISO 3454 and ISO 4375).

6.1.7.2 The meter used to measure the streamflow may be a rotating element current meter (see ISO 2537), an ultrasonic (acoustic) current meter, an electromagnetic current meter, a pendulum current meter, a pitot tube or any other suitable measuring instrument.

6.1.7.3 The procedure for measuring the width, depth and velocity and for computation of the discharge are described in ISO 748.

6.1.8 Measurement by moving boat

6.1.8.1 A current meter is used to measure the speed of flow in the channel. The meter is suspended from a boat which traverses the channel normal to the streamflow. During the traverse, an echo sounder records the geometry of the cross-section and a continuously operating current meter senses the resultant of the stream and boat velocities. At intervals, the angle between the current meter which aligns itself in a direction parallel to the movement of the water past it, and the preselected path of the boat or the distance to a fixed point on the bank are measured.

The component of the velocity in the direction of the stream at points across the channel is computed from the measured resultant velocity and either the angle of the resultant or the distance of the boat from a fixed point. The discharge is the sum of the products of the stream velocity, depth and distance between observation points.

6.1.8.2 The meter should be a propeller type current meter suspended either from a rod with means of measuring the angle of the meter relative to the boat, or from a cable when the distance of the boat and meter from the fixed point on the bank is measured at intervals. No angle indicator is required if both distance from a fixed point and time of observation are recorded at intervals.

6.1.8.3 The procedure for measuring the width, depth and velocity and computing the discharge are described in ISO 4369.

6.1.9 Measurement by floats

6.1.9.1 The speed of the current is measured by recording the time taken for a float to travel a known distance along the channel. Observations are made using floats at different positions across the channel. The width and depth are measured at the same time in shallow channels which may be waded, or at some other convenient time in deeper channels.

6.1.9.2 The floats used may be surface, sub-surface, double or rod floats as described in ISO 748.

6.1.9.3 The procedure for the measurement of the width, depth and velocity, and the computation of discharge is described in ISO 748.

6.2 Dilution gauging methods

6.2.1 Principle of method of measurement

A tracer liquid is injected into a stream and at a point further downstream, where turbulence has mixed the tracer uniformly throughout the cross-section, the water is sampled. The change in concentration between the solution injected and the water at the sampling station is a measure of the discharge.

The tracer may be injected gradually (constant rate method) or suddenly (gulp, pulse or integration method), and may be chemical, radioactive or a fluorescent dye. The procedure is described in ISO 555, Parts 1 and 2.

6.2.2 Preliminary survey

A preliminary survey shall be carried out to determine the hydraulic and mixing characteristics of the site, paying due regard to the need to establish a stable stage-discharge relation, and the requirement of obtaining a satisfactory measuring reach necessary to obtain good mixing of the chemical or tracer.

6.2.3 Selection of site

6.2.3.1 The site selected should be such that it is possible to measure the whole range and all types of flow which may be encountered or which it is required to measure. Great care is required to make a satisfactory choice of a site suitable for the measurement of discharge by the dilution method.

6.2.3.2 There shall be no loss or gain of water in the measuring reach (for example by a tributary joining or a distributory leaving the main flow, or overflow from or to the banks of the stream). Its length shall be such that, allowing for the natural mixing action of the stream, the solution injected at its beginning is uniformly diluted throughout the sampling cross-section.

6.2.3.3 In addition to the requirements of 6.2.3.2, it is desirable that the distance between the injection and sampling sections be as short as possible. This reduces the time required to obtain a measurement and decreases the quantity of tracer needed.

6.2.3.4 To comply with the requirements of 6.2.3.2 and 6.2.3.3, a reach should be chosen in which the river is as narrow and as turbulent as possible, free of dead water zones, with numerous transverse currents to promote lateral mixing. Grassy and vegetation-grown zones, as well as separation zones of the river into arms, should be avoided. Mixing may be improved by disturbances such as bends, narrows, shelves, falls etc. Very wide channels should be avoided, and reaches where the stream divides into a number of branches should not be used.

6.2.3.5 When examining a potential measuring reach, it is advisable to make preliminary tests to ensure that efficient mixing in the river will be achieved, to choose the injection and sampling cross-sections, and, once these have been chosen, to determine the duration of the injection period. In most cases the sampling cross-section will be chosen for the water level recorder.

6.2.3.6 For determination of length of measuring reach, a concentrated solution of the dye fluorescein may be injected for a relatively short time at a point on the potential injection section. Study of the diffusion of the solution will show whether there are any dead zones or similar side tracking of the chemical and be a rough guide on the minimum distance between the injection and sampling cross-sections.

6.2.3.7 For computation of length of measuring reach, a guide to the length of the measuring reach which may be required is given by the following formulae :

a) If the injection rate across the channel is proportional to the flow through the panels forming the section

$$l = 10\, r\, h$$

where

l is the mixing length

r is the ratio of mean velocity to friction or shear velocity

h is the mean depth.

b) If the injection is at a point in the channel

$$l = \frac{0,13\, b^2\, C\, (0,7C + 2\sqrt{g})}{g\, h} \text{ in SI units}$$

where

b is the mean width of wet section in the measuring reach (metres)

h is the mean depth of water in the reach (metres)

C is the Chezy coefficient.

6.2.4 Design and construction

6.2.4.1 The gauging station shall consist of a measuring reach and a reference gauge.

6.2.4.2 In many instances the equipment necessary to make a measurement of discharge will be transported to and from the permanent installation. Details of such equipment necessary for this purpose are given in ISO 555, Parts 1 and 2 to which reference should be made.

6.2.4.3 A station bench mark shall be established to conform to 5.5.4.

6.2.4.4 The reference gauge shall conform to 5.4.2 and to ISO 4373.

6.2.4.5 The design and construction of the stilling well shall conform to 5.4.3 and to ISO 4373.

6.3 Slope area method

6.3.1 Principle of method of measurement

The water surface slope and the mean area of cross-section of the channel are measured in a selected reach which is as straight and uniform as possible. Assuming a coefficient of roughness, the mean velocity is computed using a flow formula relating velocity, roughness, hydraulic mean radius and slope. The discharge is then the product of mean velocity and mean area of cross-section of flow. The method is covered in ISO 1070.

6.3.2 Preliminary survey

A preliminary survey should be made to ensure that the physical and hydraulic features of the proposed site conform to the requirements of ISO 1070.

6.3.3 Selection of site

6.3.3.1 The river should be fairly straight and uniform in section, free from obstructions and vegetation, show no progressive tendency to scour or accrete, and be free of the effect of tributaries.

6.3.3.2 The length of the reach should be such that the difference in water levels is not less than ten times the uncertainty in the difference in water levels.

6.3.3.3 The flow should be contained within defined boundaries.

6.3.4 Survey for a permanent gauging station

6.3.4.1 After the preliminary survey, a topographical survey should be made when selecting a permanent site. This should include a plan of the site indicating the width of the water surface at a stated stage, the edges of the natural banks of the channel, the line of any definite discontinuity of the slope of these banks and the toe and crest of any artificial flood bank.

6.3.4.2 All obstructions in the channel or floodway should be indicated.

6.3.4.3 A longitudinal section of the channel should be drawn from a point downstream of a control, where this exists, to the upstream limit of the reach showing the level of the deepest part of the bed and water surface gradients at low and high stages.

6.3.4.4 The reach containing the measuring section should be checked to ensure that it contains no discontinuities that may affect the measuring results. At least five cross-sections should be surveyed in the measuring reach, two cross-sections upstream from the measuring section and two downstream, at distances upstream and downstream of not less than one bank-full width of the channel.

6.3.4.5 The detailed survey of the reach should be extended through the floodway to an elevation well above the highest anticipated flood level. The spacing of levels or soundings should be close enough to reveal any abrupt change in the contour of the channel.

6.3.4.6 The bed of the reach should be examined carefully for the presence of rocks or boulders, particularly in the vicinity of the measuring section.

6.3.5 Design and construction

6.3.5.1 The gauging station shall consist of a natural or artificial measuring section and two reference gauges.

6.3.5.2 The positions of the cross-sections shall be marked on the banks and the sections surveyed at intervals, and before and after floods.

6.3.5.3 The loss of water from the main channel by spillage can often be avoided by constructing flood banks to confine the flow in a defined floodway.

6.3.5.4 Minor irregularities in the bank or bed causing local eddies may be eliminated by trimming the bank to a regular line and a stable slope, and by removing from the bed any large stones or boulders.

6.3.5.5 Where not already existing a suitable access to the site should be constructed, where possible, to provide safe passage at all stages of flow and in all weathers for personnel and for any vehicles used for the conveyance of instruments and equipment.

6.3.5.6 All key points at the site should be permanently marked on the ground by markers sunk to such a depth below the surface as will ensure them against movement. Cross-section markers should be set on the line of the cross-section to facilitate the repetition of levels or soundings when the section is checked.

6.3.6 Definitive survey

6.3.6.1 After the gauging station has been constructed a definitive survey should be made.

6.3.6.2 The gauges should be precisely levelled and the levels related to a common datum.

6.3.6.3 The distance between the gauges should be accurately measured.

7 Station for the measurement of discharge : regular measurements

The methods which follow are most suitable for relatively frequent measurements often made over a relatively long period.

7.1 Stage-discharge station

7.1.1 Principle of method of measurement

In a stable channel with satisfactory downstream control of water level there may be a unique relation between stage and discharge. In such channels it is more economic to establish the relation between stage and discharge and thereafter to deduce the discharge from measurements of stage only. The station may be calibrated by the velocity area method using a stationary current meter (ISO 748), moving boat (ISO 4369), floats (ISO 748), or by dilution gauging methods (ISO 555, Parts 1 and 2).

7.1.2 Preliminary survey

7.1.2.1 A preliminary survey should be made to ensure that the physical and hydraulic features of the proposed site conform to the requirements for the method selected to measure discharge for the calibration of the station.

7.1.2.2 The survey should establish that the proposed site is in a stable stretch of river and free from standing waves at high flow, weed growth and adverse ice conditions.

7.1.3 Selection of site

7.1.3.1 The site selected should be such that it is possible to measure the whole range and all types of flow which may be encountered or which it is required to measure. The whole range of measurement may be referred to one reference gauge, or certain ranges of discharge may be referred to different gauges. Different methods of calibration may be employed for separate parts of the range, the particular conditions relative to each of the methods of calibration being specified in the relevant International Standard for the measurement of liquid flow in open channels (see clause 2).

7.1.3.2 The operation of a station depends upon the assumption that the elevation of the free surface for practical purposes is a unique function of the discharge. In the case of stations affected by hysteresis, the rise and fall should be calibrated separately by discharge measurement.

7.1.3.3 It is desirable to select a site where the relationship between stage and discharge is substantially consistent and stable, there should not be any variable backwater effect and the channel itself should be stable. However, this may not be possible on all alluvial rivers. For such rivers, the stage-discharge relation is generally applicable only for the period for which it has been determined.

7.1.3.4 The site should be sensitive, such that a significant change in discharge, even for the lowest discharges, should be accompanied by a significant change in stage. Small errors in stage readings during calibration at a non-sensitive station can result in large errors in the discharges indicated by the stage-discharge relation.

7.1.3.5 A comparison should be made between the change in discharge and the corresponding minimum change in stage to ensure that the sensitivity of the station is sufficient for the purpose for which the measurements are required.

7.1.3.6 Sites where weed growth is prevalent should be avoided if possible.

7.1.3.7 There should be no vortices, dead water or other abnormalities in flow.

7.1.3.8 Sites where poor ice conditions are prevalent should be avoided if possible.

7.1.3.9 Access to the site should be feasible under most conditions.

7.1.4 Survey for a permanent gauging station

7.1.4.1 After the preliminary survey, a topographical survey should be made when selecting a permanent site for a suitable measuring section. This should include a plan of the site indicating the width of the water surface at a stated stage, the edges of the natural banks of the channel(s), the line of any definite discontinuity of the slope of these banks and the toe and crest of any artificial flood bank.

7.1.4.2 All obstructions in the channel or floodway should be indicated.

7.1.4.3 A longitudinal section of the channel should be drawn from a point downstream of a control, where this exists to the upstream limit of the reach showing the level of the deepest part of the bed and water surface gradients at low and high stages.

7.1.4.4 The reach containing the measuring section should be checked to ensure that it contains no discontinuities that may affect the measurement results. At least five cross-sections should be surveyed in the measuring reach; two cross-sections upstream from the measuring section and two downstream, at distances upstream and downstream of not less than one bankfull width of the channel.

7.1.4.5 The control should be defined by one or more cross-sections or by a close grid of levels over the area.

7.1.4.6 The detailed survey of the reach should be extended to an elevation well above the highest anticipated flood level. The spacing of levels or soundings should be close enough to reveal any abrupt change in the contour of the channel.

7.1.4.7 The bed of the reach should be examined carefully for the presence of rocks or boulders, particularly in the vicinity of the measuring section.

7.1.4.8 When the station is to be calibrated using current meters to measure velocities, exploratory measurements of velocities should be made in the proposed measuring section and in the cross-section immediately upstream and downstream. When possible, the method of velocity distribution described in ISO 748 should be used for these measurements to determine the feasibility of using reduced point methods.

7.1.4.9 When floats are to be used for velocity measurements, trial runs of floats should be closely spread across the width of the channel.

7.1.4.10 When dilution techniques are to be used to calibrate the station, trial measurements should be made to check the efficiency of mixing (ISO 555, Parts 1 and 2).

7.1.4.11 These velocity measurements described in 7.1.4.8, 7.1.4.9 and 7.1.4.10 should be repeated at more than one stage to ensure that any abnormality of flow is detected.

7.1.5 Design and construction

7.1.5.1 The gauging station shall consist of one or more natural or artificial measuring sections and a reference gauge. Normally a water level recorder is installed to produce a continuous record of stage. It may be desirable to establish gauges at both banks particularly when there is any risk of differential level.

7.1.5.2 The positions of each cross-section should be defined on the banks of the river by clearly visible and readily identifiable permanent markers, and a station bench mark shall be established to conform to 5.5.4.

7.1.5.3 If a control regulates the stage at low discharges at the gauging section, it should be situated at the downstream end of the reach, and any measuring section should be sufficiently remote from it to avoid any distortion of flow which might occur in that vicinity. It should be close enough to ensure that a variable stage-discharge relation will not be introduced through the effect of wind or weed growth in the channel. Higher discharges are most often controlled by the general characteristics of the channel for a considerable distance downstream.

7.1.5.4 The reference gauge and water level recorder should be located as closely as possible to the measuring reach unless floats are used to measure the velocities in which case the reference gauge and water level recorder should be located near the mid-point of the measuring reach.

7.1.5.5 Where the main requirements necessary for a suitable gauging site, as specified, are not present conditions may be improved as described below.

a) The loss of water from the main channel by spillage can often be avoided by constructing flood banks to confine the flow in a defined floodway.

b) Minor irregularities in the bank or bed causing local eddies may be eliminated by trimming the bank to a regular line and a stable slope and by removing from the bed any large stones or boulders.

c) Unstable banks should be protected wherever possible. Such protections should extend upstream and downstream of a measuring section for a distance equal to at least one quarter of the bankfull width of the channel in each direction. In the case of float gauging the whole of the measuring reach should be protected.

d) Instability of the bed may sometimes be corrected by introducing an artificial control which may also serve to improve the stage-discharge relation (sensitivity) or to create conditions in the measuring section for instruments to be effectively used. Occasionally, it may be possible to eliminate variable backwater effect by introducing an artificial control. Artificial controls, are, however, not practicable in large alluvial rivers.

NOTE — An artificial control is a simple structure built in a channel for the reasons given in 7.1.5.5 d). It may be a low dam or a contraction which is seldom designed to function as a control throughout the entire range of stage. Such artificial control structure should be designed in accordance with the conditions at the site where it is to be built. In the design of controls the following major points should be considered :

a) the shape of the structure should permit the passage of water with minimum disturbance of the flow regime upstream or downstream of the control;

b) in order to provide adequate sensitivity, the profile of the crest of a control should be designed so that a small change in discharge at low stages will cause a measurable change in stage;

c) the control should have structural stability and be permanent;

d) if any alterations are made to the natural conditions, the subsequent re-establishment of stability may take some time;

e) care should be taken to monitor the stability effect of a control by periodic surveys.

7.1.5.6 Where not already existing, a suitable access to the site should be constructed, where possible, to provide safe passage at all stages of flow and in all weathers for personnel and for any vehicles used for the conveyance of instruments and equipment.

7.1.5.7 All key points at the site should be permanently marked on the ground by markers sunk to such a depth below the surface as will secure them against movement. Cross-section markers should be set on the line of the cross-section to facilitate the repetition of levels or soundings when the section is checked.

7.1.5.8 The reference gauge shall conform to 5.4.2 and to ISO 4373.

7.1.5.9 The stilling well shall conform to 5.4.3 and to ISO 4373.

7.1.5.10 The water level recorder shall conform to 5.4.4 and to ISO 4373.

7.1.6 Definitive survey

7.1.6.1 The definitive survey, repeated as required at not more than annual intervals, should include the accurate determination of the elevations and the relative positions of all the station installations and any other key point or significant features of the site. It is desirable to correlate the elevation with the National Survey datum through the station bench mark.

7.1.6.2 Bed profiles should be checked after a flood.

7.1.7 Operation of station

7.1.7.1 The production of a satisfactory record depends on the station being maintained in full operating order at all times. This requires efficient attendance on the recorder and proper maintenance of the station, its equipment and its calibration.

7.1.7.2 Where a station is only fitted with a reference gauge or reference gauges (vertical, inclined, wire weight or hook) and no water level recorder, the local observer should be required to furnish readings at specified intervals of all the gauges in his care. Preferably the readings should be made at fixed hours. The intervals between the readings should be determined by the rate at which the water level at the site usually changes, but arrangements should be made to have additional readings when the water level is changing more abruptly than usual.

It is essential that the gauge observer records the exact time of each gauge observation.

7.1.7.3 When a recorder is provided, visits by the observer may be made throughout the period to verify that the recorder is operating satisfactorily. The observer should be required to record observations of the water level by the reference gauge and also the exact time for comparison with the recorder clock. To relate the readings to a chart trace, the observer may mark the chart by slightly raising or lowering the float wire in the case of a float-operated recorder. At all stations, the observer should record any obstruction of the channel, for example, by weeds or ice, should note any casual obstruction of the channel, inlet pipe(s), measuring structure or transducer mountings by flood debris or from any other cause and keep the site and equipment generally clean and tidy, paying particular attention to legibility of the reference gauge. The observer may be required to despatch all records, tapes or charts to the record office for processing immediately they have been completed together with any relevant notes or observations.

7.1.7.4 Every gauging station should be inspected whenever any incident which might affect its accuracy is notified by the observer.

7.1.7.5 All recorders and recorder clocks should be cleaned and lubricated in accordance with manufacturers' instructions or as indicated by experience under prevailing operating conditions.

7.1.7.6 The elevation of all key points (including particularly the zero of the reference gauge) which were surveyed in the definitive survey (see 7.1.6) should be checked by reference to the station bench mark at least annually or following any flood when equipment might have been damaged by debris or by ice. At the same time any vertical gauge should be tested for verticality. Where feasible the correlation of the station bench mark with the National Survey datum should be checked at intervals of not greater than five years.

7.2 Slope-stage-discharge or fall-discharge

7.2.1 Principle of method of measurement

In a stable channel with a varying downstream control of water level when there is no unique relation between stage and discharge, there may be a relation between the water surface slope, stage and discharge. In such channels it is economic to measure both water surface slope and water level from which the discharge is deduced. The station may be calibrated using a stationary current meter (see ISO 748), moving boat (see ISO 4369), floats (see ISO 748), or by dilution gauging methods (see ISO 555, Parts 1 and 2).

7.2.2 Preliminary survey

See 7.1.2 stage-discharge station.

7.2.3 Selection of site

7.2.3.1 The site selected should be such that it is possible to measure the whole range and all types of flow which may be encountered or which it is required to measure. Different methods of calibration may be employed for separate parts of the range, the particular conditions relative to each of the methods of calibration being specified in the relevant International Standard for the measurement of liquid flow in open channels (see clause 2).

7.2.3.2 At any gauging station with twin gauges, the site should be sensitive such that a significant change in discharge, even for the lowest discharges, should be accompanied by a significant change in fall between the two gauges. Small errors in stage reading during calibration at a non-sensitive station can result in large errors in the discharge indicated by the slope-stage-discharge relation.

7.2.3.3 A comparison should be made between the change in discharge and the corresponding minimum change in stage to ensure that the sensitivity of the station is sufficient for the purpose for which the measurements are required.

7.2.3.4 Sites where weed growth is prevalent should be avoided if possible.

7.2.3.5 There should be no vortices, dead water or other abnormalities in flow.

7.2.3.6 Sites where poor ice conditions are prevalent should be avoided if possible.

7.2.3.7 Access to the site should be feasible under most conditions.

7.2.4 Survey for a permanent gauging station

See 7.1.4, stage-discharge station.

7.2.5 Design and construction

7.2.5.1 The gauging station shall consist of one or more natural or artificial measuring sections and two water level gauges one of which is the reference gauge. Water level recorders may be installed to produce a continuous or an intermittent record of stage.

7.2.5.2 The positions of each cross-section should be defined on the banks of the river by clearly visible and readily identifiable permanent markers and a station bench mark shall be established to conform to 5.5.4. It may be desirable to establish gauges at both banks particularly when there is any risk of differential level.

7.2.5.3 The length of the reach should be sufficient to make any observational error negligible relative to the fall of level between the two gauges. Further, there should be no additions to, or withdrawals from, the flow between the two gauges.

7.2.5.4 If a control regulates the stage at low discharges at the gauging sections, it should be situated at the downstream end of the reach, and any measuring section should be sufficiently remote from it to avoid any distortion of flow which might occur in that vicinity. It should be close enough to ensure that a variable stage-discharge relation will not be introduced through the effect of wind or weed growth in the channel. Higher discharges are most often controlled by the general characteristics of the channel for a considerable distance downstream.

7.2.5.5 The reference gauge and water level recorder should be located as closely as possible to the measuring reach unless floats are used to measure the velocities in which case the reference gauges and water level recorder should be located near the mid-point of the measuring reach.

7.2.5.6 Where the main requirements necessary for a suitable gauging site, as specified, are not present conditions may be improved as described in 7.1.5.5.

7.2.5.7 Where not already existing, a suitable access to the site should be constructed, where possible, to provide safe passage at all stages of flow and in all weathers for personnel and for any vehicles used for the conveyance of instruments and equipment.

7.2.5.8 All key points at the site should be permanently marked on the ground by markers sunk to such a depth below the surface as will secure them against movement. Cross-section markers should be set on the line of the cross-section to facilitate the repetition of levels or soundings when the section is checked.

7.2.5.9 The reference gauge shall conform to 5.4.2 and to ISO 4373.

7.2.5.10 The stilling wells shall conform to 5.4.3 and to ISO 4373.

7.2.5.11 The water level recorders shall conform to 5.4.4 and to ISO 4373.

7.2.6 Definitive survey

7.2.6.1 The definitive survey, repeated as required at not less than annual intervals, should include the accurate determination of the elevations and the relative positions of all the station installations and any other key point or significant features of the site. It is desirable to correlate the elevations with the National Survey datum through the station bench mark.

7.2.6.2 Bed profiles should be checked after a flood.

7.2.7 Operation of station

See 7.1.7, stage-discharge station.

7.3 Notches weirs and flumes

7.3.1 Principle of method of measurement

The principle of the method of measurement is to establish a relation between head and discharge usually in the laboratory and to apply this relation to the field installation. A measurement of head only is therefore required at the gauging station and this value inserted in the appropriate formula to obtain a value of discharge.

The particular formula and conditions of application governing each measuring structure are specified in the relevant International Standards given in clause 2. Wherever possible the laboratory calibration should be verified in the field.

7.3.2 Preliminary survey

A preliminary survey shall be made of the physical and hydraulic features of the proposed site to check that it conforms (or may be constructed or modified so as to conform) to the requirements necessary for measurement of discharge by the structure as specified in the relevant International Standards given in clause 2.

7.3.3 Selection of site

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

a) the adequacy of the length of channel of regular cross-section available (see 7.3.3.5);

b) the uniformity of the existing velocity distribution;

c) the avoidance of a steep channel (Froude number should not exceed about 0,5);

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, including seasonal weed growth) 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 means of controlling seepage;

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;

j) uniformity of section of the approach channel.

7.3.3.2 If the site does not possess the characteristics necessary for satisfactory measurements, or if an inspection of the stream shows that the velocity distribution in the approach channel deviates appreciably from uniformity, the site may have to be rejected unless suitable improvements are practicable. Alternatively, the performance of the installation should be checked by independent flow measurement.

7.3.3.3 The flow conditions downstream of the structure are important in that they control the tail water level which may influence its operation. The structure shall be so designed that it cannot become drowned under the operating conditions specified in the relevant International Standards. Construction of a measuring structure in a river or stream may alter conditions and cause scouring downstream of the structure.

7.3.3.4 If the flow in the approach channel is disturbed by irregularities in the boundary, for example, large boulders or rock outcrop, or by a bend, sluice gate or other feature which causes asymmetry of discharge across the channel, the accuracy of gauging may be affected. The flow in the approach channel should have a symmetrical velocity distribution and this can most readily be ensured by providing a long straight approach channel of uniform cross-section.

7.3.3.5 A length of approach channel five times the water surface width at maximum flow will usually suffice, provided flow does not enter the approach channel with high velocity via a sharp bend or angled sluice gate.

7.3.3.6 Conditions in the approach channel can be verified by inspection or measurement for which several methods are available such as floats, velocity rods, or concentrations of dye, 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.

7.3.4 Design and construction

7.3.4.1 The gauging station shall consist of an approach channel, a measuring structure including its associated upstream gauges, a downstream channel and a reference gauge. Normally a water level recorder is installed to produce a continuous record of head.

7.3.4.2 The structure shall be rigid and watertight and capable of withstanding flood flow conditions without damage from outflanking or from downstream erosion. The axis shall be in line with the direction of flow of the upstream channel, and the geometry shall conform to the dimensions, given in the relevant International Standards (see clause 2).

7.3.4.3 The surfaces of the flume throat and the immediate approach channel shall be good : they may be constructed in concrete with a smooth cement finish or surfaced with a smooth non-corrodible material. In laboratory installations, the finish shall be equivalent to rolled sheet metal or planed, sanded and painted timber.

7.3.4.4 Vertical side walls to effect a contraction in plan shall be symmetrically disposed with respect to the centre line of the