INTERNATIONAL STANDARD

ISO 9213

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Measurement of total discharge in open channels — Electromagnetic method using a full-channel-width coil

Mesurage du débit total dans les canaux découverts — Méthode électromagnétique à l'aide d'une bobine d'induction couvrant toute la largeur du chenal

Reference number
ISO 9213:1992(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established 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. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 9213 was prepared by Technical Committee ISO/TC 113, *Measurement of liquid flow in open channels*, Sub-Committee SC 1, *Velocity area methods*.

This first edition of ISO 9213 cancels and replaces ISO/TR 9213:1988, of which it constitutes a technical revision.

Annexes A, B, C and D of this International Standard are for information only.

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Measurement of total discharge in open channels — Electromagnetic method using a full-channel-width coil

1 Scope

This International Standard specifies procedures for the establishment and operation of a gauging station, equipped with an electromagnetic flow-meter, in an open channel or a closed conduit with a free water surface.

The field of application is limited to sites where the magnetic field is generated by an electromagnetic coil which traverses the full channel width.

This International Standard does not apply to flowmeters which operate by using the Earth's magnetic field.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 748:1979, *Liquid flow measurement in open channels — Velocity-area methods.*

ISO 772:1988, *Liquid flow measurement in open channels — Vocabulary and symbols.*

ISO 5168:—[1], *Measurement of fluid flow — Evaluation of uncertainties.*

ISO 1100-2:1982, *Liquid flow measurement in open channels — Part 2: Determination of the stage-discharge relation.*

ISO 7066-1:1989, *Assessment of uncertainty in the calibration and use of flow measurement devices — Part 1: Linear calibration relationships.*

IEC 68-1:1988, *Environmental testing, Part 1: General and guidance.*

IEC 68-2-28:1990, *Environmental testing, Part 2: Tests — Guidance for clamp heat tests.*

IEC 801-3:1984, *Electromagnetic compatibility for industrial-process measurement and control equipment, Part 3: Radiated electromagnetic field requirements.*

IEC 801-4:1988, *Electromagnetic compatibility for industrial process measurement and control equipment, Part 4: Electric fast transient/burst requirements.*

3 Definitions

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

4 Principles of operation

4.1 The electromagnetic gauge operates on a principle similar to that of an electric dynamo. If a length of conductor moves through a magnetic field, a voltage is generated between the ends of the conductor. In the electromagnetic gauge, a vertical magnetic field is generated by means of an insulated coil which is located either above or beneath the channel. The conductor is formed by the water which moves through the magnetic field; the ends of the conductor are represented by the channel walls or river banks. The very small voltage generated is sensed by electrodes on the channel banks, and these are connected to the input of a sensitive voltage measuring device. The faster the velocities, the greater is the voltage which is generated.

1) To be published. (Revision of ISO 5168:1978)

4.2 The basic physical relationship between the variables is:

$$V = vbB \qquad \dots (1)$$

where

- V is the voltage generated, in volts;
- v is the average velocity of the conductor, in metres per second;
- b is the length of the conductor, in metres, and is equal to the width of the channel;
- B is the magnetic flux density, in teslas[2].

4.3 In the case of an operational gauge having an insulated bed and a square coil just wider than the channel, the voltage generated is approximately 0,8 times that given by equation (1). This reduction in voltage is caused by the shorting effect of the water upstream and downstream of the magnetic field.

Numerically, the empirical relationship (± 3 %) is:

$$\varphi \approx vbH \qquad \dots (2)$$

where

- φ is the electrode potential, in microvolts;
- v is the average water velocity, in metres per second;
- b is the channel width, in metres;
- H is the average magnetic field strength, in amperes per metre.

NOTE 1 The physical relationship between B and H in free space, air or water is given numerically by:

$$B = H \times 4\pi \times 10^{-7}$$

where B and H are in different units.

4.4 In the case of an operational gauge having a non-insulated bed, the voltage generated is reduced by the shorting effect of the bed. The signal is reduced in proportion to the ratio of the bed to water conductivity. The higher the water conductivity, the less the reduction. The reduction should not be allowed to exceed a factor of 10, because the signal levels may be too low to be measured accurately and the reduction factor too variable to be determined with confidence. For water of high electrical conductivity (i.e. greater than 500 µS/m) (e.g. raw sewage flowing in a concrete or brick channel) the reduction is small, of the order of 10 %. For a natural river, the reduction will be large and variable, governed by the bed and water conductivities, and the voltage generated may be only one-tenth that of a gauge having an insulated bed. The configuration is therefore normally only suitable for special situations.

4.5 For a typical case of an insulated channel having a full-width coil of 500 ampere turns, located beneath the channel, and a water velocity of 1 m/s, the voltage generated will be approximately 500 µV.

It should be noted that this magnetic field decreases with vertical distance from the plane of the coil, in accordance with classic physical principles. The average field across the channel width should be calculated over the entire range of water depths if a theoretical calibration is to be obtained.

4.6 In the ideal case where the magnetic field strength is constant over the entire wetted section, then taking into account equation (2) the discharge, Q, is given by:

$$Q = vbH \qquad \dots (3)$$

and thus

$$Q = \frac{\varphi h}{H} \qquad \dots (4)$$

where h is the depth of water, in metres (see 8.2.6).

In an operational gauge in which the coil is mounted above the channel, the water near the bed will move in a less strong magnetic field relative to that near the surface, and so a non-linear relationship between Q and depth is necessary.

Normally this relationship is expressed by a simple equation of the form

$$Q = (K_1 + h - K_2 h^2)\varphi / H \qquad \dots (5)$$

where K_1 and K_2 are constants.

4.7 The coil may be buried under the channel (see figure 1) or bridged across the channel above the highest water level (see figure 2).

A bridged coil configuration is normally used where the physical presence of the coil is aesthetically acceptable and not subject to vandalism. On wider channels, a bridged coil may, however, be impractical. A buried coil may be impractical to use in existing reinforced concrete channels. The choice of the type of coil will normally be made on a financial basis, as technically the only significant difference between the two types is the way in which the magnetic field varies with depth.

2) 1 T = 1 Wb/m^2.

4.8 The channel cross-section may be rectangular, trapezoidal or circular. However, if there is a large range of depth and only a single coil located either above or beneath the channel, the magnetic field strength at different depths will differ. If this is the case, the contributions to the average generated voltage at various depths will not all have the same constant of proportionality and the average voltage will deviate from the ideal of "$v \times b \times$ constant" in equation (2). If large vertical velocity gradients exist, the spatial integration will be erroneous. For a coil located beneath the bed, the magnetic field will be stronger near the bed than near the water surface.

4.9 The magnitude of the field is proportional to the electric current flowing through the coil. This current will normally remain relatively constant, but owing to ambient temperature fluctuations affecting the resistance of the coil cable, and fluctuations of the mains voltage, it may vary slightly. It is necessary, therefore, to measure the current and to carry out a proportional correction to the flow calculation made.

4.10 Each volume of water flowing in the cross-section will contribute to the electrode voltage, and for an ideal arrangement the voltage will be proportional to the true spatial integration of the velocity across the section. In practice, deviations from the ideal integration are small, which makes the method suitable for sites where the velocity profiles are irregular and variable. The method is suitable, therefore, for sites where there is considerable weed growth, limited variable accretion, upstream bends and large obstructions in the reach.

4.11 With most natural channels the bed will be an electrical conductor and hence will reduce the induced voltage owing to electrical current leakage (see 4.4). It will usually be necessary to line the channel with an electrically insulating impervious membrane to reduce the current leakage to an acceptable level (see figure 1).

4.12 Problems are caused by the Earth's magnetic field, the electrolytic effects of the electrodes in the water and external electrical interference. These may be overcome by reversing at regular intervals the magnetic field produced by the coil. This is achieved by reversing the current. Measurements are taken with the field first in one direction and then in the other.

5 Selection of site

5.1 A site survey should be carried out if necessary as outlined in annex A to measure any external electrical interference (e.g. power cables, radio stations or electric railways). Areas of high electrical interference should be avoided.

5.2 Owing to the high power consumption of the coil, equipment intended to measure flow continuously cannot reasonably be operated from its own power supply.

Where the electrical power supply is derived from an external power source, the system shall be arranged so as to restrict the amount of current passed through the ground. On sites where protective multiple earthing (grounding) is used, i.e. where the neutral line is grounded everywhere power is supplied, special permission to disconnect the neutral-to-ground link on the power supply may have to be requested. The power supply voltage shall be within $\pm$ 20 % of its nominal value.

A 1 kW source of electrical energy should be available for river gauges.

5.3 The site shall afford adequate on-bank working space for handling the membrane and cable during construction, and good access for operation and maintenance.

5.4 Since the magnetic field reduces as distance from the coil increases, it is recommended that the ratio of coil width to the vertical distance between the coil and any water being measured be not less than 2. For narrow deep channels, this may mean that a coil many times wider than the channel is necessary.

5.5 For non-insulated channels the signal attenuation due to bed leakage increases as the width-to-depth ratio increases. In this case, it is recommended that the width-to-depth ratio does not exceed 10. However, for insulated channels, operation with width-to-depth ratios of 200 is possible.

5.6 The site characteristics shall be such that the calibration of the station can be checked by an alternative method.

5.7 Sites shall be selected where there is no spatial variation in water conductivity. Whether or not the channel is insulated, the accuracy of the method will be reduced if the spatial conductivity is not uniform across the section. Gradual variations with time are unimportant provided that the spatial uniformity of the conductivity is maintained. This requirement makes an electromagnetic gauge unsuitable for channels in which fresh water flows over saline water, which often occurs in estuaries. Provided that these requirements are met, the quality of the water will not affect the operation of the gauge. Similarly the conductivity of the water will not affect the operation of a gauge in an insulated channel provided that it exceeds 50 µS/m.

Rapid changes in water quality with time will produce changes in the steady (or slowly changing) voltages between the electrodes. Such changes will bias the amplifier stages of the electronic system.

5.8 In a non-insulated channel the accuracy of measurement is reduced. However, in this situation a preliminary survey shall be carried out to measure the conductivity of the water and bed to estimate the signal reduction before deciding whether the site is suitable (see 4.4 and annex A).

6 Calibration

6.1 After a station has been installed, a rating equation, for example in the form of equation (5), based on the coil configuration and range of stage shall be established and checked by using a current-meter or other method.

6.2 Care shall be taken to ensure that the act of check gauging does not affect the working of the electromagnetic gauge. Any activity in the river should be carried out outside the limits of the coil and insulated section to reduce electrical interference from current-meters and support cables, and to avoid wave action generated by wading and boats.

7 Applications

7.1 The electromagnetic gauge is particularly suited for measuring the flow of untreated domestic effluent and treated effluent discharge into rivers, the flow of potable water in a treatment works and the flow of cooling water in power stations.

7.2 Different versions of the electromagnetic gauge are suitable for measuring flow in rivers, partly-filled pipes or culverts carrying storm water, raw effluent or foul sewage.

The advantages of the method include the following:

a) tolerates weed growth;

b) tolerates entrained air;

c) tolerates temperature stratification;

d) tolerates suspended sediment or floating debris in the water;

e) tolerates deposited sediment or other accretion on the channel bed;

f) tolerates variable backwater;

g) tolerates upstream inflows; however, if the inflow conductivity is significantly different from that of the main channel, there shall be sufficient distance for adequate mixing;

h) can detect a minimum velocity of about 0,001 m/s;

i) tolerates irregular velocity profiles, including skew flow and severe eddy currents in the measurement area;

j) is suitable for gauging very shallow water;

k) inherently integrates the velocity profile over the entire channel cross-section;

l) affords a wide range of stage and discharge measurements;

m) provides adequate quality of measurement;

n) does not constrict the flow;

o) can measure reverse flow.

8 Design and construction

8.1 General

The electromagnetic gauging station should consist of the following elements (see figures 1 and 2):

a) a field coil installed beneath or above the channel;

b) a pair of electrodes, one on each side of the channel;

c) an insulating membrane, normally necessary;

d) an instrumentation unit, including a coil power supply unit;

e) equipment housing;

f) a water level measuring device (see 8.2.6).

8.2 System equipment

8.2.1 Coil

8.2.1.1 The sensitivity of the equipment to the flow is improved by increasing the strength of the field. This is proportional to the number of turns in the coil and also to the current flowing through the coil. The energy required to produce the magnetic field in a coil of a certain size, number of turns and current is inversely proportional to the cross-sectional area of the conductors which make up the coil. It is also proportional to the electrical resistivity of the material used for the conductors. A compromise should be made, therefore, between the capital cost of the cable, electricity running costs and strength of electrical interference, and the resolution required in the determination of flow.

In practice, a coil with a square configuration slightly larger than the channel width and of some 200 to 1 000 ampere turns, should cover most practical situations.

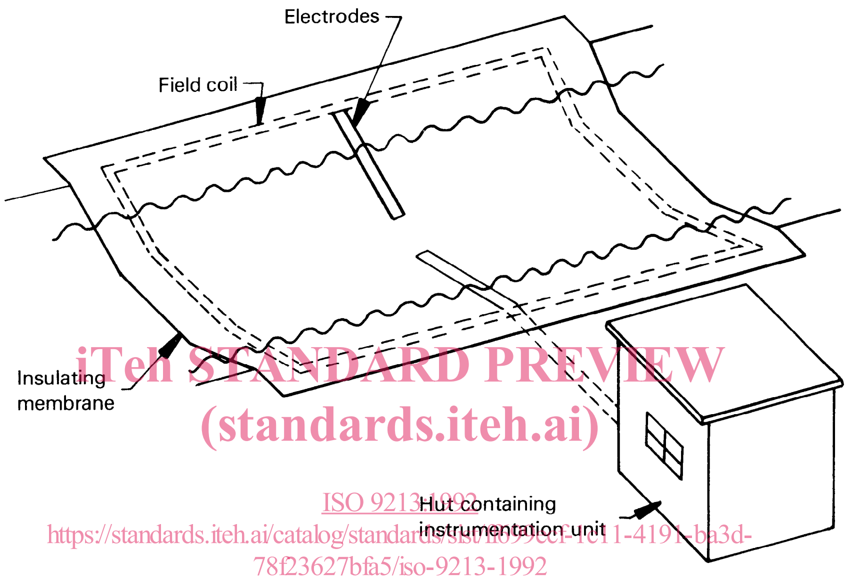

Figure 1 — Buried coil configuration

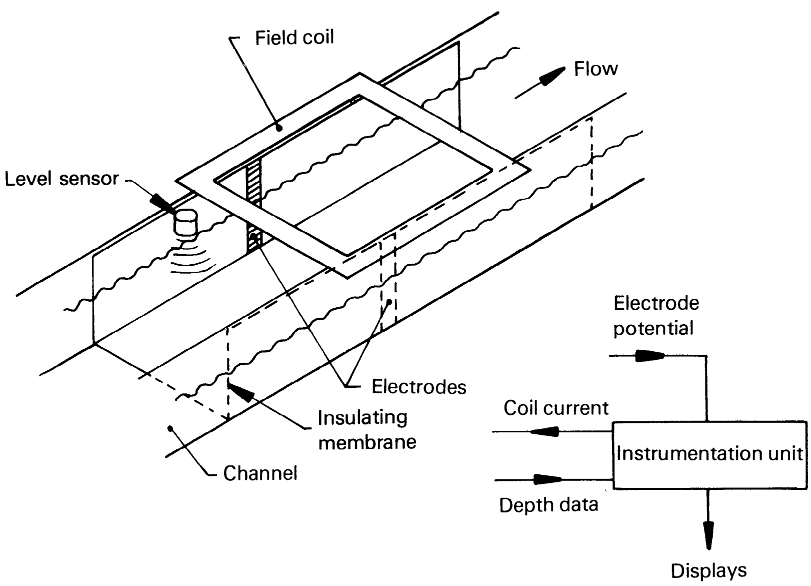

Figure 2 — Bridged coil configuration

8.2.1.2 Any electrical leakage between the coil and the water in the channel will create voltages across the width of the channel. These voltages cannot be separated from those generated by the movement of water through the magnetic field and will produce an apparent offset in the readings of the equipment.

If the coil is located beneath the channel, the use of a polyethylene-insulated cable with a polyethylene outer sleeve is recommended. In all cases, the insulation between the coil and earth (or the water surrounding the coil) shall exceed $5 \times 10^8\ \Omega$.

8.2.1.3 The coil shall be installed in ducting (normally of about 250 mm diameter) to afford access for maintenance of the cable. Construction constraints normally require the coil to be square in plan.

For a bridged coil, a lesser grade of insulation such as poly(vinyl chloride) (PVC) is acceptable. The coil shall span the full width of the river above the maximum stage at which measurements are required. If the coil is likely to be submerged, it shall be able to withstand impact by floating debris. If meaningful measurements are required in this condition, the insulation shall exceed $5 \times 10^8\ \Omega$ when submerged, and no metal shall be in contact with the water.

8.2.1.4 It is recommended that the coil be wound with a multi-core cable (e.g. 12 cores each of 4 mm^2 cross-section, insulated from each other, sheathed overall) to simplify installation. It is recommended that the cable is not armoured with steel, otherwise the field may be partially contained in the armouring. Non-ferrous armouring is permissible, but the armouring shall be insulated from the water to avoid leakage of the induced signal.

8.2.1.5 If the equipment is installed in a potentially explosive atmosphere, the coil shall be of limited power and shall be protected against accidental mechanical damage. For such duty, a typical coil is a 300 turn, 4 mm^2 cross-section copper conductor, with a maximum possible current of 5 A. The coil should be encased in an approved plastic trunking, and surrounded by concrete 50 mm thick. Alternatively, double-insulated conductors wound inside an approved glass-reinforced plastic trunking with an approved junction box may be used.

8.2.1.6 The frequency at which the magnetic field is reversed shall be low enough to permit a stable field to be established, but not so low as to permit polarization effects to become significant. Frequencies of the order of 1/2 or 1 cycle every second (0,5 Hz to 1 Hz) are recommended. The coil current should be either measured or, alternatively, stabilized at a fixed value.

8.2.1.7 A typical coil design is described in annex B.

8.2.2 Electrodes

8.2.2.1 It is recommended that the electrodes be made from stainless steel strip or tube. In clean water rivers, they should be covered by a mechanical filter to reduce varying oxidation potentials generated by wave action of the water. Typically, the width of flat electrodes may be in the range 50 mm to 100 mm. Tubular electrodes should be of the order of 10 mm to 20 mm diameter. The filter may take the form of a perforated plastic tube of 80 mm diameter placed around the electrode.

8.2.2.2 In channels containing foul water which is liable to putrify, the electrode mounting shall not permit such water to become trapped in pockets or crevices near the electrode, and no mechanical filter shall be used.

8.2.2.3 The potential between the electrodes is likely to reach several hundred volts in the event of a lightning strike in the vicinity of the gauge. To protect the instrumentation from such an event a Zener[3)] barrier is essential between the electrodes and the input to the instrumentation (see IEC 801-3 and IEC 801-4).

8.2.2.4 The inductive coupling between the signal cable and the coil shall be a minimum. This can be achieved by the feed from the electrode on the far bank passing in a straight line through the coil centre to bisect the plan area of the coil. An alternative arrangement is to take two signal cables from the far bank electrode: one cable passes through the same ducting as the upstream coil cable and the second electrode cable passes through the downstream coil ducting. The signals from these two cables are added together using a resistance network. Ducting for the electrode cables either shall cross the channel beneath the insulating membrane (if used) or shall be bridged across the channel.

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3) A Zener barrier is a voltage- and current-limiting circuit which protects against high voltage inputs from lightning strikes. It also reduces the risk of hazardous voltages being presented to the electrodes by faulty electronic equipment.

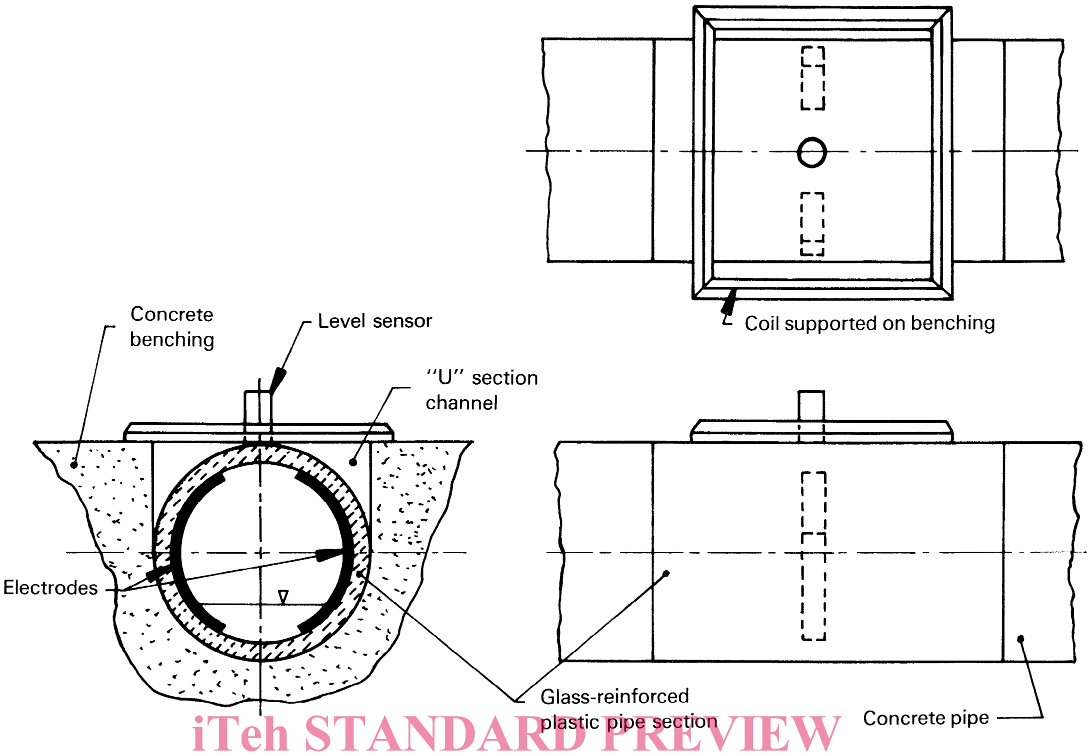

Figure 3 — Coil configuration for partially filled pipes

8.2.2.5 In open channels the electrodes should be supported in guides mounted on the walls or banks on either side of the channel. Such mountings shall extend throughout the full depth of flow. The guides may consist of slotted plastic rods for flat electrodes or perforated plastic tubing for tubular electrodes. Alternatively the electrodes may be moulded into glass-reinforced plastic units, with only one face of the metal electrode exposed. The guides shall be secured to the channel walls or banks, but the membrane shall not be punctured (except as specified in 8.2.3.4) (see figure 1).

In closed conduits the electrodes shall be installed as part of the preformed pipe section (see 8.2.3.6 and figure 3).

8.2.3 Insulating membrane

8.2.3.1 If the channel is to be lined, an insulating membrane shall be used which is tough enough to withstand the stresses involved. A high density polyethylene sheet 2 mm or 3 mm thick, or equivalent material, is recommended. The resistivity of the material shall be greater than 10^{12} $\Omega \cdot m$.

8.2.3.2 The membrane shall be mechanically anchored and sealed at the leading and side edges to protect against local scour and seepage. The lining shall be laid and secured in such a way as to prevent subsequent movement. The bed at the trailing edge shall be protected against damage by local scour.

8.2.3.3 In practice the membrane may be covered by a variety of materials to protect it against damage. Acceptable protection on the river bed is a 100 mm thick layer of concrete (this shall not be reinforced). The banks of the river may be protected by rock-filled non-metallic gabions or, in some instances, a layer of concrete. In a rectangular channel, the membrane may be set behind a vertical wall of concrete or similar material, such as concrete blocks or clay bricks. No metal reinforcement or wire rope shall be used within the insulated reach.

8.2.3.4 The membrane shall not be punctured, except along the edges for anchoring purposes. For this reason the take-off point to a stilling well shall be beyond the limits of the membrane.

8.2.3.5 In a concrete channel the upstream leading edge and sides of the membrane should be battened to the concrete or fixed by similar means. In a river, the edges of the membrane may be anchored by concrete bagging to trap the membrane in a trench.

8.2.3.6 It is recommended that the length of the lining is not less than 1,5 times the channel width at the maximum stage at which measurements are to be made. The lining shall be centred with respect to the coil centre.

In closed conduits a special preformed section shall be inserted in the conduit, as shown in figure 3. The resistivity of the material shall be greater than $10^{12}\ \Omega{\cdot}m$.

8.2.4 Instrumentation unit

8.2.4.1 The instrumentation shall consist of a power supply to drive the coil, a sensitive detector to measure the electrode voltage and other electronic processing units to compute the discharge from the site parameters and water depth. The electronic system detects and measures the required signal in the presence of interference the magnitude of which may be many thousands of times greater. To obtain meaningful determinations of flow, measurements shall be averaged over a period of several minutes.

8.2.4.2 An *in situ* data-logging system may be included with an instrument to record data on one or more of a variety of recording devices.

8.2.4.3 To check the equipment, a digital output display shall give a continuous display of discharge and depth with built-in indicator alarms to detect electronic faults. It shall also be possible to display other fundamental variables, including the electrode potential, coil current and engineering parameters in the instrumentation, such as power supply voltages. Where a non-insulated channel is used, the display shall be capable of indicating the water resistivity and the measured bed resistance.

8.2.4.4 The displays shall have the following resolutions:

electrode voltage:	0,1 µV
coil current:	0,01 A
depth:	1,0 mm

8.2.4.5 A means of altering the averaging period as an aid to checking shall be provided.

8.2.5 Equipment housing

The electronic system shall not be subjected to temperatures outside its design range when in operation. The housing shall be secured against the ingress of corrosive or explosive gases, if these are likely to be present. Ventilation and sufficient working space shall be provided to enable maintenance engineers and field staff to work in the housing for periods of several hours.

8.2.6 Water level gauge to determine h in equation (4) or (5)

A water level measuring device shall be interfaced with the electromagnetic processor.

The equipment datum shall be at the mean level of the insulation at the bottom of the channel, below the level of the bottom of the electrodes. If the insulation is covered with a protective layer of concrete or other non-conducting material, then the datum is the mean level of the top of this covering.

The zero point of the gauge should be at a datum preferably at or below the point of zero flow.

8.3 Measurement of water and bed conductivity

If the equipment is established on a non-insulated channel, regular measurement of water conductivity and bed leakage is required. The ratio between these parameters shall be determined to an uncertainty of within 5 % and the value thus determined used in the flow determination.

8.4 Measurement of coil current and electrode voltage

The uncertainty in the measurement of coil current shall not exceed 1 % of the measured value.

The uncertainty in the measurement of voltage generated by the movement of water in the magnetic field shall be ± 0,5 µV or ± 1 % of the actual value, whichever is greater.

8.5 Measurement interferences

The signals generated by the movement of water through the magnetic field produced by the coil will vary from a few to several hundred microvolts. Typical values by which the signals will be modified by interference from various sources are given in table 1.

Table 1

Source	Interference
Power frequency (50 Hz or 60 Hz)	± 1,5 V between electrodes and ground ± 5 mV between electrodes
Radio frequency	± 40 mV between electrodes and ground ± 5 mV between electrodes
Lightning	± 1 000 V between electrodes and ground ± 300 V between electrodes
Polarization	± 2 V between electrodes and ground ± 1 V between electrodes

The direct current polarization potentials will change with changing water quality. When gauges are being designed for use in foul sewers, polarization changes of 0,01 V/min should be allowed for.

8.6 Flow computation

8.6.1 The equipment shall measure the difference in electrical potential between the electrodes, which is generated by the flow of water, and shall reject the electrical interference. To achieve this, the electronic equipment shall

a) control accurately the switching of the coil;

b) measure the coil current when it is stable;

c) protect the electrode potential measuring circuits against the electrical surges induced in the electrodes and connecting cables when the coil current is reversed;

NOTE 2 This is necessary because the induced signal is large (perhaps equivalent to a potential of 5 000 μV) and cannot be distinguished from the required water-induced signal except by its time of occurrence.

d) measure the polarization potential between the electrodes and provide a bias to the potential measuring circuits so that they can operate within their linear region;

NOTE 3 The polarization potential is large, perhaps 10^6 times the required resolution of the electrode potential.

e) measure the potential between the electrodes (ignoring common-mode potentials between electrodes and ground) and obtain an average over each coil cycle;

f) calculate the component of the average potential between the electrodes which is in phase with the magnetic field;

NOTE 4 This component will be a measure of the signal generated by the flow of water. The calculation should take into account any changes in bias introduced to enable the circuits to operate in their linear range.

g) from the average potential which is generated by the flow of water, calculate flow in accordance with equation (5) (see 4.6).

NOTE 5 H can be calculated from the coil current (which may be a variable) and the dimensions of the coil and the channel.

8.6.2 The electrical interference is regarded as random, and so will in the longer term average to zero. In order to obtain consistent measurements of flow, the data shall be averaged over periods generally between 2 min and 15 min, depending on the degree and frequency of the interference.

8.6.3 The averaging period shall be accurately defined and shall be of limited duration so that comparisons can be made between the flow computed using the electromagnetic technique and that computed using an alternative calibration technique. A moving average technique, updated every 0,5 min and representing flow averaged over 15 min, is recommended for river use.

8.7 Power supply failure

8.7.1 The equipment shall withstand without damage the disconnection or reconnection of any of its major assemblies. In the event of the mains power supply voltage falling temporarily to a low value, no damage shall be sustained.

The equipment shall be capable of withstanding periods of 12 h with no power before dampness causes a temporary deterioration in performance. No permanent damage shall occur for power failures of less than 7 days.

The equipment shall automatically return to correct operation upon restoration of the power source (see IEC 68-1 and IEC 68-2-28).

8.7.2 The mean time between failures of the complete system, comprising the coil drive, electrode potential measurement, depth measurement, display and recording, shall be at least 2 years.

8.8 Operating manual

An operating manual shall be provided detailing the characteristics of the equipment and the equation relating the measured variable to flow. It shall also provide details of check procedures to be carried out at regular intervals and normal site visit checks.

9 Uncertainties in flow measurement

9.1 Calibration graph

Analysis of the uncertainties in the calibration relation shall be carried out as specified in ISO 7066-1 and ISO 1100-2.

Generally for an insulated channel, the random uncertainty at the 95 % confidence level in the value predicted from the calibration relation may be of the order of ± 2 %. The corresponding uncertainty for a non-insulated channel may be much higher, depending on the site and the number of observations