OPERATIONAL MANUAL
FOR
HYDROLOGICAL INSTRUMENTATION

(PR-HWRSD-02)

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NCHM

National Centre for Hydrology and Meteorology

Manual

To Hydrological Instrumentation

(PR-HWRSD-02)

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Preface

Hydrology is the science that studies the occurrence, distribution, movement, and quality of water on Earth. It is an interdisciplinary field that combines knowledge from geology, meteorology, chemistry, biology, and engineering to understand the complex interactions between water, land, and the atmosphere. This hydrology instrumentation manual is designed to provide a comprehensive overview on installation and operation of various hydrological instruments for the National Centre for Hydrology and Meteorology.

The Standards and manuals for hydrological instrumentation have been published by the World Meteorological Organization (WMO) and Indian Standards Organization (ISO). The content in this manual has been adapted from the aforementioned international standard guidelines and manual. This manual consists of three chapters dealing with water level observation instrumentation, discharge observation instrumentation and sediment observation instrumentation.

This Manual has been prepared by the Technical Standard and Research Division. We would like to express our sincere gratitude to the experts who contributed their time, knowledge, and expertise to prepare this manual. We hope that this manual will be a useful resource for Engineers involved in hydrological instrument installation and maintenance.

Content

DEFINITIONS

Automatic Water Level Station (AWLS) – It is a hydrological monitoring site that measures and records the water level or stage of a river, lake, or other water body automatically and continuously. It typically consists of a water lever sensor, a data logger, and a telemetry system.

Acoustic Doppler Current Profiler (ADCP) – A device that uses sound waves to measure water velocity in a river or other water body. ADCPs can be mounted on boats or buoys and can provide detailed information about flow patterns and currents.

Automatic Weather Station (AWS) - A weather monitoring station that collects data on various meteorological parameters, such as temperature, humidity, wind speed and direction, and precipitation. AWSs can provide real-time data on weather conditions, which can be used for hydrological modelling and forecasting.

Aqua Profiler – A hydrological instrument that is used for measuring water velocity and depth in rivers, streams, and other bodies of water. It is a type of acoustic Doppler current profiler (ADCP) that uses sound waves to measure the speed and direction of water flow. An Aqua Profiler can be mounted on a boat or fixed structure such as bridge or pier and can measure water velocity at multiple depths and locations simultaneously.

Bubble Gauge – a device used to measure water depth in a river or stream. The gauge consists of a small tube with a pressure transducer at the bottom and a gas-filled bladder at the top. The pressure transducer measures the pressure of the gas in the bladder, which is proportional to the water depth.

Backwater (BW) — a rise in stage produced by an obstruction in the stream channel caused by ice, weeds, control structure, etc. The difference between the observed stage for a certain discharge and the stage as indicated by the stage-discharge relation for the same? discharge is reported as the backwater at the station

Bank, right or left — the margin of a channel as viewed facing downstream. The expression "right" or "left" applies similarly to structures on the right or left, such as abutments and cableway towers.

Bubble Gauge — a term commonly applied to a water level recording system that uses a gas purge technique.

Cableway System - A cableway system in hydrology is a transportation system that uses a suspended cable or wire rope to transport personnel, equipment, and hydrological instruments across a river, stream, or other water body.

Control — the condition downstream from a gauging station that determines the stage-discharge relation. It may be a stretch of rapids, a weir or other artificial structure. In the absence of such features, the control may be a less obvious condition, such as a convergence of the channel or even simply the resistance to flow through a downstream reach. A shifting control exists where the stage-discharge relation tends to change because of impermanent river bed or banks.

Data Logger – A device used to record data collected from hydrological instruments over time. Data loggers may store data internally or transmit it in real time to a central data management system.

Discharge — it is expressed in terms of volume, with either a stated or implied reference to time. The term "discharge" is herein considered synonymous with "streamflow."

Discharge Measurement — the determination of the discharge at a gauging station on a stream; an observation of no flow is classed as a discharge measurement.

Float Gauge —a manual gauge consisting of a float that rides on the water surface, rising and falling with the surface. The float's movements are transmitted to an indicating device.

Gauge Correction — any correction that must be applied to the gauge observation or gauge reading to obtain the correct gauge height.

Gauge Datum — the permanent horizontal plane to which gauge heights are referred.

Gauge Height — the height of the water surface above the "gauge datum"; it is used interchangeably with the terms "stage" and "water level."

Gauge Observation or Gauge Reading — an actual notation of the height of the water surface as indicated by a gauge; it is the same as a "gauge height" only when the 0.000 mark of the gauge is set at the "gauge datum."

Gauging Station — a location where systematic records of stage or stage and discharge are obtained. This is also referred to as a "hydrometric station”.

Global Positioning System (GPS) – is a satellite-based navigation system that uses a network of satellites in orbit around Earth to determine the location, speed, and time of a GPS receiver on the ground.

Inclined Gauge — a manual gauge made by setting a staff gauge on an incline.

Manual Gauge — a non -recording type of gauge from which observations of stage are obtained.

Marking – It is the process of identifying and recording the position of a water level gauge or other hydrological instruments relative to a known reference point, such as benchmark or a fixed structure.

Painting — this refers to the wide ink trace on water level recorder charts that is caused by short-term water level fluctuations or by a malfunction in a recorder having a gas purge system.

Rain Gauge – A device used to measure the amount of rainfall that falls in a particular location over a given period of time. Rain gauges may be manual or automated, and may use various techniques to measure precipitation, including tipping buckets, weighing mechanisms, or optical sensors.

Reference Gauge — the gauge to which a water stage recorder is set.

Reference Mark — a point of known elevation from which measurements may be made to a water surface. It is also known as a "measuring point."

Sediment – It refers to solid particles that are carried by the water, and deposited in rivers, streams, and other bodies of water.

Shift — a change in the stream control which alters the stage-discharge relationship. This change can be either temporary or permanent.

Slope-area Measurement — a method of computing peak flow at a gauging station by determining the water surface profile and channel dimensions over a short reach of a stream.

Staff Gauge — see "vertical gauge."

Stage — a general term used to describe the height of a water surface and, in a particular application, may be either a gauge height or a water elevation.

Streamflow — the actual flow in a stream. The term "streamflow" is herein considered synonymous with "discharge."

Telemetry System – A communication system used to transmit data from remote hydrological monitoring stations to a central data management system. Telemetry systems may use various communication methods, such as satellite, mobile communication and radio communication.

Total Station – It is a surveying instrument that combines a theodolite, which measures angles horizontally and vertically, with a distance meter that measures distances electronically. Total stations are used in surveying and mapping applications to measure distances, angles, and elevations of points on the Earth's surface.

Vertical Gauge — a manual gauge consisting of a graduated plate or rod which is set vertically in a stream bed or attached to a solid structure. It is also known as a "staff gauge."

Water Quality Sensor - A device used to measure various parameters related to water quality, such as temperature, pH, dissolved oxygen, and turbidity, Water quality sensors may be deployed in rivers, lakes, and other water bodies to monitor water quality over time.

Water Elevation — the height of the water surface referred to standard datum.

Water Level — see "gauge height."

Water Level Recorder — an instrument that records water levels in analog or digital form. The recorder may be actuated by a float or by any one of several pressure systems.

Water Level Sensor – A device used to measure the water level or stage in a river, lake, or other water body. Water level sensors may use a variety of techniques, including pressure sensors, radar, or ultrasonic waves.

Winches - They are commonly used in cableways for hydrological applications to provide tension to the cable, control the speed of the cable car, and to transport personnel and equipment across the river or other water body.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The National Centre for Hydrology and Meteorology (NCHM) is an autonomous scientific and technical organization of the Royal Government of Bhutan responsible for understanding the behaviours of atmosphere, its interaction with cryosphere and water bodies, the weather and climate and distribution of the country's water resources. One of the key mandates of NCHM is to maintain and operate a network of hydrological instruments across the country. These instruments are used to measure water level, discharge and sediment concentration for the river network in Bhutan to understand the hydrological cycle in Bhutan, which is critical for managing water resources, long term planning and disaster management. Given the importance of hydrological information, NCHM places great emphasis on the proper installation and maintenance of hydrological networks.

The hydrological station are broadly divided into the following categories;

a) Principle River Gauging Station- Primary Hydrological Stations operating permanently to furnish data for long term regional hydrologic studies.
b) Secondary River Gauging Station- Hydrological stations established at smaller rivers to take measurement of water level.
c) Automatic Water Level Stations- Automatic water level station recording and transmitting measurement of various hydrological parameters to the central Database.

The national hydrological monitoring network consists of 22 principal river gauging stations, 8 secondary river gauging stations and 45 automatic water level stations located mostly on the north-south running rivers. There are sediment sampling stations that operate in parallel with some of the river gauging stations. The following hydro-meteorological parameters are generally measured depending upon the purpose of observation; a) River water level, b) River discharge, c) Suspended sediment in river.

This Hydrological Instrumentation Manual provides guidance on the selection, installation, operation, and maintenance of hydrological instruments used for water level, discharge and sediment data collection from the field. This helps to ensure that the data collected is accurate and reliable, which is essential for many applications, including water resource management and disaster risk reduction in Bhutan.

1.2 DOCUMENT TITLE

This document is identified as Hydrological Instrumentation Operational Manual, PR-HWRSD-02 prepared and maintained by Technical Standard and Research Division, National Centre for Hydrology and Meteorology.

1.3 RESPONSIBILITY

In preparation of this manual, care has been taken to ensure that the information contained herein is accurate, reliable and complete. However, suggestions for improvements or comments concerning apparent errors or omissions should be forwarded in writing to:

The Director
National Centre for Hydrology and Meteorology
Doeboom Lam, Thimphu
P.O Box: 207

Holders of hard-copies of this Manual are responsible for ensuring that the Manual is kept up to date. This includes inserting new chapters or chapter amendments in a timely manner and complying with any instructions on amendment advice.

1.4 OBJECTIVE

The objective of the hydrological instrumentation manual are:

1) To provide guidance on the proper site selection and instrument installation for water level, discharge and sediment monitoring. This ensures the hydrological data collected with the use of these instruments is accurate, reliable, and consistent.
2) To ensure the instruments are installed and operated safely and effectively, thereby reducing the risk of equipment damage.
3) To provide maintenance and troubleshooting reference materials for the instrumentation official.

1.5 SCOPE

This manual covers the site stations network design including types of station and proper site selection criteria, and instrumentation guidance for various instruments used by NCHM to monitor water level, discharge and sediment.

CHAPTER 2

WATER LEVEL STATION INSTRUMENTATION

2.1 INTRODUCTION

A water level station is the hydrological monitoring site to measure the level of a river or stage of a river. It consists of a gauge which is an instrument that is used to measure the water level, and a data logger, which records the data. The water level data collected from the station site can be used for a variety of purposes, including flood forecasting, water resource management and disaster risk reduction. The water level station in the field is manned by the field staff and the reading for those sites are taken daily at 9:00 AM and 3:00 PM BST.

2.2 GAUGE DATUM

2.3 GAUGE STATION NETWORK DESIGN

2.3.1 Network Design for Water Resources Development

Two types of gauging stations are usually needed in a stream gauging network designed for a regional study of water resources development, namely, hydrologic and special stations.

2.3.1.1 Hydrologic Stations

Hydrologic stations are those established to determine the basic streamflow characteristics of the region. They are established only on streams that have natural flow, or on developed streams whose records can be adjusted, by the use of auxiliary records, for such manmade effects as diversion, storage and import of water.

There are two types of hydrologic stations – principal and secondary:

i) Principal hydrologic stations (also called primary stations) are intended to be operated permanently; in showing time trends they furnish data of importance to regional hydrologic studies;

ii) Secondary hydrologic stations are intended to be operated only long enough to establish the flow characteristics of their watersheds, relative to those of a watershed gauged by a principal, or primary, hydrologic station. The length of time that a secondary hydrologic station is operated is dependent on how well its records correlate with those of a principal station. The better the correlation, the shorter the required period of operation. It should be noted that where full range measuring structures are employed in the network they are generally, by definition and cost, regarded as permanent stations.

2.3.1.2 Special Stations

Special stations are those established to provide specific information at a site for one or more of the following purposes:

i) Inventory the outflow from a basin, either developed or undeveloped, to show the quantity of water potentially available for later development. If the station measures natural flow, it may be operated for a definite time period, the length of which is dependent on the degree of correlation with a principal hydrologic station;
ii) Management and operation of an existing project, A station to be operated during the entire life of the project;
iii) Fulfilment of legal requirements, agreement, or basin compact. A station to be operated during the entire life of the legal requirement;
iv) Design of a proposed project. If the station measures natural flow, it may be operated for a definite term that is dependent on the degree of correlation with a principal hydrologic station.

In designing the network, all types of stations should be considered simultaneously, because both principal and secondary hydrologic stations may often be strategically located to also serve as a special station. For example, a hydrologic station, by virtue of its location, may provide the data for one or more of the special purposes listed above.

2.3.2 Network Design for Flood Frequency Study

Regional flood frequency studies are used for the design of dam spillways, bridges, and culverts, and for the delineation of flood plains. The basic data for such study are records of annual peak discharge at stream sites throughout the region. Peak discharge data will be available for the principal streams at sites in the network of continuous record gauging stations that were established for the study of regional water resources. In addition, such data will usually be available for a number of smaller streams. However, a myriad of small streams is usually found in a region, and because of the high number of such streams, it is not economically feasible to gauge more than a small percentage of them. The network of standard gauging stations should therefore be augmented by a network of relatively inexpensive crest stage gauges to provide more adequate coverage.

Crest stage gauges are sometimes referred to as partial record gauges because they obtain peak flow data only. Other types of gauges, such as low cost pressure transducers and ultrasonic gauges, coupled with inexpensive data loggers, may also be used to expand a data network. The detailed explanation of Flood Frequency network design is given in WMO 144, Clause 2.2.2.

2.3.3 Network Design for Low Flow Frequency Studies

Regional studies of low flow magnitude and frequency are useful in the planning, design, and management of water supply facilities. Low flow data provided by the network of continuous record gauges in a region can be supplemented by establishing a more comprehensive network of low flow partial record sites. These low flow sites should be distributed to measure natural flow streams in the region, including ephemeral, intermittent, and perennial streams. They should include a wide range of drainage, physiographic, and climatological characteristics. A low flow partial record network can be designed in a similar manner to a crest stage gauge network.

A minimum of 8 to 10 low flow discharge measurements spanning a period of 3 to 4 years are recommended at the low flow partial record site. A statistical regression of the corresponding discharges is used to define the low flow magnitude and frequency relation for the partial record low flow site, based on the low flow magnitude and frequency relation at the long term hydrologic station. After sufficient low flow measurements are obtained to define a frequency relation at the low flow site, that site can be discontinued and a new site established on another stream in the region. In this way, low flow magnitude and frequency can be defined for a region at a much reduced cost.

Low flow partial record gauges usually do not require permanent field equipment. They are established for the purpose of making occasional discharge measurements of low flow, and do not require the measurement of stream stage. For this reason, low flow stations are inexpensive to operate and are virtually maintenance free.

2.3.4 Site Selection

Note: Refer PR-HWRSD-01, Clause 2.3.

2.4 CONTROL

The conversion of a record of stage to a record of discharge is made by use of a stage-discharge relation. The physical element or combination of elements that maintains the relation is known as a control.

Additional information about controls can be found in Carter and Davidian (1968), Rantz and others (1982), Manual on Stream Gauging (WMO-No. 519) and Guide on Hydrological Practices (WMO-No. 168), ISO (1983, 1995, 1996, and 1998) and WMO (1044).

2.5 ATTRIBUTES OF A SATISFACTORY CONTROL

If the control is subject to change, the stage-discharge relation is likewise subject to change, and frequent discharge measurements are required for the continual recalibration of the stage-discharge relation.

The two attributes of a satisfactory control are stability and sensitivity. Sensitivity may be defined as an indication of the quickness and extent of response to an increase in discharge by an increase in stage. Generally, a low water control is considered to be sensitive if a change of no more than 2 per cent in discharge is represented by a change of one unit of recorded stage.

Where natural conditions do not provide the stability or the sensitivity required, artificial controls should be built if they are economically feasible.

2.6 INSTRUMENTATION

2.6.1 Direct Water Level System

Non-recording gauges are still in general use as auxiliary and reference gauges at water-stage recorder installations to serve the following purposes:

i) As an auxiliary or reference gauge
ii) As a temporary substitute when the intakes are plugged or there is an equipment failure.

The types of non-recording gauges generally used are staff, wire-weight, chain, float-tape and electric tape. Staff, wire-weight and chain gauges are normally used as reference or auxiliary gauges at recording gauging stations. Float- and electric-tape gauges and the vertical staff gauge are used inside stilling wells. Staff gauges are read directly whereas the other four types are read by measurement from a fixed point to the water.

There are several types of non-recording gauge used by the NMHS across the world such as Staff Gauge, Electric Tape Gauges, Wire-Weight Gauges and Chain Gauges. However, the chapter covers the details of Staff Gauge only as NCHM only uses the staff gauge method.

Figure 1: Staff Gauge

2.6.1.1 Vertical and Inclined Staff Gauge

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

2.6.1.1.1 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.
d) They shall be resistant to wear when exposed to flowing water and the effect of solid matter carried in suspension,

They shall be resistant to alternate drying and wetting and also in respect of the resistance to wear or fading of the markings, and the material shall have low coefficient of expansion with respect to temperature and wetting effect

2.6.1.1.2 Material

The material of which a gauge is constructed should be durable and should have a low coefficient of expansion.

a) Reinforced Cement Concrete

If reinforced cement concrete is used for the manufacture of staff gauges it shall be ensured that the concrete is cast in steel formwork and is well compacted and cured to ensure strength and durability

b) Steel Standard

T-Section or angle section shall be used.

c) Wood

The wood used shall be straight, uniform, and well-seasoned to avoid warping, shrinkage and swelling due to alternate wetting and drying or due to changes of temperature.

d) Paint

A base coat of white enamel should protect the concrete, steel and wood. The paints used for the graduations should be permanent in nature and remain unaffected by water.

2.6.1.1.3 Graduation

Graduations should be clearly and permanently marked. The numerals should be distinct and placed in such a way that there is no possibility of any ambiguity.

a) The graduations shall be marked clearly, either by etching or by painting on the gauge posts or enamelling on steel plates, which are nailed or screwed to gauge post
b) The graduations shall be such as can be read in centimetres, centimetres and metres distinctly
c) The smallest graduation shall correspond to 5 mm
d) Gauge plates shall be manufactured in suitable lengths with the width of scale not less than 50 mm. 6.5

The markings of the subdivisions shall be accurate to 0’5 mm and the cumulative error shall not exceed 0’1 percent or 0’5 mm whichever is greater.

2.6.1.1.4 Installation and use

2.6.1.1.4.1 General

(*a*) The gauge should preferably be placed near the bank so that a direct reading of water level may be made.

(*b*) The gauge should be located as close as possible to the measuring section without affecting the flow conditions at this point.

(*c*) It should be readily and conveniently accessible so that the observer may make readings as near as possible to eye level.

2.6.1.1.4.2 Vertical Gauges

The gauge board or backing plate should be securely fastened to the surface of a wall or to piles having a vertical face parallel to the direction of flow.

2.6.1.1.4.3 Inclined Gauges

An inclined gauge should be installed in such a manner as to follow closely the contour of the river bank and should be calibrated in situ by precise levelling from the station.

2.6.2 Indirect Water Level System

2.6.2.1 Pressure Gauges

2.6.2.1.1 General

The term *bubble gauge* is a general term that refers to various configurations of instrumentation designed to measure the water level on the basis of pressure differentials. A gas such as nitrogen is bubbled through a fixed orifice mounted in the stream and the water pressure at the orifice is transmitted through the gas tube to a pressure sensor located in the gauge house where it is converted to a measurement of stream stage.

2.6.2.1.2 Water Density Compensation

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

2.6.2.1.3 Changes in Gas Weight

If the gas technique is used to transmit pressure, provisions should be made for compensating for changes in the density of the gas with temperature and pressure.

2.6.2.1.4 Range

The range of the instrument should be adequate to accommodate the anticipated range in water level.

2.6.2.1.5 Response

The response of the instrument should be sufficiently rapid to follow any expected rate of change in water level.

2.6.2.1.6 Environmental Requirements

The recorder should operate satisfactorily over the prevailing ranges of ambient temperature and relative humidity.

2.6.2.1.7 Material

All parts of the recorder should be manufactured of materials which will resist corrosion under conditions of field usage.

2.6.2.1.8 Installation

a) The instrument should be installed in the field with the orifice or intake only slightly below the zero-flow stage, or other defined low point-of-use.
b) An adequate supply of gas or compressed air should be provided. The supply should have a delivery pressure in excess of the range to be measured.
c) A pressure - reducing valve should 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 should be installed so that the discharge of gas supplied to the system can be properly adjusted.
d) The pressure should be set to prevent water from entering the tube, even under the most rapid rates of change expected.

Two essential components of a bubble gauge system, in addition to the pressure sensors, are (a) a gas-purge system, and (b) a bubble-gauge orifice. These are described in the following sections.

a) Gas Purge component

The gas-purge system is a critical component of a bubble gas system. It is designed to feed a gas, usually nitrogen, through a system of valves, regulators and tubing to an orifice located at a fixed elevation in the stream. The continuous formation of bubbles at the orifice transmits the pressure head (depth of water over the orifice) caused by the stream stage to the pressure sensor located in the gauge house. The pressure sensor is vented to the atmosphere to compensate for barometric pressure changes.

Figure 2: gas-purge system

b) Bubble-gauge orifices

The gas-purge system bubbles a gas into the stream through an orifice. The standard USGS orifice is mounted in a 300 mm (2-inch) pipe cap so that it can be attached to a 300 mm (2-inch) pipe. The orifice assembly is installed so the orifice remains at a fixed elevation in the stream and the proper placement in the stream is essential for obtaining an accurate record of stage. If possible it should be installed where stream currents are not high and where sediment accumulations are not likely to cover the orifice. If high velocities are expected near the orifice it is recommended that it be installed inside a static tube, which should be a vertical mount perpendicular to the direction of flow. Another option for high velocity situations is the use of an orifice gas chamber. The chamber is a bell-shaped housing with a bottom plate that contains numerous holes. The chamber is attached to the orifice with the plate facing down; this allows the formation of a large bubble of gas. The large bubble stabilizes the line pressure and also can eliminate painting that is sometimes seen at bubble gauges. They are vented to the atmosphere to compensate for barometric pressure changes.

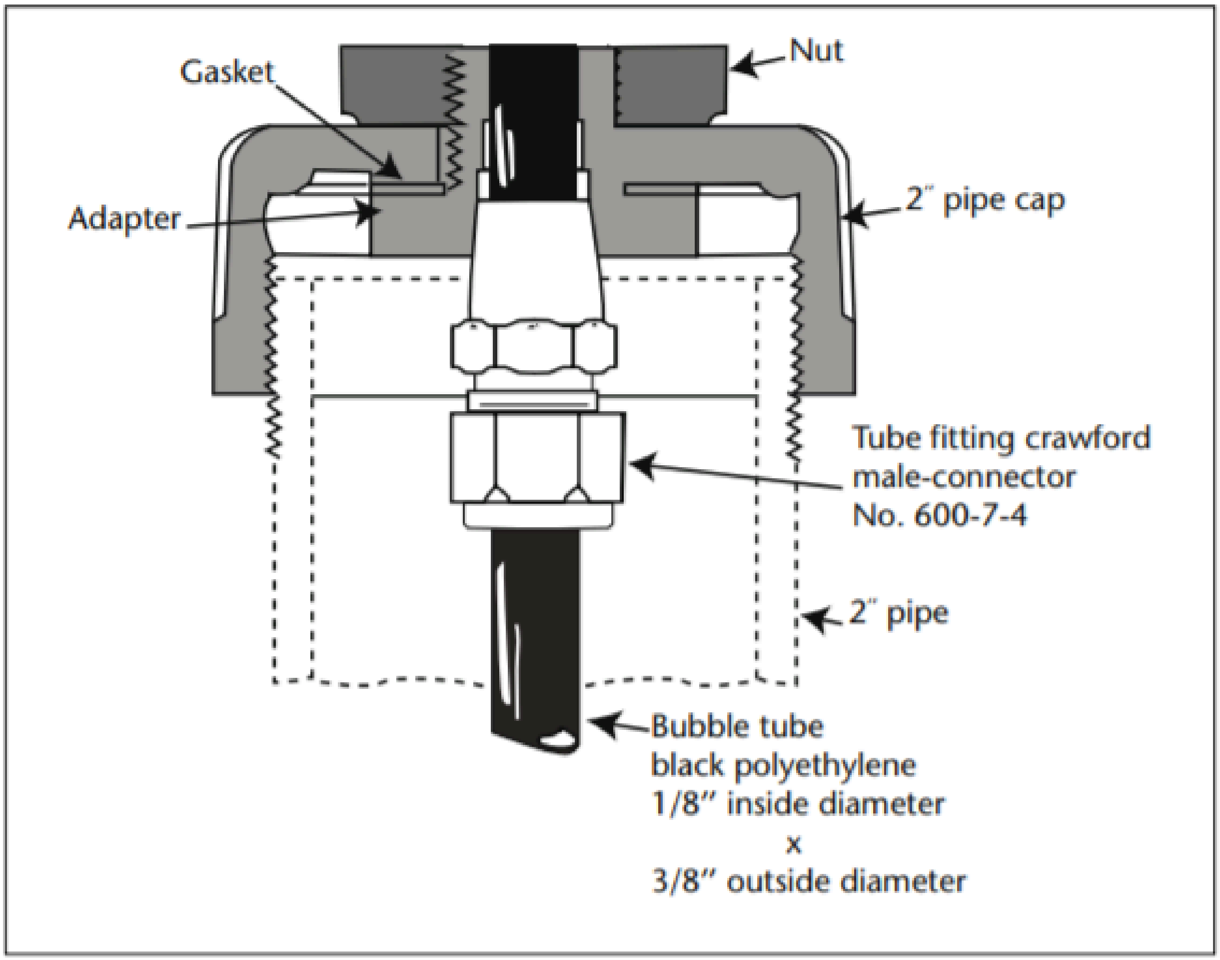


Figure 3: Typical Details of a bubble-orifice assembly

2.6.2.1.9 Transducers

a) Non-submersible/Gas purge pressure transducers

Non-submersible pressure transducers are generally used as the pressure sensor for bubble-gauge systems. These transducers are connected to the gas-purge unit to receive the pressure input from the stream. The transducers are internally programmed to convert the gas pressure to units of water head (Meters of water over the orifice) and to then transmit the data to an Electronic Data Logger (EDL) or Data Collection Platform (DCP). Pressure transducers generally have internal compensation for temperature changes and various other adjustment provisions to compensate for water density variations, purge gas weight, local gravity variations and gauge-datum adjustments.

b) Submersible pressure transducers

A number of submersible pressure transducers are commercially available for use primarily in groundwater wells. However, in some applications they have been used for streams and reservoirs. Submersible pressure transducers are usually self-contained units having a transducer element and electronic circuitry. Some also contain a data logger and battery. These units can be mounted directly in the stream or reservoir. Water level is determined by the difference between hydrostatics pressure and atmospheric pressure. Relative submersible pressure sensors have an integrated vented tube to atmosphere for measuring and compensating for atmospheric pressure. Absolute submersible pressure sensors measure only hydrostatic pressure and atmospheric pressure is measured by additional pressure sensor integrated with an EDL. Temperature variations affect the accuracy of pressure measurement and traditional units do not generally meet the accuracy requirements for primary stage recorders. Currently there are units on the market that have an integrated temperature sensor. Effect of temperature variations is corrected by mathematical calculations in the sensor electronic circuitry and measurement accuracy is substantially better. Submersible units may be damaged or destroyed by freezing temperatures thus they must not be placed in streams or reservoirs that freeze around the sensor.

2.6.2.2 Radar (Non-Contact System)

2.6.2.2.1 General

Radar (radio detecting and ranging), or radio wave transmission, is a distance measuring method. A radio wave is the propagation of an electromagnetic field and, therefore, is performed at the speed of light. The advantages of radar are that the signal is generally immune to weather conditions and the radio wave used for this application is harmless to humans and wildlife. The useable sensor-to-water sensing range is typically from near zero to about 35 m.

2.6.2.2.2 Accuracy Requirements

The instrument operates without a stilling well and should have a typical absolute accuracy ± 3 mm for 15-m to 30-m range sensors.

2.6.2.2.3 Installation

- The instrument shall be mounted in air where it is accessible for maintenance
- The mounting of the instrument must be robust and unable to move so as to ensure the datum of the instrument does not change
- The radar instrument must be level, and
- The radar may be mounted on an arm extending over the flow.

Note: The arm shall be long enough to ensure that the conical beam does not strike channel walls. Alternately, it may be mounted on a bridge span beyond interference from abutments, piers and other structural features.

2.6.3 Recording Instruments

2.6.3.1 General

A water-level recorder is an instrument that automatically records a continuous, or quasi continuous, record of the water-surface stage with respect to time. Water-level recorders may be paper chart recorders (analog), paper punch-tape Analog Digital Recorders (ADR), Electronic Data Loggers (EDL). The basic requirements for a recorder are to systematically and accurately keep a record of the gauge height with respect to time so that a stage hydrograph of the fluctuations of the water surface can be produced for archiving and analysis.

The accuracy requirements are described in PR-01 HWRSD.

2.6.3.2 Types of Recording Instruments

a) Electronic Data Loggers

Electronic Data Loggers (EDLs) are devices that can be programmed to electronically record stage data on a specific, regular time interval or on a user-defined schedule which may vary according to stage or other variable.

An electronic data logger shall be able to store at least the equivalent of four digits per reading. Where a data logger includes the sensing device, the resolution and uncertainty shall relate to the stored value. The advantages of an EDL for data storage are that they can store large amounts of data without frequent servicing and they can be programmed to collect data according to specific needs. A major disadvantage is that the recorder stage cannot be easily viewed in the field by graphical methods without downloading the data to a portable field computer that has plotting software designed for stage hydrograph viewing.

b) Chart Recorders

A paper chart recorder, also referred to as an analog recorder, provides a continuous graphical trace of water stage with respect to time. Where a chart recorder is to be used as the primary source of data, the resolution and uncertainty parameters shall take account the changes in dimensions of the recording medium due to atmospheric variables

2.6.3.3 Data Collection Platforms/Instrument Shelters

2.6.3.3.1 General

Data Collection Platforms (DCPs) are referred to in the commercial industry as a unit designed to acquire data and transfer the data to another location. Data may be transferred by a telephone line, cellular phone, a radio or satellite.

The recorder housing shall:

- be installed above maximum possible water level
- fully protect the equipment from: all inclement weather, spray, condensation, insects, vermin, and the general public
- Provide sufficient room for: equipment field books telemetry equipment (if applicable), and downloading loggers be clean and dry on the inside, and have an exterior appearance that blends in with the landscape as much as possible.

  Note: The appearance can protect the recorder and associated equipment from the elements and from interference by the public and wildlife.
- All equipment within the housing shall be installed in a secure and orderly manner.

Note: For example, wires, cables, pulleys must not interfere with operation and servicing.

2.6.3.3.2 Types of Housing

a) Walk-in type

A 'walk-in' housing may be:

- a small shed, or
- Separately on the ground nearby.

b) Chest Height type

A 'chest height' recorder housing may be a smaller design mounted:

- If the sensor is connected only by cable or tubing, in a suitably protected location.

Note: Exposed cabling and tubing also requires protection from the elements and interference.

2.6.3.4 Telemetry Systems

Telemetry system in hydrology refers to a system of remote sensing and communication technologies that are used to collect, transmit, and receive hydrological data from a network of monitoring stations located in rivers, streams, and other bodies of water.

Telemetry systems for transmitting the data from a gauging station in a remote location include telephone network modems, Global System for Mobile Communications (GSM)/ General Packet Radio Service (GPRS) data modems and radio transmitters.

2.6.3.5 Timing

2.6.3.5.1 Digital

The uncertainty of digital timing devices used in water level measuring devices shall be within +-150s at the end of a period of 30 days.

2.6.3.5.2 Analogue

The uncertainty of digital timing devices used in water level measuring devices shall be within +-15min at the end of a period of 30 days.

2.6.3.6 Typical Gauging Station Instrumentation Configurations

2.6.3.6.1 Instrument shelter, bubble gauge, non-submersible pressure transducer and electronic water level recorder/Data Collection Platforms

The configuration of the bubble gauge, non-submersible pressure transducer, DCP and electronic data logger is shown in the figure below:

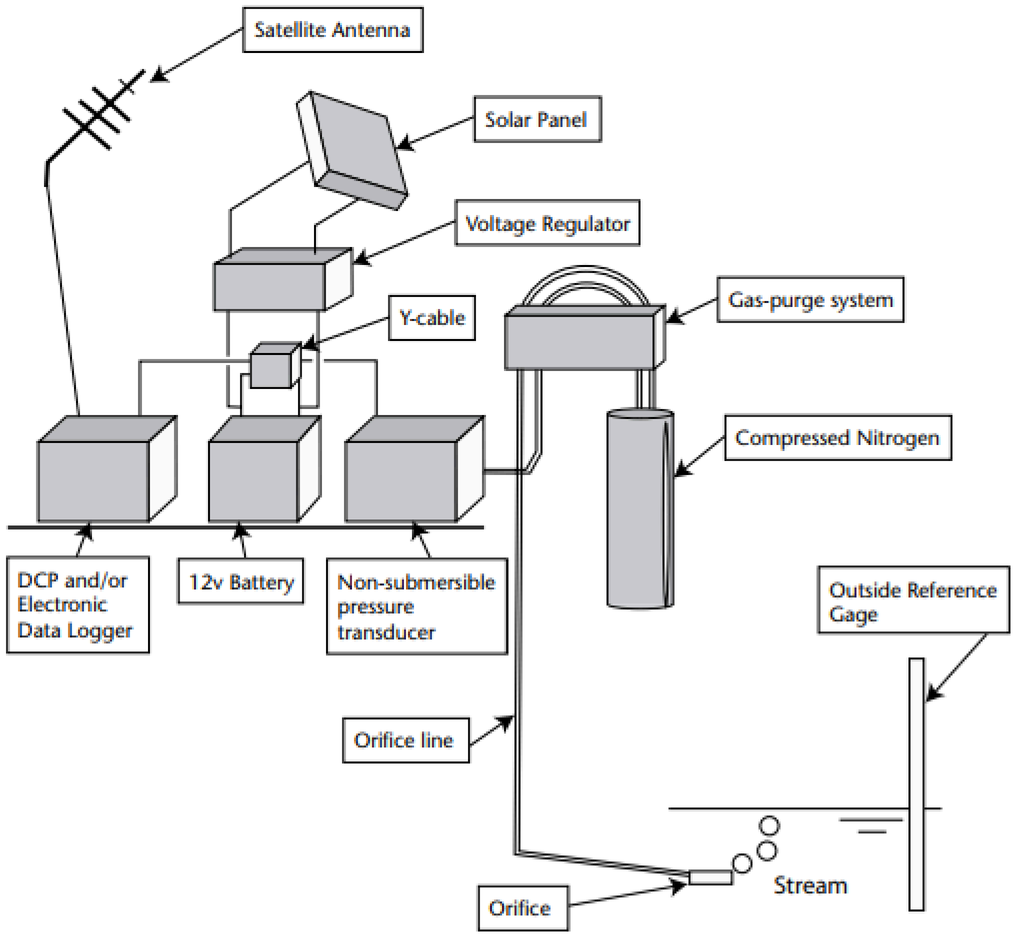


Figure 4: Schematic of bubble gauge, non-submersible pressure transducer, DCP and electronic data logger.

2.6.3.7 New Stage Station Design

A new gauging station is usually established for the purpose of obtaining a record of streamflow, reservoir contents or other purpose.

2.6.3.7.1 Site selection

Details for choosing an acceptable gauge site are described in this manual and in PR-01 HWRSD. The following criteria summarize the requirements for choosing a site where accurate stage records can be obtained:

a) If the stage record is to be used for computing streamflow, the requirements for controls, rating curves, backwater and other streamflow variables must be considered in selecting the site as well as the acquisition of stage data.

b) The site should be selected so the intakes or orifice are in a pool if possible, where stream velocity is low and not subject to significant turbulence. If this is not possible the intakes should be located in a slack-water zone where they are protected from high velocity;
c) The gauge stilling well and the instrument shelter may be located on a stream bank, bridge, dam or other suitable structure provided the other site selection criteria are met as closely as possible. The gauge structure should be located to avoid damage during floods;
d) If the gauge is located at or near a bridge, it is recommended that it be located on the downstream side. If this is not possible then it should be located far enough upstream to be out of the zone of drawdown caused by the bridge during medium and high water;
e) The site should be selected where an instrument shelter can be installed for housing a bubble gauge.
f) The gauge intakes should be low enough to record the lowest expected stage. In cold climates they should be below the frost line and protected from freezing if possible;
g) The instrument shelter should be above the 200 year flood level;
h) The distance between the stream and the stilling well and/or instrument shelter should be minimized;
i) The site should have a suitable location for one or more outside auxiliary gauges. These could be staff gauges, chain gauge, wire-weight gauge or tape-down reference point. The auxiliary gauges should be easily accessible and located in a position so that accurate gauge readings can be made easily. They should be in the same pool as the gauge intakes and should provide readings that are indicative of the readings obtained through the intakes;
j) If the gauge site is for the purpose of measuring stage in a lake or reservoir and it is near the outlet structure, the gauge intakes should be located upstream of the zone of drawdown of the outlet structure;
k) Conditions at the site should be such that an accurate datum can be maintained. Appropriate reference marks and reference points should be located both on and off the gauging structure to maintain accurate and timely level surveys of the gauge.

2.6.3.7.2 Other Requirement

The details about the types of sensor, recording instruments and data collection platform required during the installation of new station are described in the section 2.6.2 and 2.6.3. While installing the new stations, the engineer shall ensure that there is adequate power supply and internet accessibility facilities. Before setting up the station, NCHM shall seek permission from the local government and ensure other official/legal formalities are performed.

CHAPTER 3

RIVER DISCHARGE MEASUREMENT INSTRUMENTATION

3.1 INTRODUCTION

Streamflow, or discharge, is defined as the volumetric rate of flow of water in an open channel, including any sediment or other solids that may be dissolved or mixed with it.

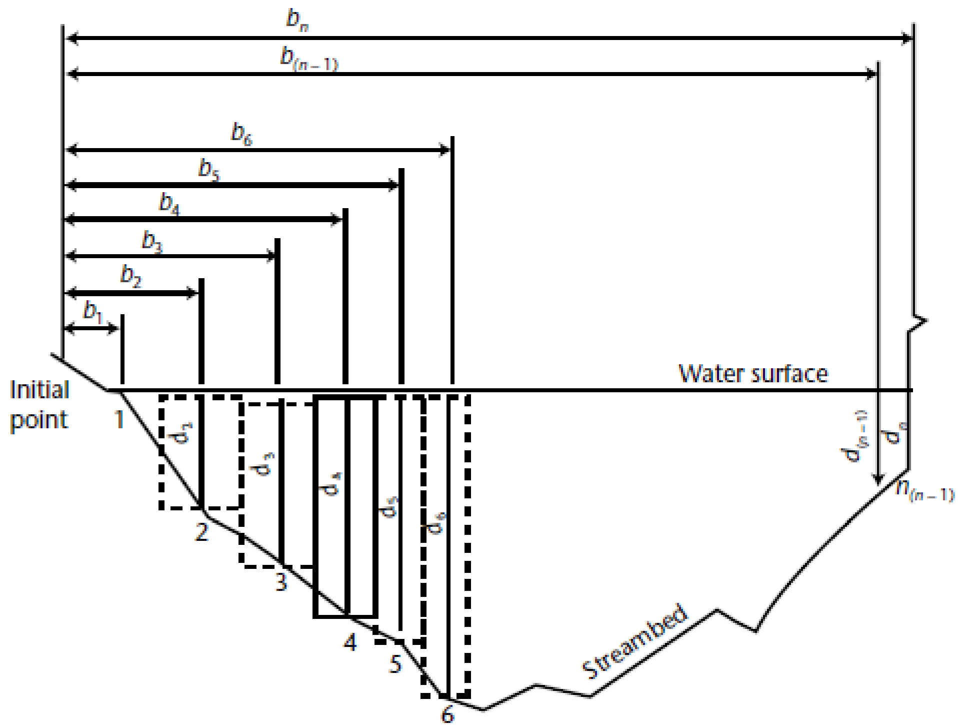
The discharge is made by sub-dividing a stream cross section into segments and measuring the depth and velocity in a vertical within each segment. The total discharge for a current meter measurement is the summation of the products of the partial areas of the stream cross section and their respective average velocities. This computation is expressed by the equation:

$$Q = a_i v_i$$

where Q = total discharge, in cubic metres per second (m3/s), a_i = cross-section area, in square metres (m^2), for the ith segment of the n segments into which the cross section is divided, and v_i = the corresponding mean velocity, in metre per second (m/s) of the flow normal to the i^{th} segment, or vertical.

In the *midsection* method of computing a current meter measurement it is assumed that the mean velocity in each vertical represents the mean velocity in a partial rectangular area. The mean velocity in each vertical is determined by measuring the velocity at selected points in that vertical, as described in a later section of this Manual. The cross-section area for a segment extends laterally from half the distance from the preceding vertical to half the distance to the next vertical, and vertically, from the water surface to the sounded depth.

The cross section is defined by depths at locations 1, 2, 3, 4. . . . *n*. At each location the velocities are sampled by current meter to obtain the mean of the vertical distribution of velocity.



Notes:

1,2, 3,.................. *n*: Observation verticals

b_1, b_2, b_3,........... b_n: Distance, in metres, from the initial point to the observation vertical

d_1, d_2, d_3,........... d_n: Depth of water, in metres, at the observaion vertical

Dashed lines: Boundaries of subsections: the one heavily outlined is discussed in text.

3.2 ROTATING ELEMENT TYPE CURRENT METERS

3.2.1 General

NOTES: (a) The material in this section of the annex is based on ISO 2537 (1988) entitled "Liquid flow measurement in open channels — Rotating element current meters".

The principle of operation for a mechanical meter, or rotating element current meter, is based on the proportionality between the velocity of the water and the resulting angular velocity of the meter rotor. By placing a mechanical current meter at a point in a stream and counting the number of revolutions of the rotor during a measured interval of time, the velocity of water at that point can be determined from the meter rating. The operational requirements, construction, calibration, and maintenance of rating element current meters is described in ISO 2537 (2007).

Table 1: Current Meter Configurations, usage's, and recommended ranges of depth and velocity

Meter	Contact Chamber	Counting Method	Rating	Velocity Range, feet per second	Depth Range, feet	Remarks
Price AA	Standard, cat-whisker and penta gear	Headphones, CMD[2] or EFN[3]	Standard	0.2 to 12	1.5 or greater	The Price A4 meter can be used as a low velocity meter if equipped with an optic contact chamber
			Individual	0.1 to 12		
	Magnetic	CMD[2] or EFN[3]	Standard	0.2 to 12		
			Individual	0.1 to 12		
			Standard or Individual	0.1 to 12		
Price AA, low velocity	Optic Cat-whisker with double contact lobe on shaft. No penta gear	Headphones, CMD[2], or EFN[3]	Individual	0.1 to 12	1.5 or greater	This is the traditional Price AA low velocity meter. An Individual rating is recommended, however a standard rating can be used if less accuracy is acceptable.
Price pygmy	Cat whisker	Headphones, CMD[2] or EFN[3]	Standard or Individual	0.2 to 4.0	0.3 – 1.5	
Price, winter WSC[4] yoke, polymer cups	Cat whisker	Headphones, CMD[2] or EFN[3]	Individual with suspension device	0.1 to 12	1.5 or greater	This meter is recommended for conditions where slush ice is present.
	Magnetic or Optic	CMD[2] or EFN[3]				
Price, winter WSC[4] yoke, metal cups	Cat whisker	Headphones, CMD[2] or EFN[3]	Individual, with suspension device	0.1 to 12	1.5 or greater	This meter is recommended for conditions where slush ice is not present
	Magnetic or Optic	CMD[2] or EFN[3]				

1) Low and high velocity limits shown in the table are based on a small to moderate extrapolation of the lower and upper meter calibration limits. It is not recommended that the meters be used for velocities less than the lower limit. The velocity rating for the price meter may allow additional extrapolation in the upper range to about 20 fps. The upper range of the Price pygmy meter rating may be extrapolated to about 5 fps. Standard errors within the meter calibration limits are less than +/- 5% in all cases. Standard errors in the extrapolated range of velocities are unknown, but are probably within +/- 5%.

2) Current Meter Digitizer, Observe cautions for low velocities. See text.
3) Electronic Field Notebook such as Aquacale or DMS. Observe cautions for low velocities. See text
4) Water Survey of Canada

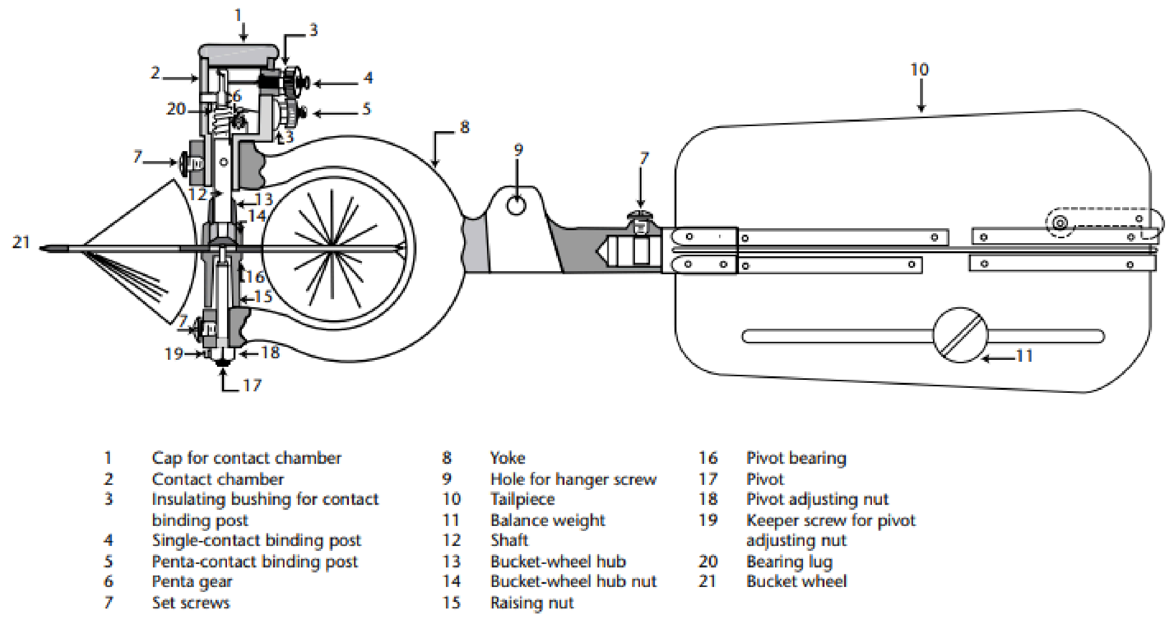


Figure 5: Assembly drawing of the Price AA current meter

The usual procedure, after selecting and laying out the section, is to measure and record at each vertical the: (a) distance from the initial point, (b) depth, (c) meter position, (d) number of revolutions, (e) time interval, and (f) horizontal angle of flow. The starting point can be either bank. The edge of water, which may have a depth of zero, is considered the first vertical. The hydrographer should move to each of the verticals in succession and repeat the procedure until the measurement is completed at opposite bank

3.2.2 Depth measurements Instruments

3.2.2.1 Wading Rod

A wading rod is used for measurement of stream depth when the water is shallow enough for making a wading measurement. The rod is placed in the stream so the base plate rests on the streambed and the depth of water is read on the graduated main rod. When the setting rod is adjusted to read the depth of water, the meter is positioned automatically for the 0.6-depth method. The 0.6-depth setting is the setting measured down from the water surface. It is the same as the 0.4 depth position when measured up from the streambed.

3.2.2.2 Sounding Lines and Weights

Water depth is measured with sounding lines and weights when the depth is too great for use of a wading rod, and when measuring conditions require that measurements be made from a bridge, cableway or boat.

When using one of the sounding reels, a counter or dial is used to determine the length of cable that has been dispensed. Depths are measured to the nearest 0.03 m when using a sounding line and weight.

3.2.3 Width measurements Instruments

3.2.3.1 Tapes and Tag Lines

Tag lines used for wading measurements are usually made of either galvanized steel aircraft cord with solder beads at measured intervals, or Kevlar, which is marked with black ink and waxed to resist abrasion. A Kevlar tag line consists of a Kevlar core with a nylon jacket.

The standard markings for Kevlar tag lines is one mark every 0.6 m (2 feet), two marks every 3 m (10 feet), and 3 marks every 30.5 m (100 feet). The standard lengths of tag lines are 91, 122, and 152 m, but other sizes are available. In Europe the standard lengths of tag lines are 100, 125 and 150 m but other sizes are available.

Larger reels, used for boat measurements, are designed to hold more than 900 m of 3.2 mm diameter steel tag line. Three different types of reels are available as follows:

a) A heavy-duty, horizontal-axis reel without a brake, and with a capacity of more than 600 m of 3.2 mm diameter steel cable
b) A heavy-duty, horizontal-axis reel with a brake, and with a capacity of more than 900 m of 3.2 mm diameter steel cable;
c) A vertical-axis reel without a brake, and with a capacity of almost 250 m of 3.2 mm diameter cable

3.2.3.2 Surveying Methods of Width Measurement, Transit and Electronic Total Station

For very wide streams where it is not practical to string a tag line for discharge measurements from a boat, surveying methods can be used to measure stream width and stationing for measurement points. With total station instruments, a direct reading of the distance from the instrument setup point to the boat can be made. One example of a commercially available total station instrument is shown in Figure 6 below. Accurate distance measurements with total station instruments can be made over distances of more than 1.5 km, provided the boat can be seen and is not obstructed by intervening objects.

Figure 6: Total Station Surveying Instrument

3.2.3.3 Differential Global Positioning System

Stationing of measurement points for very wide streams, such as flood plains that may be several miles wide or large tidal estuaries, can be determined with a Global Positioning System (GPS) instrument. GPS instruments utilize satellite telemetry from a network of 24 satellites and radio trilateration to compute positions for any point on the earth. To obtain the accuracy necessary for a discharge measurement the raw GPS positions must have differential corrections applied on the basis of simultaneous readings at a base station. Some GPS units contain built-in differential correction receivers that automatically make the corrections instantaneously. Other GPS units may use a separate receiver that attaches to the GPS unit with a cable. In either case base station data are received by radio signal from nearby ground base stations.

A surveying type of GPS unit with capability of storing and recalling data is preferred. These units may or may not have built-in or attached differential correction receivers. If instantaneous differential corrections are not made, then the coordinate data must be post-processed using correction data obtained after-the-fact from a separate GPS base station. Various agencies collect and provide the base station data via the internet. Coordinate data for the measurement points are downloaded from the GPS unit to a computer for post-processing. Software is available to make the differential corrections, to compute corrected coordinates of the measurement points, to automatically compute distances between measuring points and to plot a map of the measurement points.

Accuracy of GPS coordinates will vary depending on the type of GPS unit and whether or not differential corrections are made. Coordinates without differential corrections can be in error by as much as ± 90 m because of various errors in the system. This obviously is not acceptable for discharge measurements. However with proper care in making observations and after differential corrections are made, errors can be reduced to less than ± 1 m and even less in ideal conditions. This is acceptable for wide flood plains and estuaries.

3.2.4 Instrumentation

3.2.4.1 Operational Requirements

NOTE: Current meters of conventional construction are intended to operate in a horizontal or near horizontal position. Current meters designed to operate in other positions are not covered by this section.

a) The equipment should maintain alignment with the flow in such a way that the rotating element responds to flow movement as intended. If a pivoted suspension is incorporated within the current meter, it should permit freedom in the vertical plane to ensure correct alignment with the liquid flow.
b) The current meter should offer minimum resistance to the force of the current.
c) The rotating element of the current meter should be such that, when driven by the fluid, it rotates at an angular velocity which has a known relation to the velocity of the flow within the calibrated velocity range
d) The meter should respond rapidly and consistently to changes in velocity; the manufacturer should state the expected response rates.

Unless indicated otherwise, the current meter should be suitable for use in silty and/or saline waters.

3.2.4.2 Constructional features

The propellers should be made from a material which will not allow them to be easily distorted or bent.

The resisting torque of the bearings should be as small as possible and should be constant during use. Bearings should be lubricated as stated by the manufacturer. Provision should be made to keep silt and

The revolutions of the rotor should, by means of mechanical contracts or by means of magnetic, optical or other devices, give a clear and positive signal at all velocities within the effective range of the meter. If electrical connections are used, they should be appropriately waterproofed.

Manufacturers should stipulate the maximum conductivity of water in which the meter can be used.

For the measurement of low velocities, it should be possible to choose the frequency of signals transmitted by the counting mechanism in such a way as to reduce to a minimum the errors entailed in measurements of normal duration.

For the measurement of high velocities, if the frequency of the signals is such that they can no longer be counted or indicated properly, a device that will detect all input signals at these high velocities should be provided.

Spare parts should be fully interchangeable so as to have uniform functional characteristics and should cause less than 2 per cent divergence from the calibration.

Current meters should be constructed of corrosion-resistant materials throughout or of materials that are effectively protected against corrosion encountered in natural waters. The meter should be of sufficiently rugged construction to maintain calibration under conditions normally encountered.

3.2.4.3 Calibration

3.2.4.3.1 General

When current meters are calibrated, either individually or by groups, a calibration document as specified should be furnished with each meter.

Group ratings should be based on the calibration of a group of current meters of uniform manufacture. The sample calibrated should be adequate in number and should comprise, if possible, both new current meters and well-maintained used current meters.

If group ratings are used, the calibration of meters should be periodically checked to ensure that they continue to operate within the expected tolerances.

Individually calibrated current meters should be recalibrated on a routine basis at yearly intervals or after 300 hours of use, whichever is the shorter.

Apart from the regulations above, a current meter should be recalibrated whenever its performance is suspect.

For the reliability of the calibration, the rating laboratory should state tolerance limits at the 95 percent.

As a check for goodness of fit of the calibration curve, the manufacturer or rating laboratories should state the standard error of the data for the lower and upper limits of calibration, and for at least two intermediate points. The standard error should be stated as a percentage of the mean velocity class and should be related to the 95 per cent confidence limits.

3.2.4.3.2 Conditions for satisfactory calibration

To obtain a satisfactory calibration of a current meter several conditions must be satisfied:

a) The counting of pulses and the measurements of time and distance must be accurate;
b) The carriage must run smoothly and at constant speed so that oscillatory motion, whether longitudinal or lateral, is not transmitted to the meter. Timing of runs with cable-suspended meters must not be started until to and fro oscillations initiated during acceleration are damped out;
c) The method of suspension of the meter should be that used during field measurements;
d) The axis of the meter must be parallel to the water surface and to the long dimension of the tank;
e) Residual motion of the water must be negligible;
f) Measurements should not normally be made within a range of speeds where there is an Epper effect The size of the effect and the range of speeds within which the effect is appreciable vary with the size of the meter and the dimensions of the tank. It is larger with larger meters and may be negligible with miniature meters. For a given meter the effect is larger in a small tank than it is in a large one.

3.2.4.4 Maintenance

NOTE: In general, under conditions of normal operation, the user should follow recommended check procedures before and after each discharge measurement, as laid down in the manufacturer's operations and servicing manual.

a) The meter should be examined, before and after each discharge measurement, for worn or damaged bearings, proper shaft alignment, correct operation of contact points and deformation of the yoke or cup-wheel in the case of cup-type meters, or of the propeller in the case of propeller-type meters.
b) For inspection, it should be possible to dismantle and reassemble the current-meter assembly in the field, without specialized workshop facilities and by personnel without specialist training. The tools which are required to carry out this operation should be supplied as standard accessories.
c) Before use, the meter should be tested for correct operation by the signal test. By turning the rotors lowly, the number of rotations should be compared with the number of pulses received. For current meters with a generator, it should be checked that the output varies with rotor speed.
d) The condition of the current meter should be determined by the spin test, both before and after being used for a discharge measurement

NOTE: The spin test is performed as follows: Place the meter in the normal operating position, with the rotor protected from air current; spin the rotor by hand; as it nears its *stopping point, observe its motion carefully to see whether the stop is abrupt or gradual. If the stop is abrupt, the cause should be found and corrected before the meter is used.*

e) The manufacturer should specify the duration of spin which should be expected for any particular type of current meter.
f) The duration of the spin should be timed and noted, and compared with the minimum duration specified for the current meter.
g) After each discharge measurement, or more frequently for extended measurements, all bearing surf a c e s should be thoroughly cleaned and, where appropriate, lubricated. The oil used should have the same

A suitable protective case for transport and storage should be provided for the current meter, the spare parts and the maintenance tools. IV-5.9 A comprehensive operational and servicing manual should be supplied with each instrument. It should present full instructions and be illustrated where necessary.

3.3 ACOUSTIC DOPPLER EFFECT SYSTEM

3.3.1 ADCP Moving Boat System

The ADCP method uses a moving boat to traverse the stream, just as the manual and automatic methods, however instrumentation is different. The ADCP method measures velocity magnitude and direction using the Doppler shift of acoustic energy reflected by material suspended in the water column providing essentially a complete vertical velocity profile. It also tracks the bottom providing stream depth and boat positioning. A complete description of this method will be given in the following paragraphs. The use of

ADCP System is in pilot phase at the time of writing this guide.

3.3.2 Aqua Profiler

The Aqua Profiler is a line of acoustic Doppler velocimetry flow meters for permanently installed and portable applications. The Aqua Profiler® precisely measures water velocities in open channels and pipes. With its high accuracy and competitive cost, the AquaProfiler is a perfect choice for long-term real-time monitoring or to obtain instantaneous measurements where time savings are an important aspect. It uses advanced Doppler technology to establish the velocity in many separate space points (cells) along the measurement axis and develop the flow profile.

Aqua Profiler System is in pilot phase at the time of writing this guide.

3.3.3 Non-Contact Stationary River Flow Measurement

The system may consist of a radar-based velocity sensor and an ultrasonic or radar based water level sensor. The system is designed for continuous operation and suitable for measurements of flows not only in rivers and open channels, but also in municipal waste water and storm water sewers. A compact construction combined with the contact-free measurement principle enables an easy installation and use. The velocities on the water surface are typically within 10 % of the average velocity. The system should have developed a Finite-Difference-Algorithm that yields an accurate determination of the average velocity from the measurement of the surface velocity at a known point of the flow surface.

The system is used as piloting stage at the time of developing this guide.

3.4 CABLEWAY SYSTEM

3.4.1 Elements of a cableway system

A cableway system can be designed to be operated from the river or be designed to be operated from a suspended personnel carriage. The general arrangement of the following elements is common to both systems:

a) Towers or cableway supports;

b) Track or main cable;

c) Anchorage;

d) Backstays;

e) Suspension cable.

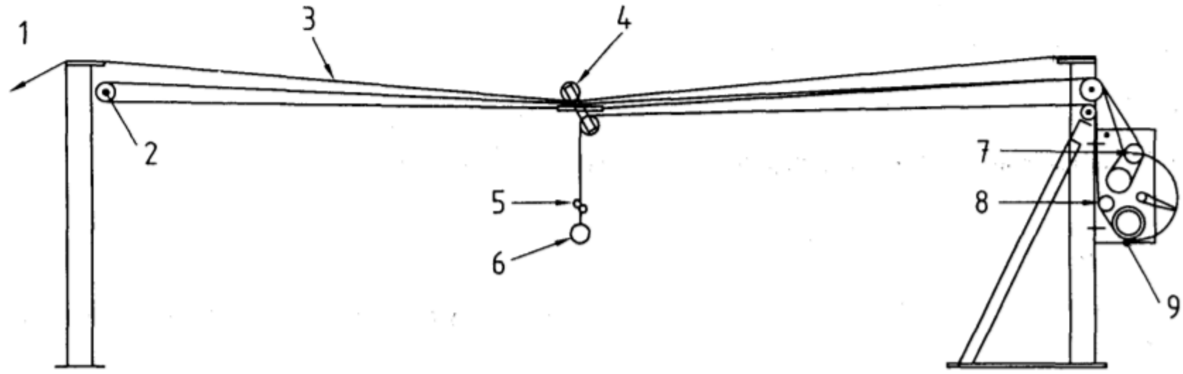
The main differences are:

— The carriage of a backside system requires a tow cable;

— a bank side system requires a more complicated winch arrangement;

— The personnel carriage has to provide a safe platform for the operator;

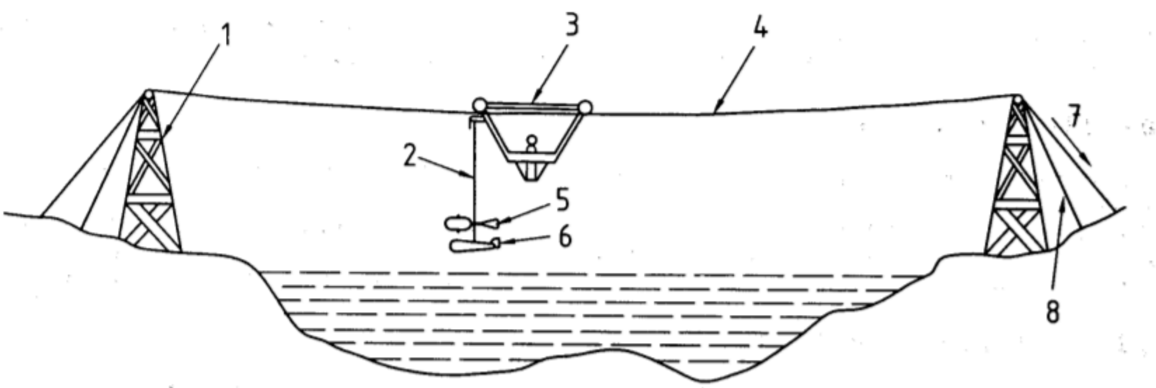
— More stringent design requirements may apply to a system which employs a personnel carriage.



Key

1 Backstay
2 Traversing cable return pulley
3 Track or main cable
4 Traveller and/or instrument carriage
5 Current meter
6 Sinker or sounding weight
7 Distance measurement
8 Depth measurement
9 Cable drum

Figure 7: Cableway system — Bankside operation, with loop-traversing cable and spooled sounding cable



Key

1 Tower
2 Suspension cable
3 Personnel carriage
4 Track or main cable
5 Current meter
6 Sounding weight
7 To anchorage
8 Stayline

Figure 8: Cableway system — Suspended personnel carriage

3.4.1.1 Cableway supports

The cableway supports, one on each bank, support the main cable span across the stream. They may also provide mountings for the winch and the pulleys (sheaves) carrying the tow and suspension cables.

3.4.1.2 Main track or main cable

The track or main cable is designed to carry the whole suspended load. The track may be attached directly to stayed cableway supports or be supported on saddles on the cableway supports and led directly to an anchorage.

3.4.1.3 Anchorage

Anchorages are required to carry the loads induced in the cableway and tower system. Depending upon the design of the system, they may be anchorage points for track and backstays or guy-lines, tower foundations subject to compression or tower foundations subject to compression and moment.

3.4.1.4 Tow cable for a bank side system

The tow cable is required to move and position the instrument carriage. Generally the tow cable is arranged as an endless loop from the instrument carriage over guiding sheaves on the winch tower, round a driving pulley or drum, across to an idler pulley (sheave) on the tower on the opposite bank and back to the carriage. An alternate arrangement uses a spooled tow cable with a single fixing point on the carriage. This arrangement depends upon the equal and opposite force provided by the suspension cable.

3.4.1.5 Suspension cable

The suspension cable provides the means of raising and lowering sensing or sampling equipment in the stream. The free end of the cable is fitted with ‘connectors to attach equipment aid sounding weights. The suspension cable is likely to contain an insulated conducting core to provide a signal path from suspended instruments.

3.4.1.6 Instrument carriage for a bank side system

The instrument carriage is provided with one or more track wheels running on the main cable (track), a pulley to support the suspension cable and a point of attachment for the tow (traveller) cable.

3.4.1.7 Personnel carriage

The carriage, from which gauging observations are made, travels along the main cable. It is suspended from track wheels running on the main cable. The carriage may be moved along the main cable manually or by a power unit. The carriage can be designed to be operated from either the standing or sitting position or both. A cableway employing a personnel carriage shall comply with the safety requirements for passenger cableways where such standards exist specially for horizontal fixed cableways, in all aspects not covered by this International Standard.

3.4.1.8 Winch arrangements for a bank side system

A double drum winch is one that provides both traversing and sounding functions within one piece of equipment. One drum controls the suspension cable, the other controls the movement of the carriage. The latter may be a spooling drum or take the form of a friction drive pulley driving an “endless” loop. Both drums may be driven simultaneously in traversing mode and, in sounding mode, the traversing drum may be locked to allow operation of the suspension cable drum only. This operation may also be carried out using two single drum winches. Measuring counters may be fitted to record horizontal and vertical cable movement.

3.4.1.9 Winch arrangements for a personnel carriage

A winch (sounding reel) is attached to the carriage (cable car) to raise and lower the sounding weight. The winch is required to operate properly under the load of the sounding weight but both the winch and its mountings should be capable of accommodating the breaking load of the suspension cable with a factor of safety of two. The winch may be hand operated or power driven.

3.4.1.10 Lightning protection

In areas where electrical storms are considered a risk to cableway operators, provision shall be made to reduce the likelihood of injury from a lightning strike on the cableway system. In countries where lightning is infrequent and lightning protection not considered necessary, work instructions should allow for abandonment of operations in the event of an electrical storm.

3.4.2 Functional requirements of cableway components

3.4.2.1 Safety factors

3.4.2.1.1 General

Factors of safety shall be applied to ensure that the equipment is able to cope with normal working without failure and to protect the operator in case of abnormal but foreseeable incidents. The most likely risk of failure of properly maintained cableway systems lies with the possibility of the suspended equipment becoming caught up on a large floating object.

Trees being carried down on a flood are the most likely source of this danger. The excess loading is applied to the system through the suspension cable. In a bankside system, the tension in this cable is equal to, and balanced by, the tension in the "return" side of the tow cable. In both bankside systems and systems with personnel carriages, the load in the suspension cable is also applied to the main cable (track) through the carriage. For both arrangements, the factor of safety for normal working shall be achieved by specifying the 'suspension cable in relation to a maximum working load. The specification of all other cables shall be with respect to the breaking load of the specified suspension cable.

3.4.2.1.2 Suspension cable

The suspension cable shall be selected to provide a minimum factor of safety of 5 in relation to the maximum authorized suspended load. The maximum authorized suspended load is the sum of the maximum authorized sounding weight plus an allowance for the mass of sensing/sampling equipment.

3.4.2.1.3 Tow cable

The tow (traversing) cable shall be selected to provide a factor of safety of 1,25 with respect to the breaking load of the suspension cable.

3.4.2.1.4 Track cable

The track cable shall be selected to provide a factor of safety, with respect to the breaking load of the suspension cable, as follows:

a) Bankside cableway system with instrument carriage: 2

b) Cableway with suspended personnel carriage: 5

3.4.2.1.5 Marking

Cableways shall be clearly marked to indicate maximum authorized sounding weights and approved suspension cable specification. The use at an established site, of a suspension cable with a breaking load greater than specified, reduces the factor of safety with respect to the track cable.

3.4.2.2 Cableway supports

3.4.2.2.1 Approaches

A safe and convenient approach should be available throughout the year on both banks so that an observer may have easy access to the installation for inspection and operation and if it is recognized that access to the far bank may not always be possible in difficult terrain. If this is the case, it should be recognized in the operation procedures for that site.

3.4.2.2.2 Design Load

The cableway supports shall be designed to withstand the breaking load of the track cable selected, together with any relevant wind loading. Attention shall be paid to lateral loading as a consequence of drag on the suspended load and allowance made for the extreme condition as the suspension cable approaches breaking point.

3.4.2.2.3 Foundation Placement

The foundation of the tower should extend from below the frost line to at least 300 mm above ground level. The size and design of the foundation is dependent on soil conditions and is beyond the scope of this International Standard.

3.4.2.2.4 Height

The height of the cableway support shall be such that all parts of the equipment, suspended from the centre of the span, will be at least 1 m above the highest flood level to be measured, but at no time present a hazard to navigation or wildlife. Consideration should also be given to marking the cableway in areas where canoes and aircraft are used in its vicinity. In certain localities, high structures may be governed by regulations requiring the provision of aircraft warning lights and warning signs on the track cable.

3.4.2.2.5 Corrosion protection

Materials used in the construction of cableway supports shall be protected against corrosion.

3.4.2.3 Selection of main cable or track

The main cable shall be corrosion resistant. Wire rope maybe used for spans up to 300 m. For longer spans it may be necessary to use special cables.

3.4.2.4 Anchorage

3.4.2.4.1 Design

Anchorages shall be designed, in accordance with standard engineering practice, to withstand such forces as may be induced upon them at the point of failure of the main cable.

3.4.2.4.2 Inspection accessibility

The point at which a cable is attached to an anchorage shall be so placed that it can be easily inspected.

3.4.2.5 Backstays

Where backstays are provided as part of the tower design they shall be of corrosion-resistant steel and be able to withstand the forces developed at the point of failure of the main cable.

3.4.2.6 Tow cable

Provision shall be made to be able to adjust the tension in a tow cable configured as an endless circuit. Adjuster should be accessible to the operator to allow adjustments to the tension before gauging commences.

3.4.2.7 Carriages

3.4.2.7.1 Instrument carriage for a bankside system

3.4.2.7.1.1 Carriage track wheels

The permissible bending radius of the track cable shall be taken into account in the design of the carriage. This is usually expressed as a multiple of the rope diameter and should be obtained from the rope manufacturer. Where an instrument carriage has more than one track wheel, the carriage should be articulated so that the resultant force is applied mid-way between the track wheel axes, or, the geometry of rigid carriages should be arranged so that the load is distributed equally to each track wheel. Traditional symmetrical triangular designs should be considered to transmit the whole load through a single track wheel.

3.4.2.7.1.2 Load requirements

The carriage shall be capable of withstanding a load equivalent to the breaking load of the suspension cable.

3.4.2.7.1.3 Carriage Design Considerations

It shall be simple in design, be designed to be captive on the track and effectively retain the sounding cable in the operational position. It shall be corrosion resistant.

3.4.2.7.1.4 Carriage Operational Requirement

It shall permit the operation of equipment without hindrance.

3.4.2.7.2 Personnel carriage

3.4.2.7.2.1 Design

The carriage can be designed to be operated and used

a) In a standing position; or

b) In a sitting position.

The number of personnel permitted to occupy the carriage shall be clearly indicated on the installation together with the maximum mass of survey equipment and the maximum sounding weight permitted. The materials used in construction should be suitable for operation in the extremes of temperature. This is particularly important in seats and panels which may come into contact operating personnel. The carriage (cable car) shall be designed to withstand the breaking load of the suspension cable together with the specified maximum loaded capacity of the carriage, excluding the sounding weight, with a factor of safety of 2.

3.4.2.7.2.2 Brake

The carriage shall be provided with a brake or holding device to secure it in any desired positions on the main cable for the purpose of taking measurements.

3.4.2.7.3 Winches

3.4.2.7.3.1 General

3.4.2.7.3.1.1 Brake

It is desirable for the winch to be fitted with a load-activated brake so as to hold the suspended load and stop the handle from rotating when the winch is released in any mode of operation.

3.4.2.7.3.1.2 Locking device

The winch shall be provided with a locking device for the purpose of holding suspended instruments at a desired depth, in steps not greater than 20 mm.

3.4.2.7.3.1.3 Level Wind Device

The winch shall be designed so as to wrap the cable evenly around the drum.

3.4.2.7.3.1.4 Mechanical Advantage

The gearing of a manually wound winch shall be related to the maximum recommended sounding weight, or be ~ adjustable to provide an optimum relationship between effort at the winding handle and pay-out rate. The effort 3 required on the handle to raise the maximum recommended sounding weight should not exceed 90 N.

3.4.2.7.3.1.5 Drum Diameter

The diameter of any drum shall not be less than the minimum winding diameter recommended for the cable.

3.4.2.7.3.1.6 Signal Transmission

Where the suspension cable is required to have an electrical signal core to transmit signals from the suspended equipment, the winch shall be provided with a method of transmitting these signals to the recording equipment.

3.4.2.7.3.1.7 Power Winch Requirements

Electrically or hydraulically driven winches should be provided with a facility to vary operating speed. In case of power failure, the winch shall be automatically braked or employ a gear train which cannot be driven by the load. It should have provision for manual operation to allow the recovery of equipment. Motor controls should incorporate overload protection and include “soft start” to reduce shock loading. Controls should require hand pressure for operation and default to “stop” in the absence of hand pressure.

3.4.2.7.3.2 Winches in bank side systems

3.4.2.7.3.2.1 Torque Limiter

To protect the operator in the event of accidental overload, a winch designed for bankside operation should be fitted with a torque limiter in the tow-cable drive system, set to slip under a load on the tow cable equal to twice the maximum suspended load. If a separate winch is employed to control the tow cable, it should be fitted with a torque limiter set to slip at a load equal to twice the maximum suspended load.

3.4.2.7.3.2.2 Load Requirement

The winch shall be able to withstand a loading greater than the breaking load of the suspension cable, applied simultaneously to the suspension cable and the tow cable.

3.4.2.7.3.2.3 Cable Deployment

The winch shall be designed to ensure that the tow cable and suspension cable are paid out at approximately the same rate.

3.4.2.7.3.2.4 Interlocking Mechanism

It shall be possible to operate the suspension cable drum independently of the tow (traversing) cable drum for ‘j depth positioning. The arrangement for engaging and disengaging the two drums shall incorporate an interlocking 1 mechanism so that the tow-(traversing-) cable drive is immobilized in the sounding mode and connected to the sounding cable drive in the traversing mode. It shall not be possible to achieve an intermediate state that allows the tow-cable drive to free-wheel.

3.4.2.7.3.2.5 Mounting Design

The mountings used to attach the winch to the tower shall be designed to accommodate a load in shear, equal to six times the breaking load of the suspension cable. This includes a factor of safety of 3.

3.4.2.7.3.3 Winches on Personnel Carriages

3.4.2.7.3.3.1 Torque Limiter

The winch controlling the suspension cable from a personnel carriage should be fitted with a torque limiter to allow the drum to turn and pay out cable, without interfering with the operation of the load-activated brake, which should continue to prevent the handle from rotating under overload conditions.

3.4.2.7.3.3.2 Release Device

The cable termination on the winch shall be such that it will release or break free in the event of the cable becoming fully unwound under overload conditions.

3.4.3 Maintenance, examination and testing

3.4.3.1 General Examination

Cables and anchorages shall, as far as is practicable, be examined for general condition before each gauging exercise. Particular attention should be paid to wire ropes attached to anchorages close to the ground to ensure that waterproof protection is intact. Observation of signs of deterioration however superficial shall be logged according to a specified procedure for consideration by the responsible person.

3.4.3.1.1 Bank Side Systems

At intervals of 12 months, each cable and anchorage shall be thoroughly inspected; Wire ropes are most open to corrosion where they are bent round a thimble or pulley. Particular attention should be paid to the tow cable where it lies “parked” over the pulley on the far bank. During the periods when the cableway is not in use, the cable will tend to rest with the same section of rope bent round this pulley and it is common for cables to deteriorate at this point. Similarly the wires in the main cable may be spread due to bending round thimbles and where rope grips are used. These points should receive special attention and be treated with a rope preservative.

3.4.3.1.2 Systems with suspended personnel carriage

A thorough annual inspection is required for a passenger cableway system. This inspection is the same as for a cableway system operated from the bank but shall include the safety of the passenger in addition. Particular attention should be paid to potential corrosion of the passenger carriage and the tower or "A frame supports. Significant corrosion induced pitting of these components requires replacement before the cableway may be used. The foundations of the tower should also be inspected. Significant spalling, cracking, or other deterioration of the foundations requires repairs before use of the cableway. Similarly, should there be any suggestion of movement of the foundations, the cableway shall not be used until they have been checked and, if necessary, redesigned and replaced.

3.4.3.2 Static Testing

3.4.3.2.1 Bankside System

Following inspection and execution of any remedial action required, the complete cableway installation should be subject to a static-load test. The load applied shall be twice the maximum sounding weight approved for the installation. At the end of the test, with the carriage in the "home" position (i.e. close to a support tower) and the test load within 100 mm of the ground, the winch torque limiter (where fitted) should be adjusted so that it just slips under the test load.

3.4.3.2.2 System with Suspended Personnel Carriage

At prescribed intervals and after repairs or replacement of components, the cableway should be tested with a static load equal to or greater than the breaking strength of the suspension (sounding) cable. Static-load testing, depending on conditions, shall be scheduled at intervals not exceeding 5 years. Cableways subject to severe corrosion or wear should be tested more frequently. Static-load testing shall be carried out by loading the carriage progressively. This maybe conveniently achieved by suspending a tank below the carriage and adding water until the desired load is achieved. A dynamic test can be introduced if required, by allowing the loaded carriage to traverse the cable during the test. As there is clearly a risk of cable failure during the test, all work shall be carried out with personnel in a safe location during testing.

3.4.3.3 Lubrication

All mechanical accessories shall be properly lubricated and observed to operate freely. Static ropes shall be treated with a rope dressing, as needed.

3.4.3.4 Checking the Sag

The sag shall be checked at regular intervals, particularly when large changes in temperature occur. Significant changes should be investigated before re-tensioning the cable. Care shall be taken to avoid over-tensioning the cable. If the unloaded tension is greater than required to achieve the designed working sag, it can possibly lead to overloading, produce a reduction in the factor of safety and cause premature failure of the installation. Where large temperature variations are likely to cause problems of this type the use of a counterweight tensioning system should be considered. The sag should also be checked before and after a test loading has been carried out.

3.5 DIRECT DEPTH SOUNDING AND SUSPENSION EQUIPMENT

3.5.1 Scope and Field of application

NOTES: The material in this section of the annex is based on ISO 3454 (1983) entitled "Liquid flow measurement in open channels — Direct depth sounding and suspension equipment".

3.5.2 Sounding equipment

Note: The object of sounding is to obtain the depth from water surface to channel bed. For this purpose, either a rod or a sounding line is used, depending on velocity and depth of flow.

3.5.2.1 Sounding Rod

NOTE: A sounding rod is rigid in construction. It may be either hand-held and hand-operated or provided with a support and mechanically operated.

a) The hand-held sounding rod may be used for measurement of depth up to 3 meters in velocities up to 2 m/s. *NOTE: A supported mechanically operated rod is generally suitable for depths up to 6 metres and velocities up to 2 m/s.*
b) For small depths and velocities (up to 1 meter and 1 m/s respectively) a wading rod should be used.

During measurements, the rod should be held in a vertical position.

3.5.2.2 Sounding Line

a) The sounding line should be used in situations where depth and velocities preclude the use of a sounding rod.
b) An appropriate weight should be attached to the sounding line to keep it vertical.

3.5.2.3 Sounding Weight

Sounding weights should be streamlined to offer minimum resistance to flowing water.

NOTE: An estimate of the sounding weight mass required to suit certain depth and velocity can be found using the following formula: m = 5– vd where: m is the mass of the sounding weight, in kg; – v is the mean velocity of flow, in m/s; d is the depth of water, in m.

3.5.3 Suspension Equipment

3.5.3.1 Suspension equipment

It should:

(a) Be such that the suspended measuring or sampling device may be placed at a selected depth and position, avoiding undue disturbance irrespective of the depth and velocity;

(b) Maintain the measuring or sampling device at the selected depth and position in a stable condition during the period of observation.

3.5.3.2 Rod Suspension Equipment

NOTE: Rod suspension equipment has the merit that a measuring or sampling device can be placed at the point of measurement without any appreciable deflection from the vertical.

3.5.3.2.1 Hand-Operated Rod Suspension Equipment

Wading rods should be used in shallow streams suitable for wading and may be used in water of depths up to 3 meters and velocities up to 2 m/*s*.

3.5.3.2.2 Mechanically Operated rod suspension equipment

NOTE: Although this equipment allows accurate positioning of the measuring or sampling device at the re quire depth and position it is heavier and requires careful installation and *skilled handling. Mechanically operated suspension equipment may be employed where the use of a hand-held rod becomes impracticable, but generally should not be used in depths exceeding 6 meters and velocities exceeding 2 m/s.*

3.5.3.3 Cable Suspension Equipment

Cable suspension equipment should be used in situations where depths and velocities preclude the use of rod suspension.

NOTE: Two types of cable suspension equipment are in common usage:

(a) Hand-line suspension, which can be used with weights up to 15 kg;

(b) Winding reel suspension supported on a bridge, cable car, boat or ice cover which should be used if the sounding weight exceeds 15 kg.

When the flow deflects the suspension line downstream so that the angle of the line from

The vertical exceeds four degrees, an unacceptable error in indicated depth is introduced and two separate corrections should be applied to the indicated depth:

a) An "air-line" correction for that part of the cable which is between the point of suspension and the water surface;

A "wet-line" correction for that part of the cable which is in the water. NOTE: Correction tables are given in the Manual on Stream Gaugin g (WMO-No. 519), Volume I — Fieldwork, pages 141 and 143.

3.5.4 Specific Requirements

3.5.4.1 Rods for Sounding and Suspension

3.5.4.1.1 Hand-held Sounding and Suspension Rod

This equipment should satisfy the following requirements:

(a) Its mass should be as small as possible

(b) It should be straight and have sufficient strength to withstand the force due to flowing water without significant deflection or vibration — it may be sectional to allow it to be dismantled;

(c) Construction should be of corrosion - resistant material;

(d) It should not cause significant heading up of water due to its own obstruction;

(e) The interval between graduations should permit observation to within 10 mm; graduation increments of 0.1 m, 0.5 m and 1 m should be clearly identified;

(f) It should incorporate a foot plate to prevent penetration into the bed of the channel;

(g) It should incorporate a movable mounting for equipment and a means of conveying an electric signal.

3.5.4.1.2 Mechanically Operated Sounding and Suspension Rod

In addition to the requirements in mentioned earlier mechanically operated rod equipment should have the following features: (a) A locking arrangement such as pawl-and-ratchet to hold the sounding or suspension rod in the desire d position; (b) A mechanical arrangement to raise and lower the sounding or suspension rod easily; (c) An arrangement for safely securing it to the gauging platform or structure; (d) Sufficient counterbalancing to ensure stability.

3.5.4.2 Cable Sounding and Suspension Equipment

3.5.4.2.1 Sounding and Suspension Cable

The cable used with sounding and suspension equipment should:

a) Be corrosion resistant, preformed and reverse-laid to inhibit spinning;
b) Be equipped with a suitable attachment for suspending the measuring equipment and weights;
c) Incorporate insulated conductors suitable for the transmission of signals from the instrument;
d) Be constructed to that in normal use it will not sustain any permanent bends or twists, which would affect its utility and length;
e) Have sufficient strength to support the current meter and sounding weight safely. Its elongation under load should not exceed 0.5 per cent.

NOTE: A breaking load of not less than five times the maximum sounding weight provides a suitable safety margin to allow for the loading effects of drag and the live load. Where the cable is to be used as a hand line the portion of the cable to be handled should be of a suitable material and dimension (e.g. 10-mm diameter, with PVC or rubber cover) to avoid discomfort or injury to the operator. The wet-line port i o n should have a diameter as small as possible (consistent with the conditions stated in (a) to (e) in order to minimize drag).

3.5.4.2.2 Winding Reels

Winding reels used to dispense and measure the suspension cable should satisfy the following requirements:

a) The radii of drums, pulleys and cable guides should not be less than the minimum cable bending radius recommended by the manufacturer;
b) There should be a device to measure the amount of cable paid out. It may be driven by the drum when the cable can be accommodated in a single layer, otherwise driven directly by the cable;
c) T h e re should be an arrangement to ensure that the cable is wound evenly on to the drum; the end of the cable shall be securely fastened to the drum;
d) T h e re should be a locking arrangement to hold the drum at any desired position;
e) T h e re should be provision for an electrical connection between the recording equipment and the suspended instrument;

The design of the reel should be such that hand operation will be easy, the drum may be provided with a power drive unit for raising and lowering the measuring equipment and attached weight; the method of attachment to the supporting device should be simple and safe. The supporting device may be a cable c a r, bridge board, ice frame, crane, boat boom, etc.

3.5.4.2.3 Supports and Mounting Structures for Winding Reels

Supports and mounting structures to be used on or attached to bridges, cable cars, boats, or ice:

a) Should be of adequate strength to support the winding reel together with the measuring or sampling equipment and any attached weight;
b) Should enable the measuring or sampling equipment to be lowered or raised in a vertical plane
c) giving adequate clearance from the support structure ;
d) Should incorporate a protractor to measure the deviation of the cable from the vertical;
e) Should incorporate adequate counterbalancing to ensure its stability at all times; (e) May have provision for attaching a power-drive unit;
f) Should be mobile in order that it can be easily transported and to this end it may be collapsible.

3.5.4.2.4 Sounding Weights

Sounding weights should be constructed of a dense material to minimize volume, streamlined to minimize drag and fitted with fins to provide directional stability. The location of the

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weight with respect to the measuring instrument should be such as to minimize its effect on the operating characteristics of the instrument. The anchorage point for the attachment of the weight to the suspension cable should be made as small as possible or incorporated in the body of the weight. Attaching two or more weights to the sounding or suspension cable is not recommended.

NOTE: In addition, the weight may:

(a) Be equipped with a device to detect and signal contact with the bed;

(b) Have other hydrometric equipment attached directly to it;

(c) Be part of an assembly having an overhanging support for securing hydrometric equipment

CHAPTER 4

SEDIMENT MEASUREMENT INSTRUMENTATION

4.1 INTRODUCTION

Sediment measurement instruments are essential tools used to measure the quantity and characteristics of sediment in water. These instruments are designed to collect information about sediment grain size, concentration, and distribution, among other factors. The data obtained from sediment measurement instruments is vital in determining the impact of sediment on water quality and the environment.

4.2 SUSPENDED SEDIMENT LOAD SAMPLERS

4.2.1 Functional Requirements

The design of the suspended sediment load sampler should be based on the following main technical requirements:

a) Sampler should be streamlined so as to minimize disturbance in the sediment flow;
b) Velocity of inflow at the mouth of the sampler should be equal to the velocity of stream flow;
c) Mouth of the sampler should face the direction of current;
d) Mouth should be outside the zone of disturbance of flow set up by the body of the sampler and its operating device;
e) Filling arrangement should be smooth without causing sudden in-rush or gulping;
f) Container should be easily removed, readily capped and transported to a laboratory without loss of contents;
g) Sampler should be able to collect samples at any depth from surface to 0.3 m from the bed without disturbing or contaminating the water sediment mixture at other points while the sampler is being raised or lowered;
h) Sampler should be portable but sufficiently heavy to minimize deflection from the vertical due to current drag;
i) It should be simple in design and construction and require minimum care for maintenance and repair, and

Volume of the sample obtained should be sufficient for the determination of sediment concentration.

4.2.2 General Description and Operation

4.2.2.1 Description

The suspended sediment load sampler shall consist of the following main parts:

a) Frame to hold the sampling bottle;

b) Spring cylinder and pipe;

c) Lever arrangement and

d) Sampling bottle of capacity not less than one litre, preferably +10 cc.

4.2.2.2 Frame

The frame provides arrangement for housing one **Litre** bottle in vertical direction. It is attached to a spring cylinder (or lower pipe) and to upper pipe(s), through which a flexible metallic wire or rod is passed. At the lower end of the rod (or wire), a strong rubber cork to suit the size of the mouth of the bottle is fixed and at the upper end of the rod (or wire) a lever arrangement for raising or lowering the rubber cork is fixed. The spring fitted inside the cylinder (or lower pipe) helps in keeping the rubber cork tightly pressed against the mouth of the bottle to keep it effectively closed. Pipe pieces, each of 2 m length are joined together with threaded sockets to make the pipe of required length.

4.2.2.3 Operation

The sampler with rubber cork fitted in the mouth of the bottle, is lowered by means of the pipe to the desired sampling point. The lever is pressed for raising the cork and to open the mouth of the bottle for the requisite time determined earlier for the conditions under examination to fill the bottle with water sediment mixture. On release of the lever the cork again fits in the mouth of the bottle under the action of the spring.

4.2.3 Test for Performance

The sampler shall satisfy the following tests:

a) It shall be able to collect undisturbed samples of the water sediment mixture both in quality and quantity, from depths up to 5 m and velocities under 4.5 mls.

b) The deflection in the pipe due to bending while the final assembly of the sampler operates at the specified maximum depth of 5 m and velocity 4.5 mls, shall not affect the operation and position of the sampler.

With the cork closing the mouth of the bottle, there shall be no leakage of sediment laden water either from or to the bottle, irrespective of the position of the bottle.

4.2.4 Materials

Typical examples of materials to be used for different components are given in subsequent sections and this does not preclude the use of alternative materials having characteristics equivalent to or superior to those specified.

4.2.4.1 Frame

Rust proof material, for example, brass conforming to *IS 292*.

4.2.4.2 Spring Cylinder and Pipe Extensions

Preferably of rust proof material, for example, galvanized iron pipe conforming to *IS 1239 (Part 1)*.

4.2.4.3 Spring

Strong coiled of non-corrosive steel with cadmium plating Grade A of *IS 1572*.

4.2.4.4 Bottle

Non-corrosive material with sufficient rigidity, such as brass conforming to *IS 410* with nickel plating in accordance with *IS 1068* or glass.

4.2.4.5 Cork

Rubber for cork conforming to *IS 4588*.

4.2.5 Bottle Type Sampler

4.2.5.1 Construction Details

4.2.5.1.1 General

The bottle sampler comprises the following main parts:

a) Frame,

b) Spring cylinder and pipe;

c) Lever arrangement, and

d) Sampling bottle.

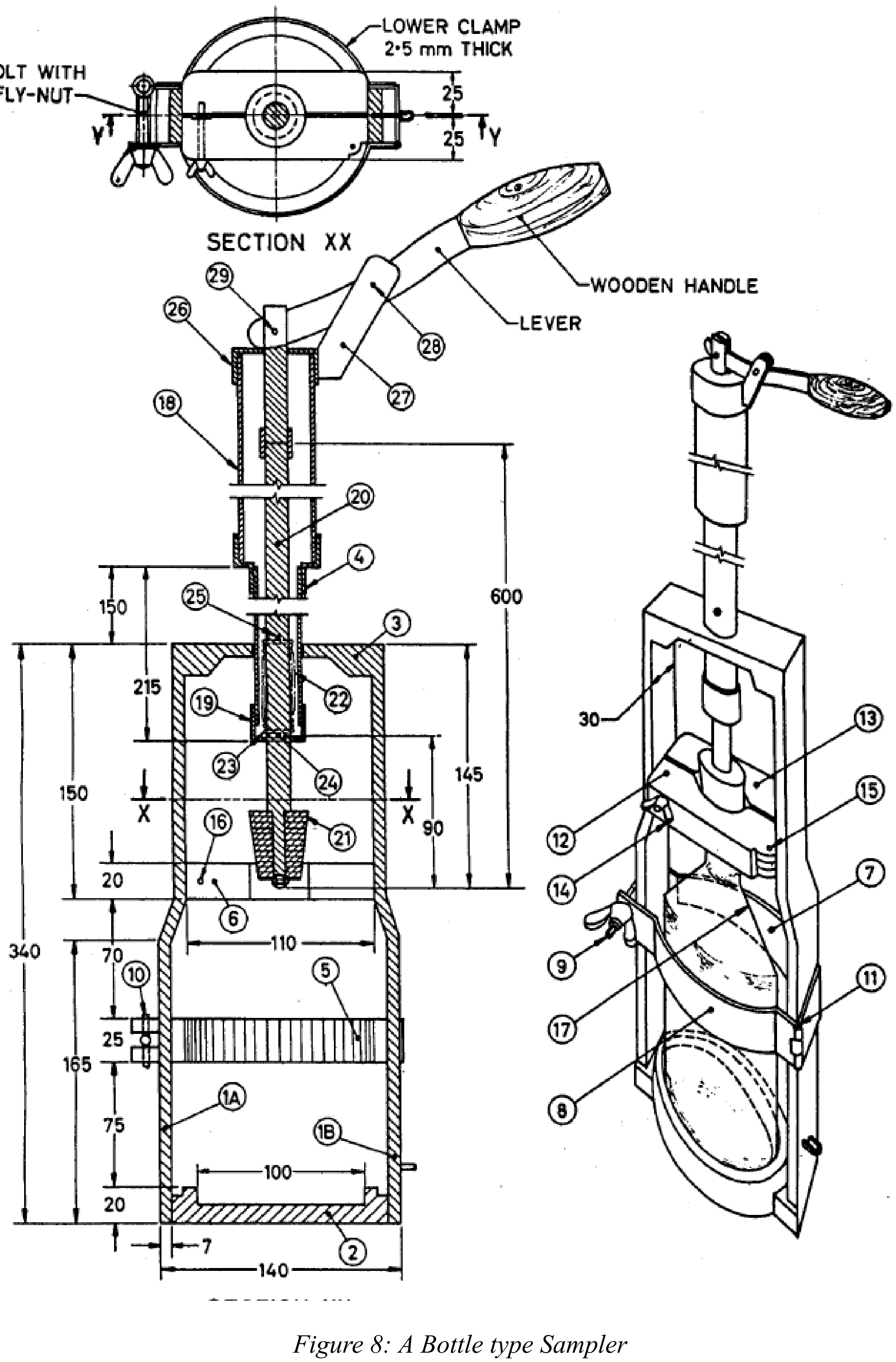
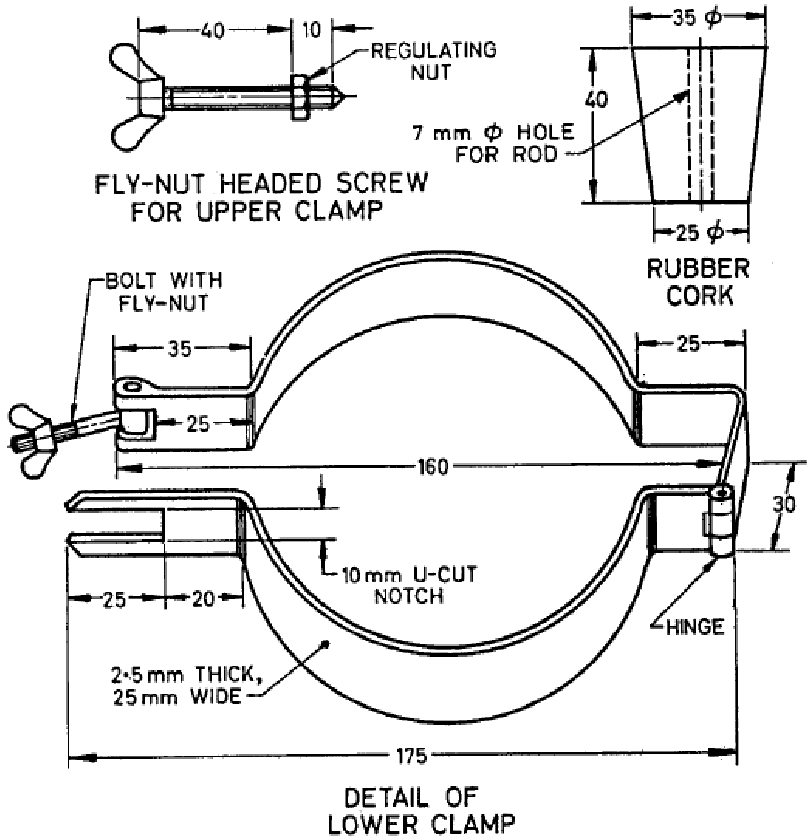


Figure 8: A Bottle type Sampler



All dimensions in millimetres.

Figure 9: Details of Clamp and Cork

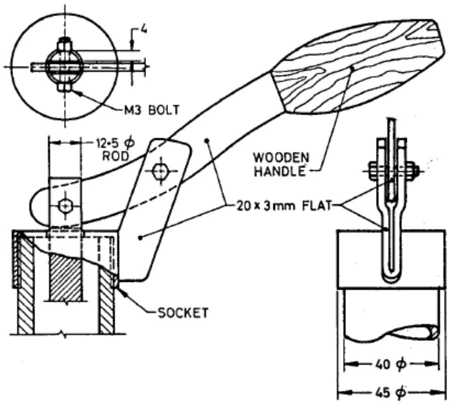


Figure 10: Typical detail of lever arrangement

4.2.5.1.2 Frame

The frame of the bottle sampler shall consist of the following three parts:

a) Framework,

b) Base plate, and

c) Clamps.

a) Framework

Note: Refer Figure 8

The framework shall consist of 2 vertical sides (1A & lB) each approximately 340 mm long, 30 mm wide and 7 mm thick. The lower end of each vertical side should be moulded at right angles to the horizontal notches in the base plate (2). A hook should be provided near the bottom of the vertical sides, which provides the means for keeping the sampler vertical. Each side shall be vertical up to approximately 165 mm height from the base, the inside distance between the two being approximately 125 mm. Both these sides shall be bent at this height to an inside distance of approximately 110mm in a height of 25 mm. These sides shall again be vertical to a height of approximately 150 mm with an inside distance of approximately 110 mm. The two sides at the upper end should be connected with each other with an elbow plate (3). It shall be approximately 110 mm long, and 25 mm thick at its two sides, having a hole in the centre for 25 mm spring cylinder (4). The framework, elbow plate and the base plate should be moulded to form one piece of casting.

b) Base Plate

It shall be a circular plate of approximately 110 mm in diameter and 20 mm in height. It shall have horizontal extended notches molding with the vertical sides of the framework. The base plate shall have a circular seat of approximately 100 mm diameter and 10 mm vertical height for housing the sampling bottle. The bottom of the circular seat on the inside should have circular grooves for proper resting of the bottle.

c) Clamps

Note: Refer Figure 8

There shall be two clamps (5 and 6), one fixed approximately at 75 mm and the other at 170mm from the upper end of the base plate respectively, the latter (6) being just above the bend of the vertical sides (1A & lB). The lower clamps (5) shall consist of two semi-circular shaped plates (7 and 8) each of approximately 230 mm total length having straight ends as shown in Figure 8, and 25 mm in width and 2.5 mm in thickness.

A bolt with fly-nut (9)65 mm long should be attached to one end of the semi-circular plate (7) through a vertical pin (10), around which it shall be able to freely rotate. Both ends of this plate (7) shall be then welded to both the vertical sides so that the bolt with fly-nut (9) is free to move on the outside of the left side (1A). The other plate (8) on one end shall have a housing notch for the bolt with fly-nut (9) fixed to the fast clamp (7) and on the other end should be attached to the right side (lB) of the vertical frame through a vertical pin *(11) so* that this plate (8) which is welded with the side (lB) can have a free movement round the pin (11). The whole arrangement have been detailed in Fig. 1. The function of the lower clamp (5) is to keep the bottle in position.

Whenever the bottle is to be placed or removed, semi-circular (8) is disengaged from the bolt (9) arid bottle is placed or removed by rotating plate (8).

The upper clamp (6) shall consist of two straight pieces (12 and 13) approximately 110 mm long, 25 mm wide and 20 mm thick. In the centre of both of these pieces, there shall be a semi-circular hole for the neck of the bottle so that when both these pieces (12 and 13) are fixed together, the neck of the bottle can fit in this circular hole. One of the pieces (12) should have a hole at one end through which a fly-nut headed screw (14) is passed. The right end of this piece (12) can rotate round for opening and closing, through a vertical pin (25) which is welded to the vertical side (l B). The other piece (13) shall have a threaded hole (16) in which the fly-nut headed screw (14) attached to the other piece (12) is tightened. One end of this piece (13) having the threaded hole (16) shall be welded to the left side (1A) and the other end welded to the right side (l B). The details of both these clamps (5 and 6) to hold the bottle (17).

4.2.5.1.3 Spring Cylinder and Pipe

4.2.5.1.3.1 General

The spring cylinder and pipe portion shall consist of:

a) Spring cylinder or lower pipe for housing the spring,

b) Upper pipe cylinder,

c) Rod or wire with rubber cork, and

d) Spring.

4.2.5.1.4 Spring Cylinder or lower pipe

Note: Refer Figure 8

It shall be made of approximately 215 mm long pipe (4) with 25 mm external and 19mm internal diameter. Both the ends of this pipe should be threaded from outside. This pipe shall pass through the central hole in the elbow plate (3) attached to the frame. The pipe (4) shall be molded or permanently fixed to the frame in such a way that an approximate length of 150 mm is protruding outside the frame. Its upper end shall be fitted with a reducing socket having approximately 40 mm as its larger diameter and 25 mm as smaller diameter. Upper pipe cylinder (18) with extension as required of approximately 40 mm external diameter should be attached to the reducing socket according It shall be approximately 100 mm long, non-corrosive strong coiled (22) and coiled round the rod. The lower end of the spring should rest on a circular metallic washer (23) which in turn should rest on a small rivet (24) fitting tightly in a hole in the rod. The rivet shall be fixed at about 90 mm height from the lower end of the rod holding the rubber cork and held in position by the lower half socket (19) fixed in the lower pipe. The upper end of the spring should be held in position by two screws (25) fixed in the lower pipe just above the framework. These screws restrict the tension of the spring when the lever is pressed for raising the cork.

4.2.5.1.5 Lever Arrangement

4.2.5.1.5.1 General

The two principal components of lever arrangement are:

a) Flat elbow shaped plates, and

b) Lever arm.

4.2.5.1.5.2 Flat Elbow Shaped Plates

Note: Refer Figure 8

A half socket (19) with a hole To the uppermost end of the upper pipe (J8) a half just sufficient for the rod to pass, shall be fixed to the lower end of the pipe to hold the spring (22) in position pipe socket (261 of approximately 45 mm outside diameter end having a hole to suit the size of the rod as shown in Fig. 1. shall be screwed. Both the flat elbow shaped plates

4.2.5.1.5.3 Upper Pipe Cylinder

Note: Refer Figure 8

Separate pipe pieces of suitable lengths, for example 2 m, shall be added to the lower pipe cylinder (4) to make the required length of the sampler for taking measurements. The diameter of the upper pipe is increased to approximately 40 mm to enable it to be **used** in greater depths and higher velocities. Its topmost end shall be attached to the lever arrangement. The pipes may be graduated in units of 0.6 m from the point of measured inlet.

4.2.5.1.5.4 Rod with Rubber Cork

Note: Refer Figure 8

Just like pipe, the rod (20) shall be made of several portions joined together with threaded sockets according to the requirements. The lowermost portion should be approximately 600 mm long and of 12.5 mm in diameter. Its upper end shall be threaded to hold the socket for extensions. The rod extension pieces available in 2 m length have got threads on both the ends and are joined together with threaded sockets. The uppermost end of these extension rods shall be fixed to the lever arrangement. (27) Should be joined by pin (28) to serve as fulcrum for the lever arm and welded to the half socket as shown in the drawing.

4.2.5.1.5.5 Lever Arm

Note: Refer Figure 8

The arm of the lever should be approximately 200 mm long and carry a wooden handle at one of its ends. This lever arm should be held between the two elbows shaped flat plates (27) through the pin (28) about which it can rotate. The other end of this lever arm should have a hole and be held between the grooves cut in the top of the uppermost portion of the rod (20) through a bolt (29) as shown in Fig. 1. Thus fixed, the lever arm shall be able to rotate round the pin (28) which serves as fulcrum and when it is pressed on its handle downwards, it shall raise the rod and thereby the rubber cork fixed to the other end to open the mouth of the bottle. On its release the rubber cork shall close the mouth of the bottle again under spring power.

4.2.5.1.5.6 Sampling Bottle

Note: Refer Figure 8

A rubber cork (21) of approximately 40 mm 8.3.5.1 It shall be a standard 1 litre bottle preferably in length, 35 mm in diameter at the top and 25 mm in of glass of suitable thickness to ensure rigidity, diameter at the bottom, shall be fixed to the lower end alternatively a 0.71 mm (22 gauge) thick brass sheet, of the lowermost rod. Details of clamp and cork have nickel plated and smoothly finished both inside and been shown in Fig. 2. Outside may be used instead of glass.

The mouth of the bottle should be30mmin diameter having a ring of 36 mm diameter made of metallic wire of 3 mm diameter so that the rubber cork shall be a tight fit in this. The bottle shall fit properly in the sampler. Its joints shall be leak proof and smoothly finished inside and outside. A tolerance of up to + 10 cc is permissible.

4.2.5.2 Pre-requisites for Satisfactory Operation of the Bottle Sampler

Note: Refer Figure 8

The bottle sampler shall meet with the following requirements, for its satisfactory operation:

a) Bottle shall remain vertical during operation.

b) Bottle should not move upward with the

c) Movement of the cork, because the passageway for water sediment mixture will get reduced and it will take longer time for the bottle to fill in. Therefore, the upper fly-nut and lower bolt arrangements shall be so designed that they do not permit any upward movement of the bottle when they are fully tightened.

Spring in the spring cylinder shall work properly such that the cork fits exactly in the mouth of the bottle. When the spring does not work properly, it should be taken out, cleaned, oiled and refitted such that the cork tits exactly in the mouth of the bottle.

d) There shall be no leakage of water into the bottle and the lower and upper ends of the rod should be joined together at the position when the cork fits tightly in the mouth of the bottle.

e) Maximum passage of water into the bottle shall exist when the lever is in pressed condition, that is, when the upper end of the cork touches the lower end of the half socket (19). Bottle should, however, not be completely filled up as over Ming is likely to introduce errors in the quantity and character of the sediment sample. For this purpose, the time required to fill the bottle should 'be obtained from preliminary observations and the lever should be pressed when the mouth of the bottle has reached the desired depth, and kept open for time slightly less than the minimum time required for complete filling, and released.

4.2.6 Marking

Note: Refer Figure 8

Each frame shall prominently show the name of manufacturer and year of manufacture in the base plate. A certificate from a well-equipped laboratory showing the details of the tests carried out, as specified in 6, shall be made available to the purchaser on demand.

4.3 REQUIREMENT OF FLOATS

4.3.1 Functional Requirements

a) The float shall be sufficiently heavy or weighted so that its greater part would be submerged in water to reduce interference due to wind. At the same time the float should be light enough to attain the velocity of the current within a short distance after being introduced into the river and it shall be sufficiently stable.

b) The paint on the float shall be such, that it is conspicuously identifiable from a distance with alternate bands of paint which are durable in or under water (black and white or red and white).

c) If a flag is used with the float, it shall be of a permanent color, conspicuously identifiable, and provision shall be made to prevent it from sliding down.

4.3.2 Materials

a) Depending upon the nature and conditions, surface floats may be made of almost any distinguishable article that floats, such as wooden desks, bottles, etc. Floating ice cakes or a distinguishable piece of drift may also be used.

b) Wooden floats are meant to be used in rivers under moderate velocity conditions with less turbulence, whilst metallic floats are meant for large turbulent rivers. Bottle floats weighted with cement mortar may also be used in conditions of relatively smooth flow.

c) Typical examples for materials to be used for different components are given in subsequent sections, however these do not preclude the use of alternative materials having characteristics equivalent to or superior to those specified.

4.3.2.1 Base and Stem

Sal wood of the best quality or any other heavier type of wood available locally shall be used. It shall be well seasoned. Specific gravity shall not be less than 0.5.

4.3.2.2 Metallic Sheet

G.I sheet, stainless steel sheet or any other suitable material.

4.3.2.3 Paint

Paint shall be color fast, durable and as specified by the purchaser.

ABBREVIATIONS AND ACRONYMS

ADCP - Acoustic Doppler Current Profiler

AWLS - Automatic Water Level Station

AWS – Automatic Weather Station

CSD - Cryosphere Service Division

DBMS - Database Management System

GPS - Global Positioning System

HWRSD – Hydrology and Water Resources Service Division

ISO – Indian Organization for Standardization

MSD - Metoerological Service Division

NCHM – National Centre for Hydrology and Meteorology

RGoB - Royal Government of Bhutan

TSRD – Technical Standard and Research Division

USGS - United State Geological Survey

WMO - World Meteorological Organization

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