TECHNICAL REPORT

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Measurement of liquid flow in open channels — Equipment for the measurement of discharge under ice conditions

Mesure de débit des liquides dans les canaux découverts — Equipement pour le mesurage du débit en présence de glace

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Contents

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 11328, which is a Technical Report of type 3, was prepared by Technical Committee ISO/TC 113, *Hydrometric determinations*, Subcommittee SC 5, *Flow measuring instruments and equipment*.

Measurement of liquid flow in open channels — Equipment for the measurement of discharge under ice conditions

1 Scope

This Technical Report deals with equipment used to measure water discharge in rivers and channels under ice conditions. It does not specify techniques for measurement and computation which are dealt with in various International Standards. ISO 9196 specifically deals with the methods for the measurement of flow under ice and this Technical Report is intended to be used with ISO 9196.

The most common technique for determining flow under ice conditions uses a modified form of the velocity-area method. This Technical Report concentrates on the specialized equipment required for gaining access through the ice sheet and obtaining area, velocity, and other information for determining the rate of flow under ice.

2 References

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

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

ISO 1100/1:1981, Liquid flow measurement in open channels - Part 1: Establishment and operation of a gauging station.

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

ISO 2537:1988, Liquid flow measurement in open channels - Cup-type and propeller-type current meters.

ISO 3454:1983, Liquid flow measurement in open channels – Direct depth sounding and suspension equipment.

ISO 3455:1976, Liquid flow measurement in open channels - Calibration of rotating-element current-meters in straight open tanks.

ISO 9196:1992, Liquid flow measurement in open channels - Liquid flow measurements under ice conditions.

ISO 9555-1: —[1], Measurement of liquid flow in open channels - Tracer dilution methods for the measurement of steady flow - Part 1: General.

ISO 9555-2:1992, Measurement of liquid flow in open channels - Tracer dilution methods for the measurement of steady flow - Part 2: Radioactive tracers.

ISO 9555-3:1992, Measurement of liquid flow in open channels - Tracer dilution methods for the measurement of steady flow - Part 3: Chemical tracers.

ISO 9555-4:1992, Measurement of liquid flow in open channels - Tracer dilution methods for the measurement of steady flow - Part 4: Fluorescent tracers.

3 Definitions

For the purposes of this Technical Report, the definitions given in ISO 772 and the following definitions apply.

3.1 **anchor ice:** An accumulation of spongy or slush ice adhering to the bottom of a stream.

3.2 **frazil ice:** Fine spicules or plates of ice suspended in water that are formed by supercooling of turbulent water.

3.3 **slush ice:** A mass of loosely packed anchor ice that has released from the bottom, or frazil ice that floats or accumulates under an ice cover.

3.4 **surface ice:** An ice sheet formed on the surface of a lake or river--also known as ice cover or ice sheet.

4 Equipment

4.1 Equipment for the velocity-area method

4.1.1 Ice cutting equipment

Winter field conditions require specialized equipment to cut holes through the ice to gain access for depth and velocity observations.

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[1] To be published.

4.1.1.1 Ice Chisels

A variety of ice chisels have been developed for manually cutting holes through the ice for making current-meter measurements, removing ice from around gage plates, removing small amounts of shore ice during the early stages of freezeup or from weirs and flumes. They are also used to test the safety of ice. Chisels are made in lengths of approximately 1,2 to 1,6 meters, with blade widths of 70 to 100 mm. A chisel weighing 5 to 6 kg is recommended. Chisels can be either all metal or have a metal cutting blade with a wooden handle. The blade should be approximately 75 mm wide and be formed with a flat single tapered edge. A "D"-shaped handle is recommended as it keeps the device from slipping through the operator's hands. The chisel cutting edge should be kept sharp at all times.

4.1.1.2 Manual ice drills

A variety of hand-powered ice drills are available for drilling holes through the ice to measure depths and obtain velocity readings. Sizes from about 125 to 200 mm are recommended. Hand-powered ice drills tend to become dull very quickly when used in ice with high sediment content.

4.1.1.3 Power ice drills

A variety of gasoline-powered ice drills are commercially available that are suitable for drilling holes through ice cover for measurement of streamflow. Most use 2-cycle air-cooled engines of 1 800 to 3 000 watts. A gearbox and centrifugal clutch should be attached to the engine so that the cutter will turn only when the engine is accelerated. It is recommended that the engine, gear train, clutch, gas tank, handles, and controls be packaged as a unit, referred to as the "powerpack" or "powerhead," so that the powerhead can be easily removed from the auger or drill.

The drill should usually be a flighted rod or tube with a cutter of various configurations on the cutting end of the assembly. A drill length of 0,75 m is recommended. Diameters of these assemblies are usually 150 to 200 mm, but may be as large as 300 mm. Replaceable cutting teeth are recommended as teeth can be easily damaged during most field use.

4.1.2 Current meters

Cup-type and propeller-type current meters are described in ISO 2537. These types of current meters are frequently used for measurement of velocity under ice cover. Operation during periods of slush ice may cause the rotating elements to become clogged, thereby giving inaccurate readings.

An open-vane meter has been adapted from the cup-type meter for winter work. The larger space between rotator parts was designed to let slush ice pass through easier. However, the meter performs poorly at low velocities and is not recommended for velocities below 0,15 m/s and use of this type meter is generally discouraged.

All rotating element meters are subject to freezing when moved from one ice hole to the next. Therefore, it is important to move rapidly and in extreme cases, heat the meter with direct heat or pour hot water over the meter before lowering it into the next hole. In less extreme cases of meter freeze-up, and in cases where the water is flowing rapidly, the action of the water and slightly above freezing water temperature will release the ice. In cases of extremely cold air temperatures, heated metering sleds can be used to keep the meter from freezing between holes. The user should ascertain that the meter is operating freely before starting a velocity observation.

4.1.3 Depth-measuring equipment

A variety of rod and cable devices are used to obtain the total depth of water and thickness of ice, which is necessary to compute the effective depth of moving water as well as for holding the current meter in the proper location to obtain velocity observations.

4.1.3.1 Rods

A variety of wading rods are available for measuring depth and holding current meters. They can range in diameter from 12,5 to 25 mm. The rod may be a fixed length, usually 1,0 m, or may be assembled by adding multiples of short sections, usually 1,0 to 3,0 m long, together. Rods may be the same type as are used for open-water measurements, may be specially designed for use under ice, or may be modifications of open-water devices. It is recommended that rods be fitted with an "ice-foot" which is a device to protect the meter and assist in determining the depth of the underside of the ice sheet.

The maximum length of rod that can be used depends primarily on the velocity of the water, but also on the diameter and material of the rod. Practical considerations will limit the length and weight of the rod that can be used. Rods shall be marked to measure depth of water in meters. The smallest unit of marking shall be 10 mm.

4.1.3.2 Cable suspension equipment (reel)

Cable suspension equipment consists of a sounding reel wound with special cable that can transmit electrical signals from the current meter. This equipment is identical to that used for open-water measurements.

The sounding reel, when used for measurements from ice cover, can be mounted on a variety of support devices including reel stands and sleds. In extremely cold areas, enclosed sleds may contain meter heating accessories. There is no standardized configuration for this equipment.

4.1.3.3 Cable suspension equipment (handlines)

Cable suspension by handheld methods can be used for measurement of flow under ice cover. The configuration and use is similar to that in open-water conditions.

4.1.3.4 Cable suspension equipment (sounding weights)

Standard sounding weights can be used for measurement of flow under ice, however, the physical size of the equipment requires either the chopping of a hole large enough to accommodate the weight, or drilling two holes with a power drill and removing the ice between them. A variety of specialized weights having sizes capable of passing through a 200 mm diameter ice hole can be used. These weights have less streamlining because of their short lengths and subsequently do not perform as well in high velocities as conventionally shaped weights. They weigh in the range of 8 to 16 kg.

A variety of folding hanger-bar adaptations can be used to allow conventional sounding weight/meter assemblies to pass through 200 mm diameter ice holes. These offer the advantage of greater stability and add to the accuracy of resulting discharge measurements. Each configuration of sounding weight and meter should be individually rated before being used in the field.

4.1.4 Width-measuring equipment

Equipment for the measurement of stream width necessary for the computation of streamflow area consists of taglines, tapes, and other instruments and are identical to those used for open-water measurements and are not described here.

4.1.5 Miscellaneous equipment

Several items of equipment have been developed over the years for the difficult conditions that exist during winter periods.

4.1.5.1 Ice thickness gage

This device is used to determine the location of the bottom of the ice or the slush layer that frequently exists below ice cover. Ice gages are constructed of light-weight aluminum tubing or a wooden stick (approximately 20 mm x 25 mm x 1 m) with an "L" shaped hook at one end. The shaft is marked in units consistent with wading rods as previously described.

The field person inserts the "L" shaped end through the ice hole and rotates it while moving it up and down until the water-slush interface or water-ice interface is located and reads this distance on the calibrated stick or tubing. This value is noted on the field notes and is used to calculate the effective depth.

4.1.5.2 Slush ice remover

Various sieve-like devices are used to remove slush ice from the hole prior to inserting the meter into the water. Some have calibrated handles and can serve as ice thickness gages as previously described.

4.1.5.3 Slush penetrator

Slush penetrators are used to work heavy accumulations of slush ice out of holes prior to inserting current meters.

The penetrator consists of an aluminum pole 1,3 m long passing through the center of a series of aluminum disks attached to it (usually by welding) at 0,3 m intervals. The penetrating end is a buttressed cone, whose circumference is the same as the disks. Extensions, loosely fitting together and held by pins, are added as required. The extensions are aluminum poles without disks.

To insure that the path is clear for the current meter, the slush penetrator is pushed down until no more resistance is encountered. By then, the slush penetrator will have reached the flowing water and can be lifted out of the hole bringing slush with it, leaving an open passageway for the meter.

4.1.5.4 Rod holders

A variety of rod holders can be used to hold a rod in place during the observation of velocity. They range from complex metal holders which sit on the ice over the hole to simple wooden handles that are held by hand or tied to the field person's waist. The meter must be held securely in the proper position during the velocity observation.

4.1.5.5 Ice creepers

Ice creepers or calks are devices intended to be worn over field boots when operating on ice. They provide improved traction when walking and working on ice, and are especially helpful when operating power drills.

4.1.5.6 Equipment sleds

Many measuring sites are located considerable distances from accessible roads or aircraft landing areas. Recreational and commercially-designed toboggans or sleds can be used directly or modified to carry power drills, rods, meters, chisels, and other equipment. These are usually pulled by field personnel on snowshoes, skis, or by snowmobile.

4.2 Dilution methods

Dilution methods can be used for measuring streamflow under ice cover. Slush ice may "trap" some tracer, resulting in inaccurate results. Details of dilution methods are described in ISO 9555-1, 9555-2, 9555-3 and 9555-4.

Equipment for making discharge measurements by dilution methods is identical with that used for open-water conditions. A number of exploratory holes are drilled through the ice to select a favorable site. Once a satisfactory site is selected, a hole is drilled for the tracer injection and 3 or more holes must be drilled at the downstream site for extraction of samples for tracer analysis. The holes may be as small as 12,5 mm to accommodate injection and retrieval devices; however, larger holes are recommended because they offer better observation of under-ice conditions when exploring for suitable sites, and will not freeze closed as rapidly. A common carpenter's brace and a long auger wood bit may be used for small diameter holes, or power ice drills described in 4.1.1.3 may be used.

A suitable measuring device is needed to measure the distance from the bottom of the ice to the streambed so that the injection point can be placed at about mid-depth. A wading rod or similar measuring device can be used.

Where the tracer solution might freeze before it is injected into the flow, the tracer can sometimes be mixed with an antifreeze solution. A determination should be made to verify that the antifreeze solution does not interfere with the desired tracer characteristics. The specific weight of the new solution should be considered so that it is injected in a way to prevent it from quickly sinking to the streambed or quickly rising to the underside of the ice prior to initial mixing of the tracer with the water.

An insulated chest or a similar storage device must be provided to prevent freezing of the water samples obtained for tracer analysis. A warming device might also be needed in the chest or with the container in which samples are stored. Freezing of the samples will not harm some tracers as long as the container holding the sample stays intact. The effect on the desired tracer characteristics of sample freezing and thawing should be determined before using the tracer for measurements where the samples might freeze.

4.3 Discharge determination by notches, weirs and flumes

The accurate measurement of discharge through control structures requires that ice buildup on, or in front of, the structure is prevented or that the ice is removed frequently during the winter period. Downstream ice should not be allowed to back water up to submerge the structure.

4.3.1 Ice removal

The equipment requirements for removal of ice from control structures are generally limited to devices that one or more persons can operate. Most frequently, ice is removed by manually chopping it away by the use of ice chisels, previously described in 4.1.1.1. Gasoline-powered chain saws can sometimes be used. Special ice-cutting chains are often available. Ice that has been cut loose must be either removed from the channel or allowed to float downstream for an adequate distance that will ensure that it will not jam and submerge the control structure.

4.3.2 Ice prevention by heating

Equipment and procedures for the method are described in ISO 9196.

4.3.3 Ice prevention by bubbling

A technique of preventing ice buildup at lock gates, piers, docked ships and similar applications by bubbling air from submerged orifices placed near these features has worked efficiently and economically. While there is not much experience with this technique at stream-gaging locations, it offers a possible technique to prevent ice buildup. Equipment required are a high volume, low pressure air pump, a pipe or tube with holes to disburse air at critical locations, and necessary tubing to connect the air source to the distribution pipe or distributor. The positioning of the orifice is critical so that the rising air bubbles are located at points that are to be kept ice free.

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Descriptors: liquid flow, water flow, open channel flow, flow measurement, measuring instruments, ice accretion, surveys.

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