International Standard ISO 6420

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Liquid flow measurement in open channels — Position fixing equipment for hydrometric boats

Mesure de débit des liquides dans les canaux découverts — Équipement de localisation de bateaux hydrométriques

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 6420 was prepared by Technical Committee ISO/TC 113, *Measurement of liquid flow in open channels*.

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Liquid flow measurement in open channels — Position fixing equipment for hydrometric boats

1 Scope and field of application

This International Standard specifies methods of determining the position of hydrometric boats with respect to known points on the banks of rivers or estuaries.

It applies to conventional surveying techniques and, in recognition of the availability of more sophisticated equipment, describes the principles of operation of currently available electronic positioning equipment. This International Standard does not cover the requirements for position fixing that occur in large scale hydrographic surveys such as those conducted on oceans.

2 Reference

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

3 Definitions

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

4 Units of measurement

The units of measurement used in this International Standard are those of the International System of Units (SI). Degrees are used in measurement of plane angles.

5 Requirements for position fixing

The necessity of using position fixing equipment arises in two types of measurements on open channels. First, it is necessary to position a boat on a measuring section in order to conduct the appropriate observations of velocity and depth for a discharge measurement. Second, in the conduct of morphological surveys, position fixing equipment is necessary to determine the positions at which depth observations and bottom samples are obtained. To meet these needs, a high order of accuracy is required.

The requirements for position fixing for stream gauging are shown in figure 1. In this case a measuring section is defined and it is then necessary to determine the distance from an initial point. This distance may be measured directly or calculated by trigonometry. Details of several surveying methods for position fixing, for example the pivot-point method, are given in annex A.

The requirements for position fixing for morphological surveys are shown in figure 2. In this case a base line having a known length is defined and its position is computed by trilateration, by triangulation or by using one angle and a distance. The position of a boat can therefore be determined through use of alignment equipment, equipment that measures angles, equipment that measures distance or by means of a combination of these types of equipment.

6 Alignment equipment

6.1 Targets

The most widely used method of giving line is the use of targets. The size and the type of targets used will depend on the channel width. Two or more targets on each bank are used to give a line. To ensure sufficient accuracy of the line, the spacing between each of the targets should not be less than about 10 % of the channel width.

6.2 Optical devices

Surveying instruments such as levels or theodolites may be used to give line by sighting along the line and using hand signals or radios to inform a boat operator of the boat's position with respect to the line.

Laser-equipped survey instruments may also be used to give line. In this case a target should be mounted on the boat and the boat manoeuvred so that the laser beam remains on the target. The target should be high enough above the water surface to eliminate the possibility of a member of the boat crew looking directly at the laser. If this is not the case; protective eyeglasses should be worn. Since the path of a laser beam in clear air is difficult to see, it is often necessary to use some other means, such as shore targets, to assist in manoeuvring the boat into the path of the laser.

Another optical device that can be used to give line depends on sets of flashing lights configured so that an observer on a boat will see different sequences of flashes if the boat is on either side of the line, and a third sequence of flashes if the boat is exactly on the line.

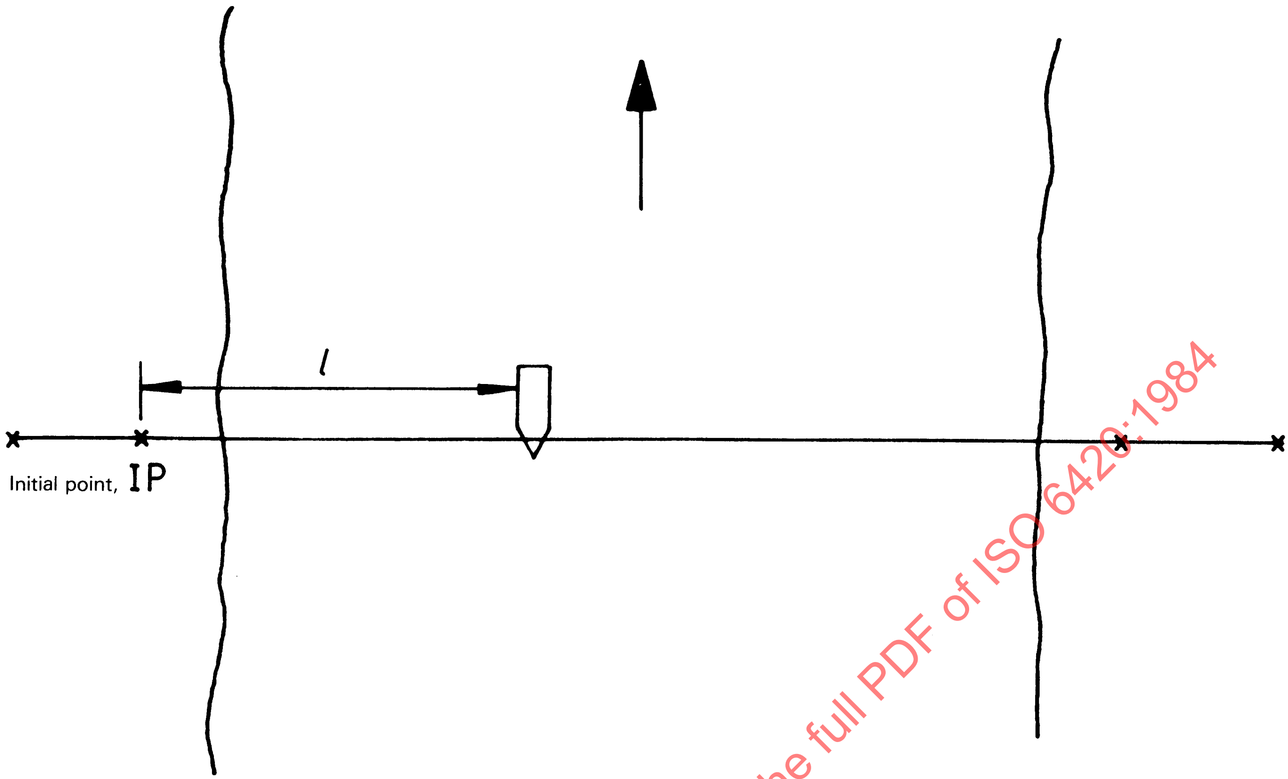

Figure 1 — Position fixing for stream gauging

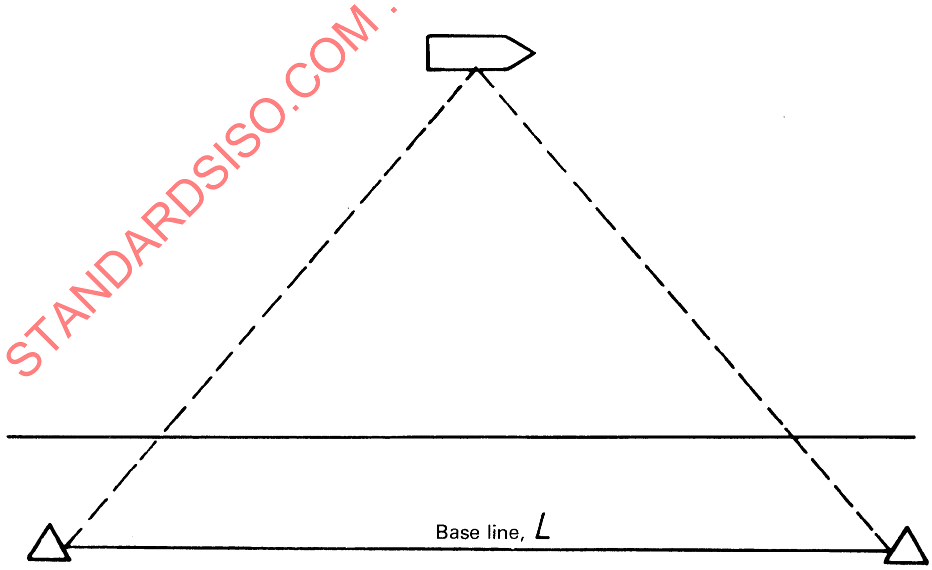

Figure 2 — Position fixing for morphological surveys

6.3 Radio frequency devices

Radio frequency devices that operate at microwave frequencies can also be used to give line. A transmitter produces trains of pulses having two slightly different frequencies (for example a difference of 300 Hz) and two different repetition rates, the energy being fed alternately to horn antennae about 6° on either side of the centreline of the course. The signals can be received on the boat and processed to detect course deviations that are of the order of ± 0,1°; positioning accuracies of ± 0,2° are feasible.

As the use of the electromagnetic spectrum is governed by the International Telecommunication Union (ITU), any use of radio frequency devices shall be licensed by the appropriate national agency.

7 Equipment that measures angles

7.1 Theodolites

Conventional theodolites placed on the river bank may be used in measurement of angles. If more than one instrument is used, hand signals or radios should be employed to ensure that angles are measured simultaneously.

7.2 Sextants

A sextant may be used from a boat to determine the angle between two points on shore. Care should be taken to ensure that the sextant is held carefully so that a horizontal angle is measured. Observations may be made to a precision of 20″ of arc although under field conditions the uncertainty in a single observation is of the order of 3′ of arc. The measured angles should be larger than 25° and the shore base line should be as long as possible, certainly not less than 50 % of the distance to the boat, in order to avoid significant positioning errors.

7.3 Electronic angle measuring equipment

Electronic angle measuring equipment is now available. These devices are, in effect, an electronic version of the sextant and have about the same accuracy. As they are usually combined with electronic distance measuring devices, details are given in 8.4.

8 Equipment that measures distance

8.1 Tag lines

The tag line is used most frequently for width measurements when measuring by boat or wading. A typical tag line consists of a marked corrosion-resistant steel cable of diameter 2 to 3 mm. The diameter of the tag line depends on the width of the channel, the velocity of the water and whether or not the same tag line is used for holding the boat and for determining its position. In the latter case, larger diameter tag lines may be needed. Long tag lines are usually wound on a drum having a diameter of at least 0,3 m and equipped with a means of braking. Tag lines are commonly used on channels up to 300 m in width and in special circumstances even wider; however, the accuracy of the tag line measurement depends on cable tension. Under favourable conditions, the error may be less than 0,1 % of the distance from the initial point to the measured point.

8.2 Rangefinders

8.2.1 The simple optical rangefinder is a device that can be used to measure distances in a range of about 30 to 500 m. When measuring the distance to an object, the point of interest is viewed through one eyepiece and a smaller, inverted image brought into coincidence with the main image using a vernier adjustment. The distance to the object may then be read directly through a second eyepiece. Typical uncertainties using a rangefinder having a 0,5 m baseline are about 0,2 % at 30 m, 1,0 % at 250 m and 2,5 % at 500 m.

8.2.2 Ranging instruments are available that use infra-red or laser radiation. They reduce to an insignificant level the problem of the degradation of accuracy with increasing distance.

8.3 Stadia rods

By using a stadia rod in the boat and an engineer's level or other stadia reading instruments on shore, the distance to the boat may be measured. If half a stadia interval is used, distances up to about 600 m may be measured without exceeding a reasonable stadia rod length. The accuracy of the distance measured is not good due to the difficulty of holding the stadia rod vertical in a boat and to the problem of reading the stadia rod correctly especially if the boat has some vertical movement as a result of rough water. The uncertainty of the measurement of the stadia interval is likely to be about 0,1 m.

8.4 Electronic distance measuring equipment

8.4.1 General

Electronic distance measuring devices can use electromagnetic waves in the frequency band from the optical region to the super-high radio frequency region. Instruments using radio waves operate on the principle that if a carrier is frequency modulated, it will exhibit a phase shift that is proportional to the distance travelled and to the modulating frequency. By using a number of modulating frequencies and comparing the phase shifts of a signal that has travelled between a master unit and a remote unit to a reference signal, it is possible to determine distance to a high degree of accuracy over a wide range of distances. Instruments that use various carrier frequencies, both optical and radio, have been developed. Typical operating frequencies are about 3 or 9 GHz.

8.4.2 Instrument performance criteria

The functional requirements for a position fixing system will vary according to user needs. The criteria that shall be used in evaluating various manufacturers' products are as follows :

a) System configuration : The system should provide a series of simultaneous distance measurements from a mobile boat (velocities up to 15 m/s) to one or two shore-based locations. The unit carried on the boat shall have a visual display of distance and shall have provision for externally triggered digital data outputs.

b) Distance determination : The distances measured shall be an independent, direct determination of the distance between the master and remote units. The system should automatically recover from any length of temporary signal loss due to interference.

c) System coverage : The field-of-view from the master unit should be 360° horizontally and at least 10° vertically. Remote shore stations should have at least a 90° horizontal and 10° vertical field-of-view.

d) System range : The system should measure distances ranging from 100 to 50 000 m. It should also be possible to use the system in a static mode to measure base line distances to the required accuracy.

e) Packaging : The system should be as small and as light as possible to permit ease of transportation and installation. The master unit should preferably be capable of being mounted in readily available electronic equipment racks and the remote units on readily available survey instrument tripods. No single piece of the system should have a mass exceeding 25 kg.

f) Antennae : The antennae should be simple and light in weight and should be capable of being remotely located up to 5 m away using coaxial cable rather than wave guide.

g) Power supply : The system should operate using conventional batteries. Power consumption should be sufficiently low to ensure not less than 8 h continuous operation of the master and remote units without battery charging.

h) Environmental : The system should be capable of operation during any ambient temperature and humidity that is likely to be encountered, typically − 20 to + 50 °C, and a relative humidity of 100 %, without condensation. Also, the system should operate without additional protection during periods of heavy rain or splash.

j) Voice communication : A voice communication system between the master and remote units is desirable.

k) Resolution and accuracy : The system shall provide distance measurements to a resolution of 0,1 m and have an accuracy that is of the order of 1,0 m plus a percentage (for example 0,001 %) of the distance measured.

9 Selection of position fixing equipment

9.1 General

The selection of position fixing equipment for a given task will depend on the accuracy requirements and the resources available, both personnel and equipment. The final system selection will involve a compromise between these factors.

9.2 Accuracy requirements

When position fixing equipment is used in stream gauging, the uncertainty in the distances from an initial point should be of the order of ± 1 % of the total width of the measuring section or ± 1 m, whichever is greater. Care should be taken to ensure that the boat is on the section line, not upstream or downstream. In morphological surveys, uncertainty should be as little as possible — normally ± 1 m is sufficient. Clause 11 describes the errors that can arise in the various methods of position fixing.

9.3 Resource requirements

Ideally a boat operator should be able to use the position fixing equipment to position a craft without the assistance of other persons. In actual practice, some position fixing techniques require the presence of one or two persons on shore and others in the boat. Where feasible, the use of intersecting target lines or electronic distance measuring equipment will enable a boat operator to work independently, while one or more persons operate gauging or other equipment.

Conventional surveying equipment is usually readily available and is frequently used. As the complexity of the equipment increases, it is less likely to be available; however, some types of position fixing equipment may be obtained on a rental basis. In considering equipment, it should be kept in mind that some types may provide greater accuracy and may reduce personnel or data computation requirements.

10 Operating instructions manual

A comprehensive manual shall be supplied, where necessary, with each piece of equipment. The manual shall provide full operating instructions complete with illustrations and accurate circuit diagrams, where applicable. The manual shall also contain maintenance and fault finding information, and a list of recommended spare parts. If particular safety precautions are required, these shall be stated.

11 Errors

11.1 General

Many methods of position fixing do not lend themselves to rigorous analyses of errors since they involve the use of the human eye in, for example, aligning targets under dynamic conditions. The accuracy of such observations depends on an individual's visual acuity plus the atmospheric and lighting conditions at the time of the observation. As observations for position fixing frequently involve sighting on a moving target, repetition of an observation does not always improve the accuracy of the observation. The preferred procedure is to use a number of simultaneous and independent observations.

The errors that occur in position fixing tend to be random in nature; systematic errors become a problem only when instruments are improperly adjusted or calibrated. The calibration of an instrument should be verified prior to use by measuring, for example, known angles or distances.

11.2 Errors in position fixing for stream gauging

Position fixing for stream gauging may involve the use of intersecting target lines, in which case the uncertainty in the fix is unpredictable although it will tend to be inversely proportional to the length of base line, or may involve the use of a target line which establishes the section line plus measurement of a distance or an angle. In this case, results are more predictable. If a fix is made when a boat is upstream or downstream of the section line, the result is a translation error along the section line away from the reference point or line.

These translation errors tend to be small in comparison to instrument error even for significant deviations upstream or downstream of the section line. For example, a translation error of ± 0,1 m is produced when a boat is 5 m off the section line at a distance of 100 m. Translation errors can be compensated for to some extent if the true distance to the far shore is known. The uncertainty in the fix is therefore dependent mainly on the instrument used in making the fix.

If it is assumed that a boat is exactly on the section line and position is determined by measuring one angle, the uncertainty in the fix will depend on the magnitude of the angle measured. For example, assume a 100 m base line at right angles to the section line and a sextant reading accuracy of ± 3′ of arc. The uncertainty in the distance along the section for various angles (see figure 6) becomes :

80° - ± 2,90 m

60° - ± 0,35 m

40° - ± 0,15 m

20° - ± 0,10 m

When distance measuring equipment is used, the uncertainty generally increases with distance measured. The figures given in clause 8 are typical.

11.3 Errors in position fixing for morphological surveys

In the case of morphological surveys, an uncertainty ellipse is set up around the measured boat position. When trilateration is used, the ellipse is smallest when the boat position is at right angles to the base line and increases in size as the boat moves away from this position. When angular measurement is used, the uncertainty ellipses tend to be more uniform in size.

Annex A

Position fixing for stream gauging

A.1 Alignment techniques

Four targets, A, B, C, D, are fixed two on each bank along the cross-section line at known positions (see figure 3). One more target, E, is fixed on one of the banks along a line at right angles to the cross-section line and passing through the target at point B. An observer, with a target in hand, then moves on the opposite bank from C, towards a position N, along a line perpendicular to the cross-section line, until the corresponding target E on the opposite bank, the target on the boat M and the target at N, are all in line. The perpendicular distance from N to C is measured and the position of the boat computed from the formula :

$$l_{MC} = \frac{l_{CN} \times l_{BC}}{l_{BE} + l_{CN}}$$

If the channel is so wide that objects on the opposite bank are not clearly visible, the position of the boat may be fixed from measurements made on one bank only (see figure 4). Two target lines perpendicular to the cross-section line are established on one bank of the river. The position of the boat is computed from the formula :

$$l_{MD} = \frac{l_{DE} \times l_{CD}}{l_{DE} - l_{CN}}$$

When the river is wide and flat land is available, the pivot-point method may be used. In figure 5, the distance l_{AP} is approximately half the width of the river and l_{PD} is about one-fifth of l_{AP}. On a line DD′, points are marked at fixed intervals depending on the width between the selected verticals. The boat moving on the cross-section line AA′ can be fixed in the selected vertical by lining up with points P and E_1, E_2, etc. A second set of pivot-points on the other bank can be used if required.

A.2 Angular techniques

A base line is established at right angles to the cross-section line or at an angle, ε, if necessary, and angles measured from shore using a theodolite, angles α or γ in figure 6 or from the boat using a sextant, angles β or δ in the same figure. The position of the boat is computed from one of the following formulae

a) using a sextant, base line not perpendicular

$$l_{MB} = \frac{l_{BF}}{\sin \delta} \times \sin (\varepsilon + \delta)$$

b) using a theodolite, base line not perpendicular

$$l_{MB} = \frac{l_{BF} \sin \gamma}{\sin (180 - \gamma - \varepsilon)}$$

c) using a sextant, base line perpendicular

$$l_{MC} = l_{CE} \cot \beta$$

d) using a theodolite, base line perpendicular

$$l_{MC} = l_{CE} \tan \alpha$$

A.3 Distance measuring techniques

A cross-section is established, being defined by targets where necessary, and the distance measured directly as shown in figure 1.

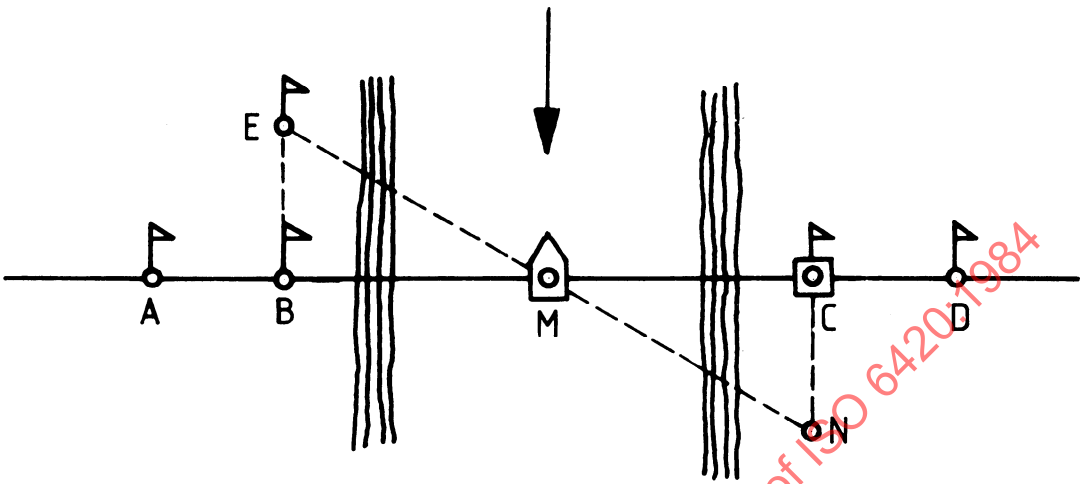

Figure 3 — Position fixing by projection from opposite bank

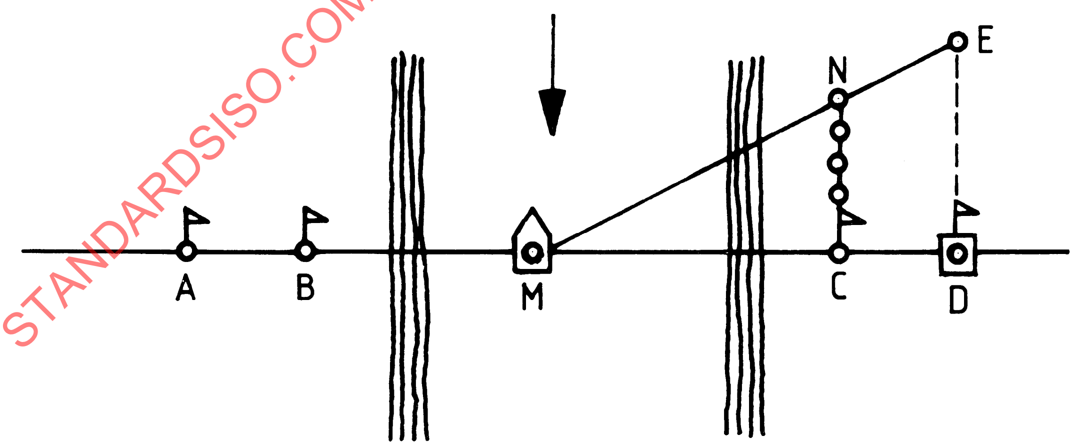

Figure 4 — Position fixing by projection from one bank

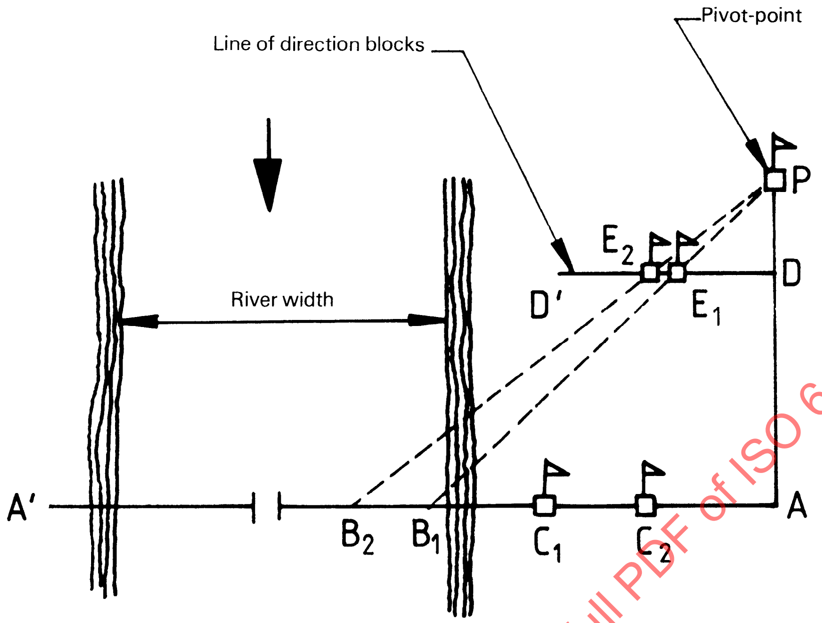

Figure 5 — Position fixing by the pivot-point method

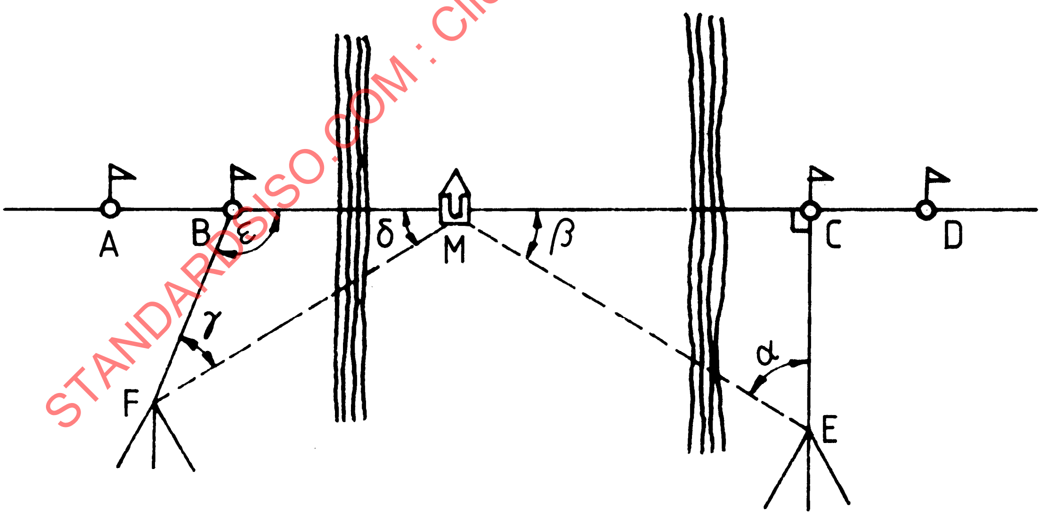

Figure 6 — Position fixing by angular techniques