HYDROLOGICAL PROCEDURE NO. 15

RIVER DISCHARGE MEASUREMENT BY CURRENT METER

JABATAN PENGAIRAN DAN SALIRAN
KEMENTERIAN PERTANIAN MALAYSIA

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Jabatan Pengairan dan Saliran
Kementerian Pertanian Malaysia

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1.0 INTRODUCTION

Most qualitative analyses of hydrologic problems require basic information on the quantity of water flowing in rivers and streams. Current meter gauging provides the most convenient, accurate and economical means of measuring river discharge.

The primary objective of current meter gauging is to establish a relationship between water level (stage) and discharge at the gauging site, and so permit direct computation of river discharge and runoff from continuous water level records.

The importance of accurate discharge measurement is all too obvious; the resulting stage discharge relationship could well form the basis for designing a hydro-electric power, irrigation or flood protection scheme.

2.0 CURRENT METERS

2.1 General

A current meter is a precision instrument designed to measure the velocity of flowing water. There are two main designs in current use:

(*a*) the bucket wheel or cup type meter (e.g. Watts, Pygmy) which has a vertical axis of rotation, and

(*b*) the propeller type meter (e.g. Ott, Amsler) which has a horizontal axis of rotation parallel to the streamflow.

The velocity of flow at a point is determined by observing the number of revolutions of the propeller (or bucket wheel) during a specific time interval; usually 50 seconds. A calibration equation or rating table converts the revolution rate to velocity.

Each revolution of the propeller (or bucket wheel) is signalled by means of a make-break contact or commutator-brush contact. The electrical impulse produced by completion of the electrical circuit is registered by a counter.

The body of the instrument has provisions for affixing a tail-fin to align the instrument with the flow direction and connecting other auxiliary equipment (hanger bar, wading rods, etc.).

For specific information regarding design, components, assembly, and operation of individual types of current meter, refer to the appropriate instrument manual. Manuals for the Ott C31, and Ott C2 current meters are included in Appendix 1.

2.2 Operating velocity ranges for current meters

The following table lists the operating ranges for types of meter currently in use in Malaysia:

Type of meter	OPERATING RANGE m/sec	
	Minimum	Maximum
Small Ott C2; propeller pitch 0.25 m	0.03	2.5
Large Ott C31; propeller pitch 0.25 m	0.015	2.5
Large Ott C31; propeller pitch 0.50 m	0.015	5.0
Pygmy	0.03	1.8
Watts Mark IV	0.03	5.5
Amsler 505	0.01	6.0
Mashpriborintorg Hydrometric Runner; propeller 1	0.06	5.0

Measurement accuracy decreases rapidly towards the operating velocity boundaries and the following ranges are recommended in practice:

(1) the minimum flow velocity should exceed 0.05 m/sec.

(2) the maximum flow velocity should not exceed 4.0 m/sec or 0.8 maximum operating range whichever is less.

Measurement in velocities less than 0.05 m/sec requires a well maintained instrument of high quality. Small imperfections in mechanical operating condition, difficult to detect in the field, can create additional inertia affecting a change in the minimum operating velocity. This applies particularly to contact pressure for instruments equipped with make-break contact devices (e.g. Pygmy, Watts).

Measurement in velocities exceeding 4 m/sec is usually hazardous in practice. Gauging such velocities can only be achieved from a cableway or bridge. A weight of at least 50 kg is required to overcome the drag on the meter (and weight) and to position the meter in the flow. Gauging under such conditions is extremely tiring. At these flood velocities saltated bedload and sediment can cause serious damage to the instrument during the process of sounding the depth of water.

Meter damage may also result from flood debris (logs, trees, etc.). When gauging rivers carrying flood debris it is advisable to use the more streamlined propeller type meter. Bucket wheel meters are particularly susceptible to interference from grass, algae, etc. winding around the vertical spindle; and pieces of driftwood denting the cups. In addition experiments have shown that the propeller type meter is better suited than the cup type meter for use in turbulent flow conditions.

2.2.1 OBSERVING REVOLUTION RATE FOR VELOCITY DETERMINATION

Three main methods are in current use for counting the number of revolutions made by the propeller or bucket wheel:

(*a*) earphones
(*b*) buzzer
(*c*) counters

All methods rely on an electrical signal produced by the make-break contact at each revolution or, as for the Watts and Amsler meters, at a fixed number of revolutions of the propeller or bucket wheel.

Revolutions are counted for an observation time period of between 40-70 seconds. The time to complete any one of the standard revolution counts (i.e. 2, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 120, 150, 200, 250, 300, 400, 500) is observed. To count more than 80 revolutions in 40 seconds using earphones or buzzer becomes increasingly difficult and a counter should be used. Counters may be fixed time or non-fixed time, the former counting the number of revolutions in a fixed time of, say, 50 secs.

Following is a summary of recommended counting method depending on revolution rate:

(*a*) For *less than* 20 revolutions in 40 seconds, use earphones, buzzer or non-fixed time counter.
(*b*) For 20-80 revolutions in 40 seconds, use earphones, buzzer or counter (fixed or non-fixed time).
(*c*) For greater than 80 revolutions in 40 seconds, use fixed or non-fixed time counters.

The signal return for the Watts meter can be adjusted to produce one signal for every 5 revolutions, and the Amsler has settings for one signal every 10, 20 or 40 revolutions. For these instruments, a buzzer or earphones are generally used to count revolutions.

Operating manuals for the Ott Z100, Z41 and F6U counters are included in Appendix 2.

2.3 Field Testing and Maintenance

2.3.1 THE SPIN TEST

The condition of the current meter must be inspected before and after each gauging. Whilst it would be desirable to test the starting velocity of the meter i.e. the velocity required to overcome the inertia and friction of the propeller or bucket wheel and its mechanism, such a test is not possible in the field. Instead, the operating efficiency is examined by means of a spin test.

The spin test is carried out with the meter in a stationary, level position, well protected from any breeze. The propeller or bucket wheel is started spinning by blowing or by giving it a flick with a finger, and timing the duration of the spin (i.e. from start to stop) with a stop watch.

Minimum acceptable spin test times are:

(*a*) 20 seconds for propeller type meters, (Ott, Amsler).
(*b*) 45 seconds for small bucket wheel meter, (Pygmy).
(*c*) 75 seconds for large bucket wheel meter, (Watts).

Experienced officers can evaluate the condition of a meter by observing the motion of the propeller or bucket wheel at very slow speeds. A meter whose spin is erratic, slows down rapidly, or stops abrubtly is immediately suspect and will produce a spin test less than the minimum standard. Such a meter should not be used until operating efficiency has been restored.

Common causes for sub-standard spin tests are given in the following table:

Cause	Action
Propeller type	
(1) Damaged propeller or bent propeller shaft.	(1) Return instrument to Instrument Service Depot, Ampang.
(2) Dust or grit in ball-race.	(2) Wash and oil complete meter with special attention to ball-race.
(3) Worn ball-race.	(3) Replace.
(4) Signal contact spring pressure too heavy (seldom the cause for Ott and Amsler meters).	(4) Difficult to adjust and should be attempted only by experienced officers.
Bucket wheel type	
(1) Damaged yoke or bucket wheel.	(1) Return instrument to Instrument Services Depot, Ampang.
(2) A worn, rusty, fractured or rough pivot point.	(2) Replace pivot.
(3) A damaged or corroded pivot bearing.	(3) Return instrument to Instrument Services Depot, Ampang.
(4) Signal contact spring pressure too heavy.	(4) Difficult to adjust and should be attempted only by experienced officers.

2.3.2 FIELD MAINTENANCE

The current meter is an expensive and delicate precision instrument and must be carefully maintained to achieve consistent gauging accuracy. Field maintenance is the responsibility of the officers using the meter. Before departure to the field for gauging operations they must ensure that the meter box contains (in addition to the meter and tail-fins):

(*a*) correct tools for dismantling and assembling the meter and its components,

(*b*) adequate supplies of lubricants, and cleaning materials, (brushes, rags etc.),

(*c*) suitable spares (ball-race, pivots etc.).

At the end of each day of gauging work the meter used should be dismantled for cleaning. Rinse the instrument components in *hot* water to remove oil, grease, grit and silt. Clean each component with a brush and rag and set aside to dry. Correctly oil the components during reassembly of the instrument. *Never* use any oil other than the recommended type and grade. In the case of the Ott meter the oil in the contact chamber should be changed every second day. Never use undue force when dismantling or assembling the instrument. For dismantling, washing, oiling and assembling procedure refer to the relevant instrument manual.

Meters should only be removed from the carrying box at the gauging site—many an assembled meter is damaged when a field officer trips over, or slides down a wet river bank getting to the gauging site. To avoid damage in the vehicle, it is advisable to strap the meter carrying boxes onto a special rack.

2.3.3 ANNUAL REPAIR, SERVICING AND RECALIBRATION

All current meters are to be returned to the Instrument Services Depot, Ampang, on an annual basis for repairs, servicing and re-calibration. Meters should be returned one at a time so as not to disrupt the normal gauging programme. Damaged meters should be returned immediately, accompanied by a request for a replacement.

Following repairs and servicing the meter is recalibrated. The meter is secured under a rating car which travels on rails along the top of a tank (approx. 60 m long × 1.5 m wide × 2.0 m deep) towing the meter through still water at a constant velocity for a given time. A series of runs at various velocities is required to produce an accurate meter rating, which is obtained by relating the velocities to the related number of revolutions for the given time.

3.0 DISCHARGE MEASUREMENT THEORY

3.1 Theory

If the cross sectional area (A) and the mean velocity ($\bar{V}$) are known the discharge (q) can be computed from

$$q = \bar{V} A$$

Because the depth of water and velocity of flow is not uniform throughout the whole cross section, accurate discharge measurement is achieved by dividing the cross-section into a series of sub-areas, called sections. Each section is bounded by the water surface, the stream bed and two imaginary vertical lines, called verticals (Fig. 1 (*a*)). Each vertical is a common dimension for two adjoining sections and fixes the point at which water depth and flow velocity observations are made.

Sufficient velocity observations are made to establish the mean velocity at each of the two verticals bounding the section and the mean velocities (e.g. V_1, V_2) for the two verticals are then averaged to give the mean velocity for the section.

$$\text{e.g.} \quad \bar{v}_{1,2} = \frac{v_1 + v_2}{2}$$

The area of each section is obtained by averaging the depths e.g. d_1 & d_2 observed at the bounding verticals multiplyed by the distance between the bounding verticals.

$$\text{e.g.} \quad a_{1,2} = \left(\frac{d_1 + d_2}{2} \right) w_{1,2}$$

The product of mean velocity and area for each section gives the sectional discharge.

$$\text{e.g.} \quad q_{1,2} = a_{1,2} \bar{v}_{1,2}$$

And summation of all the sectional discharges gives the total discharge.

$$\text{e.g.} \quad q = q_{0,1} + q_{1,2} + q_{2,3} \ldots + q_{n,n+1}$$

where n is the number of verticals.

3.2 **Observation Method**

It will be immediately apparent that gauging accuracy is related directly to site characteristics. A site with an irregular shaped bed with large boulders and non-uniform flow conditions will require many more depth and velocity observations to reach the same degree of accurary achieved by a few verticals on a smooth flowing channel with a regular cross-section.

3.2.1 VELOCITY MEASUREMENTS

The mean velocity in a vertical is obtained by measuring the velocity at specified points in the vertical using a current meter. Velocity distribution between the water surface and the stream bed approximates a parabola, approaching zero velocity at bed level, and maximum velocity at about one third of the depth below the surface. (Fig. 1 (*b*)).

Experience has shown that the mean velocity in the vertical can be obtained by velocity observations at a few selected points as follows:

(*a*) One point method, located at 0.6 of the depth below the surface (0.6d).

(*b*) Two point method; points located at 0.2 and 0.8 of the depth below the surface (0.2d, 0.8d).

(*c*) Three point method; points located at 0.2, 0.6 and 0.8 of the depth below the surface (0.2d, 0.6d, 0.8d).

(*d*) Multiple point method; with observation points at 0.1, 0.2, 0.4, 0.6, 0.8, 0.9 of the depth.

The choice of method is dependent to a large degree on the gauging accuracy required and the time available to complete the gauging. A gauging involving 20 verticals with one point method (i.e. 20 × 0.6d) takes about 1 hour actual gauging time. A two point gauging (20 × 0.2d and 0.8d) takes about 1¾ hours.

In general it can be said that a mean velocity in a vertical derived from a single point measurement will rarely provide the degree of accuracy required. At the other end of the scale, the multiple point method is much more accurate but requires a longer time to complete, and during a flood gauging whereby the stage is changing continuously, the extra accuracy achieved by a multiple point gauging is offset by the error in assessing the mean stage height. If fewer verticals are measured in order to speed up the gauging, then errors in assessing the mean sectional velocity and area result.

Except for special cases *the two point method is considered the best compromise.*

3.2.2 AREA MEASUREMENT

(*a*) *Measurement of width*

The number and spacing of verticals will depend on the shape of the cross-section and the horizontal distribution of velocity; usually an irregular cross-section has a non-uniform velocity distribution.

In Malaysia, as in most countries, it is normal practice to space the verticals evenly. For wading or boat gauging the width is measured by measuring tape or tagline stretched from one bank to the other. By convention, the zero end of the tape or tagline is secured to the left bank (looking downstream).

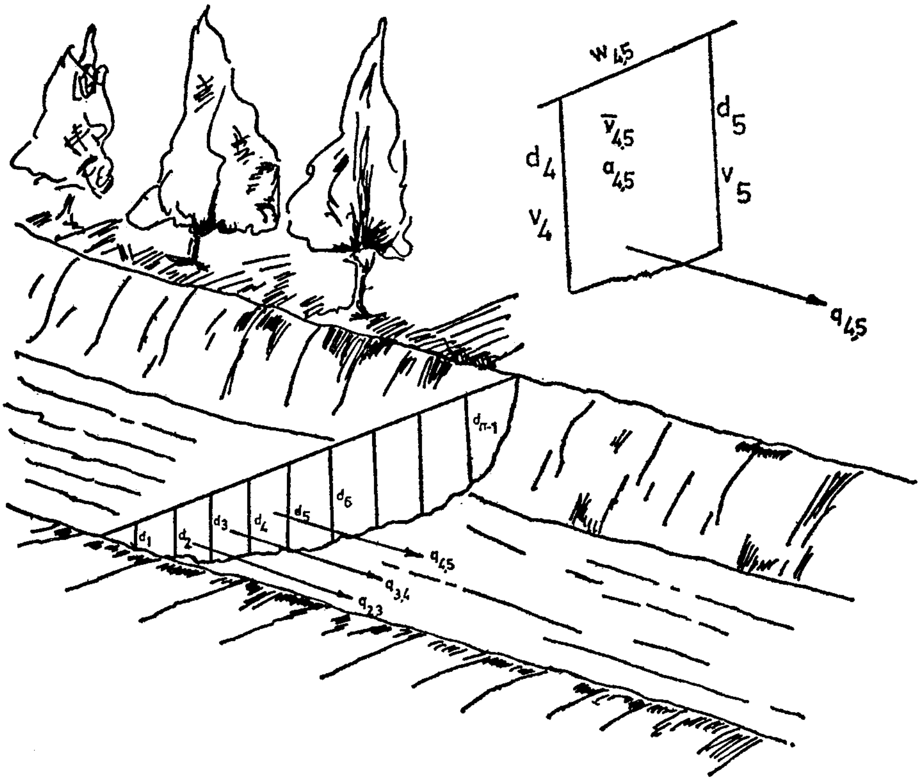


Fig.1 (a) : Discharge Measurement Theory

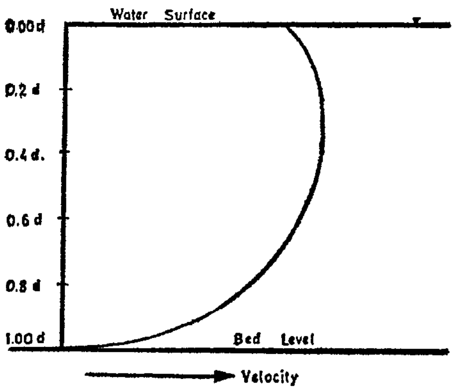


Fig. 1 (b): Typical Depth Velocity Curve Profile.

On cableways the tow cable is marked except in the case of double winch counter operation when this is not necessary (*see* Section 6.4.1). For bridge gauging the distance may be permanently marked on the side of the deck.

(*b*) *Measurement of depth*

The depth recorded at each vertical must be the true vertical distance from water surface to the bed of the river.

For wading gauging the depth is measured by the wading rod supporting the meter. For cableway, bridge and boat operations, the depth is recorded by means of a gauging winch and counter. Depth measurement in fast flowing river is discussed in Section 8.2.

3.2.3 RECOMMENDED PRACTICE

In the following table, an attempt has been made to prepare, as far as is possible, a list of recommendations regarding the gauging method. Due to the variable nature of gauging sites, the recommendations should not be regarded as strict rules, but more as a set of guidelines to assist final decision.

Max. depth (m)	Max. Vel. (m/s)	Gauging method	Minimum No. of verticals	Vel. obs. method
0.25	2.5	Wading using small Ott or Pygmy meter	15	0.6d
0.25	1	Wading using small Ott meter	15	0.6d
1	1	Wading using large Ott or Watts meter	15	0.2d and 0.8d
≥1	<1.5	Cableway, bridge or boat gauging using large Ott, Watts or Amsler meter	15	0.2d and 0.8d
≥1	>1.5	Cableway or bridge gauging using large Ott or Amsler meter	15	0.2d and 0.8d

4.0 WADING GAUGING

4.1 Site Selection

For river discharge measurement the wading gauging technique is superior to all other current meter gauging methods and should always be used where the combined effects of velocity and depth of water permits gauging with safety.

Safe wading gauging is possible where

$$d \times V \leq 1$$

where d is maximum depth (meters) of water and V is the maximum velocity (m/sec).

A wading gauging need not be taken at the same section used for cableway or bridge gauging. Provided there is no additional inflow, wading gaugings may be taken at any section within 200 meters upstream or downstream of the water level recording station.

A good wading site has the following attributes:

(*a*) A regular section with maximum depth not exceeding 1.2 metre.

(*b*) The horizontal velocity distribution should be fairly uniform with maximum velocity near the centre of the channel.

(*c*) There should be no "dead" water in the section (i.e. flow velocity throughout the section must exceed 0.1 m/sec).

(*d*) The river bed should be free of projections (i.e. boulders, snags, etc.) for a distance of at least 5 metres upstream and 2 metres downstream of the gauging section.

(*e*) The channel should be straight for at least five times the width upstream and two times the width downstream of the gauging section.

Such a site seldom exists in practice, but an otherwise poor site can invariably be improved by a little manual effort. This may involve moving boulders and other obstructions, narrowing the section, building or removing a boulder rapid downstream to improve the depth or velocity distribution. This site reconstruction work is most important when gauging small rivers.

4.2 Equipment

The following is a checklist of equipment required for wading gaugings:

(*a*) current meter (with tail-fins, if applicable).

(*b*) counter and stop watch.

(*c*) electrical leads for connecting meter and counter.

(*d*) wading rods, baseplate and depth adjustment clamp.

(*e*) tagline, or 30 m plastic/linen tape.

(*f*) gauging card and pencil.

(*g*) miscellaneous tools and spares (e.g. pivot, screwdriver, pliers, electrical leads).

A field party should, if possible, be equipped with two meters, one small Ott or Pygmy if measurement in less than 0.3 m of water is expected, and one large Ott or Watts for deeper wading or cableway measurement. Each meter should be equipped with a counter, stopwatch and suitable spares.

4.3 Gauging Method

Procedure for conducting a wading gauging is as follows:

(*a*) Assemble the current meter (at the site); secure the instrument to the depth adjustment clamp and position the clamp onto the wading rod.

(*b*) Connect the electrical leads to the counter and current meter. Reset the counter and give the propeller or bucket wheel a light flick to ensure the counter is counting the revolutions.

(*c*) Carry out a standard spin test, observing the time of spin with the stopwatch. Note the time on the gauging card.

(*d*) Enter on the gauging card the name of the river, site, instrument type and number, date and time of the gauging. Read the water level on the stick gauge and record the level and time of observation on the gauging card.

(*e*) Secure the tagline or tape between projections (rock, peg, tree branch, etc.) on the river banks, ensuring that the tagline (tape) is normal (at right angles) to the direction of flow, is stretched reasonably tight, and at a convenient working height.

If the river bed and channel are stable and a permanent wading section can be selected, then pegs (wooden peg or iron pin) on both banks should be established for locating the tagline (tape) in the same position for subsequent river gauging measurements.

(*f*) Observe the total distance across the river and divide by 20. Round the answer off upwards to two significant figures (e.g. 1.24 = 1.3 m; 121 = 130 m etc.) to obtain the approximate spacing between verticals. Whilst recommended, it is not essential to have regular spacing between verticals. Where the horizontal velocity distribution is particularly uneven it is preferable to reduce the vertical spacing in the faster flowing section, and space verticals further apart in the slower flowing section.

(*g*) Read the tagline (tape) at the water's edge and observe the depth (usually zero) with the wading rod to the nearest 0.005 metre (i.e. 0.5 cm).

(*h*) Proceed to first vertical, observe distance and depth of water.
Depth measuring in fast flowing rivers can be accomplished by sliding the index finger down the rod and positioning the finger tip on the side of the rod at the water level. Holding the finger steady, the rod is raised and the depth observed.

(*i*) Guidelines for selecting the depth *below water surface* at which point velocity observations will be conducted are given as follows:

Meter type	Depth d (metres)	Vel. Observation depth
Small Ott, Pygmy	≤ 0.25	0.6d
Small Ott, Pygmy	> 0.25	0.2d and 0.8d
Large Ott, Watts	≤ 0.50	0.6d
Large Ott, Watts	> 0.50	0.2d and 0.8d

(*j*) Set the current meter to the observation depth remembering that the zero datum for wading rods is at the baseplate which rests on the bed of the river. So in order to make a point velocity observation at 0.6d *below the water surface* the meter must be set at 0.4d from the bottom of the baseplate. Similarly 0.8d corresponds to 0.2d from the baseplate, and 0.2d to 0.8d from the baseplate.

(*k*) Lower the meter into the water and reset the counter. Wait 5 to 10 seconds for the propeller (or bucket wheel) to "take up" velocity, then start the counter. Observe the number of revolutions recorded by the counter for the specified preset time duration, usually 50 seconds. Provided there are no disruptions from floating debris, only *one* count observation is required for each point velocity measurement. If the count appears suspect when compared to observations in the previous vertical, a check count should be conducted.

(*l*) While taking depth and velocity measurements the wading rod should be positioned vertically with the top of the rod touching the tagline (tape). The operator should stand at arms length, behind and to one side at the wading rod so that disruptions to the flow caused by the operator standing in the river do not influence the current meter measurement.

(*m*) Meters not equipped with tail-fins are difficult to hold pointing upstream when measuring high velocities. Operators must ensure that the meter is clamped firmly to the wading rod, and the meter pointing upstream at the beginning and end of the velocity observation. Special care is required with the small Ott meter where the propeller is only a friction fit to the main shaft, and can be easily lost if the instrument is allowed to point downstream in fast flowing water.

(*n*) Continue this procedure for the other verticals. For each vertical, record the tagline (tape) distance, depth, depth of velocity observation (0.6d, or 0.2d and 0.8d), and count time and revolutions for each velocity observation. Record the tagline distance for waters edge at the opposite bank and the time of completion of the gauging. Read and record again the water level on the stick gauge and the time of observation.

(*o*) Pack the meter into the carrying box *before* leaving the site.

5.0 BRIDGE GAUGING

5.1 Site Selection

Road and rail traffic bridges are commonly used for river gauging purposes. The water section at the bridge is confined, especially during severe floods, and the bridge deck offers an ideal structure from which to conduct the river gauging. However bridges seldom offer the ideal gauging site, and their suitability for gauging purposes may be limited by one or more of the following reasons:

(*a*) the bridge *not at* right angles to the direction of flow.

(*b*) poor channel alignment upstream of the bridge. The approach conditions can create turbulent flow or poor velocity distribution at the bridge site.

(*c*) the flow velocities at the bridge being too low or too high at certain stages for efficient and accurate gauging operation.

(*d*) severe flow disruption caused by piers and abutments. Debris often collects around the base of piers (especially wooden piles) and abutments during flood periods which hinders gauging operation, and affects the quality of the results obtained. If such trapped debris includes heavy branches and logs then the bridge site should not be used.

(*e*) the type of bridge structure may make gauging operation difficult and laborious. Winding a 50 kg weight up to the top by hand in order to manoeuvre the gauging crane and current meter around obstacles (e.g. lampposts, bridge truss, etc.) and onto the next vertical, tends to discourage field staff from completing the recommended number of verticals.

(*f*) continuous traffic over the bridge can make bridge gauging extremely hazardous. Operation safety can be improved by placing warning signs (SURVEY PARTY—GO SLOW) on both sides of the bridge and stationing one man with a flag to control traffic.

The old type wooden truss bridge with wooden piles is notoriously bad for bridge gauging and should be avoided. Special gauging bridges are sometimes constructed for small spans (up to 15m) equipped with a bridge rail designed for crane operation (A-frame), or removable planks for sledge frame operation. Because of less stringent loading restrictions public foot-bridges often contain lengths of clear span (with no piers) far exceeding those found on heavy traffic road bridges. Such public foot-bridges can prove to be ideal gauging sites.

5.2 Site Preparation

River gauging from a bridge is almost always performed by suspending the current meter and weight from a winch mounted on a gauging crane, commonly referred to as an A-frame. Wading rods can sometimes be used on smaller rivers where the distance from the river bed to the gauging bridge deck does not exceed 3 metres. Rod suspension is an efficient gauging method and should be used in preference to gauging crane and winch wherever site conditions permit.

Gauging measurements should be made from the upstream side of the bridge. This permits the operators to observe the presence of flood debris. However if the upstream side of the bridge is particularly unsuitable (trusswork, old bridge piers or piles etc), the downstream side may be used.

For permanent bridge gauging sites the positions of the verticals should be painted on the bridge rail or deck of the bridge. The left bank abutment or end of the bridge rail is normally taken as the initial point for width measurement. Between 15 and 20 permanent verticals are marked off at even spacing (except where coincident with bridge piers) across the bridge and the distance from the initial point painted at the mark. Verticals should not be established within

1 metre either side of a pier or of an abutment. This provides a safe clearance for some fish-tailing movement of the current meter and weight during flood gauging. Obtain the permission of the appropriate authority before proceeding with marker painting.

When calculating the discharge, the effect of the pier (execpt for extreme cases) is totally neglected and the sectional area and velocity derived by the usual method, provided that the gauging section is upstream of the pier for a distance more than two times the pier width.

Where this condition cannot be satisfied (especially where the piers are very broad) then the sounding and velocity observation should be determined 1 meter on either side of the pier and a close estimation of the velocities be made of immediately adjacent to the piers. The area and velocity for this section is then derived by the usual method, treating this as the end section for the portion of the river between the edge of the river and the pier or between pier to pier (i.e. in the case of more than one pier).

5.3 **Equipment**

The following is a checklist of equipment required to carry out a bridge gauging:

(*a*) current meter, complete with tail-fins.

(*b*) counter and stopwatch.

(*c*) electrical leads for connecting meter to cable connector, and from winch to counter.

(*d*) tagline or tape (30m plastic/linen).

(*e*) A-frame gauging crane.

(*f*) gauging winch—Russian type, fitted with cable connector.

(*g*) hanger bar—to connect weight and current meter to cable connector.

(*h*) weights—Columbus type 14, 23, 35 or 46 kg as required.

(*i*) drift protractor—if required.

Check that the baseplate of the gauging winch fits the mounting plate on the gauging crane and that the hanger bar fits the weights, current meter and cable connector.

5.3.1 BRIDGE GAUGING A-FRAME

The A-frame is a manually operated gauging crane, designed to utilise the bridge railing as a support for the crane jib; the jib being adjustable to suit the height of the bridge rail (Plate 1). The crane can be readily transported and stored by either detaching the jib, or by releasing the bracing stays and rotating the jib downwards and lashing it to the frame. The base of the A-frame is fitted with rubber wheels and the underside of the jib is equipped with a rubber roller; these features improve mobility, enabling the crane to be easily manoeuvred and positioned on the bridge.

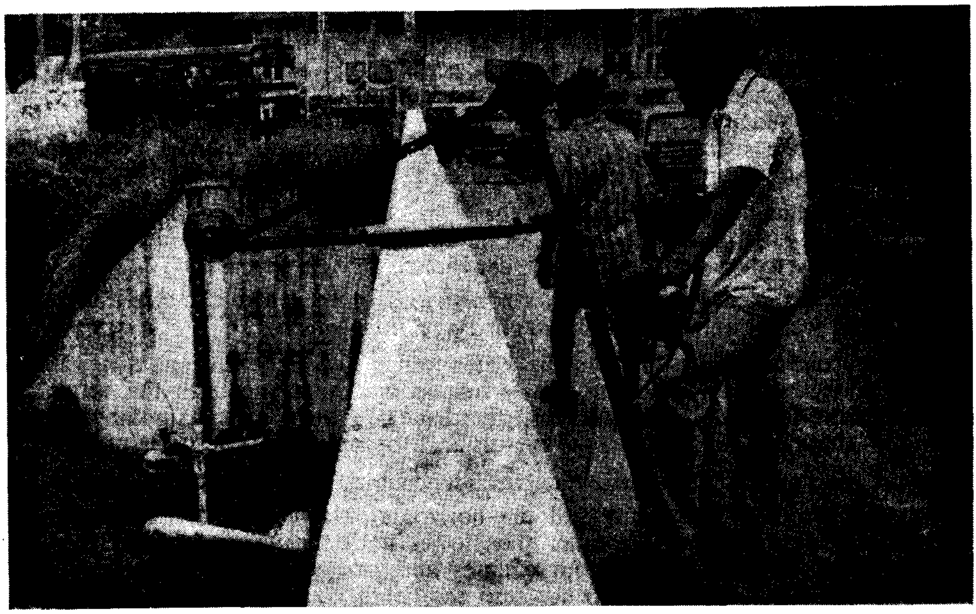


Plate 1: Bridge gauging using A-frame and Watts type current meter.

The A-frame is equipped with a mounting plate designed for mounting a Russian winch (Neva/ Luga system), but could be used for other winch types equipped with a baseplate matching the mounting plate. The winch is firmly secured by placing the winch studs through the holes on the winch stand and tightening the wing nuts.

5.3.2 RUSSIAN GAUGING WINCH

The Russian gauging winch has a digital counter for measuring the length of cable paid out. Because the counter is directly meshed with the winch drum it is *absolutely essential* that there be only a *single layer* of cable on the drum, otherwise depth errors during the gauging operation will result. The counter has a zero reset facility and records to the nearest centimetre (0.01m).

The winch drum is fitted with a 2.8 mm diameter suspension-conduction cable, with a breaking strain of 150 kg. The winch and crane are designed to operate with a *maximum weight* of 50 kg.

Special care must be taken to wind the suspension-conduction cable evenly onto the drum to minimise cable damage.

5.4 Gauging Method

(*a*) Set the current meter in a horizontal position and carry out a standard spin test observing the time of spin. Note the time on the gauging card.

(*b*) Assemble the gauging equipment on the bridge deck. With the A-frame resting in position against the bridge rail, fit the gauging winch and pay out 1 to 2 m of cable from the winch. Secure the weight to the bottom of the hanger bar. Assemble the current meter with tail-fin and slide it onto the hanger bar, locating and securing the current meter about halfway down the hanger bar. Secure the cable connector to the top hole of the hanger bar and complete the electrical connection (with a short piece of electrical cable, if necessary) between the current meter and the cable connector.

(*c*) Tilt the A-frame back until the jib is almost vertical and wind up the meter until the connector is nearly touching the pulley. Carefully lower the A-frame towards the bridge rail and gently rest the jib roller on the bridge rail, centering the jib roller about opposite the water's edge.

(*d*) Rest your foot on the bottom cross member to steady the A-frame while positioning and conducting the gauging. Stand to one side of the A-frame (one man to each side); *do not sit* on the bottom cross member or lean on the crane. Under adverse circumstances, floating debris (uprooted tree) could foul the meter and weight and pull A-frame, winch and operator over the bridge rail.

Where floating debris is present the bottom cross member should be lashed (chain and hook) to the bottom bridge rail, *before* the meter and weight are lowered into the water. *One* officer should be appointed "debris watcher" whose task is to observe and warn the operators of approaching debris likely to foul the cable, meter and weight. Given sufficient warning, trouble can be avoided by winding up the meter clear of the water surface before the debris reaches the bridge.

(*e*) If the positions for verticals are not marked permanently on the bridge, stretch a tagline (tape) along the deck close to the upstream bridge rail. Observe the approximate distance from one water's edge (often the abutment) to the other. Divide the distance by 20, rounding up to two significant figures, to get the approximate spacing between verticals. Some adjustment to the spacing may be required to avoid bridge piers.

(*f*) Enter on the gauging card the name of the river, site, instrument type and number, date and time of the gauging. Read the water level on the stick gauge and record the level and time of observation on the gauging card.

Measure the distance between the horizontal axis of the current meter and the bottom of the gauging weight and record this *depth correction constant.*

(*g*) With the jib centred about opposite the water's edge lower the current meter until about 50 cm from the water surface and gently manoeuvre the crane until the water's edge is aligned with the meter and cable. Record the distance from the initial point. If the water's edge is the abutment simply read off the distance opposite the abutment.

(*h*) Proceed to the first vertical, positioning the crane jib roller opposite the mark.

Lower the gauging equipment until the horizontal axis of the current meter is at the water surface. Zero the depth counter then lower until the weight touches the river bed. Read the depth shown by the depth counter and *add the depth correction constant* to obtain the true depth of water. Do *not* zero the depth counter.

During flood gauging the high velocity in association with discoloured water makes bed level detection insensitive and the exact point at which the weight touches the bottom is sometimes difficult to detect.

Electrical depth sounding equipment should be used where soft river bed sediments are suspected. The depth sounder is an electrically operated device protruding from the underside of the Ott type gauging weight. Connected in series with the normal current meter circuit the bed level is detected by observing the revolution counter. When the detector touches the river bed the circuit is shorted out and counting ceases.

(*i*) Guidelines for selecting the depth below water surface at which point velocities will be taken are given as follows:

Meter Type		*depth d (metres)*	*Vel. observation depth (metres)*
All types (excluding Small Ott and Pygmy)	...	≤ 0.50	0.6d
		> 0.50	0.2d and 0.8d

Raise the current meter to the observation depth. Reset the revolution counter, wait 5 to 10 seconds for the propeller (or bucket wheel) to "take up" velocity then start the counter. Observe the number of revolutions recorded by the counter for the specified preset time period; usually 50 seconds.

Provided there are no disruptions from floating debris only one count observation is required for each point velocity measurement. If the count appears suspect, when compared to observations in adjacent verticals, a check count should be conducted.

(*j*) At completion of all point velocity measurements for the vertical, raise the current meter and weight well clear of the water, and slowly move the A-frame onto the next vertical.

When moving the A-frame from one side of the pier to the other side, the meter and weight should be raised to within 1 to 2 metres from the jib pulley. This prevents the meter from becoming damaged by swinging against the pier during the moving operation.

(*k*) Continue velocity and depth observations for the verticals. Observe the distance for the other water's edge using the procedure described previously in (*g*). *Read and record again* the water level on the stick gauge and the time of observation.

(*l*) After completion of the gauging, record the time, dismantle the equipment and pack the current meter away into the carrying box.

(*m*) One final point—when gauging at traffic bridges ensure that the vehicle is parked in a place that does not obstruct traffic flow or driver vision. If the bridge has no footway, warning signs should be placed at each end of the bridge.

Where the gauging crane assembly is mounted permanently on the vehicle and the gauging done from the vehicle positioned on the bridge, arrangements must be made with the appropriate traffic authority.

6.0 CABLEWAY GAUGING

6.1 Cableway Design

Cableways for river gauging purposes come in two basic designs; manned carriage where the operators carry out the gauging from a cable car, and unmanned carriage or bank operated cableways where the current meter is suspended from a traveller carriage operated from the bank.

Operator safety during flood gauging is the major point in favour of bank operated cableways. Most field staff are rightly reluctant to conduct gaugings from a manned cableway during high floods.

Bank operated cableways can be satisfactorily used for cableway spans up to 400 metres provided suitable ancillary equipment is available to facilitate traveller carriage traversing and water depth sounding.

The main cable (diameter and type dependant on length of span) is supported on two steel columns or A-frame structures and anchored at either end. The traveller carriage is suspended on the main cable and operated by 6.0 mm diameter stainless steel tow cable. The current meter and weight is suspended from a pulley on the bottom of the traveller carriage using the standard 3.5 mm diameter stainless steel suspension-conduction cable.

The operation end, of the cableway is housed to protect the equipment and to offer some shelter to the operators during adverse weather conditions.

Measurements are generally made by two or more people, but can in exceptional cases be operated by a single person.

6.2 Cableway Site Selection

Cableway site selection is closely linked to water level recorder site selection. Unfortunately the requirements for each site differ; the cableway site must be selected for sensitive discharge measurement, while the recorder site is selected for sensitive water level recording.

The stability of the stage-discharge relationship is dependant primarily on the natural controls existing at the water level recording site, which may be sited some distance upstream or downstream of the cableway site. The stick gauge and water level recorder are normally sited in a ponding zone immediately upstream for a natural control, examples of which include rock bar. narrow gorge, sharp bend in the channel, and a boulder rapid. A control is classed as stable if it maintains a constant stage-discharge relationship over a long period of time, and is classed as sensitive if a relatively small change in discharge produces a significant change in stage.

A good site for a cableway has the following attributes:

(*a*) the river reach should be straight and uniform for a distance upstream of five times, and downstream two times the width of the river respectively.

(*b*) the site should be accessible at all stages of flow.

(*c*) the flow should be confined to a single channel with no bank overflow or bypass during high flood stages.

(*d*) the bed and banks of the river should be stable with no progressive tendency for the river to scour (degradation) or deposit (aggradation) sediments.

(*e*) the horizontal velocity distribution should be fairly uniform and within the range 0.1 to 3.5 m/sec for all stages.

(*f*) the operating section must be free of large boulders, rock outcrops and debris for at least 10 metres upstream and 5 metres dowstream of the cableway section. There must be no possibility of the gauging equipment becoming snagged in an old tree stump or wedged in a rock crevice.

(*g*) the operator must be capable of viewing the entire cross section from the operating end of the cableway. This requires the housing to be designed so that the operator has a unobstructed view upstream and downstream of the cableway to observe approaching debris likely to foul the equipment. Trees and other vegetation on the operating bank should be removed where necessary.

6.3 **Traveller carriage operation**

There are two basic types of rigging commonly used for moving the traveller carriage along the main cable.

(*a*) Friction Drive: In this type the drive cable connected to the traveller (suspended from the main cable) passes over a reversing pulley on the opposite bank and over a friction winch drum on the operating side and back to the traversing carriage, to form a continuous friction drive loop system (Fig. 2 (*a*)).

The friction drive winch is a permanent installation and must be continually maintained to ensure operation efficiency.

(*b*) Haul-out Drive: In this type the drive cable connected to the traveller (suspended from the main cable) passes over a reversing pulley on the opposite bank and back to a winch on the operating side. The haul-out winch is designed to drive the carriage in one direction only; from the operating end to the opposite bank (Fig. 2 (*b*)).

The gauging winch, in addition to its normal use for depth measurement is also used for returning the carriage from the opposite bank to the operating side. By setting the haul-out winch in the "free moving" position and then "winding in" the gauging equipment, the force component drives the traveller carriage towards the operating end.

Standard gauging practice with a haul-out drive system is to haul-out to the opposite bank and begin the river gauging from that side. If the horizontal distance between successive verticals is greater than the vertical distance from the carriage to the water surface, it will be necessary to move the gauging equipment up and down a number of times to travel the required horizontal distance.

As the cable on the haul-out winch is fully paid out with the traveller carriage positioned at the operating end, it is possible, using a shackle arrangement, to detach the cable from the winch drum and remove the winch. This arrangement offers a saving in equipment, and improves winch maintenance and operation efficiency.

6.4 **Equipment**

The following is a checklist of equipment required for cableway gauging:

(*a*) current meter, complete with tail-fins.

(*b*) counter and stopwatch.

(*c*) electrical leads for connecting meter to cable connector, and from winch to counter.

(*d*) traversing winch.

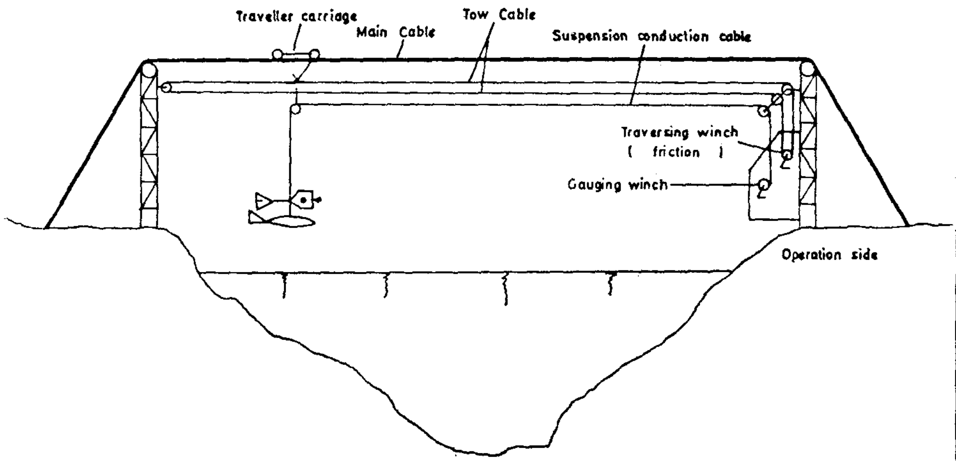


Fig 2a - Friction Drive System

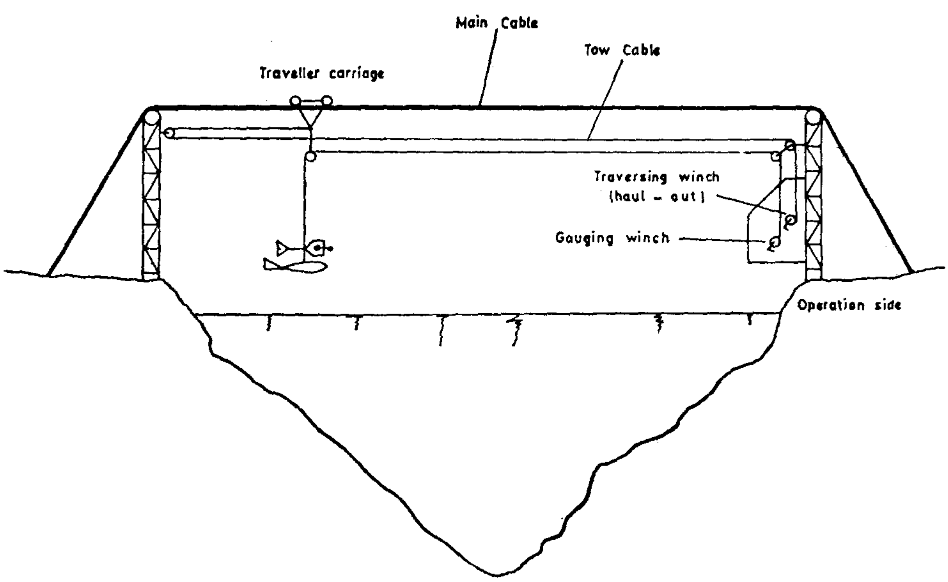


Fig 2b - Haul-out Drive System

(*e*) gauging winch, fitted with cable connector and sufficient suspension-conduction cable to cover the combined horizontal and vertical distances likely to be encountered.

(*f*) hanger bar.

(*g*) weights-Columbus type 14, 23, 35 or 46 kg or Ott type 50 or 75 kg middle-piece with electrical depth sounder as required.

Finally check that the following items are present; bolts and wing nuts for securing winches, screw bolt for the cable connector which fits the top hole of the hanger bar, weights equipped with necessary screw bolts which fit the bottom hole of the hanger bar, and that the hanger bar suits the current meter. Nothing is more frustrating than to drive 100 km to a site to find the screw bolt for the cable connector missing, or a hanger bar which does not fit. Five minutes spent fitting the weight, meter, and cable connector to the hanger bar *before* departure is time well spent.

6.4.1 WINCHES AND COUNTERS

The traversing winch controls the horizontal movement of the traveller carriage to position the traveller carriage above the preselected points of measurement across the cableway section (i.e. verticals).

The gauging winch controls the vertical movement of the current meter and weight to measure water depth and locate the current meter at the velocity observation points within each vertical.

The two winches may operate independently, or operate together, as for the standard double drum where both winches are intermeshed and controlled using a single handle.

Power operated winch systems may be justified where the cableway span exceeds 300 metres and heavy weights (more than 50 kg) are required for normal river gauging operation. The system must be reliable, operate quietly at a speed convenient to efficient gauging operation, and be readily convertible to manual operation if an emergency arises.

Digital counters register the distance of cable paid out or paid onto the winch drums. Where the counter is driven directly off the retrieving drum, then there should be *only one layer* of cable on the drum. In many cases, the counters operate from a machined wheel which operates independently of the winch drum. Frequent checks (once every six months) are required to ensure that the horizontal and vertical movements recorded by the respective counters correspond exactly to premeasured distances.

To minimise damage always ensure that the conduction-suspension cable is wound evenly onto and from the drum. Damaged cables are not only expensive to replace, but repairing or waiting for a replacement may interrupt the gauging programme.

Safety precautions must be observed while operating a gauging winch (especially power operated winches) to ensure that the operator's fingers are not caught in the revolving part of the winch. Shirt sleeves and other loose articles of clothing are equally hazardous.

Operation manuals for the Ott single and Ott double drum winches are included in Appendix 3.

6.5 Gauging Method

(*a*) Set the current meter in a horizontal position and carry out a standard spin test, recording the time of spin on the gauging card.

(*b*) Secure the traversing and gauging winches to their respective mounting plates, as required. In some cases the traveller winch is a permanent fixture or, as for the standard double drum winch the two winches are mounted in a single framework and bolted to a single mounting. Locate the winding handles.

(*c*) Hook up the tow cable to the traversing winch (if required) and then unlock the chain securing the traveller.

(*d*) Assemble the current meter and weight on the hanger bar, roll out some cable from the gauging winch over the lower pulley of the traveller, and secure the cable connector to the top of the hanger bar. Wind up on the gauging winch until the current meter is suspended. Complete the electrical connection (with a short piece of electric cable, if required) between the current meter and cable connector.

(*e*) Connect the revolution counter to the appropriate terminals on the gauging winch; give the propeller (or bucket wheel) a flick and check the signal return from the meter to the counter.

(*f*) Enter on the gauging card the name of the river, site, instrument type and number, date and time of the gauging. Read the water level on the stick gauge and record the level and time of observation on the gauging card. Measure the distance between the horizontal axis of the current meter and the bottom of the gauging weight and record this *depth correction constant.*

(*g*) Wind out the traveller carriage until the current meter is centred on the zero point. This is a permanent mark; a paint mark on the main cable, or peg, or concrete block about 2 to 3 meters out from the operating end post. The exact distance from the mark to the bearing post should be recorded on the site information card.

(*h*) Wind out the traveller carriage and current meter to the near water's edge, and record the distance, then continue to the far water's edge and record that distance. Determining the position of the water's edge is best achieved by maintaining the weight just above the water surface whilst operating the traversing winch onto target.

A plan of the river cross-section survey at the cableway site showing the fixed locations and spacings of verticals (e.g. verticals at 10 meters spacing from zero point) should be permanently hung on the wall of the gauging hut. If such information is not available then determine the total width of the channel and calculate the spacing of the verticals by dividing the width by 20 and rounding upwards to two significant figures.

Haul in the traveller carriage and meter back to the first vertical (from the opposite bank) and lower the meter until the horizontal axis of the current meter is at the water surface. Zero the depth counter, then lower until the weight touches the river bed. Read the depth shown by the depth counter and *add the depth correction constant* to obtain the true depth of water. Do *not* zero the depth counter.

Care must be taken to ensure that the current meter axis is zeroed to the water surface, especially when operating on long cableways where the current meter position may be difficult to observe without the aid of binoculars.

Difficulty is often experienced in sounding the actual river bed. Dependant on the length of cableway, the frictional resistance in the system, and the actual weight used, the exact point at which the weight touches the river bed may be difficult to detect. The ability to take accurate depth soundings on bank-operated cableways is generally achieved only by practice, the operator sensing the river bed by the weight on the gauging-winch handle.

Another way is to observe the traveller carriage, which will rise when the weight hits the river bed and the weight of the equipment is transferred from the carriage and cableway. The actual depth is indicated at the *beginning* of the upward movement, and continuing to payout cable as the carriage rises and the suspension cable goes slack results in incorrect depth soundings. Special care is required where the bed of the river is soft silt and the weight tends to sink into the sediments.

Electrical sounding equipment is now standard and should be used on long cableways (more than 50 metres) and where soft river bed sediments are suspected. The depth sounder is an electrically operated device protruding from the underside of the Ott type gauging weight. Connected in series with the normal current meter circuit, the bed level is detected by observing the revolution counter. When the detector touches the river bed the circuit is shorted out and counting ceases.

(*i*) Guide lines for selecting the depth below surface water level at which point velocities are to be taken are as follows:

Meter Type	depth, d (metres)	Vel. observation depth metres
All types suitable	≤ 0.50	0.6d
For cableway gauging	> 0.50	0.2d and 0.8d

Raise the current meter to the observation depth, as read directly on the depth counter. Reset the revolution counter, wait 5 to 10 seconds for the propeller (or bucket wheel) to "take up" velocity, then start the counter. Observe the number of revolutions recorded by the counter for the specified preset time period, usually 50 seconds.

(*j*) On completion of all point velocity measurements for the vertical, raise the meter and weight clear of the water, and haul in to the next vertical. See that the current meter remains free of weed likely to affect performance.

(*k*) Continue velocity and depth observations for the remaining verticals. Observe the distance for the water's edge and check that it agrees with the initial observation. Record the time of completion of the gauging.

(*l*) Wind the traveller carriage back to the gauging hut ensuring that the suspension-conduction cable is wound evenly onto the winch drum. Before disconnecting the counter and current meter, set the propeller or bucket wheel revolving and check the signal return from the meter to test that the suspension-conduction cable is still in good working order. *Read and record again* the water level on the stick gauge and the time of observation.

(*m*) Dismantle the equipment, and pack into the respective carrying boxes.

6.6 Cableway and site maintenance

The cross section and operating area must remain free of debris and scrub growth. Such maintenance is best done during periods of low flow.

All moving parts of the cableway installation, *including* the reversing pulley on the opposite bank, must be cleaned and lubricated frequently (at least once every six months).

7.0 BOAT GAUGING

7.1 General

Gauging from boats is resorted to when no other methods are available (i.e. no bridge or cableway), or practicable (e.g. debris trapped on bridge piers).

Boats used for gauging range from ordinary inflatable rubber dinghies, with or without outboard motors, to advanced power boats. Having no external propeller unit likely to be damaged by semi-submerged debris, jet boats have been proven superior for flood gauging work.

7.2 Equipment

Where the velocity is low and the depth of water does not exceed 3 m, gauging from a small boat using wading rods is possible. Usually, gauging operation is by cable suspension from a special gauging boom fixed (permanent or temporary) to the boat. The boom assembly includes a stand for mounting the standard gauging winch.

The following is a check list of equipment required to conduct a boat gauging:

(*a*) boat, rigged with gauging boom as required. Make sure the boom is safely secured and capable of supporting the gauging equipment.

(*b*) tagline.

(*c*) two steel pegs for securing tagline.

(*d*) tackle for tensioning tagline (e.g. a rope 10 to 15 mm diameter attached to two 50 mm long wooden blocks which are bolted together into the tagline).

(*e*) gauging winch, fitted with cable connector and sufficient cable. Make sure the winch fits the mounting on the gauging boom.

(*f*) hanger bar and weights.

(*g*) current meter, counter and stopwatch.

(*h*) life jackets, anchor.

Five minutes spent fitting the weight, current meter and cable connector to the hanger bar *before departure* is time well spent.

7.3 Site Selection

A good site for a boat gauging has the following attributes:

(*a*) a straight, uniform reach for a distance upstream of five times and downstream two times the channel width respectively.

(*b*) the site should be accessible at all stages of flow; often influenced by the availability of a good boat launching sites.

(*c*) the flow should be confined to a single channel with no bank overflow or bypass during high stages.

(*d*) the bed and banks of the river should be stable with no progressive tendency for the river to scour or deposit sediments.

(*e*) the horizontal velocity distribution should be fairly uniform and less than 2.0 m/sec. As a general rule, a site with a deep section and low velocity is easier to gauge than a shallow section with high velocity.

(*f*) the operating section should be free of large boulders, rock outcrops and snags.

7.4 Gauging Method

(*a*) Secure the tagline across the section normal to the direction of flow. This is done by driving the tagline reel spike into the ground until secure, then taking the end of the tagline to end securing it to a steel peg driven into the ground on the other bank. The end of the tagline and *not the* reel, should be transported by the boat. The end of the tagline. should be held in the hand, so that it can be readily cast off should the reel tangle—*do not* tie the tagline to the boat.

Tension up the tagline using the tagline reel, fit the tackle to the tagline, haul up on the rope and tie securely to the other steel peg driven into the ground near the tagline reel. Tie 4 to 5 flags on the tagline to warn other river users of the tagline presence.

(*b*) While securing the tagline observe and record the distance to the water's edge for both banks, and derive the channel width. Calculate the spacing of the verticals by dividing the width by 20 and rounding upwards to two significant figures.

(*c*) Place the current meter in a horizontal position and conduct a standard spin test, recording the time of spin on the gauging card.

Write down the river name, site, instrument type and number, date and time of the gauging. Read the water level on the stick gauge (where applicable) and record the level and time of observation on the gauging card.

(*d*) Assemble the equipment. Secure the gauging winch to the mounting on the gauging boom. Assemble the current meter and weight on the hanger bar, roll out some cable from the gauging winch over the pulley on the end of the boom and secure the cable connector to the top of the hanger bar. Wind up until the cable connector is about 10 cm from the boom pulley. Complete the electrical connections from meter to cable connector and from winch to revolution counter. Give the propeller (or bucket wheel) a flick and check the signal return from the meter to the counter. Measure the distance from the horizontal axis of the current meter to the underside of the gauging weight and record this *depth correction constant.*

This assembly operation is best achieved with the boat nosed up to a sand bar or shallow beach.

(*e*) Proceed to the first vertical, nosing the boat slowly up to the tagline. In low velocity flows the boat may be anchored to the tagline during the gauging measurements. In high velocity flows, the boat is nosed up to the tagline and the power of the engine is used to hold the boat on station during gauging measurements. This requires a skilled boat operator.

(*f*) Lower the current meter until its horizontal axis is at the water level. Zero the depth counter and continue to lower until the weight touches the bottom. *Add the depth correction constant* to the depth reading to obtain the true depth—do *not* zero the depth counter.

Special care is required when depth sounding from a boat. As the weight hits the river bed, the buoyancy of the boat causes the boat to rise as the weight of the equipment is transferred. Record the depth at the point when the boat *starts* to rise.

(*g*) Calculate the depths corresponding to 0.2d and 0.8d. Raise the current meter to the 0.8d position and proceed with a velocity observation. Continue to the 0.2d position and take another velocity observation.

(*h*) Continue taking depth and velocity observations for other verticals. Observe and record the distance at the water's edge and the time of completion of the gauging. Read and record again the water level on the stick gauge and the time of observation.

(*i*) Leaving one operator standing by the tagline winch, proceed to the other side to release the end of the tagline. The operator then winds in the tagline—*do not* put the tagline winch in the boat and wind in as the boat travels to the other side.

8.0 CORRECTIONS

8.1 Width corrections

There are two types of width correction, namely horizontal angle and vertical/catenary curve corrections.

(*a*) Horizontal angle corrections: A discharge gauging conducted from a bridge which is *not at right angles* to the direction of flow, requires correction to the width observation (Fig. 3 (*a*)). The true width of the channel (W) is given by:

$$W = s \times \cos \theta$$

where s is the observed width on the bridge, and θ is the angle contained by the normal to the flow direction and the direction of the bridge.

The necessary correction is effected by computing the discharge and cross sectional area in the normal way, and making the correction at the end by:

$$\text{True area} = \text{Computed area} \times \cos \theta$$

$$\text{and True discharge} = \text{computed discharge} \times \cos \theta$$

(*b*) Vertical/catenary curve corrections: These corrections are very seldom required. Bridges with long central spans are often slightly arched, and the channel width measured along the curve deck of the bridge exceeds the true horizontal width. If the bridge is to be used as a regular bridge gauge site, the *true* horizontal distance between verticals should be surveyed and marked permanently on the bridge rail.

Catenary curve corrections for cableway sag are required only if the sag exceeds 2% of the total cableway span.

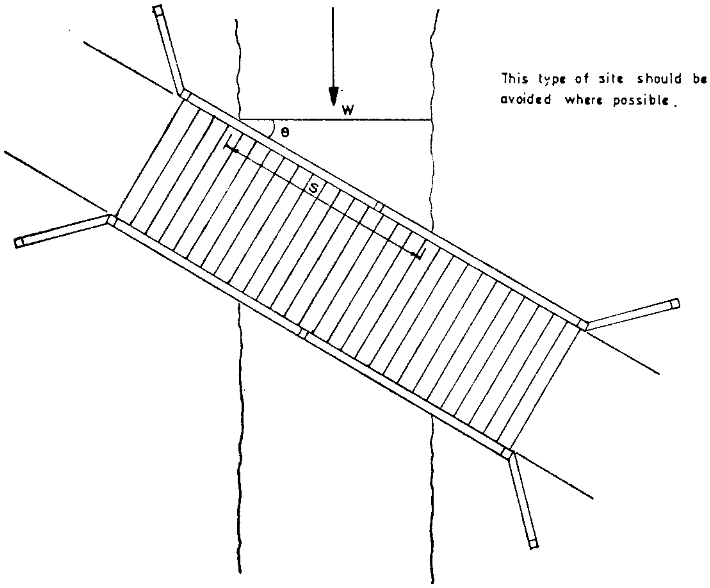
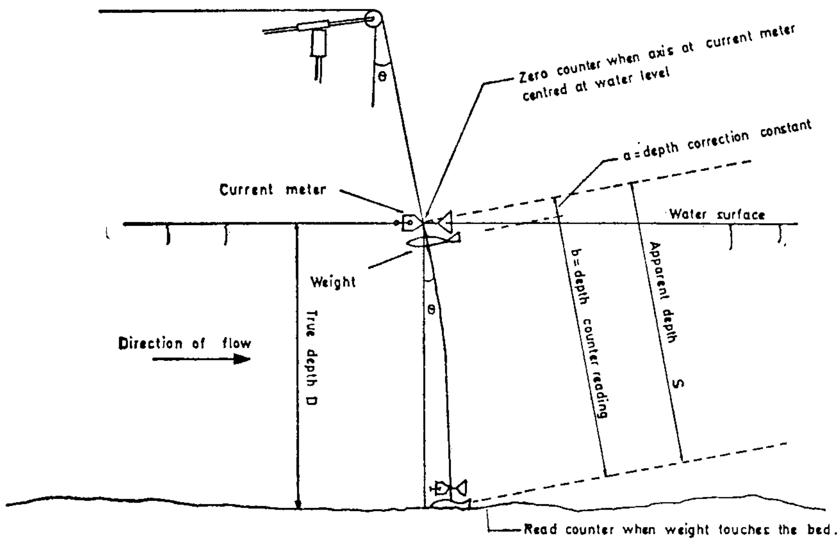


Fig 3a: Horizontal angle correction



(1) Apparent depth (wet line) $S = a + b$

(2) True depth $D = S - X$, Drift angle correction required only if $\theta > 8^\circ$, x = wet line correction (table 1)

(3) The true depth need not be calculated in the field as this only effects the computation of discharge and not the depth setting of the current meter.

Fig 3b: Drift angle correction

8.2 **Depth Corrections**

When gauging high velocity flows the increased frictional drag causes the gauging weight and current meter to drift downstream. (Fig. 3 (*b*)). The depth measured at the vertical will not be the true depth and a vertical (drift) angle correction is required.

With the current meter axis centred at the water level, zero the depth counter and observe the drift angle recorded by the gauging protractor. Lower the current meter until the weight touches the river bed, read the depth counter and *add the depth correction constant* (meter axis to underside of weight) to obtain the apparent depth. *Record this apparent depth.* Read the protractor again and record the average of the two drift angle observations (θ). Do *not* zero the depth counter.

The true depth D given by:

D = Apparent depth (s) − wet line correction (x)

need not be calculated in the field, as the drift correction affects only the computation of cross sectional area and not the depth setting for velocity observations.

Raise the meter until the depth counter reads (0.8 × apparent depth) and conduct velocity observation. Continue to (0.2 × apparent depth) etc.

Wet line correction for various depths and drift angles are shown in Table 1. If the drift angle is less than 8°, the error in depth measurement is less than 1% and correction is not necessary. Vertical drift can, in most cases, be limited to less than 8° by using a sufficiently heavy gauging weight.

As the rule of selecting the correct gauging weight,

Wt. (kg) = 5 × max. vel. (m/sec) × max. depth (m)

TABLE 1—WET LINE CORRECTION

	DRIFT ANGLE											
Depth (m)	8°	10°	12°	14°	16°	18°	20°	22°	24°	26°	28°	30°
3	0.00	0.02	0.02	0.03	0.03	0.04	0.06	0.07	0.09	0.11	0.13	0.15
4	0.00	0.02	0.03	0.04	0.05	0.06	0.08	0.10	0.12	0.14	0.16	0.19
5	0.01	0.03	0.04	0.05	0.06	0.08	0.10	0.12	0.15	0.18	0.21	0.24
6	0.01	0.03	0.04	0.06	0.08	0.10	0.12	0.15	0.18	0.21	0.24	0.28
7	0.02	0.04	0.05	0.07	0.09	0.12	0.15	0.18	0.21	0.25	0.29	0.33
8	0.02	0.04	0.06	0.08	0.10	0.13	0.16	0.20	0.24	0.28	0.32	0.37
9	0.03	0.05	0.07	0.09	0.12	0.15	0.19	0.23	0.27	0.32	0.37	0.42
10	0.03	0.05	0.07	0.10	0.13	0.17	0.21	0.26	0.30	0.35	0.41	0.47
11	0.04	0.06	0.08	0.11	0.14	0.18	0.24	0.28	0.33	0.39	0.45	0.52
12	0.04	0.06	0.09	0.12	0.16	0.21	0.26	0.31	0.36	0.43	0.49	0.56
13	0.05	0.07	0.10	0.13	0.18	0.23	0.28	0.34	0.39	0.46	0.53	0.61
14	0.05	0.07	0.11	0.14	0.19	0.24	0.30	0.36	0.42	0.49	0.57	0.66
15	0.06	0.08	0.12	0.15	0.22	0.27	0.34	0.39	0.46	0.53	0.62	0.71

9.0 GAUGING CALCULATIONS

9.1 Preparation of gauging cards

The gauging card is an important record. Field officers must ensure that all the relevant information is supplied on the gauging card. Information such as map reference, or measurement number, not available in the field should be completed immediately on return from the field.

The following is an explanation of the information to be supplied on River Discharge Measurement Forms JPT 11A and 11B, examples of which are included in Appendix 4. Entries that *must* be completed during the actual gauging are shown with an asterisk. The remainder are for office calculation purposes.

Entry	Explanation
Form JPT 11A	
1. No. Sukatan	Each discharge measurement should have its own measurement number. e.g. PK 59/74 to mean Perak, gauging No. 59 in 1974. The numbers must be listed in a separate register so that gaugings can be easily traced.
2*. Sungai	Accepted name of the river.
3*. Nama Stesyen	Accepted station name of gauging site. Every site must have *one and only one* name.
4. No. Stesyen	Every site must have a unique station number according to Hydrological Procedure No. 6.
5*. Tarikh	The date on which the measurement was made.
6*. (*a*) Waktu sukatan dimulakan (*b*) Siap	Time measurement began and ended. Use the 24 hr international system for recording time. e.g. 3.15 p.m. in the afternoon is 1515 hrs; for 6.20 a.m., in the morning, 0620 hrs.
7*. Kumpulan kerjaluar ...	Initials of field party leader.
8*. Sukatan dengan Jankarus/Pelampong	Measured by current meter/float. Cross out the method not applicable.
9. Rujukan peta	Map reference is required for all new sites.
10. (*a*) Garisan bujor ... (b) Garisan lintang ...	Longtitude and latitude of the station.
11*. (*a*) Jenis jangkarus ...	Type of current meter e.g. OTT(L), OTT(S), WATTS, etc.
(*b*) No.	Meter number; usually stamped on the body of the instrument.
(*c*) No. Kipas	Propeller number; relevant only to OTT meters equipped with interchangeable propellers, the number of which is stamped on the propeller.
(*d*) Dikadar	Date of last rating which is shown on the current meter rating table.
12*. (*a*) Keadaan jangkarus: Sebelum (*b*) Selepas	A spin test should be carried out before and after the gauging and the time of spin entered. Make comment if meter has been damaged during the gauging operation.
13*. Menggunakan Rod/Kebel	Used wading rod or cableway. Cross out the method not applicable.
14*. Jangkarus........meter atas perut.........kg. ladong	Axis of current meter (to nearest cm) above underside of (to nearest kg) kg. weight.
15*. Di-sukat dari rentangan kebal / perahu/di-ulu/di-hilir jambatan/mengarong	Measured by cableway/boat/upstream/downstream side of bridge/wading. Cross out the methods not applicable.
16*. Di-sukat.........meter ulu/hilir di.........	Measured (to nearest 50m) upstream/downstream from (permanent feature, e.g. bridge, recorder etc.) Cross out upstream/downstream as applicable.
17*. Suhu air	Water temperature to nearest degree Centigrade.
18*. Keroh/Jerneh	Turbid/clear; turbid denoting a discharge where the river bed is not visible. Cross out that not applicable.
19*. Angin: Tiada/sedikit/penengahan/kencang/ke-ulu/kehilir/melintang	Wind: Nil/slight/moderate/strong/to upstream/to downstream/across. Cross out that not applicable.
20*. Arah Arus (sudut ufuk)	Direction of current (horizontal angle) is applicable for a bridge gauging where bridge is not at right angles to the direction of flow.
21*. Beza bacaan tolok........ meter	Change in gauging height (to nearest 0.01m) metres from start to end of gauging measurement.
22*. Kadar naik/surat.......... m/jam	Rate of rise/fall in m/hr.

Entry	Explanation
23. Kadaralir.........m.p.s. ...	Discharge in cubic metres per second.
24. Luas.........meter persegi	Cross sectional area in square metres.
25. Purata Halaju.........m.s.s.	Mean velocity in metres per second.
26. Lebar.........meter ...	Width of channel in meters.
27. Aras laras bagi bacaan tolak wajar purata......... meter	Reduced level of weighted mean stick gauge height in meters derived from "Gauge Readings" table.
28*. Catitan	Remarks.
29*. Bacaan-bacaan tolok ...	Stick gauge readings. Where not taken at a constant time interval the readings should be weighted to give the correct mean height.
30*. Cara sukatan	Method of measurement is a summary of the numbers of verticals and point velocity observations.

Form JPT 11B

Entry	Explanation
1*. Jarak dari permulaan ...	Distance from initial point is the reading from the tape, tagline, or traversing winch.
2*. Sudut pugak	Vertical (drift) angle, recorded to the nearest 2°.
3*. Dalam talian basah ...	Wet line depth; for less than 1 m depth record to nearest 0.005m; for greater than 1 m depth to nearest 0.01m.
4*. Dalam pugak	Vertical depth to same accuracy requirements as in 3 above.
5*. Cara tilekan	Point velocity observation method e.g. 0.2, 0.6, 0.8 etc.
6*. Tilekan dalam	Observation depth is depth at which the velocity was observed e.g. 0.2d, 0.8d to same accuracy as in 3 above.
7*. Masa sa'at	Time in seconds is the revolution count time, recorded to the nearest 0.5 sec if not using a fixed time counter.
8*. Bilangan pusingan ...	Number of revolutions recorded in the time given in 7 above.
9. Masa purata satu pusingan	Mean time for one revolution.
10. Halaju meter sa-sa'at	
(*a*) Pada titek	(*a*) Point velocity in m/sec calculated from rating equation or from a rating table.
(*b*) Purata bagi pugak ...	(*b*) Mean of point velocities in the vertical.
(*c*) Purata muka keratan	(*c*) Mean velocity for two adjacent verticals to give mean velocity in section.
11. Luas meter persegi ...	Area of section between two adjacent verticals in square metres to three decimal places.
12. Ukor lebar	Distance between two adjacent verticals.
13. Ukor dalam purata ...	Mean depth of two adjacent verticals.
14. Kadaralir meter padu sa-sa'at	Sectional discharge in m^3/sec given by sectional area (11) multiplied by mean sectional velocity (10 (*c*)).
15*. Catitan	Remarks.

9.2 Calculation of discharge

9.2.1 MANUAL CALCULATION

Procedure for calculating the discharge from the data supplied on the gauging card is as follows:

(*a*) From the appropriate current meter rating table or equation derive the point velocities and record (pada titek).

(*b*) Calculate the mean velocity in vertical (purata bagi pugak) by averaging the point velocity observations.

(*c*) Calculate the mean velocity in section by averaging the mean velocities for the verticals bounding the section (purata muka keratan). All velocity data in m/sec should be recorded to three decimal places.

(*d*) Calculate the sectional area, by averaging the depths recorded at the bounding verticals multiplied by the distance between the bounding verticals. Record the sectional area (luas) in square metres to three decimal places.

(*e*) Multiply the sectional area by mean sectional velocity to obtain sectional discharge (kadaralir) in m^3/sec to three decimal places.

(*f*) At completion of calculations, sum the sectional areas to obtain the total cross sectional area (luas), and the sectional discharges to obtain the total discharge. Calculate the mean velocity by dividing the total discharge by total area. Round off the total area, total discharge and mean velocity data to three significant figures and enter the results on the face gauging card (Form JPT 11A).

Note: To round off to three significant figures for example:

68.083 becomes 68.1

6.8083 becomes 6.81

68083 becomes 68,100

(*g*) Calculations must then be checked by another officer, who should initial the gauging card when satisfied that all calculation errors have been eliminated.

9.2.2 PROGRAMMED CALCULATION

The time required for calculating (and subsequent checking) the discharge from river gauging data, can be shortenend considerably by the use of a programmable calculator. The incidence of calculation errors is also greatly reduced.

A typical programme together with programme instructions are included in Appendix 5.

10.0 REFERENCES

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OPERATING INSTRUCTIONS FOR THE OTT C31 CURRENT METER

The meter body (Fig. 1) is cylindrically shaped and made of nickel plated brass.

Signals are generated virtually without power by an impulse device (2) actuated by a magnet (4) mounted inside the sleeve (3) of the propeller (5). The impulse device emits a pulse on each revolution of the propeller. The encapsulation of the impulse device is completely water and pressure tight, thus allowing reliable measurements to be obtained even in chemically aggressive waters, or water with a high sediment concentration.

If effective spark quenching is provided as in the standard Ott detector and counter, the impulse device is operated with about 1.6 watts. Maximum voltage permissable is 9 volts d.c.

The propeller (5) revolves on a rugged, stationary stainless steel shaft (6). This has the advantage over a revolving shaft in that slight deformations due to inexpert handling of the current meter will not impair metering accuracy.

The oil-filled hub (Fig. 3) of the propeller (5) runs on two stainless steel ball bearings (7) which are protected from the ingress of water by a frictionless gasket designed on the capillary principle. The ball bearings are interchangeable and can be replaced without affecting the rating for the propeller.

The current meter is a precision instrument and should be handled with care in order to ensure high metering accuracy. The electrical impulse device operates without any need for servicing. If a circuit discontinuity should nevertheless develop, check whether broken wires, exhausted batteries, defective contact points at the line terminals, plugs, etc., may not be the source of the trouble. Contact trouble very seldom develops in the current meter itself except in the case of wrong treatment such as *loading with an inadmissibly high voltage.*

1. Changing the chamber oil

The special Ott oil in the hub of the propeller (5) should be changed at the end of each metering operation or whenever the current meter has not been used for a long period.

2. Cleaning and servicing bearings

If the ball bearings should become fouled with dirt whilst changing the oil, the bearings should be dismantled (Fig. 4) and cleaned with petroleum solvent (petrol, kerosene or methylated spirits).

3. Bearing replacement

If the ball bearings have to be replaced by new ones after the current meter has been in service over a long period, the procedure indicated in Fig. 4 should likewise be followed. Make sure that the bearing seats (7a) are correctly positioned. *Then place nut (11) on properly and screw tight.* In doing so, the steel shaft (6) should preferably be held in the meter body (1) as indicated in Fig. 2. After assembly, remove the protective grease from the ball bearings with petroleum solvent.

A. OTT KEMPTEN BAYERN

Universal Current Meter 10.002 - 10.049

MODEL C31

112-101 Ae

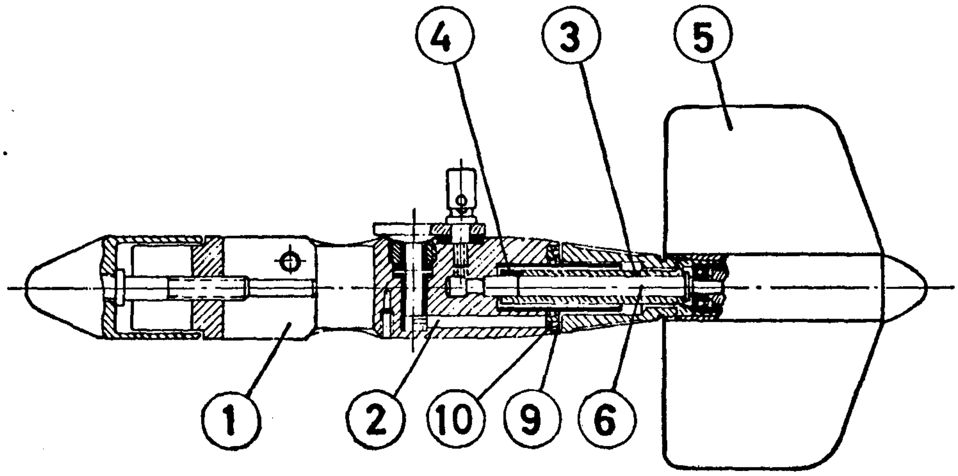


Fig. 1

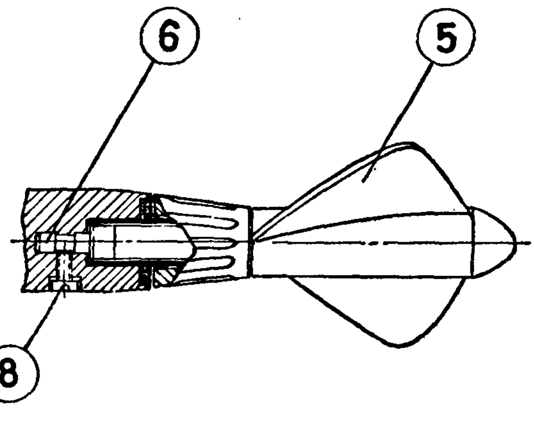


Fig. 2

A.OTT KEMPTEN BAYERN	Universal Current Meter 10.002 - 10.049 MODEL C.31	112-101 Ae

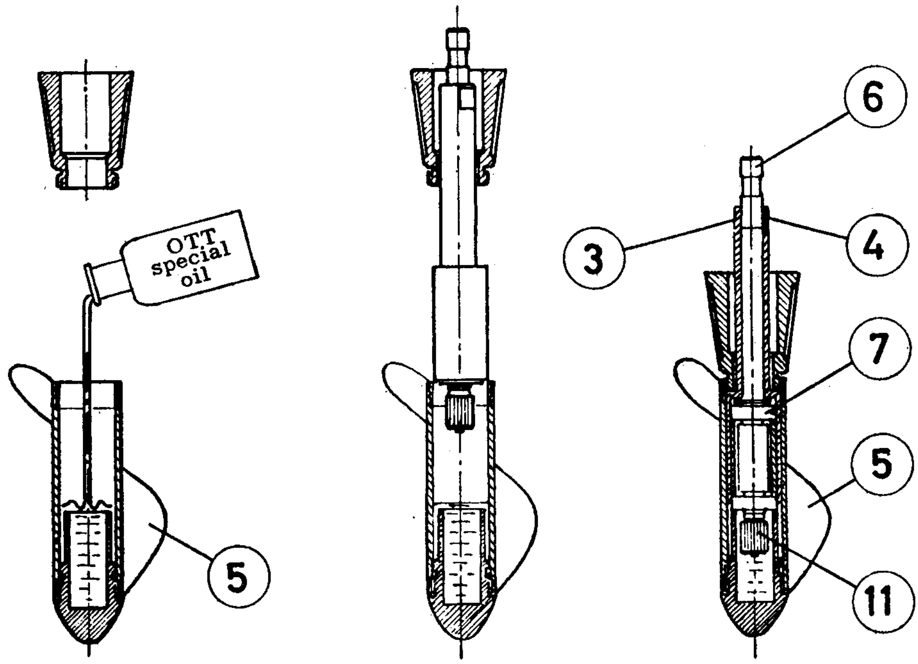


Fig. 3

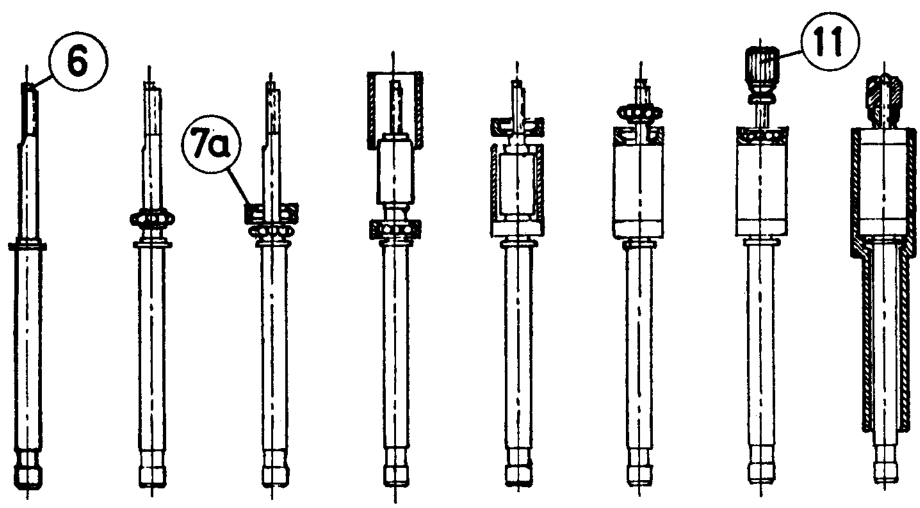


Fig. 4

OPERATING INSTRUCTIONS FOR THE OTT C2 CURRENT METER

The meter body (Fig. 1) is of streamlined shape and made of nickel-plated brass. The electrical signals are generated virtually without power by an impulse device (6) actuated by a permanent magnet which is fitted in the sleeve (5). The impulse device responds with one signal impulse for each revolution made by the propeller. The bearing races (3) and shaft operate in a water tight and pressure sealed hub chamber (9) filled with oil. This allows reliable measurements even in chemically aggressive waters. The ball bearings are exchangeable and can be replaced without affecting the rating of the current meter. The voltage applied to the current meter *must not exceed* 9V d.c.

The small current meter is a precision measuring instrument and must be treated with care in order to maintain measurement accuracy.

The electrical impulse device operates without need for servicing. If a circuit discontinuity should occur, check for contact at the cable terminals and plugs. It is very rare for contact failure to occur within the body of the current meter.

1. **Defective impulse device repair**

If the impulse device (6) should prove defective then proceed as follows:

(*a*) Loosen lock nut (13) and screw out impulse device (6).

(*b*) Screw in the new complete impulse device (6).

(*c*) Connect the counter, and adjust the mark-to-space ratio 1 : 1 (180° pause) by means of the buzzer built-in.

(*d*) Check whether the current meter makes contact over an arc of 180°. The desired adjustment can be easily made by turning the meter propeller by hand. Having completed the adjustment, the contact position must be locked by lock nut (13).

2. **Defective cable connector**

If the meter cable connector becomes defective at the duct plug, the meter cable must be shortened as shown in Fig. 4 and described as follows:

(*a*) Push the knurled nut (16) and duct plug (17) on the meter cable back to expose the old tubular rivet. Remove the old rivet.

(*b*) Strip off cable insulation for the length of the new tubular rivet (18) and twist the strands of wire together (Fig. 4b).

(*c*) Slip on the new tubular rivet and press it in at two points with KOMBI cutting pliers (Fig. 4c). Test that the rivet is firmly attached to the stranded wire.

(*d*) Pull the duct plug (17) and knurled nut (16) down over the tubular rivet (18) (Fig. 4d).

3. **Changing the chamber oil**

The Ott special propeller oil in the hub of the propeller (9) allows metering operations at different water temperatures without affecting measurement accuracy. The oil should be changed every alternate day if gauging continuously or whenever the instrument has not been used for a long period. Fill the chamber only half-full.

4. **Cleaning and servicing bearings**

If the ball bearings should become fouled with dirt the bearing races should be dismantled and cleaned as follows:

(*a*) Remove the meter propeller (1).

(*b*) Screw out locking screw (7) by means of the socket wrench (12) and take out the whole axle complete with sleeve (5).

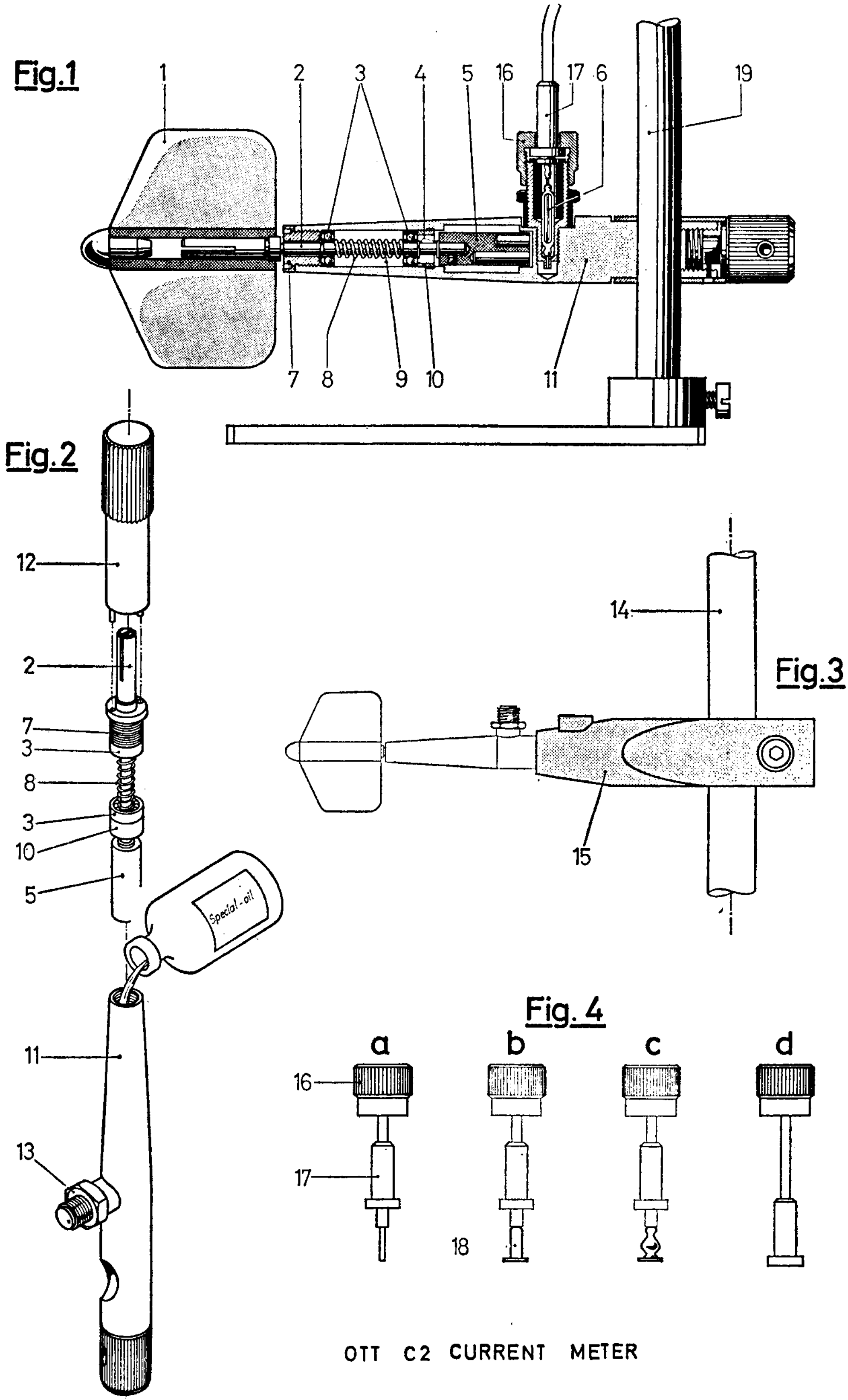
(*c*) Clean ball bearings (3) in a bath of petroleum solvent (petrol, kerosene or methylate spirits).

5. **Bearing replacement**

If it is found necessary to replace the ball races, proceed as follows:

(*a*) Remove the locking washers (4) taking care not to damage the shaft (2).

(*b*) Remove parts (5) and (10), and strip the old ball races (3) and helical spring (8) from the spindle. Insert the new ball races in the reverse sequence. The protective coating of grease must be removed from the ball bearings by washing in petroleum solvent.



OTT C2 CURRENT METER

OPERATING INSTRUCTIONS FOR THE OTT Z100 REVOLUTION COUNTER

The instrument measures impulse frequency and when used with current meters determines the number of propeller revolutions per unit of time.

During operation the counter can be positioned on a flat surface or can be carried by a shoulder strap.

1. **Operation with preset time**

Operation with preset time is the normal method used for current meter measurements.

(*a*) Presetting the measuring time: (Ref. Fig. 1)

Remove plexiglass cover (2) by means of knurled screws (3). Depress unlocking key (8) of the preset counter (5), remove cover (4) and preset the desired measuring time in 1/10 sec. If a time of 30 seconds is required then preset the number 300; for 40 secs, 400; etc. If always operating with the same measuring time, the above procedure need be carried out once only.

(*b*) Connecting the measuring cable:

Connect the pulse-transmitting cable to socket (12) after removing dust cap. Older type cables, fitted with banana plugs, can be connected to the instrument by means of an adaptor cable supplied as an accessory. By inserting the plug into the socket (12) the instrument is fed with operating voltage, which is indicated by a response of the miniature indicator (1).

(*c*) Start of operation:

Move "COUNTER" switch (7) to "ON" position. After about 10 seconds the instrument is ready for operation. Depress the "START" button and the instrument starts counting from the first transmitted impulse. At the end of the preset measuring time the instrument stops automatically, and the number of revolutions is displayed by the impulse counter (6).

(*d*) To repeat or restart the operation:

If you wish to stop operation at any point and to restart, then depress the "START" button. The preset measuring time then appears again on the preset counter (5), and after releasing the "START" button the measuring process is restarted by the next transmitted impulse.

(*e*) Example of calculating rate of revolution at propeller:

Preset time	100 sec.
Number of pulses recorded in time period	200 impulses
Impulse frequency $f = \frac{200 \text{ pulses}}{100 \text{ sec.}} =$	2 impulses/sec.

The angular velocity of the propeller (n) is given by:

$$n = \frac{\text{value at pulse counter} \times \text{propeller revolutions per pulse}}{\text{measuring time in sec.}}$$

For this example (assuming 1 propeller revolution per pulse).

$$n = \frac{200 \times 1}{100} = 2 \text{ r.p.s.}$$

2. **Operation with depth sounding equipment**

When operating with depth sounding equipment, the impulse counter stops when the sounder touches the river bed. On raising the equipment the counter restarts automatically.

3. **Operation with buzzer**

For buzzer operation, move the "BUZZER" switch (10) to the "ON" position. Buzzer operation is possible with the preset counter switched on or off.

(*a*) With counter (7) switched on:

Operation is the same as that described for operation with preset time, with each impulse being recorded with a short audible buzz. Using current meters with depth sounder equipment a continuous tone is heard when touching the river bed. At the end of the preset measuring time the buzzer is *not* switched off.

(*b*) With counter (7) switched off:

Because the buzzer has a very low power consumption, it is possible when the batteries are too weak for normal preset time operation, to conduct measurements by counting the buzzer signals and measuring the time by means of a stop watch.

4. **Battery check and exchange**

(*a*) Test batteries during normal preset time operation. With perfect batteries, the pointer of the miniature indicator must rest within the green zone.

(*b*) After loosening the four slotted screws (14) by means of a coin, and removing the bottom plate (15), the battery container becomes accessible. Insert the 6 mono-cells 1.5 v (preferably VARTA, PERTRIX 282) as shown in Fig. 2.

5. **Operation from external voltage supply**

Use the adaptor cable which has terminals suitable for connection to an external power supply. With the adaptor cable connected the built-in batteries are automatically switched off. The red banana plug of the cable is connected to "+", and the black banana plug to "−" of a 9 v/1.5 A voltage source.

6. **Completion of measurement**

After disconnecting the plug of the cable from the socket (12), the instrument is without current, even with switches (7) and (10) switched-on. The dust cap (13) should be replaced in the socket when the instrument is not in use.

Fig. 1

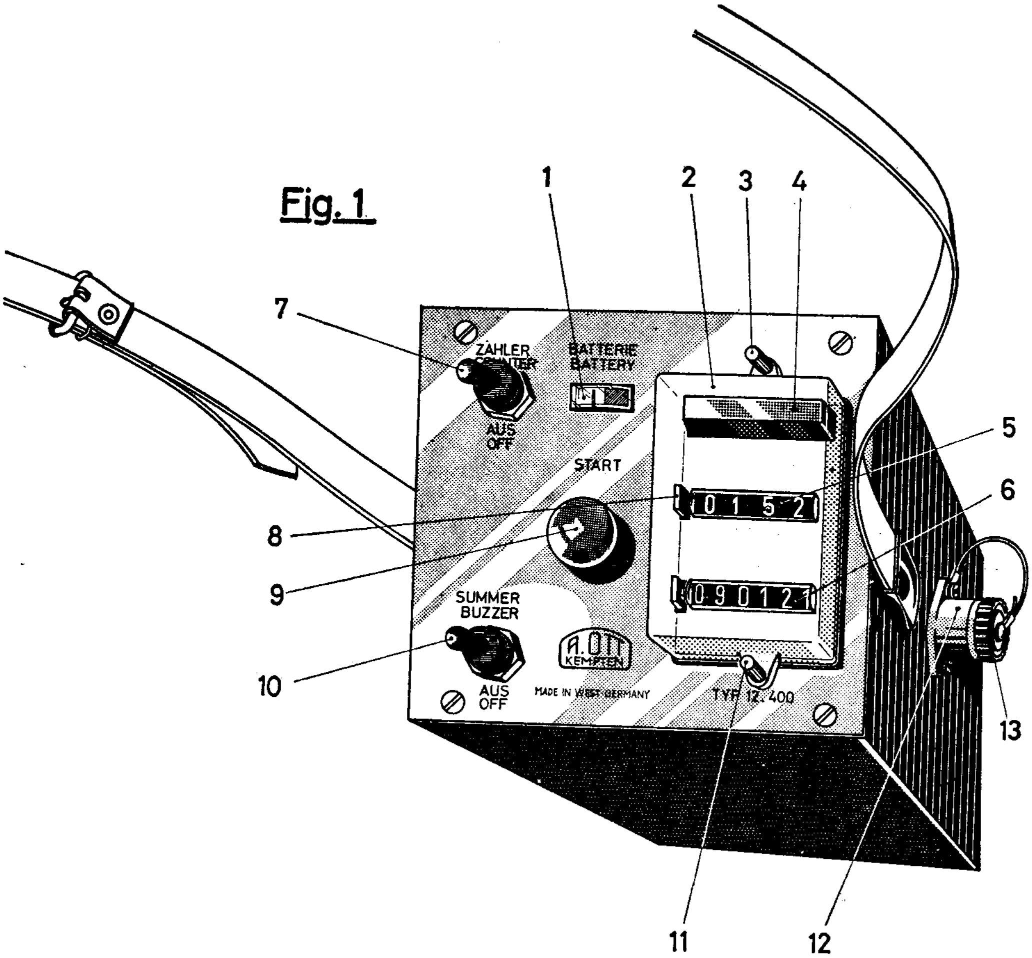
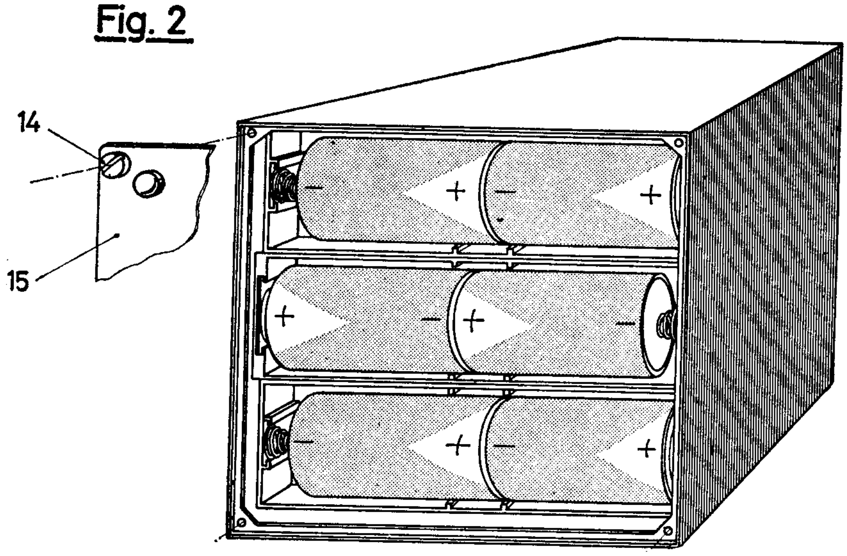


Fig. 2



OTT Z100 REVOLUTION COUNTER

OPERATING INSTRUCTIONS FOR THE OTT Z41 REVOLUTION COUNTER

The Ott revolution counter (Figs. 1 and 2) operates from a 9V d.c. power source, and is capable of counting up to a maximum of 10 revolutions per second.

The preset counting time at 50 and 100 seconds (Type 12.052), or 30 and 60 seconds (Type 12.053) is measured by a built-in interval timer to an accuracy of $\pm$ 0.5%.

The counter may also be used for free time operation whereby the time is recorder for a fixed number of revolutions.

1. **Preset time operation**

Select the required counting time using knob (1). By depressing and releasing the reset button (3), the revolution counter is reset to zero, the interval timer is rewound, and the timer and counter started automatically at the next impulse signal. As soon as the preset time has elapsed, the timer automatically stops the counting system.

2. **Free time operation**

For free time operation connect the cable terminals as shown in the table. Depressing and releasing button (3) resets the revolution counter to zero. The counter is started and stopped by pressing button (2) and the time is recorded using a separate stopwatch.

3. **Buzzer operation**

With the cable terminal connected for buzzer operation (*see* table), a buzzer sounds to signal each impulse generated by the propeller. The counter is started and stopped by pressing button (2) and the time recorded using a separate stopwatch.

Free time buzzer operation is particularly suitable for gauging low velocity flow.

4. **Cableway operation**

For gauging operation on long cableways where the conduction-suspension cable resistance between current meter and counter exceeds 15 ohms, it is necessary to use the relay. Connect the terminals as shown in the table. The inclusion of the relay permits operation with conduction-suspension cables where the electrical resistance is less than 200 ohms.

5. **Operation with depth sounding equipment**

For operation with depth sounding equipment, connect the cable terminals as for buzzer operation. When the depth sounder touches the river bed, the counter stops and a continuous tone sounds from the buzzer.

6. **Batteries**

The counter operates from six 1.5V torch batteries. Batteries are replaced by loosening screw (4), detaching the lower section of the case (5), and removing the lid (6) of the battery holder. Remove the old batteries and replace with new ones.

For operation with an external 9V d.c. power source, first remove the six 1.5V batteries as described above.

TABLE FOR CABLE TERMINAL CONNECTION ARRANGEMENTS

	With relay and buzzer	Without relay and buzzer
Preset time		
30/60 sec. ... ... 50/100 sec.	+ R and U	+ and U
Free time		
	+ R and L	+ and L

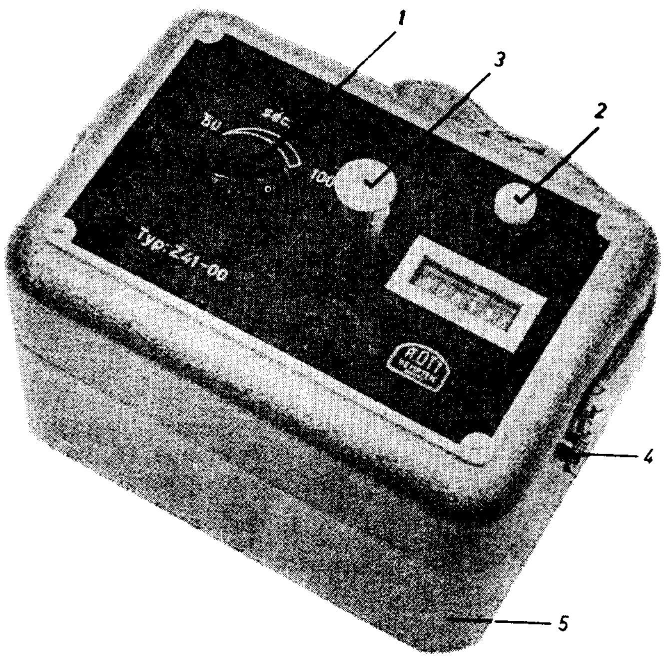


FIG. 1

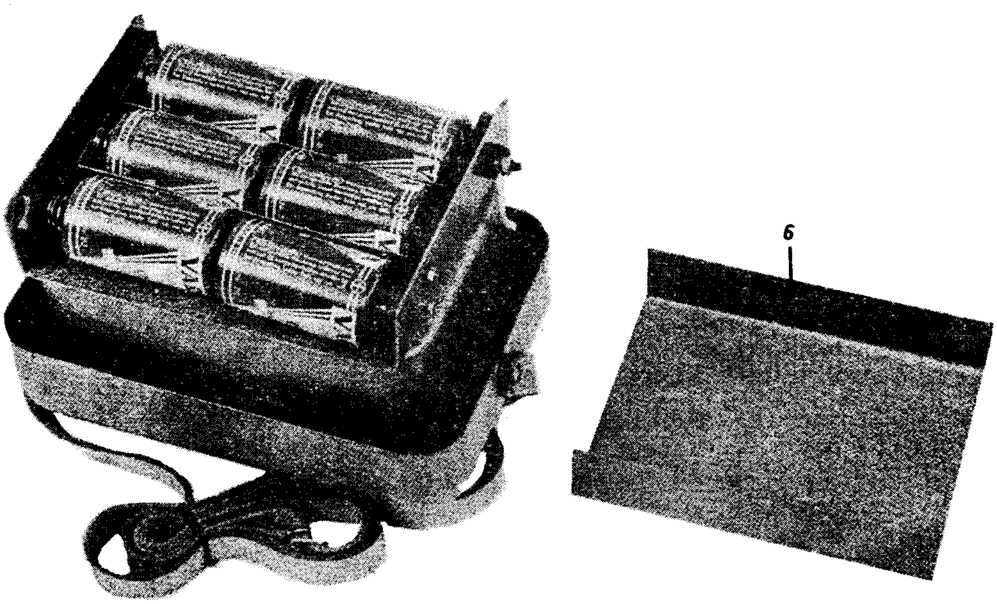


FIG. 2

OTT Z41 REVOLUTION COUNTER

OPERATING INSTRUCTIONS FOR THE OTT F6U REVOLUTION COUNTER

The F6U counter (Figs. 1 and 2) counts the electrical impulses coming from the current meter and at the same time registers the elapsed time during this operation. Depending upon circumstances it can be placed on a suitable base or be suspended from the neck by means of the attached strap.

1. Normal operation

(*a*) Wind up stop-watch.

(*b*) Check to see if the stop-watch is running; that is, if the switch lever (1) is resting on the metal covered cam of the switch (2).

If this is not so, the switch lever (1) must be lifted by hand and the switch (2) turned until the desired position is attained.

(*c*) To be certain that the stop-watch functions properly and is not damaged there must *always* be a slight play between the spring (3) and the winding knob of the watch. This play is adjustable by a screw (4).

(*d*) The watch must be held tightly within its positioning clips. Any movement in its seat can result in a failure of starting the watch.

(*e*) The switch (6) leads the electrical impulses of the current meter to the counter mechanism (5) or to the buzzer. The buzzer either signals the individual impulses from the contacts on the propeller shaft (at low current speed) or buzzes continuously after the ground feeler touches the bottom of the water channel.

(*f*) A cable serves as the electrical connection between the sockets "+", "F" and "G" on the counter and the current meter.

(*g*) Always check batteries for voltage.

By turning the switch (2), the stop-watch starts running. Then rotate the propeller by hand. The counter (5) must then register every impulse signalled from the contact on the propeller shaft.

(*h*) Measuring procedure: Start stop-watch and counter mechanism by turning the switch (2). Shut-off stop-watch and counter mechanism after selected time interval. Record elapsed time and counter reading.

$$\frac{\text{Counter reading} \times \text{Propeller revolutions per impulse signal}}{\text{Time in seconds}} = \text{Propeller revolutions per sec.}$$

For example:

Counter reading: 500.

Contact-bearing-wheel in current meter: two revolutions of propeller per impulse signal (one contact).

Time: 100 secs.

$$n = \frac{500.2}{100} = 10$$

(*i*) Should the dry cells in the counter have become too weak and thus cause the counter to miss registering, the impulse signals can be heard by means of the buzzer (throw switch 6); or, if the buzzer does no longer function, by means of head phones (sockets T).

2. Batteries

To replace the battery cells, loosen the screw (8) lift the unit out of its case and loosen the nut (9). *When putting in new batteries, observe correct polarity!*

If an auxiliary battery is used, remove battery B.

3. Cableway operation

Should a short circuit develop on the older design, where water may reach the propeller contacts or the contact in the ground feeler, and for this reason either the counting mechanism or the buzzer start working, the sensitivity of the instrument may be reduced by throwing the switch (10) from I to II.

For use with longer cables (with cable way installations or cable suspended current meters) with increased electrical resistance, switch (10) should be in position I. In this case, however, it is absolutely necessary that the contacts in the current meter, on the depth sounder, and at the cable plug and socket connections are watertight.

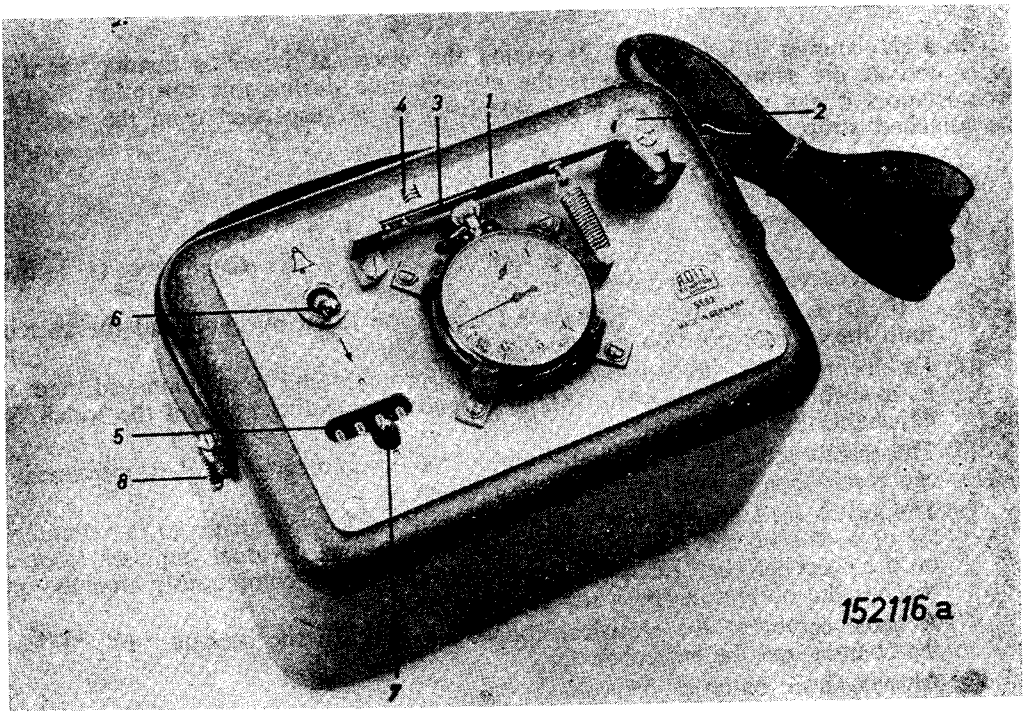


FIG. 1

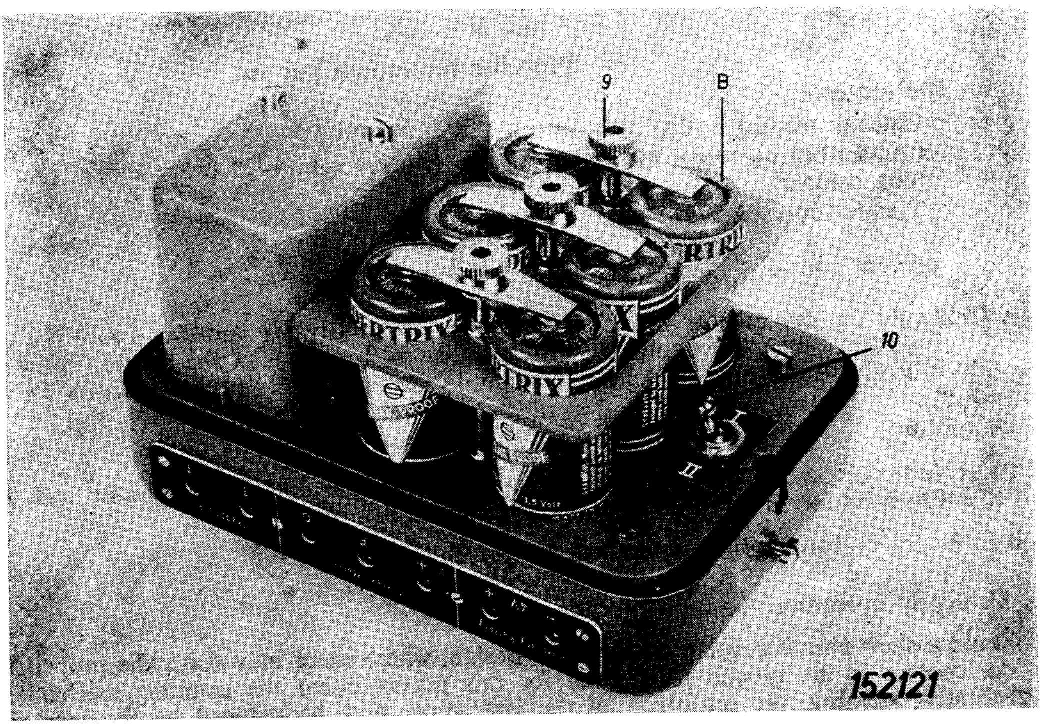


FIG. 2

OTT F6U REVOLUTION COUNTER

OPERATING INSTRUCTIONS FOR THE OTT SINGLE-DRUM WINCH

The single-drum winch (Figs. 1 and 2) is used in conjunction with cable-suspended current meter equipment weighing between 25 and 75 kg.

1. **Description**

To avoid any inadvertent lowering of the current meter and weight the winch is equipped with a safety crank acting as a load-pressure brake.

The braking power is generated by the weight of the current meter and gauging weight and increases with increasing load. When lowering the equipment, the braking torque must be overcome by a force, which is only slightly less than that required for lifting. If the crank is turned in the lowering direction, the load-pressure brake is automatically released. The clearance of the brake is automatically adjusted to compensate for wear of the friction rings (3). The friction rings (3) should be replaced when they are worn to such an extent that the pin (4) in the sector wheel (5) no longer limits the clearance.

The cable drum (1) is fitted with a casing with three slip rings for the transmission of the electrical pulses generated by the current meter. Connect the end of the cable conductors to these slip rings and via a plug, to the meter. If the contacts should give trouble, remove the cover of the slip-ring casing and check. If necessary, clean the contact springs as well as the slip rings. Then check the contact once more by turning the propeller by hand.

2. **Replacing the conductor-suspension cable**

If the conductor cable should have been damaged in the course of prolonged use, replace it as follows:

Open the cover of the slip-ring casing, disconnect the cable ends from the slip rings and withdraw them through the opening in the shaft in the interior of the drum. Unscrew the cover piece on the drum and remove the lug from the bolt.

To install the new cable, reverse the sequence of operations described above.

When connecting the cable ends to the slip rings take care to ensure that the markings on the terminals agree with those on the current meter. The depth of the meter is set by means of cable drum (1). Since the cable is reversed by the measuring drum (2), the depth can be read off the counter, which is coupled to the measuring drum. The counter can be zeroed by depressing a lever.

3. **Maintenance**

The winch should be lubricated from time to time using an acid-free, non-resinous oil.

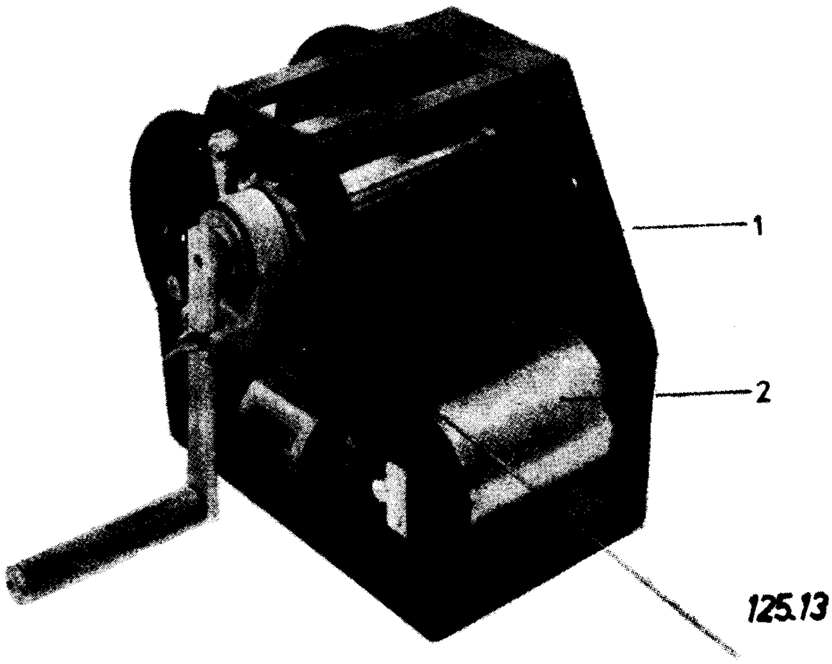


FIG. 1

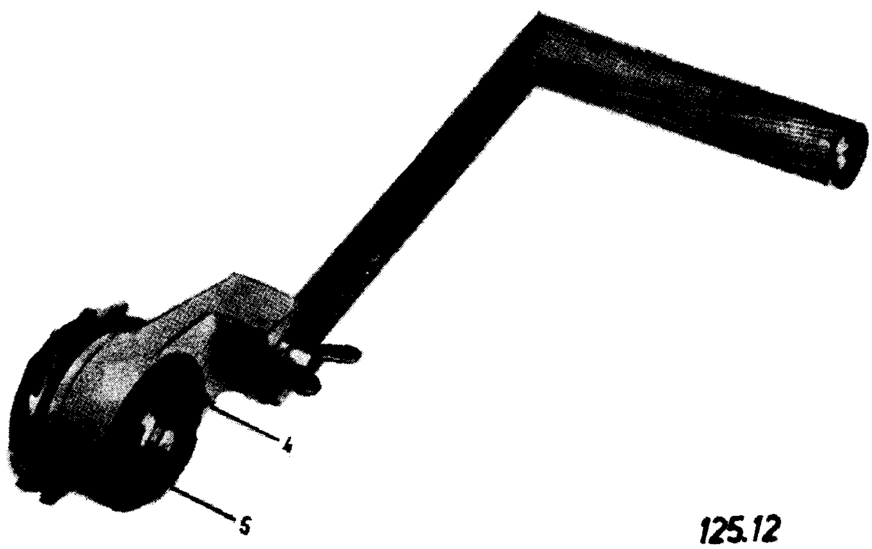


FIG. 2

OTT SINGLE DRUM WINCH

OPERATING INSTRUCTIONS FOR THE OTT DOUBLE-DRUM WINCH

The double winch (Figs. 1 and 2) is used for current meter gauging in conjunction with cable-way installations.

1. Description

The double-drum winch is equipped with the standard gauging winch (1) together with a traversing winch (2). A built-in pin coupling allows the horizontal and vertical displacement of the current meter to be controlled by a single lever (4).

Operation of the clutch by means of the lever (4) connects either the gauging winch alone or both winches to the drive shaft. In the former case, the meter is lifted or lowered, in the latter case it is also moved sideways. The clutch can be operated only when it is not in motion. Marks on the bearings of the drive shaft facilitate shifting. When the marks coincide, the clutch will engage smoothly. Horizontal displacement of the current meter is achieved by a 6 mm towline cable running over the drum (2) and a pulley. The distance can be read off the counter (3) connected to the rope drum.

The depth of the meter is set by means of the gauging winch (1). Since the cable is reversed by the measuring pulley (8), the depth can be read off the counter (5) which is coupled to the measuring pulley. Both counters can be zeroed by depressing a lever. To avoid any accidental lowering of the current meter and gauging weight, the winch is equipped with a safety crank acting as an automatic load-pressure brake. The braking power is generated by the weight of the equipment and increases with increasing load.

When lowering the equipment, the braking torque must be overcome by a force which is only slightly less than that required for lifting. As soon as the crank is turned in the lowering direction, the load-pressure brake is automatically released. The necessary clearance can be adjusted with the screw (11). The distance between screw and crank arm should be approx. 10 mm. If in the course of time the brake should be worn down to such a degree that further readjustment of the screw is impossible, dismantle the crank and turn the octagonal member against the hexagonal one until the adjustment already mentioned can be made.

The cable drum is provided with a slip-ring housing (9) with three slip rings for the transmission of the electrical pulses generated by the current meter. Connect the ends of the cable conductors to these slip rings. The six-pole plug is the connection to the indicating and counting unit.

If the contacts should give trouble, remove the cover (10) of the slip ring casing and check the contact springs as well as the slip rings and if necessary clean them. Then check the contact again by turning the propeller by hand.

2. Replacement of conductor-suspension cable

If the conductor cable should require replacing after prolonged use, proceed as follows:

Open the cover (10) of the slip-ring casing, disconnect the cable ends from the slip rings and withdraw them through the opening of the shaft in the interior of the drum. Unscrew the cover piece on the gauging winch and remove the lug from the bolt. To install the new cable, reverse the sequence of operations described. When connecting the cable ends to the slip rings, take care to ensure that the markings on the terminals agree with those on the current meter.

3. Maintenance

The winch should be lubricated before any longer series of measurements are carried out. The ball bearing of the measuring pulley should be cleaned and refilled with ball-bearing grease about once in every 5 years.

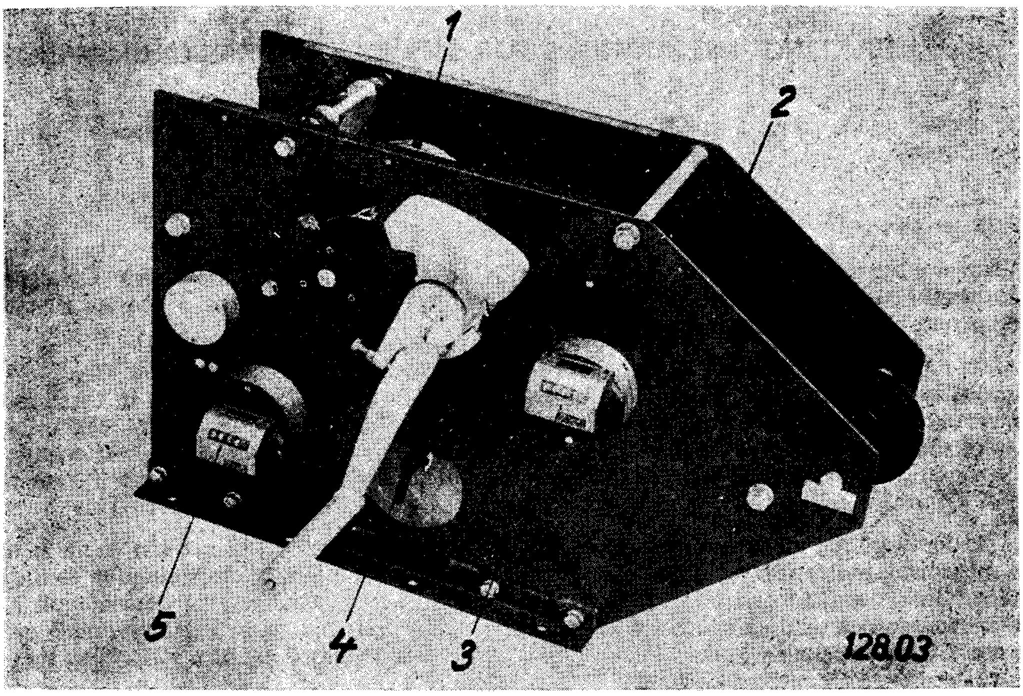


FIG. 1

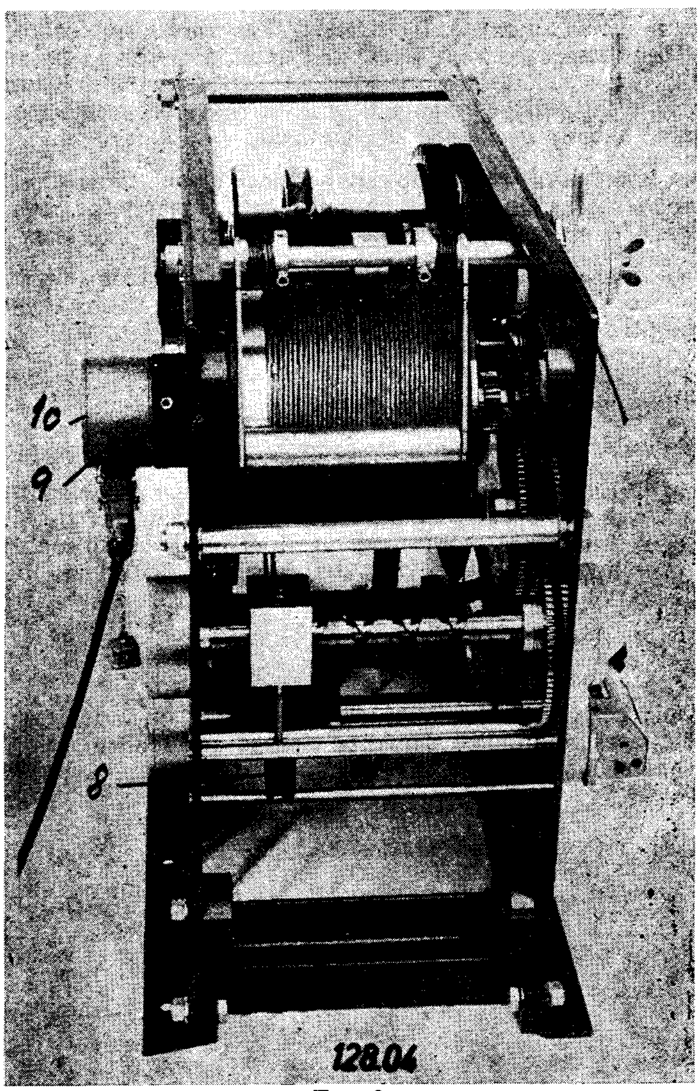


FIG. 2

OTT DOUBLE DRUM WINCH

Example Only.

No. Sukatan Tr./59/73.

(Appendix 4)

JABATAN PARIT DAN TALIAYER
SUKATAN KADARALIR SUNGAI

Sungai DUNGUN Nama Setesen JAMBATAN JERANGAU. No. Setesen 4832441

Tarikh 18.9.73. Waktu sukatan di-mulakan 1030 hrs. Siap 1155 hrs. Kumpulan Kerjaluar 2 R.K.

Sukatan dengan: Jangkarus/~~Pelampong.~~ Rujokan peta RV 790355 Garisan bujor 103° 12' 15" Garisan lintang 4° 50' 35"

Jenis jangkarus A-Ott. No. 18239 No. Kipas 2-20728 Di-kadar 30/6/1973

Keadaan jangkarus: Sabelum GOOD, SPIN TEST 110 Salepas GOOD, SPIN TEST 112

Menggunakan A-FRAME ~~Rod/Kebel.~~ Jangkarus 0.15 meter atas perut 25.0 kg. ladong

Di-sukat ~~dari rentagan kebel/perayu~~/di-ulu/~~di hilir~~ jambatan/~~mengarong~~.

Di-sukat – meter, ulu/~~hilir~~/di- JAMBATAN

Suhu ayer 21.0 °C. ~~Keroh~~/Jerneh. Angin: Tiada/.

Bachaan² Tolok		
Waktu	Alatrakam	Toloklurus
1020 hrs.	-	34.71
1210 hrs.	-	34.71
Bachaan Tolok Wajar Purata		34.71

Chara Sukatan	
Panduan Takat	No. Pugak
0.6	3
0.2 & 0.8	12
Jumlah No. Pugak	15

Arah arus (Sudut ufuk) NIL.

Bedza bachaan tolok NIL meter. Kadar naik/surut NIL m./jam

Kadaralir 61.4 m.p.s. Luas 69.2 meter persegi

Purata Halaju 0.889 m.s.s. Lebar 38.5 meter

Aras laras bagi bachaan tolak wajar purata 34.71 meter

Chatetan: Hydraulic Radius 1.69 M.

Peringatan: Semua yunit ada-lah dalam metrik. Di-hitong oleh: G.K.T. Di-semak oleh: T.H.T.U. No. lembaran 1 dari 4 helai

(Appendix 4 cont.)

Sungai DUNGUN No. Setesen 4832441 No. Sukatan Tr/59/73 No. Lembaran 2

Nama Setesen JAMBATAN JERANGAU Tarikh 18.9.73 Jumlah Helai 4

Jarak dari permulaan m	Sudut pugak	Dalam talian basah	Dalam pugak m	Chara tilekan	Tilekan dalam m	Masa sa'at s	Bilangan pusingan No:	Masa purata satu pusingan s	Halaju Meter Sa-sa'at: Pada titek m/s	Halaju Meter Sa-sa'at: Purata bagi pugak m/s	Halaju Meter Sa-sa'at: Purata muka keratan m/s	Luas meter persegi m²	Ukor lebar m	Ukor dalam purata m	Kadaralir meter padu sa-sa'at m³/s	Chatetan
5.5			0													W.E. Left Bank
											0.051	0.307	1.5	0.205	0.016	Assume 50%
7.0			0.41	0.6	0.25	40	8	5.00	0.103	0.103						
											0.140	1.450	2.0	0.725	0.203	
9.0			1.04	0.2	0.21	40	20	2.00	0.257	0.177						
				0.8	0.83	42	8	5.25	0.098							
											0.236	2.660	2.0	1.330	0.628	
11.0			1.62	0.2	0.32	40	30	1.33	0.386	0.296						
				0.8	1.30	50	20	2.50	0.206							
											0.418	3.730	2.0	1.865	1.559	
13.0			2.11	0.2	0.42	40	50	0.80	0.642	0.540						
				0.8	1.69	47	40	1.17	0.439							
											0.624	8.360	4.0	2.090	5.217	Bridge pier in between
17.0			2.07	0.2	0.41	42	70	0.60	0.857	0.708						
				0.8	1.66	46	50	0.92	0.559							
											0.927	3.710	2.0	1.855	3.439	
19.0			1.64	0.2	0.33	40	100	0.40	1.285	1.146						
				0.8	1.31	41	80	0.51	1.008							
											1.008	1.910	2.0	0.955	1.925	
21.0			0.27	0.6	0.16	41	70	0.59	0.871	0.871						

Kiraan oleh: G.K.T Di-semak oleh: T.H.TU.

(Appendix 4 cont.)

Sungai: DUNGUN No. Setesen: 4832441 No. Sukatan: Tr. /59/ 73 No. Lembaran: 3

Nama Setesen: JAMBATAN JERANGAU Tarikh: 18.9.73. Jumlah Helai: 4

Jarak dari permulaan	Sudut pugak	Dalam talian basah	Dalam pugak	Chara tilekan	Tilekan dalam	Masa sa'at	Bilangan pusingan	Masa purata satu pusingan	Halaju Meter Sa-sa'at: Pada titek	Halaju Meter Sa-sa'at: Purata bagi pugak	Halaju Meter Sa-sa'at: Purata muka keratan	Luas meter persegi	Ukor lebar	Ukor dalam purata	Kadaralir meter padu sa-sa'at	Chatetan
m			m		m	s	No:	s	m/s	m/s	m/s	m^2	m	m	m^3/s	
21.0			0.27	0.6	0.16	41	70	0.59	0.871	0.871						
											0.752	1.620	2.0	0.810	1.218	
23.0			1.35	0.2	0.27	42	60	0.70	0.734	0.634						
				0.8	1.08	48	50	0.96	0.535							
											0.691	6.840	4.0	1.710	4.726	
27.0			2.07	0.2	0.41	42	70	0.60	0.857	0.749						
				0.8	1.66	40	50	0.80	0.642							
											0.925	5.280	2.0	2.640	4.884	
29.0			3.21	0.2	0.64	40	100	0.40	1.285	1.101						
				0.8	2.57	45	80	0.56	0.918							
											1.366	7.230	2.0	3.615	9.876	
31.0			4.02	0.2	0.80	42	150	0.28	1.836	1.632						
				0.8	3.22	43	120	0.36	1.428							
											1.324	7.980	2.0	3.990	10.565	
33.0			3.96	0.2	0.79	41	100	0.41	1.254	1.016						
				0.8	3.17	46	70	0.66	0.779							
											1.086	12.820	4.0	3.205	13.922	
37.0			2.45	0.2	0.49	40	100	0.40	1.285	1.156						

Kiraan oleh: G.K.T Di-semak oleh: T.H.TU.

Sungai: DUNGUN   No. Setesen: 4832441   No. Sukatan: Tr. /59/73   No. Lembaran: 4

Nama Setesen: JAMBATAN JERANGAU.   Tarikh: 18. 9. 73   Jumlah Helai: 4

Jarak dari permulaan m	Sudut pugak	Dalam talian basah	Dalam pugak m	Chara tilekan	Tilekan dalam m	Masa sa'at s	Bilangan pusingan No:	Masa purata satu pusingan s	Halaju Meter Sa-sa'at: Pada titek m/s	Purata bagi pugak m/s	Purata muka keratan m/s	Luas meter persegi m^2	Ukor lebar m	Ukor dalam purata m	Kadaralir meter padu sa-sa'at m^3/s	Chatetan
37.0			2.45	0.2	0.49	40	100	0.40	1.285	1.156						
				0.8	1.96	40	80	0.50	1.028							
											0.805	3.460	2.0	1.730	2.785	
39.0			1.01	0.2	0.20	47	50	0.94	0.547	0.454						
				0.8	0.81	57	40	1.42	0.362							
											0.310	1.330	2.0	0.665	0.412	
41.0			0.32	0.6	0.19	62	20	3.10	0.166	0.166						
											0.083	0.480	3.0	0.160	0.040	Assume 50%
44.0			0													W.E. Right Bank
											Jumlah =	69.167			61.415	

Kiraan oleh: G. K. T   Di-semak oleh: T. H. TU.

This programme is written for a "SHARP" Compet 364P III Programmable Calculator but can be readily translated for operation on other machines having similar storage and programming capacities.

1. **Data preparation**

(*a*) Number the verticals, starting at the water's edge from 1, 2, 3 etc.

(*b*) From the relevant current meter rating table or equation obtain the point velocities, filling in the information on the gauging card.

2. **Programme instructions**

The main programme totalling 137 steps and subroutine of 41 steps should be stored permanently on sides A and B respectively on a magnetic card using the normal calculator programming procedure.

Programme operation instructions are as follows:

(*a*) Set operation switch to A (automatic); press CM, C and CA to clear the machine.

(*b*) Enter main programme (side A); press J $\overrightarrow{\text{SUB}}$ 1 and enter subroutine (side B). The programme is now entered into machine memory. Press CA.

(*c*) Press S and H light displayed. Set memory and register decimal switches to 3.

(*d*) Enter distance from initial point (jarak dari permulaan) corresponding to the water's edge. Press S and the figure 2 is displayed to signify that data for vertical No. 2 can now be entered.

(*e*) Enter distance from initial point corresponding to displayed number of vertical.
Press S.

(*f*) Enter vertical depth for the vertical (dalam pugak).
Press S.

(*g*) If there are no velocity observations at this vertical then:
Press S and the number of the next vertical will be displayed.

(*h*) If there are velocity observations, enter the point velocity (halaju pada titek) then:
Press S.

(*i*) If there is more than one velocity observation in the vertical, repeat step (*h*) for each observation.

(*j*) At end of velocity information:
Press S and sectional area (luas) is displayed.
Press S and sectional discharge (kadaralir) is displayed.
Press S and the number of the next vertical is displayed to indicate data for that vertical can now be entered.

(*k*) Repeat steps (*e*)-(*j*) for all verticals except the last corresponding to the opposite water's edge.

(*l*) Enter final distance from initial point corresponding to water's edge.
Press S
Press S again and sectional area is displayed.
Press S to display sectional discharge.
Press S and start light comes on.
Note: The programme terminates when a depth of zero is entered, assuming zero to correspond to the water's edge of the opposite bank. If the depth at water's edge is *not* zero then an additional entry has to be inserted onto the gauging card. This shows the same distance from the initial point as the water's edge entry but with depth zero, and is the first or final entry depending on the water's edge where the non-zero depth occurs.

(*m*) To read out the summed sectional areas and discharges then:
Press PS 2 to select Part 2 of the main programme.
Press S to display river discharge (kadaralir sungei).
Press S to display cross sectional area (luas).
Press S to display mean velocity (halaju purata).
Press S to display hydraulic radius and the start light comes on.
This is the end of the programme.
All outputs described in (*m*) above should be rounded off to three significant figures before entry onto the face gauging card.

'SHARP' Compet 364P-III Program Sheet

Title:
Main Programme for Stream Gauging Computations.

Memory	Memory Registers			
Main Program	1		7	Σ Sectional Discharge
	2	Counter	8	Previous depth
Subroutine 1-144	3	Sectional Area	9	Velocity Counter
	4	Previous Distance	0	Σ velocities
Subroutine 145 - 288	5	Sectional width/area	•	Wetted perimeter
	6	Previous Mean Velocity	±	Σ Sectional areas.

Step	Instr.	Note	Step	Instr.	Note	Step	Instr.	Note	Step	Instr.	Note
1	CM		37	→J		73	J→		109	7	Displays Sectional q
2	C		38	8		73	/		110	Ⓗ	
3	→J		39	X→M		75	→J		111	CM	
4	/		40	5		76	4		112	3	
5	MR		41	/		77	M+		113	MR	
6	2		42	M+		78	0		114	8	
7	Ⓗ	Distance from initial point.	43	2		79	/		115	√x≠0	
8	MR		44	0		80	M+		116	/	
9	2		45	Ⓗ	Enter depth	81	9		117	END	
10	√x≠0		46	√SUB		82	J→		118	END	
11	2		47	/		83	3		119	MR	
12	RC		48	MR		84	→J		120	7	
13	X→M		49	8		85	5		121	Ⓗ	Displays total q
14	4		50	√x≠0		86	MR		122	MR	
15	2		51	9		87	0		123	±	
16	M+		52	J→		88	÷		124	Ⓗ	Displays total Area
17	2		53	6		89	MR		125	RC	
18	J→		54	→J		90	9		126	÷	
19	/		55	9		91	+=		127	RC	
20	→J		56	CM		92	→J		128	+=	
21	2		57	9		93	6		129	Ⓗ	Displays mean Velocity
22	RC		58	CM		94	MR		130	MR	
23	MR		59	0		95	6		131	±	
24	4		60	→J		96	RC		132	÷	
25	RC		61	3		97	X→M		133	MR	
26	X→M		62	0		98	6		134	·	
27	4		63	Ⓗ	Enter Velocity	99	+=		135	+=	
28	RC		64	√x≠0		100	÷		136	END	
29	−=		65	4		101	2		137	END	
30	√x≠0		66	MR		102	+=		138		
31	7		67	9		103	×		139		
32	J→		68	√x≠0		104	MR		140		
33	8		69	5		105	3		141		
34	→J		70	/		106	Ⓗ	Displays Sectional Area	142		
35	7		71	X→M		107	+=		143		
36	⟲		72	9		108	M+		144		

'SHARP' Compet 364-PIII Program Sheet

Title:

Subroutine for stream gauging computations..

Memory	Memory Registers			
Main Program	1		7	
	2		8	
Subroutine 1-144	3		9	
	4		0	
Subroutine 145 - 288	5		•	
	6		±	

Step	Inst.	Note	Step	Inst.	Note	Step	Inst.	Note	Step	Inst.	Note
1	x→m		37	3		73			109		
2	9		38	m+		74			110		
3	mR		39	±		75			111		
4	8		40	END		76			112		
5	−=		41	END		77			113		
6	x		42			78			114		
7	+=		43			79			115		
8	x→m		44			80			116		
9	0		45			81			117		
10	mR		46			82			118		
11	S		47			83			119		
12	x		48			84			120		
13	+=		49			85			121		
14	mR		50			86			122		
15	0		51			87			123		
16	+=		52			88			124		
17	÷		53			89			125		
18	+=		54			90			126		
19	m+		55			91			127		
20	•		56			92			128		
21	mR		57			93			129		
22	9		58			94			130		
23	mR		59			95			131		
24	8		60			96			132		
25	RC		61			97			133		
26	x→m		62			98			134		
27	8		63			99			135		
28	+=		64			100			136		
29	÷		65			101			137		
30	2		66			102			138		
31	+=		67			103			139		
32	x		68			104			140		
33	mR		69			105			141		
34	S		70			106			142		
35	+=		71			107			143		
36	m+		72			108			144		

'SHARP' Compet 364-PIII Program Sheet

Title:

Subroutine for stream gauging computations..

Memory	Memory Registers			
Main Program	1		7	
	2		8	
Subroutine 1 - 144	3		9	
	4		0	
Subroutine 145 - 288	5		•	
	6		±	

Step	Inst.	Note	Step	Inst.	Note	Step	Inst.	Note	Step	Inst.	Note
1	X→M		37	3		73			109		
2	9		38	M+		74			110		
3	MR		39	±		75			111		
4	8		40	END		76			112		
5	−=		41	END		77			113		
6	×		42			78			114		
7	+=		43			79			115		
8	X→M		44			80			116		
9	0		45			81			117		
10	MR		46			82			118		
11	S		47			83			119		
12	×		48			84			120		
13	+=		49			85			121		
14	MR		50			86			122		
15	0		51			87			123		
16	+=		52			88			124		
17	÷		53			89			125		
18	+=		54			90			126		
19	M+		55			91			127		
20	•		56			92			128		
21	MR		57			93			129		
22	9		58			94			130		
23	MR		59			95			131		
24	8		60			96			132		
25	RC		61			97			133		
26	X→M		62			98			134		
27	8		63			99			135		
28	+=		64			100			136		
29	÷		65			101			137		
30	2		66			102			138		
31	+=		67			103			139		
32	×		68			104			140		
33	MR		69			105			141		
34	S		70			106			142		
35	+=		71			107			143		
36	M+		72			108			144		

62069—9-11-76.