MINISTRY OF WATER ENERGY AND MINERALS
TANZANIA

MANUAL ON PROCEDURES IN OPERATIONAL HYDROLOGY

VOLUME 2

OPERATION OF STREAM GAUGING STATIONS

1979

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MANUAL ON PROCEDURES IN OPERATIONAL HYDROLOGY

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OPERATION OF STREAM GAUGING STATIONS

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PREFACE

This Manual on Procedures in Operational Hydrology has been prepared jointly by the Ministry of Water, Energy and Minerals of Tanzania and the Norwegian Agency for International Development (NORAD). The author is Østen A. Tilrem, senior hydrologist at the Norwegian Water Resources and Electricity Board, who for a period served as the Project Manager of the project *Hydrometeorological Survey of Western Tanzania*. The Manual consists of five Volumes dealing with

1. Establishment of Stream Gauging Stations
2. Operation of Stream Gauging Stations
3. Stream Discharge Measurements by Current Meter and Relative Salt Dilution
4. Stage-Discharge Relations at Stream Gauging Stations
5. Sediment Transport in Streams – Sampling, Analysis and Computation

The author has drawn on many sources for information contained in this Volume and is indebted to these. It is hoped that suitable acknowledgement is made in the form of references to these works. The author would like to thank his colleagues at the Water Resources and Electricity Board for kindly reading and criticising the manuscript. Special credit is due to W. Balaile, Principal Hydrologist at the Ministry of Water, Energy and Minerals of Tanzania for his review and suggestions.

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1 INTRODUCTION

The objective in operating a stream gauging station is to produce a reliable, accurate and systematic record of stage and discharge at that particular site. The exact location of the station is governed to some extent by the availability of suitable physical conditions for stage and discharge measurements and for developing discharge rating curves.

A record of stage can be obtained by observing a non-recording staff gauge at set time intervals (Figure 1). A continuous record of stage is obtained by operating automatic water level recorders that sense and record the water level in the stream. Usually, the recorder is actuated by a float in a stilling well that is connected to the stream by intake pipes. The stilling well protects the float and dampens the oscillations in the stream caused by wind and turbulence. Stilling wells are usually placed in the bank of the stream (Figure 2).

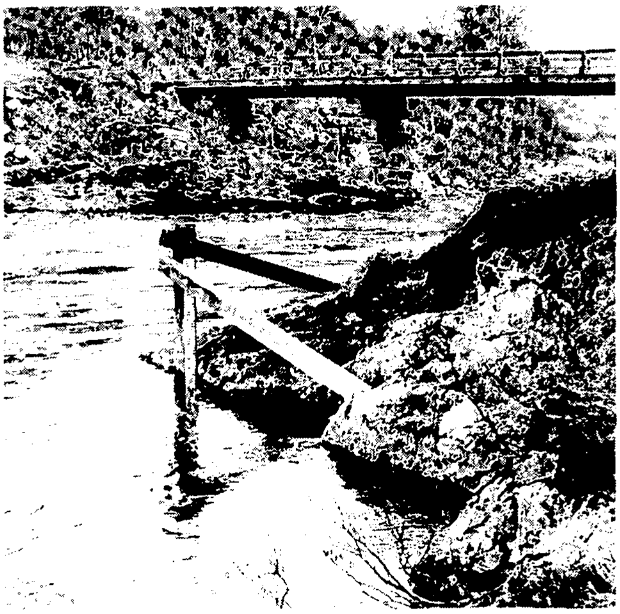


Figure 1. Staff Gauge (Bua River at Lillebudal, Norway).

A series of discharge measurements covering the whole range in stage is made initially to define the relation between stage and discharge. This operation is known as calibrating or rating the gauging station. Subsequently, discharge measurements are made at periodic intervals to verify the calibration and to define any change in the channel geometry. Discharge measurements are normally made by the current meter method. However, indirect methods are frequently used in determining flood-peak discharges.

The stability of the stream channel governs the number of discharge measurements that are necessary to define the stage-discharge relation at any time. If the stream channel is stable and permanent,

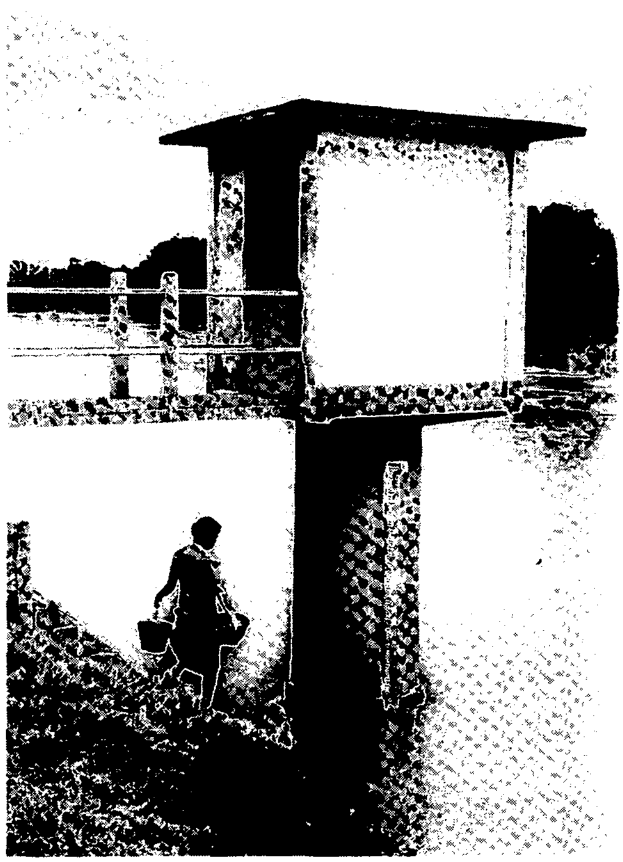


Figure 2. Automatic Water Level Recorder; house and stilling well (Cimanuk River at Djatibarang, Java, Indonesia).

one discharge measurement every 3–4 months is generally sufficient to verify the calibration, while in sand-bed streams several discharge measurements a week may be required for re-calibration because of random shifts in the bed and banks of the stream channel.

The computation of discharge records depends on the stage-discharge relation, also known as the discharge rating of the gauging station. The discharge rating may consist of a simple curvilinear relation between stage and discharge, termed the discharge rating curve, or a more complex relation in which discharge is a function of both stage and slope of the water surface.

The data obtained at the gauging station are reviewed and analysed by engineering personnel at the end of the water year. Discharge ratings are established and the stage record, also known as the gauge height record, is reduced to daily mean values. The mean discharge for each day, the total annual runoff and the maxima and minima of flow are computed. The data are then prepared for publication.

Regarding the operation of stream gauging stations, it is fundamental that observational data must be collected systematically if they are to have any value. Reliable streamflow records can only be obtained at gauging stations that are being operated continuously.

In Tanzania, there are three levels of responsibility involved in the operation of the stream gauging network. They are: a) the Central Hydrometric Office (Head Office) which sets policy and standards, provides training and carries out the final quality checks and processing of the collected data, b) the Regional Hydrometric Office which provides equipment, facilities, training, control and initial processing of the collected data, and c) the Hydrometric Field Personnel who actually measure and record the physical data and maintain the recording and gauging facilities in good condition.

The operation of a stream gauging station network consists of the following actions:

1. Observing and recording complete records of stream stage from staff gauges or by automatic water level recorders.
2. Inspecting the gauging stations and instructing the local observer in his duties.
3. Promptly carrying out repairs and maintenance whenever observations and recordings are interrupted.
4. Taking measurements of discharge at every gauging station often enough to be able, at any time, to define and maintain the discharge rating.
5. Correct analysis and computation of the collected data in the office.
6. Checking and controlling the accuracy in all parts of the data collection and computation system.

2 FIELD OPERATION

2.1 General

In a modern stream gauging system, field operations are handled by specially trained *field teams* who visit every station at set intervals, usually once a month to once every three or four months depending on the local conditions. These teams make discharge measurements at all stations. They collect the gauge records, pay the gauge observers and check their performances. If the work is not being done properly, they correct the observer at once. Gauge repairs and needed maintenance are carried out immediately. Between the field tours, the same personnel is required to do office work so as to become thoroughly familiar with all parts of the job. Good work of acceptable quality in either the field or the office can only be done by a man who knows both field and office work. An untrained man is unable to carry out the work efficiently in either place.

The data collection in the field and the computation of the data in the office are both parts of a single process – not two separate processes. Strict control of field accuracy is necessary to obtain usable records. This control is exercised by routine checks on accuracy made when, a) the field data are received at the regional office, and b) during computation and analysis of the records in the central office. These checks show where inaccurate work is being done anywhere in the system, from the original gauge readings by the observer to the final computation of the discharge records for publication. Whenever poor field work is discovered by means of the accuracy checks, it must be immediately corrected by orders from the office. This method is the only way to ensure good field work.

The essential requirement for obtaining reliable records of stage and discharge is that the field work be performed accurately and conscientiously. The final records will be only as good as the field work that goes into them because the field data is the basis for the computation of the records.

The first step necessary for the collection of accurate field data is that the field team be adequately prepared for the field trip. By being adequately prepared means that they have all the necessary information regarding the particulars of each gauging station and all the needed equipment and that the equipment is in good operating order. This is the responsibility of the *team leader.*

The team must be prepared to spend considerable time at any station in order to put it in proper order, if necessary altering the schedules of work and travel accordingly and camping on the site until the job has been completed. It must always be kept in mind, when visiting stations, that the time spent in travelling is a fixed expense, while the time spent on attention and care of the stations while there is the useful time.

After the team returns to the office from a field trip, the team leader must see to it that any necessary repairs are made to the equipment so that the team will be prepared for the next field trip or an emergency trip that it might be called on to make.

The specific responsibilities of the field personnel are to ensure that:

1. The gauges are set to correct datum.
2. The automatic water level recorders are functioning correctly.
3. The local observers are reading the gauges and recording their readings correctly as instructed.
4. All the equipment and structural installations are maintained and kept in good repair.
5. Stream discharge measurements are taken at the required time intervals.

2.2 Survey of Gauging Stations

After a gauging station has been constructed (see Volume 1 of this Manual, *Establishment of Stream Gauging Stations),* a final detailed survey is made of all the station features, including all structural installations. Of particular importance are the elevations of the station bench mark, the zero of the reference gauge, the invert of intakes for stilling wells and the point of zero flow.

2.2.1 Plan of Station

The plan should give the location and details of the station features as follows:

1. The instrument shelter or house.
2. Staff gauges and other non-recording gauges.
3. Intake pipes and static tubes.
4. Station bench mark and any auxiliary bench mark or datum marks within the instrument house for checking and setting the recorder.
5. The control.
6. The size and length of the pool above the control.
7. The position of the cableway.
8. The channel conditions below the main features of the control.
9. For artificial controls, a separate plan to scale of the structure is required.

2.2.2 Longitudinal Profile and Cross Sections

The following sections drawn to scale are required:

1. A longitudinal section of the stream reach at the station showing the bed profile, including the lowest point on the control (point of zero flow), the staff gauge, intakes for stilling well, and current meter measuring section.
2. Cross sections extended up each bank of a section control, including one through the point of zero flow.
3. A cross section through the staff gauge extended up each bank.
4. The current meter measurement site should be defined by at least five cross sections. In addition to the measuring cross section, two cross sections below and two above the measuring section should be surveyed, covering a distance equal to one bank-full width of the channel in each direction. The bed in the reach between the five surveyed cross sections should be carefully examined for the presence of rocks and boulders. All cross sections should be taken normal to the general direction of flow and should be extended to an elevation well above the highest expected flood stage. The spacing og levels and soundings must be close enough to reveal any abrupt change in the contour of the channel.
5. A cross section of the stilling pool is required approximately 3 m above any artificial control. In the calibration of weirs, it is desirable to know the flow approach condition, as any cross section variation produces changes in the velocity of approach and, therefore, the characteristics of the weir. This cross section should be checked every year.

In the survey of cross sections and bed profiles Form H.56, the *Stream Gauging Station Survey Sheet* should be used. See Sppendix A, Plate 1 for specimen of this form. The form is completed in triplicate. The original is sent to the central office, one carbon copy is kept at the regional office and one copy kept by the team leader.

2.2.3 The Stage of Zero Flow

The stage of zero flow – also termed the point of zero flow – corresponds to the lowest point on the low-water control and is defined as the gauge height at which the water ceases to flow over the control. Usually, this stage does not coincide with the zero of the reference gauge. The stage of zero flow is an important item of information and a very helpful aid in the construction of the discharge rating curve and it is included as a parameter in the discharge equation for the gauging station.

The position of the point of zero flow is easily determined for artificial controls and in those cases where the control is well-defined by a rocky barrier (ledge) over which the water flows.

For other natural controls, particularly channel controls, the determination may often be approximate. The stage of zero flow is determined by subtracting the depth of water over the lowest point on the control from the stage indicated by the gauge reading. If the gauge is at some distance from the control, an adjustment should be made for the slope. The difficulty in determining the point of zero flow is in finding the lowest point on the control, as not all controls are easily identified. Generally, a cross section is surveyed across the stream at the first complete break in the slope of the water surface below the gauge; this is usually the location of the upstream lip of the low-water control. For a channel-controlled gauging station, the maximum depth directly opposite the gauge will give a reasonable approximation of the depth to be subtracted from the gauge reading in order to obtain the stage of zero flow.

The position of the point of zero flow is best determined at time of low water when streams can be waded. In those cases where the controlling section is difficult to identify, it may be identified by surveying a close grid of spot levels or running a sufficient number of cross sections over the area of the assumed controlling section or reach.

2.2.4 Staff Gauges and Station Bench Mark

Automatic water level recorders are operated in conjunction with an independent reference gauge as to the height of the water surface above the gauge zero. This is accomplished by means of a staff gauge placed outside in the stream, and in such a way that there is no difference in head between the staff gauge and the water intake to the recorder. To have an easy way of checking whether there is a free flow of water through the intake pipe between stream and well, another gauge is placed inside the stilling well at the same datum as the outside staff gauge. The two gauges should give identical readings at all stream stages; or there should be a fixed difference between the two readings independent of the stage. The zero of the staff gauge is set below the point of zero flow. In the case of channel control, the zero of the staff gauge is set well below the lowest stage expected at the station site. Once the staff gauge has been set, its datum must not be changed, but maintained throughout the period of operation of the station. To accomplish this, the staff gauge must be referred to a permanent *station bench mark,* preferably placed well above the expected high flood-level.

The following items are to be noted when surveying the datum of staff gauges:

1. The level of each separate staff gauge section must be checked relative to the station bench mark by accurate levelling between the bench mark and the gauge sections. The level is checked by a closed levelling circuit, starting and finishing on the bench mark. The misclosure should not exceed 4 mm. The mean of the two levelling runs is taken as the difference in height between the station bench mark and the staff gauge sections. The levelling notes are entered on Form H.56 and distributed as explained above in Section 2.2.2.
2. Staff gauges are required to be check-levelled and if necessary reset three times a year: during October, during January-February and during June-July. Check-level notes are entered on *Form* H.52, *Stream Gauging Station Check Survey Sheet.* See Appendix A, Plate 2 for specimen of this form. Form H.52 should be distributed as explained in Section 2.2.2.
3. The datum of the staff gauge shall not be altered except on instruction from the central office.
4. In addition to the station bench mark, an auxiliary bench mark may be established on the recorder shelf for convenience of reading the water level in the stilling well by means of a water-surface contact sounding tape.
5. Initial survey information for the gauges and the bench marks should be kept in the recorder shelter for easy and quick reference.

2.3 Description of Gauging Station

When the survey of the gauging station has been completed, the Station Description is prepared. Two copies are made, one for the central office and the other for the regional office. The data are entered on Form H.51A, *Description of Station.* See Appendix A, Plate 3 for specimen of this form.

The following information should be included in the description of the station:

1. Name of the stream and name of the nearest village or special geographical feature located nearby.
2. The station number allocated according to the numbering system used for the region.
3. The date when the construction of the station was accomplished and the date on which observations were started.
4. The geographical location of the station in degrees and minutes of longitude and latitude. The elevation of the station if available. A barometric observation of the elevation is satisfactory, otherwise a contoured map of scale 1:50 000 may be used if available.
5. The catchment area above the station in km^2. The boundary should be drawn on the best map available and measured by a planimeter. This work is done at the central office.
6. A short description of the geographical characteristics of the catchment, such as mountains, hills, swamps, vegetation, slope and shape of catchment.
7. The total range in stage covered by the staff gauge.
8. Short statements, covering on which bank (left or right) the station is located, the distance from the staff gauges to any conspicuous feature near the site, such as a bridge, houses, rocks, a large tree, etc.
9. A short description of the river bed forming the control; such as whether the river bed and banks consist completely or partly of rocks, boulders, sand, etc.; if it is narrow or wide; if there are

traces of erosion; if the banks are covered with vegetation such as trees, scrub, etc.; and if there is vegetation in the river bed. Give a statement as to the stability of the control; if it is permanent for all stages or only partly so, or if it is a shifting control.

10. The make, type and serial number of the recording instrument should be stated. State the recording interval as 8, 16 or 32 days, or if it is a strip-chart recorder. Give the height ratio or reduction scale as 1:5, 1:10 or 1:20.
11. The reduced level of the bench mark (R.L.B.M.) means the elevation of the bench mark above the zero of the staff gauge (L.Z.G.). In general, the zero of the staff gauge is set at an arbitrary level below the level of the water surface when the water ceases to flow over the control (L.C.T.F.). If possible, the station bench mark should be connected to the National Geodetic Survey Net.
    Describe the construction of the station bench mark as bolt drilled into rock or large boulder, or cemented into heavy concrete block. Indicate its position and give its accurate distance in relation to the staff gauge or other station features. The auxiliary bench mark should be described in a similar way.
12. State whether the purpose of the station is general National investigations or to procure data for special projects.
13. Obtain information from the local people and give statements on the duration of high water and of low water, or zero flow.
14. Give distance in km from the regional office to the station and state which type of transport is to be used during dry and wet seasons. State hours or days to be spent on the trip to the station.
15. Give name of local observer and his pay per month. Also state number of readings per day.
16. Give information on the manner of collecting returns from the observer, whether by the regional office at the end of every month, sent by mail to the regional office at the end of every month, etc.
17. A sketch of the station site is required. Show the position of the gauges, the recorder, the bench marks, the cableway and other installations. The distances between each item should be based on measured distances and entered correctly on the sheet together with sketches of any conspicuous feature or structure in the vicinity of the station site.
18. Photographs giving a complete pictorial record of the stream reach at the station site should be included.
19. The Gauging Station Description should be signed by the officer-in-charge of the region except paragraphs 5 and 6, which should be completed by a skilled officer at the central office.

2.4 The Local Observer

The reading of staff gauges is the first basic step in hydrometric work. If this task is not performed accurately and properly, the rest of the work involved in operating the gauging station will have a greatly reduced value.

The frequency of gauge readings for non-recording gauges will be an important factor in the accuracy of the continuous discharge record to be converted from these readings. Normally, in Tanzania, the gauge is read three times a day, but one daily reading may be sufficient during periods of low flow and for gauges in lakes.

For most stream gauging stations, gauge heights to the nearest centimetre are of sufficient accuracy. There are certain special cases involving small streams and low flows where greater refinement is required.

The sources of error for non-recording gauges are concerned mainly with the observer. It is important when selecting an observer that a reliable, intelligent person be chosen. If the observer is careless in his duties, the gauge height record will be, of necessity, also of poor quality. Normally, it is not too difficult to find a reliable observer if the gauge site has been conveniently located.

The observer must be adequately trained. The importance of being close to the staff gauge and close to the water's surface when reading the gauge should be stressed.

A field officer, when going on field trips, should always visit and check the observer. He should add his own reading of the gauge in the observer's gauge record book. This will serve as a check to the observer's readings and will indicate to him the importance of his work. If an observer is not carrying out his duties correctly, it should be explained to him that there are ways of detecting inaccurate work by comparing his readings with observations at other stations on the same stream or on other streams in the vicinity. A persistently unreliable observer should be replaced.

The observer's instructions should include the following:

1. Gauge readings should normally be taken three times a day, at 0700, 1200 and 1800 hrs. If for special reasons the observer must take the readings at other times, these times must be stated in the remarks column of the recording book. For example: «Gauge read at 8.30 hrs.»

2. If because of illness the observer is unable to read the gauge, he should arrange for a temporary replacement (a member of his family) who should make the readings for a while. It must be stressed that on no account should «cooked-up» readings be entered in the gauge record book.
3. The observer should immediately notify the regional office of any irregularities at the station, such as gauges or other equipment damaged, vandalism, etc.
4. The observer should submit his monthly readings by mail soon after the end of the month. In remote areas where postal service is not available, the readings must be collected by the field teams on their regular visits to the stations.

The routine operation of automatic water level recorders involves replacing recorder charts, winding and regulating the clock, filling ink or sharpening the pencil, and keeping the intake pipes and stilling well free of sediment deposits. Some of these duties may be done by the local observer, others by the field personnel from the office. However, the exact division of the specific duties will depend upon the local circumstances.

2.4.1 Recording the Gauge Readings

The daily gauge readings are recorded on Form H.3, *Daily Gauge Record,* a specimen of which is reproduced in Appendix A, Plate 4. Instructions for filling out Form H.3 are as follows:

1. Enter station number, name of river and location as indicated on the form.
2. The form has two columns of dates and is supposed to cover either the first half or the second half of the month, that is, two sheets will cover one complete month.
3. Three columns are reserved for the gauge readings. The times of reading are entered at the top of the columns. One column is reserved for observation of rainfall in case a raingauge is installed at the gauging station.

2.5 Inspection of Gauging Stations

Securing reliable gauge height records requires regular inspection and maintenance of the gauges, the automatic recorders and other installations at the gauging stations. Whenever possible, any maintenance necessary for the continued operation of the station should be performed at the time of the visit.

Upon completion of an inspection trip, a *Field Inspection Report* is prepared and submitted to the central office, one copy should be held at the regional office. See Appendix A, Plates 5a and 5b for a specimen of the reporting form to be used. Separate detailed reports are required where major repairs are needed. For example, details of damage caused by floods which can not be repaired by routine maintenance are to be accompanied by sketches and survey information so that reconstruction can be planned. Special reports are required where repairs or maintenance are necessary on access roads, causeway crossings, culverts and bridges.

The sources of error for recording gauges are numerous but they can be kept to a minimum if the field personnel perform their duties efficiently.

Recorders equipped with floats, float cables and counter-weights contain necessarily some friction and lost motion which results in a slight lag in the recording of changes in the stream stage. If the recorder is cleaned and maintained correctly according to the manufacturer's instruction, this lag and friction can be kept to a minimum. A further source of error is due to the tendency of the recorder charts to expand and contract with changes in temperature and humidity and to improper alignment of the paper on the instrument.

If the clock is not adjusted properly, errors will be introduced because the pen or pencil will not be at the correct time at the end of the recording period. Lack of cleaning and maintenance of the clock are usually the causes of unreliable clock operation.

Another possible source of error is the displacement of the reference gauge due to settling or other causes. This error can be reduced by periodic checking of the datum of each gauge relative to at least one and preferably two bench marks that are entirely detached from the gauge or its support, and that are secured against destruction or change in elevation. In this respect, it may be stated that a long record of stage, which can not be related with certainty to a fixed datum throughout its recording period, will have a reduced value for most engineering, statistical and hydrological purposes.

Carelessness on the part of the field personnel servicing water level recorders represents the greatest source of error. Incorrect readings of reference gauges, inaccurate setting of pen or pencil, failure to wind the clock, failure to be certain the clock was operating after being wound, failure to put pen or pencil back on the chart, leaving the pen or pencil in the incorrect reversal, and failure to clean and maintain the recorder are some of the factors that frequently cause errors in gauge height records or loss of records. Most of the sources of errors and loss of gauge height records can be eliminated by more careful attention to details and by following the manufacturer's instructions for the various recording devices.

On arrival at the gauging station, the field team performs the following actions in this order:

1. Visits the local observer, asks for general information and inspects his recording book.
2. Inspects the recorder house and other structures to be certain no damage or vandalism has occurred since the last visit.
3. Inspects the gauging station control to determine if any visible changes have taken place or to see if there are any obstructions on the control.
4. Inspects the staff gauges and runs check-levels to see that each gauge is at its correct height.
5. Inspects the intake pipes and the static tubes.
6. Services the water level recorder. Reads all the reference gauges outside and inside the stilling well and records the readings on the recorder chart. Changes the recorder chart, fills the ink reservoir or sharpens the pencil, flushes the intake pipes or cleans the well and pipes by hand, and makes any necessary adjustments to the instruments at the station.
7. Makes a discharge measurement. The type of the measurement will depend on the discharge, the time of the year and the physical facilities at the station. The measurement is computed *before* the field team leaves the station and is plotted on the established rating curve. If the measurement plots more than 4 per cent off the rating curve, it must be checked for reasons why and if none are apparent, a new check measurement must be made and computed. If still off the rating curve, a shift in the station control has probably occurred.
8. Checks the recorder again to make sure that everything is operating satisfactorily before locking the recorder shelter.

Before leaving the station, an inventory of tools and equipment is made so nothing is forgotten and left at the station.

All field personnel should fully realize the importance of submitting an *interpretation* of the recorder chart where any discrepancies exist and that any necessary repairs and maintenance must be carried out in order to prevent them recurring. This can be done if sufficient time is spent at the station to examine the recorder in detail, taking field notes of all adjustments carried out and examining the stilling well, intake pipes, staff gauges and the station control. Where stilling well and intake pipes are silted up, steps must be taken to clear them at once, and where staff gauges or other installations need repairs, they must be repaired at once.

2.5.1 The Local Observer

The first thing the field officer does when he arrives at a gauging station, is to find the local observer. He asks for general information and inspects the recording book. Before leaving the station, the field officer adds his own reading in the remarks column of the recording book and initials it.

2.5.2 The Recorder House and Other Structures

The field officer then inspects the recorder house and other structures that are part of the gauging station to be certain that everything is in good condition and that nothing has been disturbed by unauthorised persons. If any damage has occurred at the station, the officer should make whatever temporary repairs are necessary. He should also note the extent of any damage and report it in writing to his supervisor.

2.5.3 Station Control and Stream Channel

Next, the field officer inspects the station control. It is not necessary to describe fully the channel and control conditions on each visit; the general description is given in the Station Description. However, changes in conditions between visits are important and should be recorded on the recorder chart and on the front sheet of the discharge measurement notes. Changes in the low-water control section influence the discharge rating for the low stages, while for higher stages, changes in the channel conditions for some distance below the gauge will affect the discharge rating. Conditions above the gauge may also affect the rating, such as a cut-bank that may furnish sediment that may be deposited on the control, or deposited in the pool just above the control causing changes in the velocity and direction of the approaching flow.

It is important to note whether the control is obstructed by drift wood or debris and the amount and extent of any weed or moss growth on the control. A comment should be made both on the recorder chart and on the discharge measurement form that an obstruction was found, together with an estimate of the length of time the obstruction has been present. An artificial control should be inspected closely if there is any leakage or increase of leakage since last visit, also any deterioration of both weir and banks forming the control. If there is ice in the stream, the type, location and amount of ice should be recorded.

No change should be made to the control conditions until after a discharge measurement has been taken.

2.5.4 The Staff Gauge

The field officer should inspect, read and note all gauges installed at the station. Reading of the gauges is very important because the relation of the readings provides indication of malfunction of the recorder such as blockage of intakes, and is necessary for the application of proper corrections and appraisal of the quality of the gauge height record. Check-levels should be run forward and back to the station bench mark. Any gauge out of level should be reset.

Reading of the outside staff gauge may be affected by surge. The gauge should be observed for a sufficient length of time to determine the mean of the surge and the range of the surge should also be noted. The outside staff gauge sections should all be placed firmly in the ground, the plates should be visible and clean for the whole of their length.

Two types of inside gauges are used with automatic recorders, the staff gauge and the float-tape gauge. Both types may be installed at a station. One of these gauges may be designated as the *base* or *reference gauge* to which the recorder pen is set. Generally, however, it is most practical to use the outside staff gauge as the reference gauge. The float-tape gauge should be referred to an adjustable index point set in the shelf on which the recording instrument is placed. The tape should be cut and assembled to the length equal to the elevation of the adjustable index so that it will read directly.

2.5.4.1 Check Survey of Staff Gauges

Check survey of staff gauges is entered on Form H.52 (Section 2.2.2). The general procedure for running check-levels at gauging stations is as described in the following.

1. Check-levelling of staff gauges should be carried out:
   a) Every October, January-February and June-July.
   b) Immediately before and after repairs and adjustments.
   c) Immediately after it is noticed that the discharge gaugings start to deviate more than 4 per cent from the discharge rating curve.

2. Use of Form H.52:
   a) Before going on an inspection trip, for each station enter the required information at the head of the form.
   The Stream Gauging Station Survey Sheet, Form H.56 and the first Gauging Station Check Survey Sheet, Form H.52 will contain all the necessary information.
   b) The form should be used in the field for entries of survey data.
   c) The use of an eraser for the correction of original field entries is not permitted. The erroneous figure should be crossed over with a single line and the correct figure written above.
   d) The levels should be reduced immediately after completion of the survey and an arithmetic check carried out.
   e) For general details on surveys see D. Clark, Plane and Geodetic Surveying, volume 1, pages 307–308, [2].

3. Levelling Procedure:
   a) Start levelling from the station bench mark (S.B.M.).
   b) Take intermediate sights with levelling staff placed on each separate staff gauge section and on auxiliary bench mark (A.B.M.).
   c) After the final foresight on the staff gauge zero has been obtained, change the station of the levelling instrument. Run a second level from the gauge zero closing back to the station bench mark, and again making intermediate sights on each separate staff gauge section and on the auxiliary bench mark; make also an intermediate sight on the water level in the stream as close as possible to the staff gauge.
   d) Reduce the levels and check the computation. The misclosure should not exceed 4 mm; if greater, the procedure must be repeated. The mean value of the two runs is used.

2.5.5 Intake Pipes and Static Tubes

The intake pipes should be checked by eye or by probing if necessary to see if there is sediment or gravel around the intakes. The intakes must, of course, be kept clear of deposits.

2.5.6 Servicing the Automatic Water Level Recorder

After inspecting the recorder house, the control, the intake pipes and static tubes, all the gauges, any gauging structures such as a cableway, and after having check-levelled and if necessary reset the gauges, the automatic recorder is inspected and serviced. Figure 3 shows a schematic drawing of an automatic water level recorder with stilling well and intake pipes set in river bank.

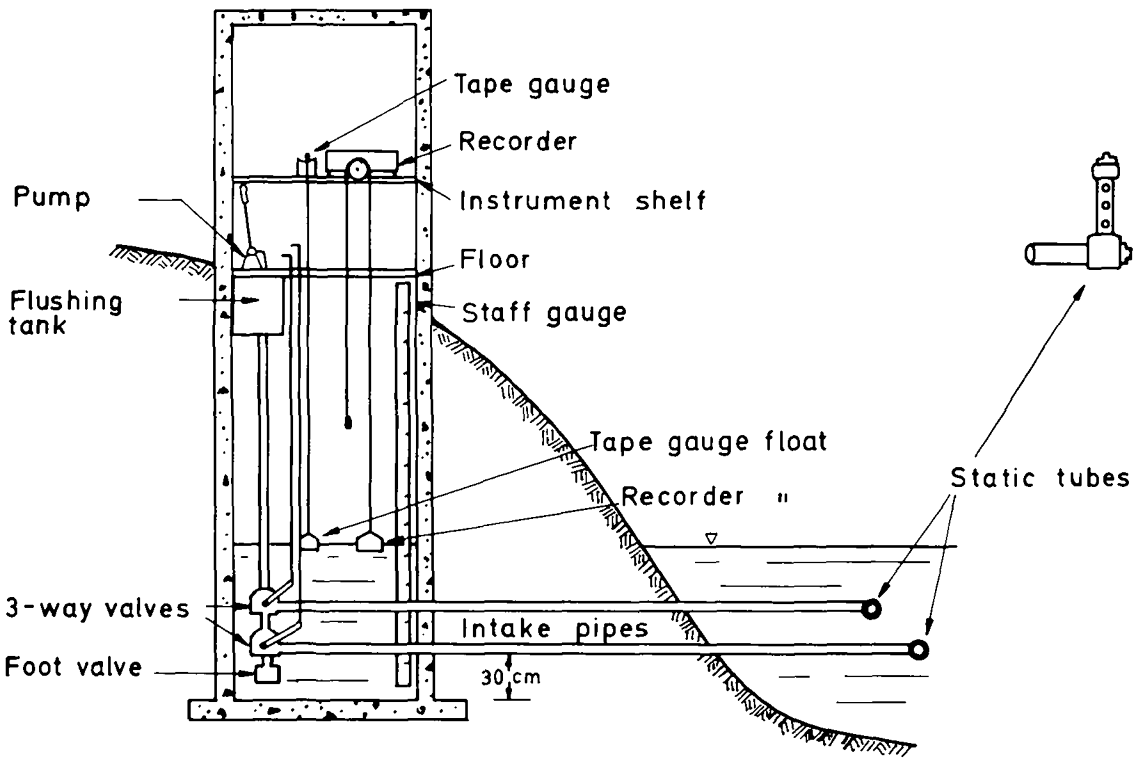


Figure 3. Standard design of Automatic Water Level Recorder; section of house, stilling well and intake.

2.5.6.1 Recording Notes on the Recorder Chart

The recorder chart is noted on the following occasions:

1. On every visit to the gauging station.
2. When the chart is removed from the recording instrument.
3. When the new chart is set on the recording instrument.

Especially when a new chart is set must care be taken to see that it is absolutely correct for time and gauge height.

The practice of recording notes may vary with the region and the individual. It is a good idea to use a rubber stamp to ensure uniformity. The stamp has generally the following items:

STATION:	Station name and No. in full.
DATE:	Day, month, year.
TIME:	Watch time, 24-hour system.
PEN:	Pen time of recorder.
O.S.:	Outside staff gauge.
I.S.:	Inside staff gauge.
F. TAPE:	Float-tape gauge.
AUTO:	Water level indicated by recorder pen
NAME:	Initials of inspector.
RMKS:	Remarks.

The notes should be recorded neatly, thus providing a permanent record suitable for reproduction and distinction.

At the time of the inspection, the time should be indicated by a vertical 3 mm long inspection mark of the pen. The pen should be raised from the chart, the float raised a few cm, the pen placed on the paper again and the float raised another few cm. The mark should not be made by rocking the float pulley because this places an undue strain on the bearings of the pulley of the recorder, and may cause the float string or float tape to slip on the float pulley. The float string or tape should be pinched by two fingers between the float and the float pulley and manually lifted.

Knowing the reduction ratio of the recording instrument, the recorded stage can be checked against the outside staff gauge. If there is any discrepancy, a circled point is made on the chart to show the correct water level and time corresponding to the scales marked on the chart. The appropriate notations are as follows and are made opposite the mark or point made on the chart: the date, time of day, gauge readings both inside and outside the stilling well and the inspector's initials.

If the recorder disagrees with the reference staff gauge by more than ½ cm, there are several possible causes for the error:

1. Obstruction of intake pipes.
2. Instrument may be out of adjustment.
3. Shrinkage or expansion of chart.

Each of these causes will be discussed below under separate headings.

Alterations in the pen setting should not be made during a normal period between chart removals and settings unless some gross error is detected, such as a blocked intake pipe or a change in staff gauge zero. In this respect, a normal run period may be defined as not more than one month. When minor discrepancies occur, any necessary adjustments in gauge height or time (as shown to be necessary from the check remarks) will be made when the chart is processed at the office.

If the pen is adjusted to a new position, write «adjusted» with an arrow pointing to the new position and explain why. On a steeply rising or recession limb of a hydrograph, the recorded reading before adjustment may also be given, as the inspection mark tends to follow the trace and makes reading difficult. The amount of error in stage is required for the error distribution by the computation personnel at the office.

If the clock is found to have stopped, indicate exactly on the chart where the pen was found and, if possible, show the direction the pen was travelling. If the clock has stopped, it is usually a good idea not to make an inspection mark on the chart because the length of the recorded line the pen was tracing may represent the range in stage during the clock stoppage.

In order to help discover faults in the operation of gauging stations, it is necessary to interpret peculiarities in the recorded trace. On visits to gauging stations, officers must inspect the trace on the chart from the time the new chart was set; the recorder may appear to be operating satisfactorily at the time of the visit, but may have developed trouble previously and temporarily rectified itself; that is, clock stoppage, intake pipe blockage, float string and counterweight fouling, etc.

If there are any unusual conditions with respect to the trace or if there is any maintenance done, or change in the control, additional notes should be made on the chart explaining these points. An interpretation of any faults in the trace should be made and where possible rectified, see Section 3.2.2.6.

After the inspection and the notation on the chart have been completed, the required repairs and adjustments such as flushing the intakes, winding the clock, regulating the speed of the clock and so forth, can be carried out.

2.5.6.2 Flushing and Clearing of Intakes and Stilling Well

All intakes must be flushed during each visit whether or not the intake pipes may appear to be blocked by deposited mud or open. The ends of the intake pipes with the static tubes should be inspected in case they may be buried. If the stilling well does not have intake pipes, the inlets or slots should be inspected for free access of water to the well. If a sand bar has formed in front of the intake, a trench has to be dug to the flow at right angles to the bank.

Mud must be removed from the stilling well when the sump at the bottom of the well has filled up and the operation of the recorder is threatened.

For small diameter stilling wells where no flushing device has been installed, the so-called displacement method or bucket method may be used to clear the intake pipe and well for mud. The method consists of pouring water into the well and stirring up the mud by use of a rod. A sufficient head may be built up in the well allowing the water to force its way out through the intake carrying the deposited mud with it in the rush.

In special cases, where the station is of short and easy access, one may rely on small portable pumps to pump out the mud accumulated in the stilling well.

Larger stilling wells may be entered by a man and cleaned out by hand. The intakes must be provided with a closing device. First, the intakes are closed and the well cleaned out. Then, the intakes are opened and cleared by using flexible sewer rods.

The clearing and checking of stilling well and intakes must proceed until satisfactory agreement between the water level in the well and the outside staff gauge is achieved. The gauges are read again after the intakes are cleared and conditions in the well have stabilised, and the changed gauge height noted on the chart and front sheet of the discharge measurement.

A stilling well with side intakes should always be made large enough for a man to enter it and clear it for deposits. If the well has horizontal pipe intakes, the intakes must be provided with a flushing device. Narrow pipe wells can be provided with a vertical bottom intake of appropriate size and placed directly in the stream attached to a bridge pier or abutments, or to a specially constructed concrete support. This latter type is not subject to silting as it is self-clearing. See Volume 1 of this Manual, *Establishment of Stream Gauging Stations*.

2.5.6.3 Instrument out of Adjustment

Once it is certain that the intake is open, the recorder setting on the chart should be checked. At this stage, if the discrepancy with the outside staff gauge was due to intake blockage alone, the recorder should read correctly. If a discrepancy still exists, the following points should be checked:

1. Initial setting of the pen.
2. Whether the float pulley adjustment screws are tight.
3. Whether or not reversal of the recorder occurs at the base line on the chart.
4. Whether the chart is coming squarely off the supply roll or is correctly placed on the drum.
5. Whether the pen is secure, but at the same time pivots freely on its support.
6. Whether the float line beads fit securely into the float pulley or the float line slides on the pulley.
7. Whether the float or counterweight are fouling the side of the stilling well, the ladder, inner tubes, etc.
8. Whether the float is leaking.

2.5.6.4 Shrinkage and Expansion of Recorder Chart

Errors due to shrinkage and expansion of the chart can be caused by varying humidity. This can amount to as much as 2 per cent expansion or contraction of the paper.

2.5.6.5 Removal and Check of Used Recorder Chart

Before the chart is removed, check the reversal at the margins and adjust the pen if necessary. This check is important because it may save many pen corrections when processing recorder charts. It is better to check the reversals before the used chart is removed because if adjusted when the new chart is set, the paper may not be in correct alignment and the adjustment may not be correct.

As the recorder chart is removed, it should be inspected very carefully for any indication of malfunctions such as flat periods, sudden vertical lines, stoppages or any obvious trouble which would call for action before leaving the station. The chart should be dated or the number of days of record counted to determine if there is any lost record or excessive corrections due to error in time.

When inspecting the chart, the trace may show that a flood has occurred since the last visit. The well should be examined for the high-water mark to compare with the recorded peak. The recording of the high-water mark in the well is especially important if the clock happened to be stopped during the flood and the pen reversed, thereby obscuring the peak recorded on the chart. If the recorder is equipped with a float tape instead of a float string, the installation of a Dahman peak-stage indicator will afford the determination of the peak. This device is a bronze clip that slides on the float tape after reaching the instrument shelf.

If the intakes were blocked and the well sealed during the peak or if for any reason the inside gauge height is not representative of the outside water surface elevation, the flood marks upstream and downstream from the well and at the staff gauge, if found, should be staked out and tied in by levelling.

2.5.6.6 Setting of New Recorder Chart

After the removed recorder chart has been inspected, a new chart is set on the recorder. Record station name, date, time, gauge readings, remarks and initials on the chart. Make a vertical inspection mark as explained above (Section 2.5.6.1) when setting the pen. Be sure the pen is not in the reversal as a result of previous reversal check. See Appendices B and C for further details of setting recorder charts.

2.5.7 Discharge Measurement

Next, the field officer makes a discharge measurement. After the measurement, he removes any obstructions from the control. He should record the stage of the stream after the obstructions have been removed and the pool has drained. This stage is to be used with the measured discharge to check the stage-discharge relation. Then he makes certain that the water level recorder has operated correctly during the time he was making the measurement.

One of the essential points to remember concerning discharge measurements is to measure the conditions in the stream as they are found without making any changes at the control. This does not mean that weeds or rocks or other obstructions cannot be removed from the selected measuring cross section or that a section can not be prepared by building dikes to cut off dead water and shallow flows in the cross section. However, algae, debris, ice or any other obstruction on the control that can be removed, should not be removed until after the measurement is completed.

Following the discharge measurement, the front sheet of the Discharge Measurement Notes should be completed. This page usually contains most of the supplementary information that is needed concerning the measurement.

If there has been more than 5 cm change in stage during the discharge measurement, it is important to copy from the water level recorder the stage record that will be needed to compute a weighted mean gauge height of the measurement.

See Volume 3 of this Manual, *Stream Discharge Measurements by Current Meter and Relative Salt Dilution* for detailed procedures in making discharge measurements.

2.5.8 Final Check of Recorder Instrument

Before leaving the station it is necessary to check that:

1. The clock is wound and running.
2. The chart is noted with correct staff gauge reading, date and time of day, name of inspector and any other pertinent remarks.
3. There is sufficient chart left on the roll to last until next visit (in case of strip-chart recorder).
4. The ink well has sufficient ink in it and that the pen is secure and pivots freely on its support.
5. The float pulley adjustment screws are tight.
6. The pen is set *on the chart* and marking properly.

2.6 Notes on Chart Faults

Apart from malfunction of the recording instrument itself, there are several other parts of the gauging station that may not function properly. Briefly, they are:

1. The stilling well and intake.
2. The staff gauge and the stilling pool.
3. The station control.

The Stilling Well and the Intake

Errors due to the well and intake pipe fall into two types, *structural* and *silting.* Distortion of the hydrograph due to structural faults results from fouling of the float or counterweight on ladders, braces, side of the well, inner tubes, etc., and grounding of the float during low flows or grounding of the counterweight during floods.

Structural defects of the static tube may lead to persistent silting, or in the case of missing or defective static tubes, excessive drawdown in the well.

The errors in the hydrograph due to silting are familiar to all, but in this connection, one point tends to be overlooked. Silting invariably occurs in the intake pipe, as this is the narrowest entry to the well. However, cleaning of the intake pipe only is insufficient to remedy the silting unless the sump is also cleaned. Cleaning the intake pipe and not the sump soon leads to a renewal of silting.

The Staff Gauge and the Stilling Pool

The major error arising from the stilling pool is due to deposition of sediment in the pool. This may or may not cause silting in the intake pipes. Even though free entry to the well is maintained, the filling ut of the pool can create an artificial control at low flows or alter the rating of the permanent control by increasing the velocity of approach, giving a higher discharge for a given gauge height.

At some stations there may be some distance between the staff gauge and the recorder intake. During high stage, differences between the staff gauge reading and the recorded water level may be noted giving an error due to the slope of the water surface. In these circumstances, never reset the recorder during high stage.

The Station Control

Under certain circumstances, the pysical dimensions of the control can be materially altered. This is usually due to material such as logs or debris building up on the control during the rising stage and perhaps being washed away prior to or during the peak of the flood, or being deposited on the control during the recession of the flood.

2.7 Maintenance of Gauging Stations

Maintenance is defined as the upkeep of property and equipment. Therefore, the purpose of gauging station maintenance is to keep the structures, equipment and instruments in first-class operating order. Any malfunction of any part of a gauging station will result in lost accuracy or in the loss of the whole record.

There are two types of maintenance: a) preventive maintenance, and b) emergency maintenance. The first type can be performed under preconceived plans and schedules while the second type must be performed in most cases without appreciable advance warning or planning.

Preventive maintenance includes any activity that will extend the life or increase the usefulness of the gauging station, such as painting, replacement of damaged or badly-worn parts or other minor repairs, checking and adjusting cableway sag, checking and tightening clipped cable connections, repairing or clearing cableway cross sections at which discharge measurements are made and checking cableway anchors to make certain anchor bars and connections are in good condition and not covered with debris.

The field officer should be furnished with å *check list* to follow so that nothing will be overlooked.

Emergency maintenance includes any activity necessary to put a gauging station back into operation after an act of vandalism, damage by high water or by other causes, or to make immediate changes at a gauging station to meet a specific need resulting from an unforeseen situation. The field officer may not always have with him all the tools and materials needed to perform emergency maintenance when such work is found to be necessary. He should attempt to put the gauge back into operation on a temporary basis, however, and notify the regional office of the situation giving an estimated list of materials needed and approximate cost of repairs. If the damage is minor and repairs can be made on the spot, this should be done.

In general, the same procedure should be followed in the performance of maintenance as is followed for construction. Maintenance is just a minor construction job. The real difference is that maintenance work might be performed by a one-man party without advance notice. Maintenance work should be performed in a professional manner and as thoroughly as construction work.

2.7.1 Maintenance of Recorder Instrument

Water level recorders are precision instruments and must be carefully maintained and serviced. It is essential that all hydrometric field personnel should be thoroughly familiar with the recorder types in use, so they can trace faults and defects in them without wasting time or causing damage to the instruments.

If, on a visit to a station, it is found that the recorder is not working, every effort should be made to find and rectify the trouble before leaving the station. If replacement parts such as clock, pen or float are necessary to get the recorder working, the field officer must arrange with the observer to take several additional readings during the day until the recorder can be brought into working order.

All bearings and parts subject to friction should be given a small drop of oil once a year. However, this must not be overdone; if too much oil is used, dust will stick to the instrument making conditions worse than no oil at all. On bearings where there are no holes for oiling, put a drop of oil on the side of the bearing with a tooth pick. Ball bearings have been oiled at the factory and this should suffice for at least five years.

Clocks should be serviced by persons thoroughly familiar with this work. It is recommended that recorder clocks needing cleaning, oiling or repairs be sent to the central office for that purpose. Always replace the cap covering the escapement port after inspection. See that caps are in place when clocks are in storage.

References Chapter 2: [1], [2], [3], [4], [5].

3 COMPUTATION AND PREPARATION OF DISCHARGE RECORDS

3.1 General

A continuous record of discharge at a gauging station is converted from the observed or recorded gauge heights by means of the discharge rating for the station.

The hydrometric office personell will scrutinise the collected data and prepare what is called a *station analysis* before the actual computations can be done. The station analysis shows the result of the examination and is prepared for each station at the end of each water year. The station analysis includes the following items:

1. A review of all field inspection reports and field surveys and a determination of any gauge corrections to be applied to the water level observations for the year.
2. A review of all discharge measurement notes.
3. A check of the discharge rating with respect to the discharge measurements taken during the year, and the determination of the rating curve/curves or shifts to be applied during the year.

When the water level is observed manually or recorded by a graphic water level recorder, all computations may be performed manually in the following order:

1. Determination and application of water level and time corrections to the recorder chart. (Applicable to recording gauge only).
2. Computation of the mean water level observation for each day or for shorter periods if the change in discharge during the day is large.
3. Application of any gauge correction to the daily mean observation to determine the daily mean gauge height.
4. Computation of daily mean discharge from the daily mean gauge height record and the discharge rating, including any shift corrections.
5. Computation of peak values of gauge height and discharge.
6. Listing of the values of daily mean gauge height and discharge, and momentary peaks.
7. Computation of mean discharge for each month and for the year.

8. Review and comparison of the computed discharge record with that of nearby gauging stations.

3.2 Computation of Daily Mean Gauge Height

Practically all gauging stations have an observer whose job includes taking manual gauge readings. These readings are used to verify and supplement the recorder-chart observations at recording stations, and for computation of the daily mean gauge heights at non-recording stations.

Daily mean gauge height is defined as the mean gauge height for a particular day. The term *mean daily gauge height* has a different definition, that is, for any day, say June 10, it is the arithmetic mean of the daily mean gauge heights for all of these individual days in a period of record.

In general, a mean gauge height is computed for each day of the year. The various procedures involved for non-recording and recording gauges are outlined below.

3.2.1 Non-recording (Manual) Stations

Normally, in Tanzania, the manual gauge at non-recording stations is read three times a day, at 0700 hrs., at 1200 hrs. and at 1800 hrs. When the flow is fairly steady, a simple averaging of the readings is used for the daily mean gauge observation. However, during periods of rapidly changing stage, a simple averaging of two or three readings may give an erroneous mean gauge observation because a peak flow could have occurred between the readings. During such periods, the observer's readings should be plotted on a length of recorder-chart paper, and guided by the timing of peaks from a nearby station, a synthetic trace is drawn. The daily mean gauge observation is computed from the synthetic trace in the same way as explained in Section 3.2.2.2., item 6.

The daily mean observation and the appropriate gauge correction (Section 3.2.2.5), if any, are entered on Form H.5 (Appendix A, Plate 7) and the daily mean gauge height determined.

3.2.2 Recording Stations

3.2.2.1 The Recorder Chart

Automatic water level recorders used in Tanzania are mostly the A. OTT Type X and a few Leupold and Stevens Type A35. See Appendix D for operating instructions for the A. OTT recorder and Appendix E for the Leupold and Stevens recorder. A new type, A71, has been introduced by Leupold and Stevens, but the operation features are the same as for type A35.

The A. OTT Type X water level recorder uses a chart 277 mm by 392 mm fixed to a rotating drum to record changes in stage and time. The chart is divided into 5 major divisions across the chart, the distance between divisions represents 0.50 m change in elevation of the water surface. Each major division has 25 minor divisions, each representing 0.02 m. The length of the chart is divided into 15½ major divisions each representing 12 hours. Each major division is divided into 12 minor divisions each representing one hour. These are the values represented by the divisions for a recording period of 8 days and reduction ratio 1:10 of stage, which are the recording period and reduction ratio recommended for most purposes. By exchanging the float pulley, the reduction ratio can be changed to 1:5 or 1:20. The recording period can be changed to 24 hours, 32 hours, 16 days or 32 days by exchanging the appropriate gears of the instrument. The same chart is used for all recording periods and reduction ratios, but the divisions of the chart will, of course, represent different values in each case.

The Leupold and Stevens Type A35 recorder uses a strip chart to record the changes in stage and time. This chart is a long roll of paper that under most conditions of use will last for 2 years before a new roll needs to be installed. Because of this feature, the recorder can be run for several months, the limiting factor being the available length of fall of the clock weight. If a clock spring is used, the normal operating time is not less than 4½ months between each winding. Six months clock springs are available on special order. The chart is divided into 25 major divisions across the chart. With reduction ratio 1:10 of stage, the distance between divisions represents 0.10 metres change in elevation of the water surface; each major division has 5 minor divisions, thus the distance between each minor division represents 0.02 metres change in elevation. Down the length of the chart major divisions are shown by heavy solid and heavy dashed lines; the distance between any two solid line divisions represents 24 hours. Between the major divisions are 12 minor divisions; the distance between each minor division represents one hour. These scales can be changed if desired, but for most purposes the above scales are suitable.

Inspection notes appear on the recorder chart on the days that a field officer has visited the station for some purpose. This means there are inspection notes at the beginning and end of each chart and there may be notes at any intermediate point. The office personnel processing the charts should examine these notes carefully for completeness and accuracy. Check the notation for pen observation and time against that shown by the trace. If any discrepancy appears, check against the discharge measurement notes, if available, or with the field officer who made the inspection notes. Any discrepancy or omission should be brought to the attention of the field officer so that correct and adequate notes will be made by him on future visits.

3.2.2.2 Processing the Recorder Chart

When processing recorder charts, it is advisable to follow systematically the steps outlined below:

1. Enter the dates in the margin at the top, or bottom, of the chart at the respective noon lines if the observer has omitted the dates.
2. Inspect the times as recorded at the beginning and end of the chart and on any intermediate days, in order to determine if any time correction should be applied. After inspecting the chart carefully to see that any difference between chart time and the actual time is not due to resetting, stoppage, etc., indicate the total time correction at the end of the chart by, for example, «Time 4 hrs. fast» or «Time 2 hrs. slow». Distribute and indicate the time correction according to the method given in Section 3.2.2.3.
3. The recorder pen is usually set to read the same as the manual reference gauge. Inspect the observations given for the manual gauge and for the pen at the beginning, intermediate points, and end of the chart and determine the pen correction to be applied. Indicate the total pen correction at the end of the chart and at any place of resetting. Distribute the total pen correction according to one of the methods described in Section 3.2.2.4 and indicate the correction on the recorder chart.
4. Examine the recorder chart to see if reversals have occurred. If so, identify the points of reversals by the abbreviation «Rev» and indicate the correction to be applied if the points of reversal should not coincide with the top or bottom line of the chart.
5. When the recorder trace is missing for part of a day, it may be estimated and marked on the chart by a dashed line for use in determining the daily mean gauge observation.
   If the recorder trace is missing for one or more days, the daily mean gauge observation may be based on the available manual gauge readings.
   When adding notes and corrections on the chart or interpolating for missing records, care must be taken to preserve the original record. *Do not trace over an original pen or pencil record.*
6. Compute the daily mean observation by one of the following two methods:
   a) Balance the areas above and below an index line by means of a template. The template consists of a thin sheet of clear plastic, 15 cm x 7 cm, with an index line etched along the major axis as illustrated in Figure 4. The mean value is determined by placing the index line over the intersection of the graph and the vertical line representing the beginning of the time interval considered. The index line is rotated around the point of intersection and area A visually balanced against area B, the mean value is read at the intersection of the index line and the vertical mid-line of the time interval.
   b) Divide the day into two or four equal parts, determine the mean for each part and then average these values to obtain the mean for the day. For example, suppose the day is divided into four parts of six hours each. The mean observation for the first period of six hours is indicated by a dot at the mid-line (the 0300 line in this case). The mean for the second six-hour period is indicated by a dot at the mid-line (which is the 0900 line). A line is drawn from the dot on the 0300 line to the dot on the 0900 line and the point at which this line crosses the 0600 line is the mean observation for the first 12 hours of the day. Do the same for the last 12 hours of the day and connect the two 12-hours means by a straight line. The point at which this line crosses the noon line is the mean observation for the day.
7. Compute the daily mean observations by applying the appropriate pen corrections and reversal corrections (where applicable). In arriving at the daily mean observations the individual corrections applied to each daily mean observed value should be shown separately rather than as a net correction. The daily mean observation is entered on the recorder chart just above the lower margin of the chart.
8. Compute the daily mean gauge heights by applying to the daily mean observations the appropriate gauge corrections for the manual gauge to which the chart record is referred. Form H.5 (Appendix A, Plate 7) is used for the computation. This procedure may be delayed until the end of the water year when the gauge corrections applicable to that year have been determined. Application of the gauge correction may or may not be shown on the recorder chart. If gauge corrections are applied on the chart, use

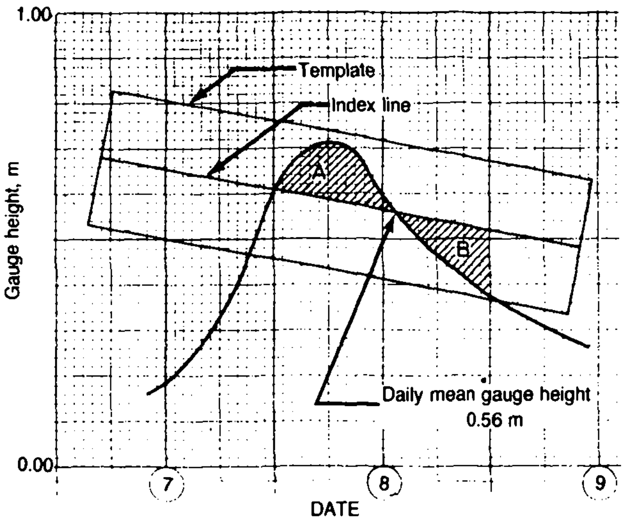
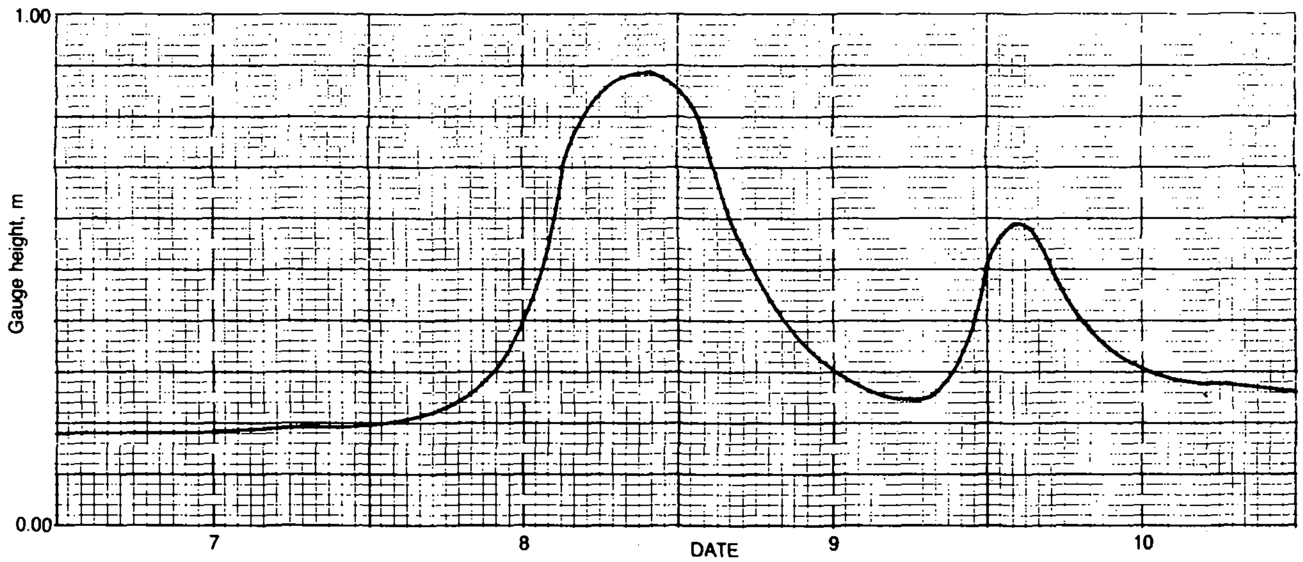


Figure 4. Graphical averaging of recorded water level.

the abbreviation «GC» after each gauge correction figure.

9. The daily mean gauge height normally is used to compute the daily mean discharge. However, a daily mean discharge determined directly from the daily mean gauge height may be in error for a number of reasons, including the following:
   a) the rate of change in stage,
   b) the relative condition of the river (high or low),
   c) the shape of the stage hydrograph for the day and the proportion of time during which the stage is relatively high or low,
   d) the relative curvature of the discharge rating curve in the range of stage recorded during the day.
10. To obtain a more accurate determination of the daily discharge, it may be necessary to subdivide the day into two or more parts, determine the mean gauge height for each part, determine the discharge for each mean gauge height and from these compute the weighted mean discharge for the day (Figures 5 and 6). If the resultant weighted mean discharge differs from that determined using the mean gauge height by more than a selected allowable limit, say 2 per cent, then subdivision is necessary for all similar conditions. A suggested method of determining the necessity for subdivision is to use an allowable range table. An allowable range table may be prepared by trial and error.
11. Mark the maximum and minimum instantaneous gauge observations for the year on the chart.



Hour	G.H.	x	Q	Hour	G.H.	x	Q	Hour	G.H.	x	Q	Hour	G.H.	x	Q
				0–8	0.22	2	9.50	0–4	0.73	1	54.00	0–4	0.57	1	32.50
				8–12	0.31	1	9.50	4–8	0.50	1	24.50	4–8	0.46	1	21.50
0–24	0.18	1	3.20	12–16	0.56	1	31.00	8–12	0.35	1	12.00	8–12	0.34	1	11.30
				16–20	0.83	1	68.00	12–16	0.27	1	7.20	12–24	0.28	3	23.10
				20–24	0.88	1	77.50	16–20	0.25	1	6.10				
								20–24	0.36	1	12.70				
Σ 3.20 $\bar{Q}$ = 3.20/1 = 3.20				Σ195.50 $\bar{Q}$ = 195.5/6 = 32.58				Σ116.50 $\bar{Q}$ = 116.50/6 = 19.42				Σ 88.40 $\bar{Q}$ = 88.40/6 = 14.73			

Figure 5. Computation of daily mean discharge when the stage varies significantly during the day.

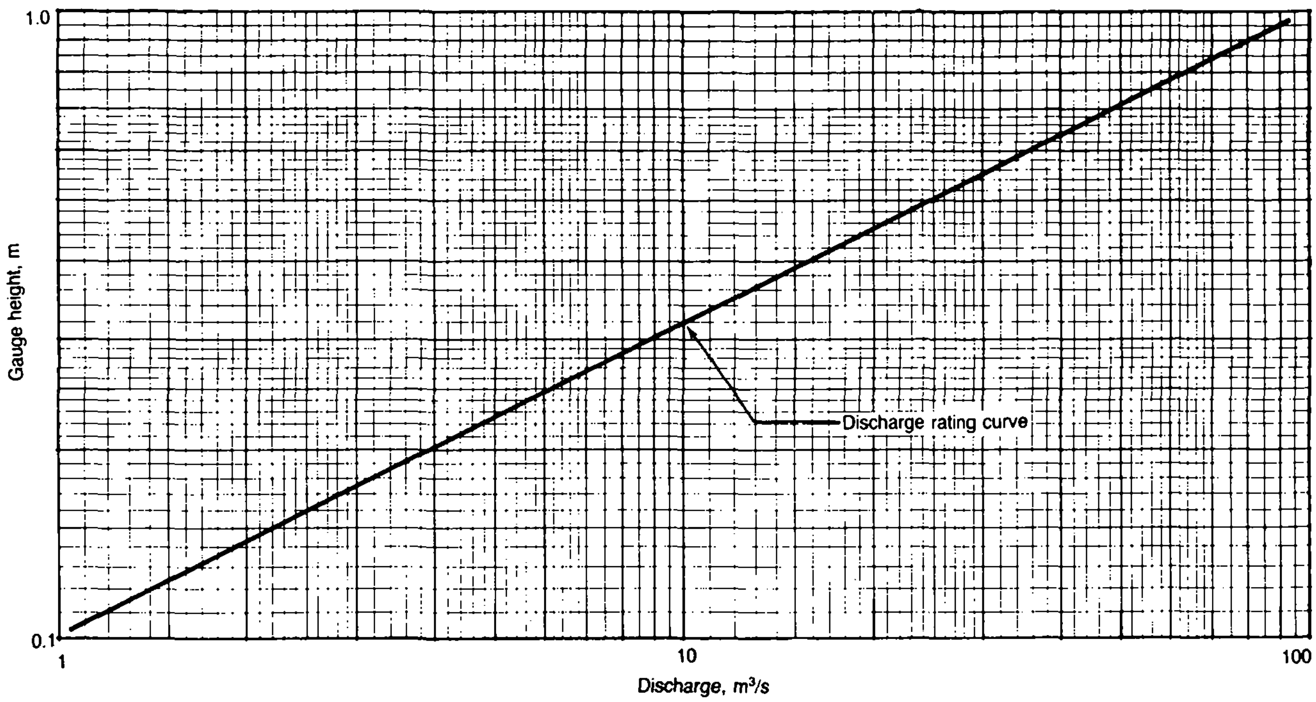


Figure 6. Assumed discharge rating curve on which computation in Figure 5 is based.

12. If the period of usable record and the period covered by the chart are not the same, the period of usable record should be indicated at the beginning of the chart with a note explaining why the remainder of the chart record is not to be used. Do not destroy a chart even if all of it is considered unreliable as the presence of it on the files will show that a useful record was not obtained for that particular period.

3.2.2.3 Correction of Pen Time

When the clock runs fast or slow, the rate at which the recorder chart moves in the time direction under the pen will also be fast or slow. It is assumed that a clock running fast or slow does so at a constant rate. Therefore, a clock that runs say 7½ minutes slow each day (24 hours period) will be an hour late at the end of 8 days of operation and if a field officer visits the station at the end of 48 days, he will find the pen time showing 6 hours slower than correct time.

Corrections are made to the nearest hour. In the above example, the error was less than one-half hour during the first four days and no correction is needed; from the fifth to the twelfth day the clock was progressively slower from one-half hour to one and one-half hours and the correction is one hour, from the thirteenth to the twentieth day the clock will be from one and one-half hours to two and one-half hours slow and the correction is two hours. The correction increases by one hour every eight days with the maximum correction occurring during the final five days.

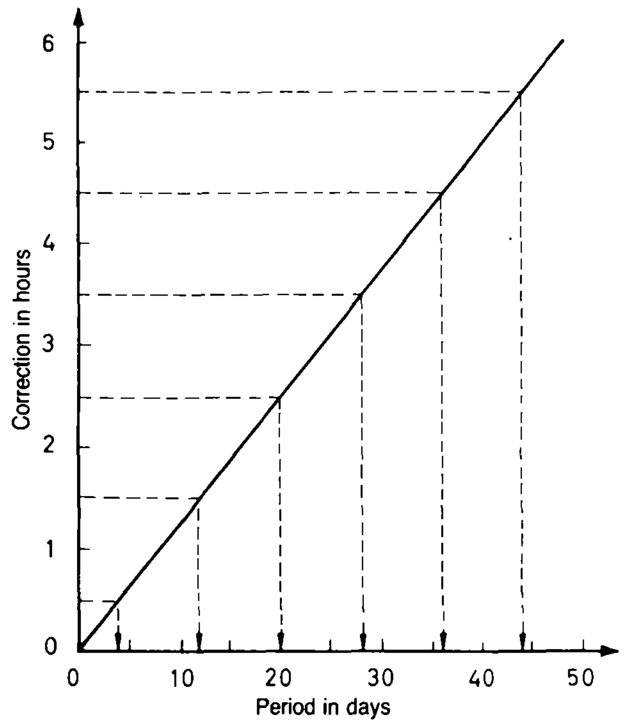
Time corrections are conveniently done graphically. Using ordinary graph paper, mark the maximum correction along the ordinate axis and the number of days along the abscissa axis. Draw a straight line from zero days and zero correction to the intersection of the last day and the maximum correction. Where this line intersects the horizontal lines through the ½, 1½, 2½, etc., hour correction, are the days when the correction changes. The method is illustrated in Figure 7.

In practice, it is customary to use calendar dates instead of days. Thus, the days of correction-change are given as the actual date appearing on the recorder chart.

Time corrections are shown on the recorder chart by moving the midnight line for the day in the proper direction.

3.2.2.4 Correction of Pen Observation

Corrections for the difference between the pen observation and the manual gauge reading are made in exactly the same way as time corrections. For example, assume that the pen trace was + 0.06 m off the manual gauge reading at the end of the 48 days period. Then, $^{48}/_{6} = 8$ shows that the pen reading gradually increased in error by 1 cm every 8 days.



Day	Correction in hours
0–4	0
5–12	+ 1
13–20	+ 2
21–28	+ 3
29–36	+ 4
37–44	+ 5
45–48	+ 6

Figure 7. Time correction of recorded water level.

Corrections are made to the nearest 1 cm. Therefore, by applying the same principle as that used for the time correction, the correction of the pen observation would be:

Day	*Correction in cm*
0 - 4	0
5 - 12	- 1
13 - 20	- 2
21 - 28	- 3
29 - 36	-4
37 - 44	- 5
45 - 48	- 6

Corrections for pen observation errors can also be made graphically. The principle is the same as shown above for graphical time corrections.

3.2.2.5 Gauge Correction

The elevation of the staff gauge relative to the station bench mark is as a rule checked at intervals and a report submitted to the office (Section 2.5.4.1). Should the staff gauge be found to be displaced, the gauge correction to be applied is entered on the *Gauge Correction Distribution Sheet* (Appendix A, Plate 6).

If the date on which the change occurred is known, the correction to the gauge readings is applied straight forward. If the date on which the change occurred is not known, assume that the change occurred uniformly and distribute the correction in accordance with one of the two following methods:

1. Divide the correction by the number of days to find the *change per day*. For example, suppose the correction was found to be 0.00 m on March 20 and + 0.04 m on March 30. The number of days is 10 and the correction would be 0.04 m. The change per day is 0.004 m. The corrections that should be applied are illustrated in Figure 8.
2. When the correction is small and the number of days is large, the preferable method is to divide the number of days by the correction. For example (Figure 8), suppose the correction is 0.00 m on May 25 and + 0.03 m on October 15. Dividing the period of 144 days by 3 gives 3 intervals of 48 days each. Then, no correction will be applied during the first one-half interval of 24 days, that is, from May 25 to June 17. An increase of 0.01 m in the correction will be applied during each of the next two intervals of 48 days, that is, a correction of 0.01 m from June 18 to August 4 and 0.02 m from August 5 to September 21. The remaining 0.01 m correction will be applied during the remaining one-half interval, that is, the final correction of 0.03 m will be applied from September 22 to October 15.

The Gauge Correction Distribution Sheet should be prepared up to the date of the first datum check of the staff gauge in the following year.

The daily mean gauge readings as averaged from observer's Daily Gauge Record Book (Form H.3; Appendix A, Plate 4) or processed from the automatic water level recorder charts, are entered on the Water Levels Discharge Sheet (Form H.5; Appendix A, Plate 7). The gauge corrections are entered on the same sheet and the correct gauge heights computed.

3.2.2.6 Unusual Trace Configurations

Unusual recorder-trace configurations result from the automatic water level recorder functioning under abnormal conditions and can result from malfunctions of the recorder, the stilling well and intakes, and from erratic behaviour of the stream and con-

GAUGE CORRECTION DISTRIBUTION SHEET

STATION NAME . . . . STATION NO. . . . .

TYPE OF GAUGE . . . . YEAR 19 68 . . . .

Correction: 0.00 on December 16, 1967

Day	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0:00	0.00
2												
3												
4								0.01				
5								0.02				
6												
7												
8												
9												
10												
11												
12												
13												
14												
15										0.03		
16										0.00		
17						0.00						
18						0.01						
19												
20			0.00									
21			0.00						0.02			
22			0.01						0.03			
23			0.01									
24			0.02									
25			0.02		0.00							
26			0.02									
27			0.03									
28			0.03									
29		0.00	0.04									
30			0.04	0.00		0.01			0.03		0.00	
31	0.00		0.00		0.00		0.01	0.02		0.00		0.00

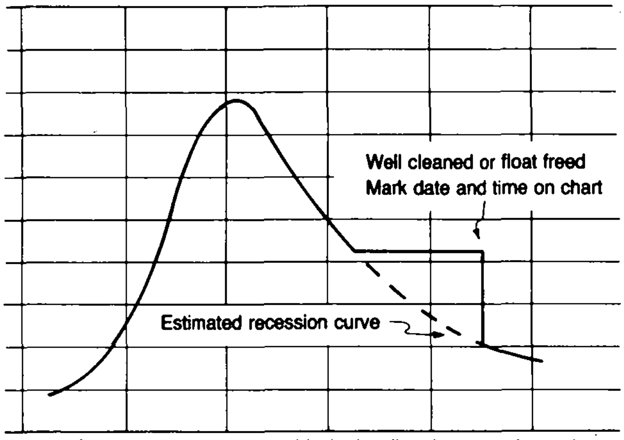
Correction: 0.00 on January 14, 1969

Remarks . . . . Computed by . . . . Date . . . .

. . . . Checked by . . . . Date . . . .

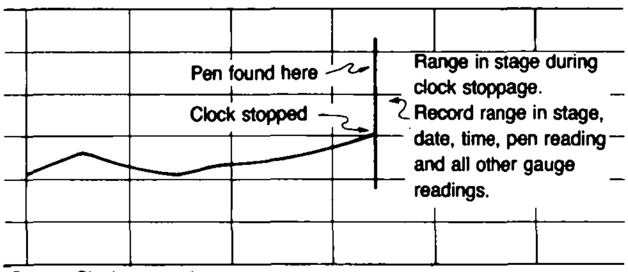
Figure 8. Distribution of gauge correction.

trol. The unusual trace caused by malfunctions of the recorder, stilling well and intakes are mechanical malfunctions and can be prevented. The unusual trace caused by behaviour of the stream and control can not be prevented. The hydro officer should be familiar with the unusual trace patterns so that he can form a mental image of past events by looking at the recorder chart. Figures 9–12 show some unusual recorder-trace patterns and their causes and corrections.



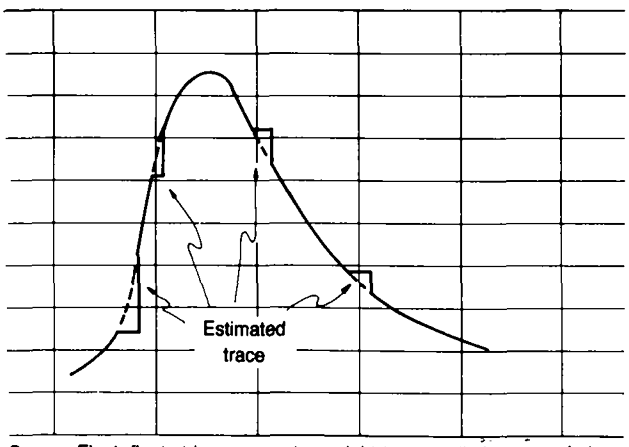
Cause: Stilling well silted, intakes blocked or float hung on obstructions.
Correction: Clean well and intakes or remove obstructions.

Figure 9. Unusual recorder-trace configuration.



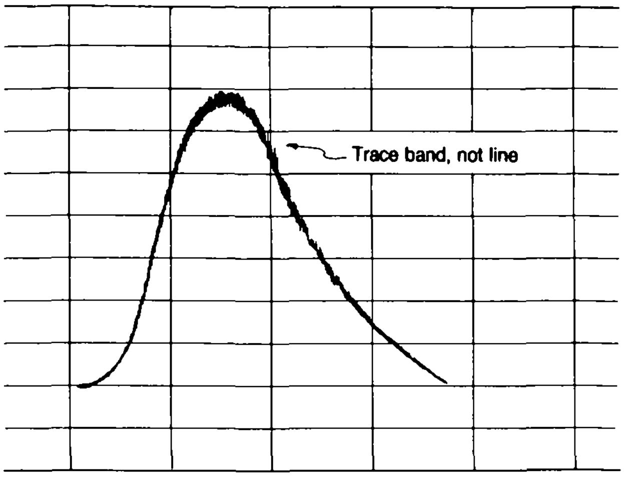
Cause: Clock stopped.
Correction: Wind clock or replace clock if it is out of order.

Figure 10. Unusual recorder-trace configuration.



Cause: Float, float-string, or counter weight temporarily hung on obstruction in well or on instrument.
Correction: Find and remove obstruction.

Figure 11. Unusual recorder-trace configuration.



Cause: Surge at high stage.
Correction: Use static tubes or decrease size of intake.

Figure 12. Unusual recorder-trace configuration.

3.2.2.7 Incomplete and Inaccurate Records

Recorder or stilling well malfunctions or peculiarities in the hydraulic characteristics of the stream channel or stilling well can cause the recorder to fail to register the water level or to register it erroneously. Depending on the cause and what information is available to replace or supplement the pen record, the incomplete or inaccurate pen record can be classified into one of the following classes:

1. No record.
2. Doubtful record.
3. Reconstructed record.

No record is the result of the failure of the recorder to mark a normal trace line in either or both directions; that is, for time (clock stopped) or water level (intake or well silted, float hung up, etc.). When the clock is stopped, the recorder will still register the water level, but all fluctuations will be recorded on a single vertical line. This means, of course, that the range in stage occurring during the period of clock stoppage will be recorded, but intermediate fluctuations will not be shown, nor will the time of occurrence of the extremes be known.

From the recorded range in stage and by use of supplementary data, most notable the observer's gauge readings and comparison with records of nearby stations, a fair idea can be developed of the time that extremes and fluctuations occurred.

When the recorder marks time correctly but it is obvious that the water level is not being recorded, no range in stage can be obtained. Again, the observer's notes and comparison with nearby stations can be used to estimate the missing record. Also, the estimates may be supplemented in some cases with high water marks at or near the recorder site.

Occasionally, because of malfunctions of the recorder, the pen trace will not agree with the observer's notes or with high water marks; or a hydrographic comparison with records at nearby stations will reveal a gross difference during a certain period. Inspection of the chart trace may or may not indicate where a malfunction might have begun or it may be evident that a malfunction has occurred and the trace is in error but the magnitude of the error cannot be defined. If it seems that the record is nearly correct but some doubt exists, then it is classified as a *doubtful record.* If there is enough record available, supplemented by other data to indicate clearly the correct water level, the record is classified as *reconstructed.* In cases where reasonable doubt exists or the record can not be reconstructed reasonably well from a fragmentary trace, the record is disregarded and treated as a *no record.*

3.3 The Discharge Rating Curve

The relation of stage to discharge at a stream gauging station is governed by the so-called station control. A control consists of all the physical features of the stream channel which determine the stage of the stream at a given point for a certain discharge. These features include the size, slope, roughness, alignment, constrictions and expansions, and the shape of the channel bed. The stage-discharge relation at any particular station is important. The discharge rating curve is developed from a graphical analysis of the discharge measurements plotted on graph paper. A correct analysis of the data depends on a knowledge of the characteristics of the channel, a knowledge of open-channel hydraulics, and on experience and judgment. The development of discharge rating curves where more than one control is effective and the number of discharge measurements is limited, generally requires judgment in interpolating between the measurements and in extrapolating beyond the highest measurement. This judgment is particularly necessary where the control is unstable and shifting and various discharge measurements represent different positions of the discharge rating curve.

If variable backwater or highly unsteady flow exists at a gauging station, the discharge rating cannot be described by stage alone. The discharge under these conditions is a function of both stage and the slope of the water surface. Stage-fall-discharge ratings are usually determined empirically from observations of the discharge, the stage at a base gauge and the fall of the water surface between the base gauge and an auxiliary gauge downstream. If the flow is very unsteady, as in a tidal reach, the acceleration head governs the energy slope. Under this condition, unsteady-flow equations must be used to describe the variation of discharge with time.

Procedures for the establishment of discharge ratings and the development of shift corrections for unstable channels are given in Volume 4 of this Manual, *Stage-Discharge Relations at Stream Gauging Stations.*

3.3.1 Shift and Backwater Corrections

For many stations a shift in the station control or a backwater condition may occur at certain times during the year as a result of weed effect, ice conditions, etc., following which the stage-discharge relation normally reverts to its earlier curve. During such periods, shift or backwater corrections are determined from available discharge measurements; these corrections are used to compute daily corrections which are applied in the determination of the daily discharges.

However, apart from these measurements which plot off the curve for reasons indicated above, the majority of the measurements will plot somewhat off the curve as a result of normal scatter. For these, no correction is computed.

Following is an example of the computation of a) shift and backwater corrections, and b) the difference between measured discharge and the indicated discharge from the discharge rating curve.

a) From a discharge measurement, the mean gauge height is 3.62 m and the discharge is 31.5 m^3/s. From the discharge rating curve, the discharge of 31.5 m^3/s corresponds to a gauge height of 3.43 m, indicating that a shift correction of – 0.19 m would have to be applied to the mean gauge height for the day to produce results consistent with the discharge measurement.
b) From a discharge measurement, the mean gauge height is 2.81 m and the discharge is 7.08 m^3/s. From the discharge rating curve, the gauge height of 2.81 m corresponds to a discharge of 6.96 m^3/s. The difference between the measured discharge and that indicated by the discharge rating curve is $(7.08 - 6.96) \div 6.96 \times 100 = 1.7\%$, which is normal scatter.

A discharge measurement may plot substantially off the stage-discharge curve. If after careful analysis and review, no satisfactory cause of its departure from the stage-discharge curve can be determined, the measurement should be eliminated from use in the computation.

3.4 Check of Accuracy of Hydrological Records

In the collection and computation of hydrologic data, all computations must be checked for numerical errors, because everyone makes mistakes at times. In addition, it is necessary for supervisors or senior officers to make careful extra checks at certain critical points to be sure that the work is being done correctly. These checks will ensure that the records are as accurate as possible; they can also eliminate the need for a large amount of recomputation and reanalysis in future years.

Some of these checks will indicate where changes or improvements are necessary in the field procedure or field work. The critical check points are shown in Figure 13 and are described below.

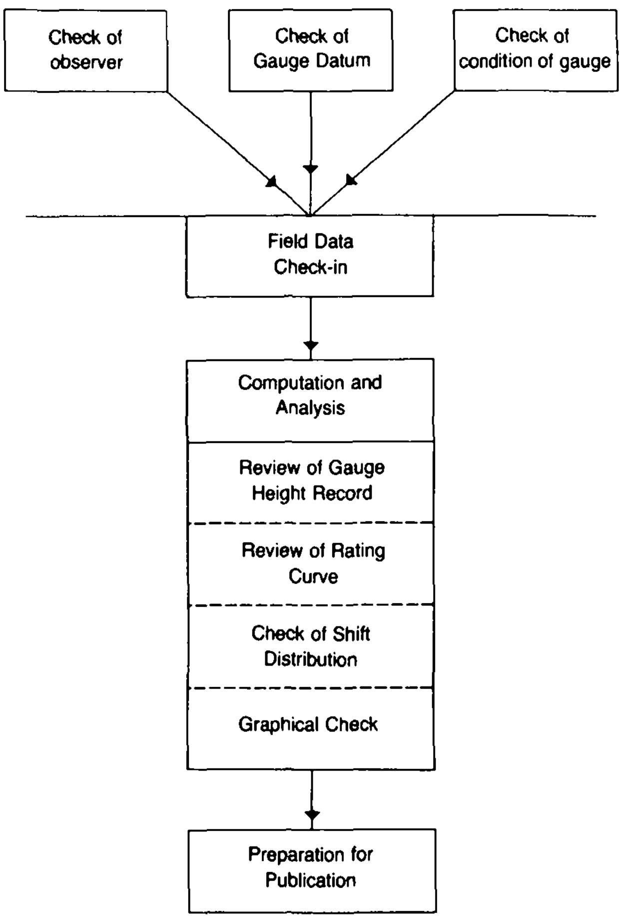


Figure 13. Accuracy-checks in flow of hydrological data.

3.4.1 Field Checks

3.4.1.1 Check of Local Observer and Condition of Gauging Station

As described in Chapter 2, the following points must be carefully checked when the field team arrives at a gauging station and the actions taken reported to the central office:

1. Observer's book must be checked to see that it is correct and up to date. If it shows careless work, the observer should be corrected at once.
2. Condition of gauges must be inspected and emergency repairs or cleaning of mud done at once. If major repairs are needed, they should be noted for central office action.
3. Control should be inspected and conditions noted, any obstructions on the control should be cleared away.
4. Recorder setting and notations should be checked. If there are any errors, the observer should be instructed accordingly.

3.4.1.2 Check of Gauge Datum

To avoid confusion and mistakes, every gauge must be kept at the correct datum. All gauges should be checked by level at least once a year and if found to be displaced, they should be reset correctly. A gauge should also be checked any time it has been damaged and whenever a discharge measurement is made. A report is to be furnished to the central office giving the results of the check and actions taken as discussed in Section 2.5.

3.4.1.3 Check-in of Field Data to Office

This is a very important function; the officer responsible must record all data received as they come into the office and he must control all routine field work. He must examine the following:

1. Discharge Measurement Notes to be sure the measurements are done correctly and to note recommended maintenance for action.
2. Observer's readings to see that gauge observations are complete and without bad-looking periods.
3. Recorder charts to note all charts received and to request missing charts, to see that intakes and wells are open and that gauge readers are doing correct work.
4. Stream Gauging Station Check Survey Sheets and Field Inspection Reports to see what action may be needed.

This officer must see that all data are correctly filed after they are checked-in.

3.4.2 Computation and Analysis Checks

The computation and analysis of records require working with all of the field data collected during the year. Often, mistakes or omissions in field work may be found. The officer responsible must be informed of any such cases found so that he can take steps to remedy the situation. There are three special checks or reviews made during computations and analysis of records, as shown in the following.

3.4.2.1 Review of Gauge Height Records

This review is made to be certain that the gauge readings are correct, that no changes have been made in gauge datum and that the office computation of daily mean gauge heights is correct, as follows:

1. Gauge height record is scanned for the year for unusual long flat periods and for breaks appearing in stage.
2. Reports, measurement notes and notations should be examined to see if there were changes in gauge datum.
3. Daily mean gauge height computations are examined on each monthly form (Form H.5) to be sure they are done correctly.
4. Any necessary corrections are made and the personnel responsible are notified of any poor field or office work found.

3.4.2.2 Review of Rating Curve

This check is made to be sure that the reasoning used in the stage-discharge analysis is correct and that the rating curves are correctly drawn. This review should only be made by a well-ecperienced senior officer. Correctness of the discharge record will depend greatly on the reasoning used in the rating curve analysis.

3.4.2.3 Check of Shift Distribution

Shifting control adjustment is a special technique in analysis required for unstable, sandy or muddy rivers. This technique is difficult and the Shift Distribution Form should be checked by an experienced officer before discharges are computed. See Volume 4, Section 3.3.4 of this Manual.

3.4.2.4 Check of Discharge Hydrographs

This is a graphical check of accuracy for all of the work done through the computations of discharge records, as it is a comparison between daily discharges at different stations on the same river or on nearby rivers. The comparison is made after the daily discharges of two or three stations have been computed and plotted on a single daily discharge hydrograph form. The record is scanned for periods that do not compare well between stations. Any poor periods are checked for possible errors in gauge height or for shifts in the discharge rating that may have occurred between the discharge measurements. High-water periods are examined to see that each record falls in proper relation with upstream and downstream discharges, that is, if the rating curve extension is correct. If no reason can be found for an obvious error, the poor period may be estimated rather than corrected.

If rating curves have not been established, the graphical check is carried out by plotting the daily mean gauge heights and comparing the gauge height hydrographs.

References Chapter 3: [4], [5], [6], [7], [8], [9].

REFERENCES

1. Corbett, D.M. and others
   1945: Stream-gaging procedure. – United States Geological Survey Water-Supply Paper 888, Washington D.C., 245 p.

2. Clark, D.
   1957: Plane and geodetic surveying for engineers. – Constable and Company Ltd., London, 673 p.

3. Kutena, F.Z.
   1963: Operation and maintenance of stream gauging stations. – Lecture Notes for Hydrometric Training Course (12.00), Water Development and Irrigation Department, Dar es Salaam.

4. Grover, N.C. and Harrigton, A.W.
   1966: Stream flow – measurements, records and their uses. – Dover Publications Inc., New York, 363 p.

5. World Meteorological Organization – Economic Commission for Africa
   1969: Hydrometeorological instruments, observations and networks in Africa. – Proc. of Seminar on Hydrometeorological Instruments, Methods of Observation and Establishment of Hydrometeorological Networks in Africa, Addis Ababa 1967, Geneva, 231 p.

6. Carter, R.W. and Davidian, J.
   1968: General procedure for gauging streams. – United States Geological Survey, Techniques of Water Resources Investigations, Book 3, Chapter A6, Washington D.C., 13 p.

7. International Organization for Standardization (ISO)
   1973: Liquid flow measurements in open channels – Establishment and operation of a gauging-station and determination of the stage-discharge relation. – Ref. No. ISO 1100–1973 (E), Geneva.

8. Ozga, W.J.
   1968: Manual of hydrometric office procedures. – Department of Energy, Mines and Resources of Canada; Ottawa, 79 p.

9. Caughran, G.W.
   1974: Important points for checking accuracy of hydrologic records. – Lecture Notes, Institute of Hydraulic Engineering Bandung, Bandung, (Indonesia), 6 p.

APPENDIX A
HYDROMETRIC FORMS USED IN TANZANIA

Form H.56

STREAM GAUGING STATION SURVEY SHEET

RIVER . . . . AT . . . . NO. . . . .

TYPE OF SURVEY . . . .

B.M. . . . . DATUM . . . . NO. OF SHEETS . . . .

SURVEY MADE BY . . . . REF. L/B NO. . . . .

B.S.	I.S.	F.S.	R	F	R.L.	CHAINAGE	REMARKS

PLATE 1

Form H.52

STREAM GAUGING STATION CHECK SURVEY SHEET

RIVER . . . . AT . . . . NO. . . . .

BENCH MARK . . . . DATUM . . . .

REDUCED LEVEL OF BENCH MARK . . . .

LAST SURVEY MADE . . . . 19 . . . .

	LAST SURVEY R.L.	NEW SURVEY R.L.	DIFFERENCE
0 OF 0 TO 1 METRE GAUGE			
1 OF 1 TO 2 METRE GAUGE			
2 OF 2 TO 3 METRE GAUGE			
3 OF 3 TO 4 METRE GAUGE			
4 OF 4 TO 5 METRE GAUGE			
5 OF 5 TO 6 METRE GAUGE			
6 OF 6 TO 7 METRE GAUGE			

NEW CHECK SURVEY MADE BY . . . . DATE . . . . 19 . . . .

CHECK BY . . . . DATE . . . . 19 . . . .

B.S.	I.S.	F.S.	RISE	FALL	R.L.	REMARKS

R.H.O.	A.G.E.	R.C.E.

R.H.O. = REGIONAL HYDROGRAPHIC OFFICE
A.H.E. = ASSISTANT HYDROGRAPHIC ENGINEER
R.C.E. = RATING CURVES ENGINEER

PLATE 2

MINISTRY OF WATER DEVELOPMENT AND POWER
DEVELOPMENT RESEARCH DIVISION
HYDROLOGICAL SECTION

DESCRIPTION OF STATION

STATION NAME ____________________

AREA OF CATCHMENT __________ STATION NUMBER __________

LATITUDE __________ LONGITUDE __________

ESTABLISHED __________ 19 ______ BY __________

NAME OF OBS. __________ P. O. ADDRESS __________

PAY SHS. ______ DISTANCE ______ FREQUENCY OF OBS. ______

LOCATION OF STATION WITH RESPECT TO TOWNS, BRIDGES, HIGHWAYS, RAILROADS, TRIBUTARIES, ISLANDS, FALLS, DAMS, ETC.

____

DESCRIPTION AND LOCATION OF THE GAUGE AND OTHER EQUIPMENT:

____

LOCATION AND DESCRIPTION OF INITIAL POINT FOR SOUNDINGS:

____

CONTROL

____

GAUGE HEIGHT OF ZERO FLOW ______

DIMENSIONED SKETCH OF WELL, INTAKES, GAUGES

BENCH MARKS

DESCRIBE FULLY, GIVE ELEVATION ABOVE GAUGE DATUM, TYPE OF CONSTRUC
NUMBER, MARKINGS, ELEVATION ABOVE ANY STANDARD DATUM.
MAKE SKETCH BELOW.

ELEVATION OF GAUGE DATUM:

PREPARED OR REVISED BY	DAT

SKETCH OF STATION LOCATION

(SHOW HOW TO GET TO STATION AS WELL AS STATION LAYOUT)

MAKE A SKETCH SHOWING THE RELATIVE LOCATION OF THE STATION, GAUG
BENCH MARKS, TRIBUTARIES, TOWNS, ETC. USE MILEAGE LOG IF HELPFUL.

FORM H 51

PLATE 3

ORIGINAL

DAILY GAUGE RECORD

Gauging Station
No...............

W.Dv. & I.D. Form H. 3

Readings of.. ....River

at...for month of.............................19......By..............................

Date *Tarehe*		Gauge Readings *Kiasi cha Kipimo*			Rainfall *Kipimo cha mvua*	Remarks *Mengineo*
		Saa..............	*Saa*..............	*Saa*..............		
1	16					
2	17					
3	18					
4	19					
5	20					
6	21					
7	22					
8	23					
9	24					
10	25					
11	26					
12	27					
13	28					
14	29					
15	30					
	31					

This form must be dispatched fortnightly, deleting inappropriate date column.

PLATE 4

FIELD INSPECTION REPORT FOR STREAM GAUGING STATION

1. The Date of visit was . . . . at . . . . Hours,
   at which time Gauge Reading was . . . .

2. The Gauge Reader was (not) present. His book was (not) examined and (not) found correct. All records have (not) been collected.

3. All Staff Gauges, range . . . . ,
   were firmly supported, excepted range . . . .
   A check survey has (not) been carried out.

4. The A.W.L. Recorder, Type . . . . , has (not) been checked. It was (not) matching the Gauge Reading. The used charts were (not) collected. My remarks are:
   a) Silting problem:
   b) The clock:
   c) The pen:

5. The Control was (not) clear and my remarks are:

6. The B.M. and the A.B.M. have been checked and my remarks are:

7. The Gauging Section was (not) clear and my remarks are:

8. The Gauging Facilities are:
   For Low Stage by . . . .
   For Medium Stage by . . . .
   For High Stage by . . . .
   My remarks are:

9. C.M. Measurements have been carried out yielding the following results:

PLATE 5 a

NO.		TIME	G.H.	MEAN G.H.	Q	A	MV	DEV.	DATE	STAGE	REM.
1	S									Low Med High	
	F										
2	S									Low Med High	
	F										

10. The C.M. Measurements have been plotted in my own File and more calibrations are required in the following range:

11. The following Particulars have been done:

12. Additional Information:

13. Recommendations:

Team Leader

This report has been checked and my comments are:

Regional Hydrological Officer

Approved:

Senior Hydrologist

PLATE 5 b

GAUGE CORRECTION DISTRIBUTION SHEET

STATION NAME . . . . STATION NO. . . . .

TYPE OF GAUGE . . . . YEAR 19 . . . .

Correction:

Day	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												

Correction:

Remarks . . . . Computed by . . . . Date . . . .

. . . . Checked by . . . . Date . . . .

PLATE 6

THE UNITED REPUBLIC OF TANZANIA WDID. Form H. 5

WATER LEVELS DISCHARGE SHEET

....DISTRICT GAUGING STATION No.................................

....REGION SHEET No...

RIVER...AT ....

MONTH...............................19.....

Date	Time	Gauge reading in Meter	Correction	Corrected gauge reading	REMARKS	DISCHARGES	
						Actual	Mean

G P Dsm 8498/10-73/15c pds. of 200lvs./4up

RECEIVED ....19.....

FORM H 3 CHECKED BY ....

COMPUTED BY ....

CHECKED BY ....

Signed ....

Designation ....

....*19*.....

PLATE 7

APPENDIX B

OBSERVER'S INSTRUCTION FOR REPLACING CHART ON A. OTT TYPE X WATER LEVEL RECORDER

OBSERVER'S INSTRUCTION FOR REPLACING CHART ON A. OTT TYPE X WATER LEVEL RECORDER

1 Removal of used chart

1.1 Read water level on outside reference gauge. Check that inside water level in stilling well reads the same as water level on reference gauge.

1.2 Make an *inspection mark* on chart by holding float line between two fingers, raising float 4–5 cm and then releasing it. The pen (pencil) has now made a short vertical line on the chart. This line indicates at which *instrument time* the recorder is being inspected.

1.3 Lift drum from its bearings and remove used chart.

1.4 Write the following information in upper right corner of chart:
- a) Date.
- b) Time of day.
- c) Water level readings on outside reference gauge and in stilling well.

2 Setting of new chart

2.1 Read water level on reference gauge and in stilling well.

2.2 Write the following information in upper left corner of new chart:
- a) Name of river.
- b) Name of station.
- c) Date.
- d) Time of day.
- e) Water level readings on outside reference gauge and in stilling well.

2.3 Mark gauge heights corresponding to the outside staff gauge along left edge of chart as follows (for gauge scale 1:10):
If reading on staff gauge is between 0.00 and 2.50 m, mark left edge on chart 0.00, 0.50, 1.00, 1.50, 2.00, 2.50.
If reading on staff gauge is between 2.50 and 5.00 m, mark left edge on chart 2.50, 3.00, 3.50, 4.00, 4.50, 5.00.
If reading on staff gauge is between 5.00 and 7.50, mark left edge on chart 5.00, 5.50, 6.00, 6.50, 7.00, 7.50.

2.4 Mark chart with a circled point which corresponds to correct water level read on staff gauge and correct time of day.

2.5 Now, attach chart to drum remembering that left edge of chart shall touch left rim of drum.

2.6 Wind watch, but not too hard.

2.7 Fill up ink well as required. If the recorder has a pencil, sharpen it if necessary; best hardness is F or HB.

2.8 Replace drum in its bearings.

2.9 Set pen to show correct time and water level as follows. Setting time: Turn drum until pen points at correct timeline on chart.
Setting water level: Turn knurled knob, positioned on outer side of float line pulley, until pen is in position of the point marked on the chart (paragraph 2.4).
Now, chech once more that the pen is in the correct position regarding both time and gauge height.

2.10 Finally, check that the pen is moving in the correct direction. The rule is: *With rising water level, the pen should move from left to right.*
To check: raise float by pulling float line. If the pen moves from left to right, the recorder is correctly set. If the pen does not move to right but to left, then move the pen-holder all the way through inversion loop on spindle and back to its former correct position. This operation is accomplished by turning knurled knob positioned on outer side of float pulley.

2.11 Job is finished. Close hood of instrument.

APPENDIX C

OBSERVER'S INSTRUCTION FOR REPLACING CHART ON LEUPOLD AND STEVENS TYPE A WATER LEVEL RECORDER

OBSERVER'S INSTRUCTION FOR REPLACING CHART ON LEUPOLD AND STEVENS TYPE A WATER LEVEL RECORDER

1 Removal of used chart

1.1 Read water level on outside reference gauge. Check that inside water level in stilling well reads the same as water level on reference gauge.

1.2 Make an *inspection mark* on chart by holding float line between two fingers, raising float 4–5 cm and then releasing it. The pen (pencil) has now made a short vertical line on the chart. This line indicates at which *instrument time* the recorder is being inspected.

1.3 Write following information on chart:
a) Date.
b) Time of day.
c) Water level readings on outside reference gauge and in stilling well.

1.4 Pull knurled disc, positioned on right side of instrument (just beneath knurled knob of supply cylinder), to the right and rotate it to disengage chart drive friction rollers. (Rotation in one direction – against you – lowers the rollers slightly to facilitate chart adjustment. Rotation in the other direction – from you – lowers the rollers further for installation of new chart).

1.5 Run chart forward by turning knurled flange of take-up cylinder until graphic record is just beyond back edge of writing plate. Using edge of writing plate as guide, cut chart with a knife. Lift take-up cylinder out of its bearings, pull it out of the chart and then pull or shake chart clamp out of chart. Replace take-up cylinder in its bearings.

2 Setting of new chart

2.1 Remove writing plate, remove supply cylinder from recorder and remove large knurled washer nut from supply cylinder. Remove old chart core.
Observe that the core of the new chart is flush with one end and protrudes from the other end. Slip new chart on to supply cylinder with flush end towards flange. Tighten knurled washer firmly. Replace supply cylinder in its bearings, flange to the left.

2.2 Check that knurled disc at right side of instrument is holding friction rollers in lowest position.

2.3 Crease chart paper about 2 cm from the end so that paper stands out radially from supply roll. Thread creased edge down between chart drive cylinder and friction rollers. Replace writing plate and pull chart up around and over drive cylinder and writing plate.

2.4 Pull chart until it is 2–3 cm beyond take-up cylinder and its left edge is against and square with knurled flange of take-up cylinder. Install chart clamp. Hold knurled knob of supply cylinder and rotate knurled flange of take-up cylinder away from you. While keeping chart paper taut by lightly restraining supply cylinder shaft, rotate take-up cylinder until it has at least three full turns on the cylinder.

2.5 Write the following information on chart:
a) Name of river.
b) Name of station.
c) Date and year.
d) Time of day.
e) Water level on reference gauge and inside stilling well.

2.6 Wind clock as follows:
Screw crank handle counterclockwise into end of winding shaft. Push winding shaft in until gears engage and wind until *stop stop* sign appears on spring-reel nearest to you. Replace crank handle in its holder.

2.7 Start pen in lower half of chart paper, remembering that the close-spaced heavy lines represent intervals of 10 cm on the outside staff gauge (for gauge scale 1:10). Proceed as shown in example below.
Example. We read water level 2.23 m on outside staff gauge. The time is 08.00 hrs. Now, choose an arbitrary line on the chart to represent 2.20 m on outside staff gauge. This 2.20 m line should be so placed as to minimise the number of reversals of the pen at the margins of the chart paper. In our example, we select line number 12 from the bottom of the chart paper to represent a gauge height of 2.20 m. Mark a point showing water level 2.23 m and time 08.00 hrs. on the chart and circle this point.
Note: Before proceeding as described above, make sure that the communication between river and stilling well (stilling pipe) is in order. If inside water level does not read the same as outside water level, the stilling well and intakes

are probably blocked by mud and silt and must be cleaned.

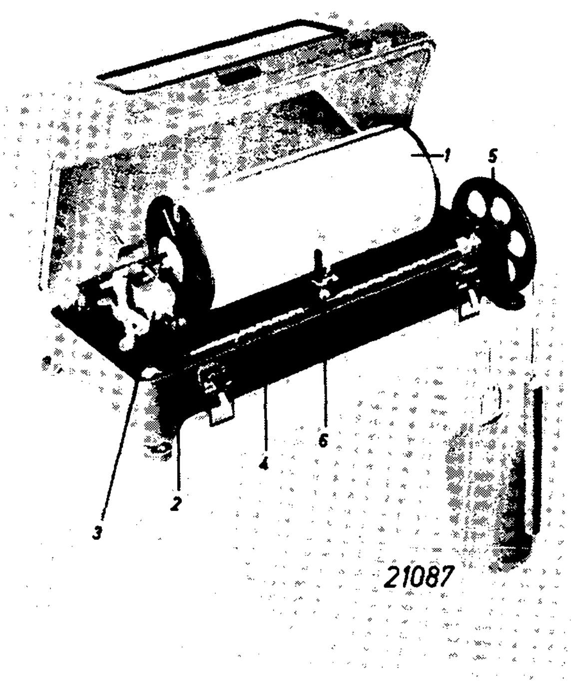
2.8 Positioning pen on circled point. This is done as follows.
Setting time: With pen raised from chart, turn knurled knob of supply cylinder away from you until pen points at correct timeline on chart. Return friction rollers to their drive position by pushing knurled disc to the left.
Setting water level: With the two knurled screws on float pulley clamp loosened and pen still raised from chart, move pen carriage by turning float pulley clamp until pen is positioned opposite circled point previously made. Lower pen to chart exactly on circled point. Tighten the clamp screws.

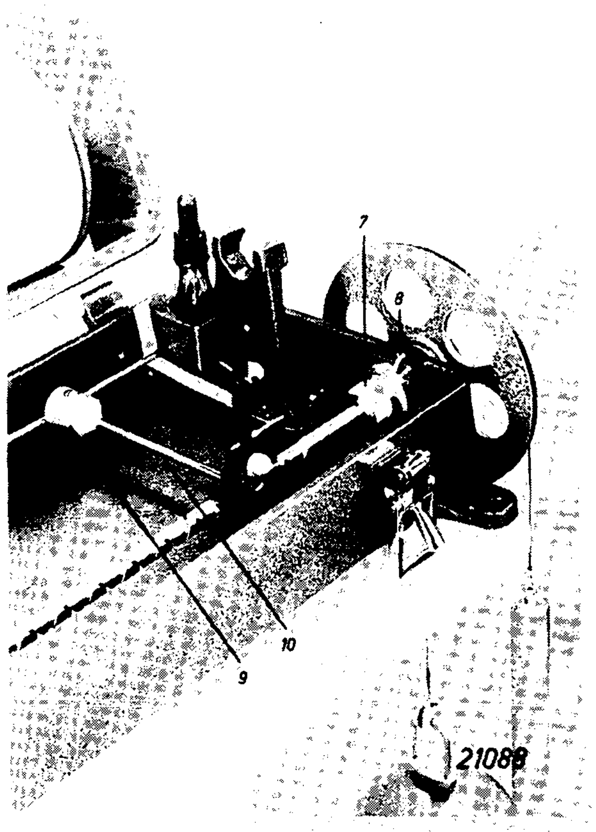
2.9 Check that pen moves in correct direction. The rule is: *With rising water level, the pen should move from left to right.* To check: raise float by pulling float line. If pen noves to the right, the recorder is correctly set. If pen does not move to right but to left, then loosen the two knurled clamp screws of float pulley and move pen carriage towards etther margin of chart all the way through the reversal and back to its former correct position. Tighten the two clamp screws.

2.10 Job is done. Close hood of instrument.

APPENDIX D
ASSEMBLY AND OPERATING INSTRUCTIONS FOR A. OTT TYPE X WATER LEVEL RECORDER

A. OTT TYPE X WATER LEVEL RECORDER





1. Drum for recorder chart.
2. Gear wheels for drum rotation.
3. Type «A» clock for 24, 32 hours, 18, 16, 32 days drum rotation.
4. Reversing spindle.
5. Float pulley.
6. Driver with ink recording attachment.
7. Threaded sleeve.
8. Shank screw for lock nut.
9. Counter weight.
10. Weight bar with recording lever.

Note: Picture 21088 shows the ink recording device detached and a pencil lead attached.

To set up and operate the gauge, proceed as follows:

Since the instrument is shipped with its clockwork mechanism and drum removed, first attach these components.

<u>Inserting the clockwork mechanism:</u>

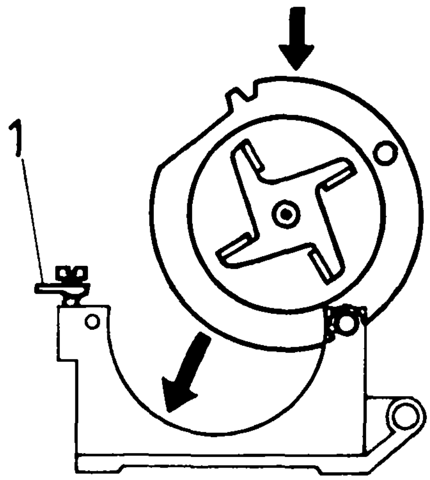


Fig. 1

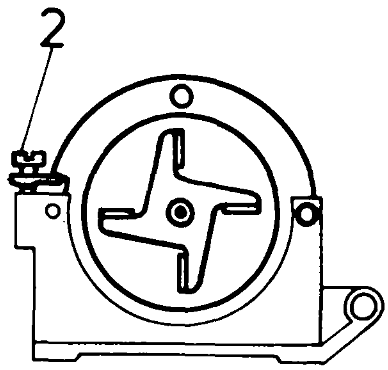


Fig. 2

1. Insert the clock and lower it into position, with the retaining lug 1 swung out (Fig. 1)

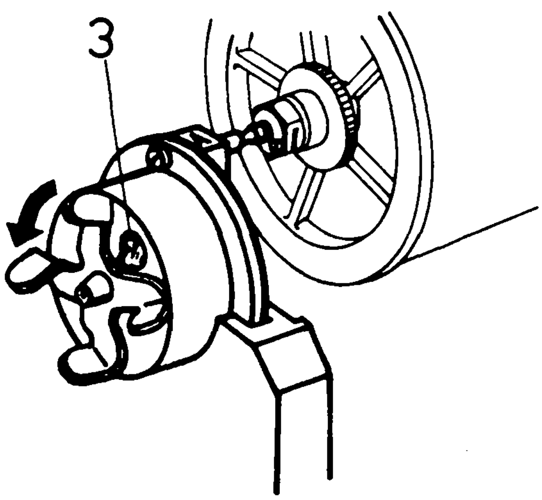
2. Swing the lug 1 into position and tighten the screw 2 (Fig. 2). To remove the clock, proceed in the reverse order.

<u>Winding and regulating the clock:</u>
Type "A" clock operates 32 days,
type "B" clock operates 28 hours,

It is advisable to wind the clock whenever the chart paper is exchanged, regardless of the frequency with which this is done.
Wind the clock in the direction of the arrow, holding the drum fast with your hand. When setting the drum for faster rotation, do <u>not</u> hold it fast, but let it turn freely.

Should the clock be fast or slow, correct it at 3:

- = slower
+ = faster



Attaching the chart paper

Chart paper with time overrun: The chart paper is held in place by a strip of metal 4. To fit the paper, press the retaining strip in the direction of the arrow and see that the left-hand edge of the paper touches the rim of the drum. Then press the retaining strip down again and push it back until it snaps into its original position.

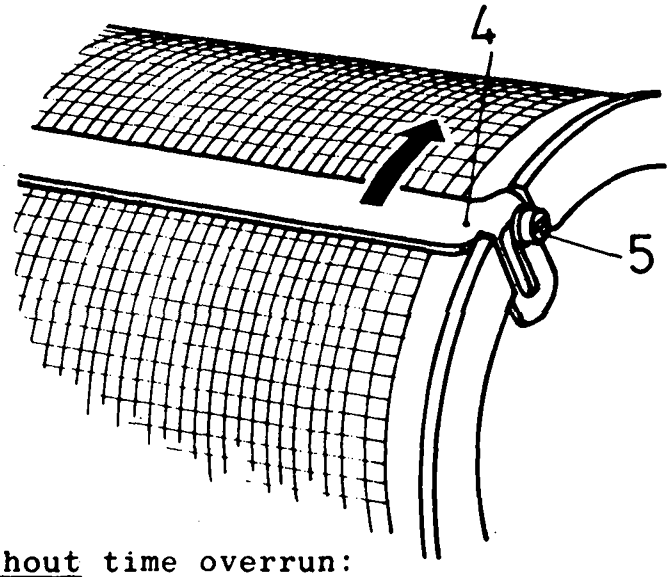
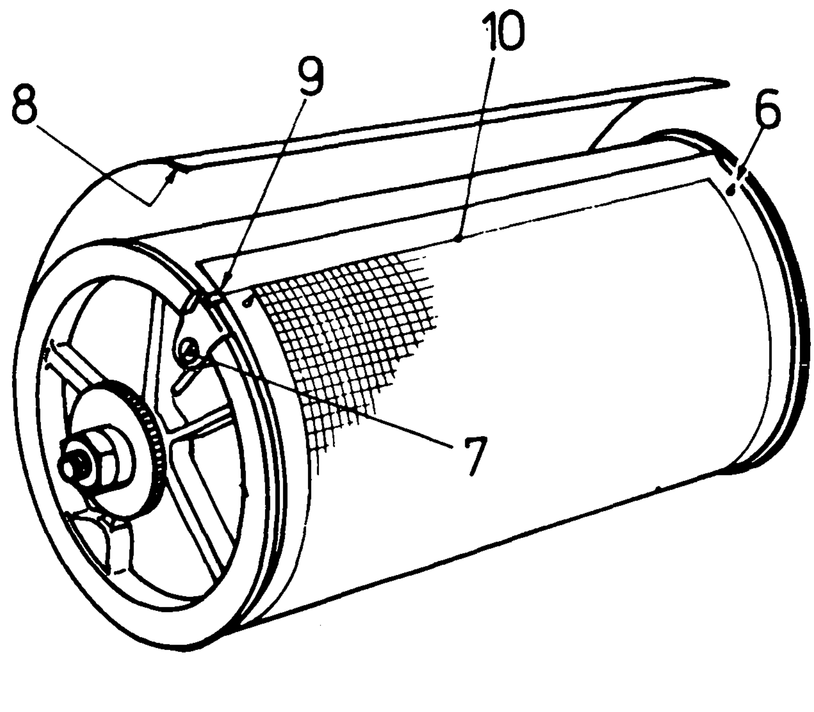


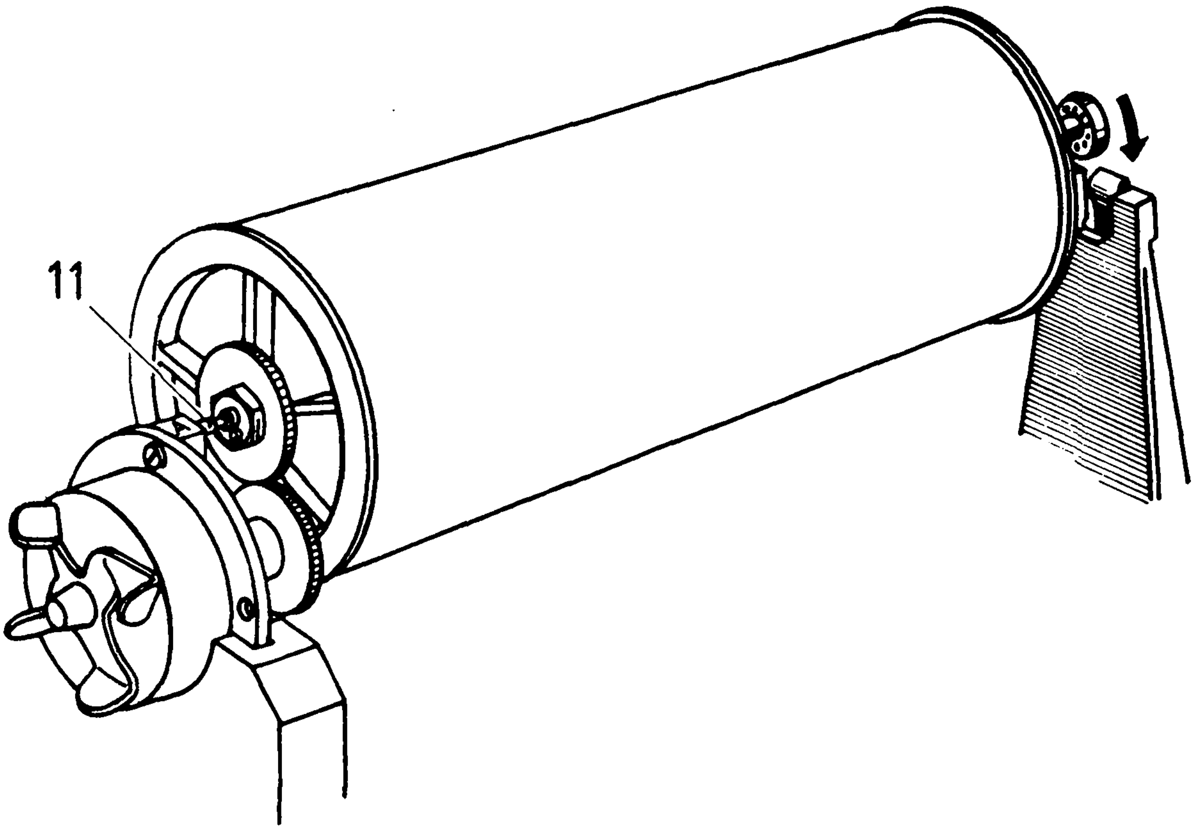
Chart paper without time overrun:
If the drum rotates several times during one period of recording, the retaining strip 4 must be removed to avoid its obstructing the stylus, and charts have to be used which have a gummed edge 8. Remove the retaining strip by loosening the two screws 5. The two pins 6 are provided to hold the paper in place and, after loosening the screws 7, should be pushed out until they protrude about 2 mm. Then retighten the screws.



Attach the chart with gummed edge 8 as shown in the illustration. The longitudinal groove 9 serves to guide a knife or razor blade during removal of the chart. The beginning of the graduation 10 should be aligned with the center of the groove 9.

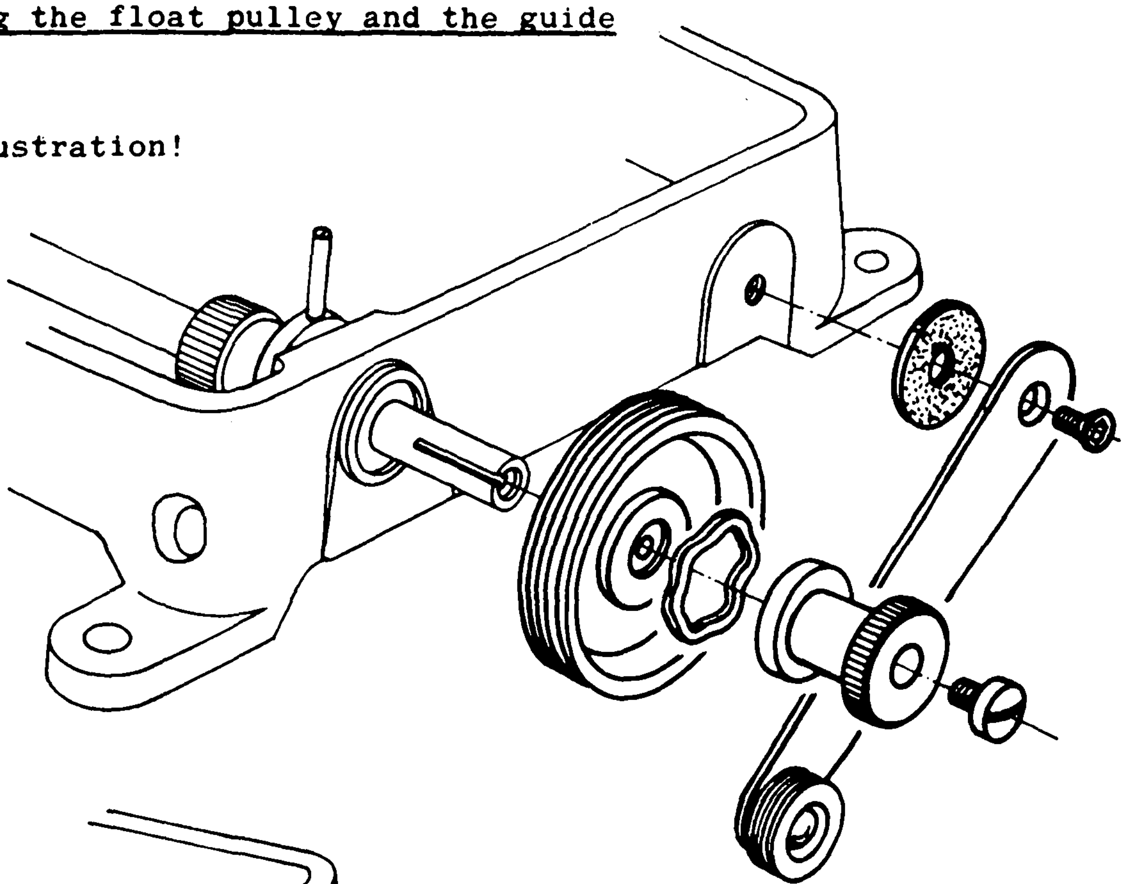
Installing or removing the drum:

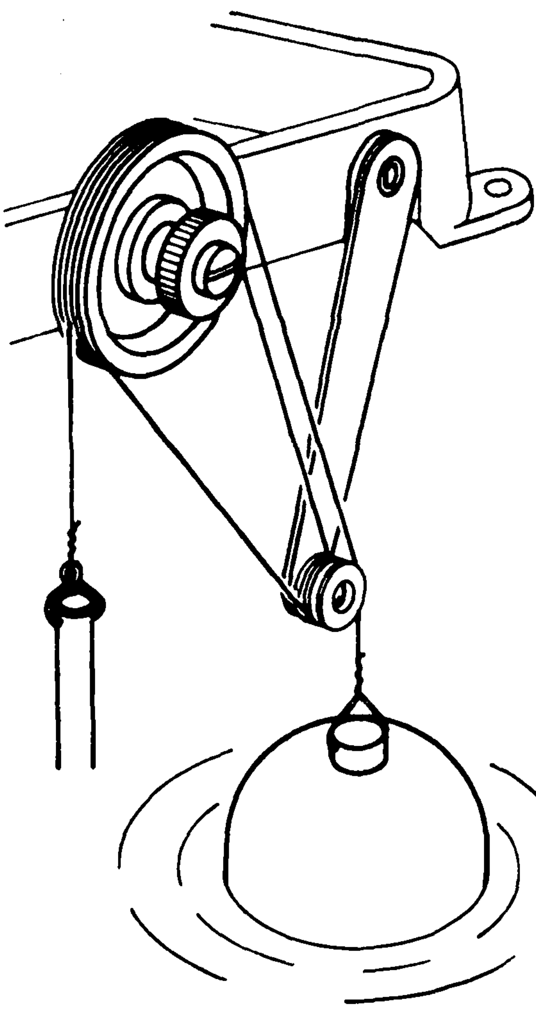
Slip the drum onto the journal 11 on the left and insert it into the opening of the support (arrow) on the right. For removal, proceed in the reverse order.



Mounting the float pulley and the guide pulley:

See illustration!





Positioning the float cable

Position the float cable as shown in the illustration. The following rule applies: with rising water level the tracing head should move from left to right. If necessary, move the tracing head all the way through the inversion loop on the spindle.

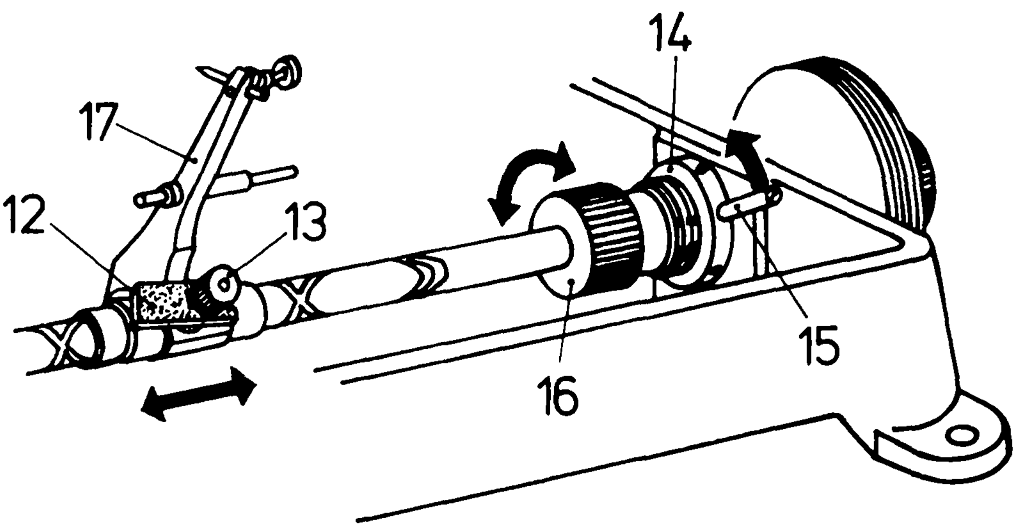
Length of cable:
Distance between gauge and the lowest lowwater level +0.5 m.

Adjusting the tracing head

Remove the cardboard strip 12. Turn the float pulley and check whether the guide shuttle in the driver 13 properly engages the cross slot.

Depending on the printing register of the chart paper, the left-hand graduation line may not coincide accurately with the reversal point of the reversing spindle. In this case, a fine adjustment of the tracing head is required, which must, however, not disturb the constant adjustment of the float in relation to the tracing head.

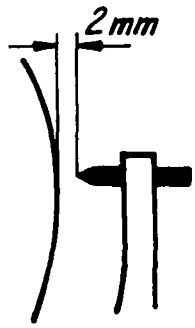
Fine adjustment:
Loosen the lock nut 14 with the aid of the threaded pin 15. Rotation of the threaded bush 16 clockwise or counterclockwise will slightly shift the tracing head 17 to the left or right. After adjustment, retighten the lock nut 14 while holding the bush 16.



Mounting the recording stylus:

a) Pencil or silver stylus:

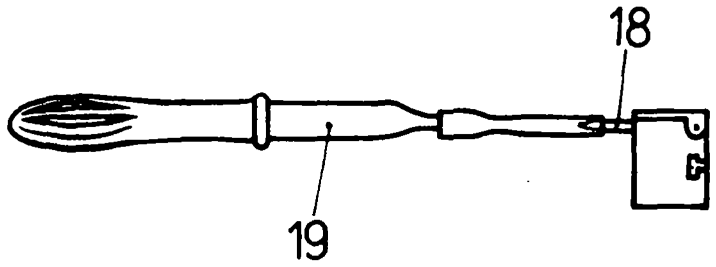
The stylus is automatically lifted from the drum as the hood is opened. Adjust the pencil or silver stylus so that the póint is about 2 mm away from the paper when the hood is open. If necessary, sharpen the pencil. As the hood is closed, the stylus is automatically brought into contact with the drum with the proper pressure for recording.



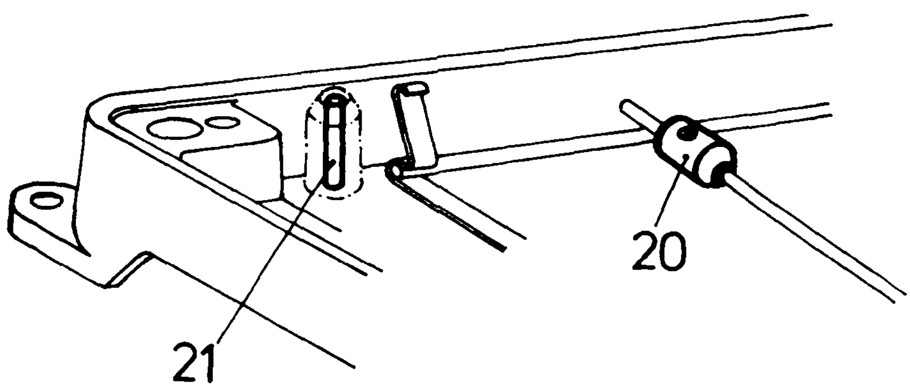
Note: For recording with a silver stylus, use only barite paper.

b) Ink recording:

Introduce the capillary glass pen 18 into the ink-well and remove the protective tube. As the well is filled with ink, this will automatically rise right up to the point of the pen due to the capillary effect. Should this fail to occur, the ink may be sucked into the capillary with the aid of the pipette 19 supplied (press and release).



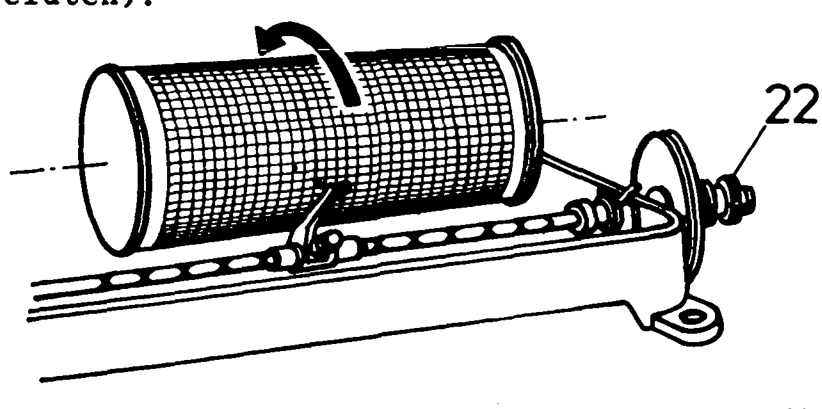
Note: For ink recording remove the weight 20 and slip it onto the pin 21 for further use.



Setting the tracing head:

a) Time:
Turn the drum in the direction of the arrow until the stylus points at the proper time line on the chart (horizontal line)

b) Water level:
Turn the knurled wheel 22 clockwise or counterclockwise until the stylus is properly set for the existing water level. Hold the float pulley fast during the adjustment (friction clutch).



Maintaining a dry atmosphere in the instrument with the aid of silica gel:

Silica gel, which is treated with a color indicator, has the property of withdrawing moisture from the ambient atmosphere and is therefore used to keep the air enclosed in an instrument dry (i.e. to eliminate condensation).

The instruments are supplied with silica gel cartridges which should be kept in the holders provided for the purpose.

The interchangeable cartridge is contained in an airtight can.

Due to its color indicator, silica gel appears blue when it is dry and red when saturated with water.

Red silica gel has lost its drying property and must be replaced by the blue desiccant.

Ineffective silica gel (red) can be renewed by drying at 120 - 130° C. This is done in the cartridge. The drying process is completed as soon as the silica gel has resumed its dark blue color.

After cooling, the silica gel must immediately be put away in a hermetically sealed can (if necessary, seal with insulating or Scotch tape) until it is required for use.

The desiccant cartridge should be exchanged every time a new roll of chart paper is inserted.

Regular servicing of the gauge:

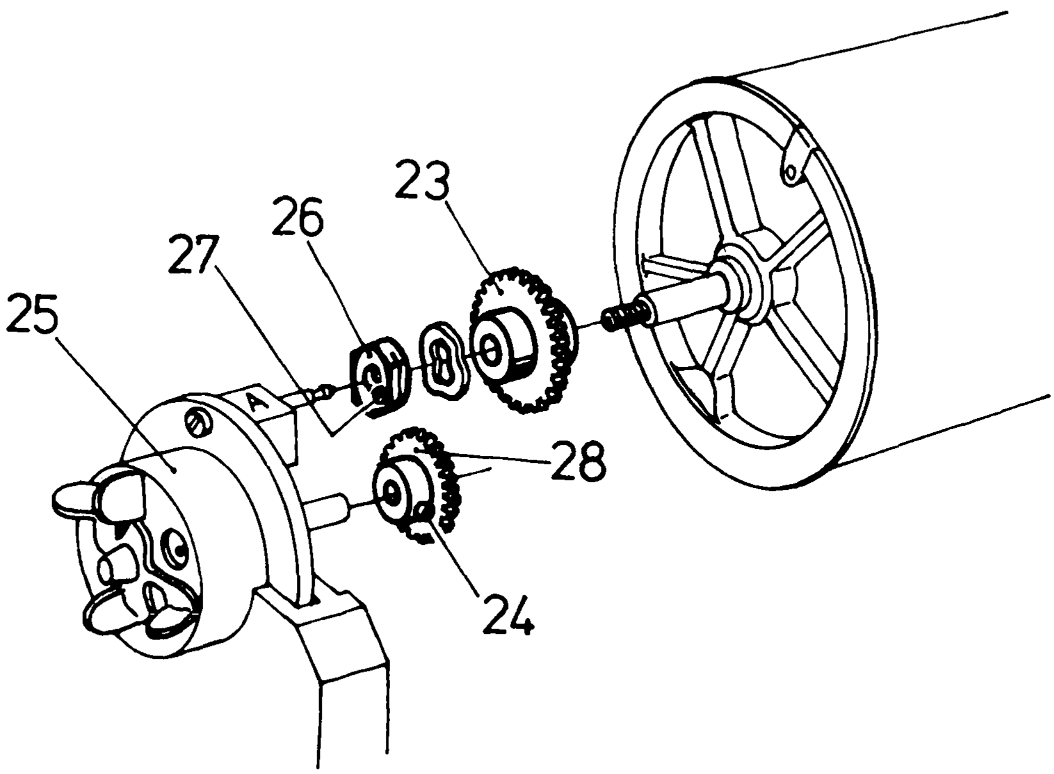
It is advisable to clean the instrument from time to time. Above all, clean the grooves of the lead spindle and the transmission gears with the aid of a brush or similar tool. Do not oil any part of the instrument!

The clockwork mechanism has been lubricated at the factory with a special oil for use at temperatures down to -30°C. This should be duly taken into consideration in the case of overhaul.

Changing the recording period

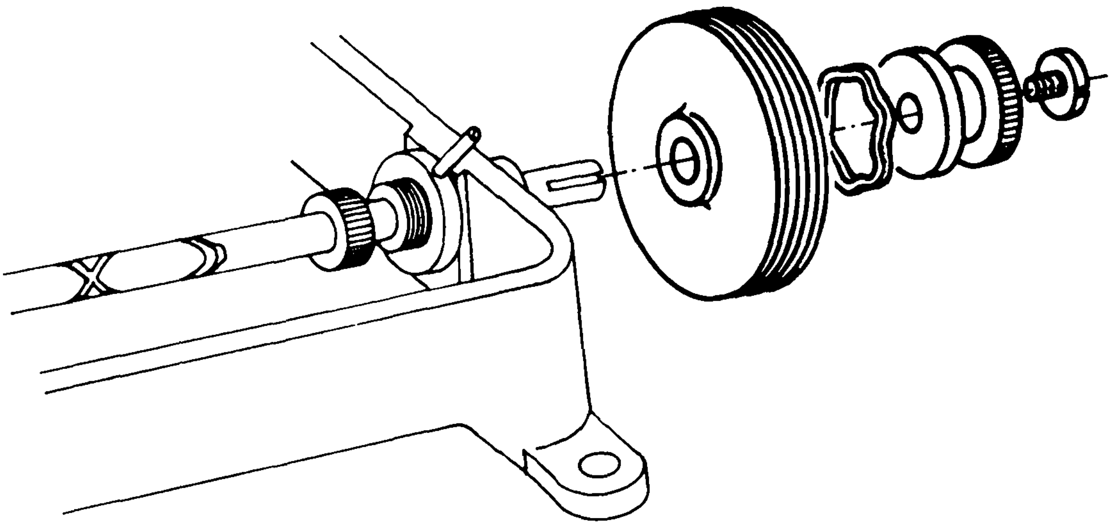
To change the recording period, either the two gears 23 and 24 or the clockwork mechanism 25, or the clockwork mechanism and the two gears have to be exchanged.

To change the gear 23, first unscrew the lock nut 26 and loosen lock screw 27. When the new gear has been slipped in place, tighten the lock nut 26 only just enough to allow smooth motion of the drum in relation to the gear 23 (friction clutch), or the clockwork mechanism will be damaged. Then retighten the lock screw 27. The gear 24 can be removed after loosening the screw 28.



Changing the reduction ratio:

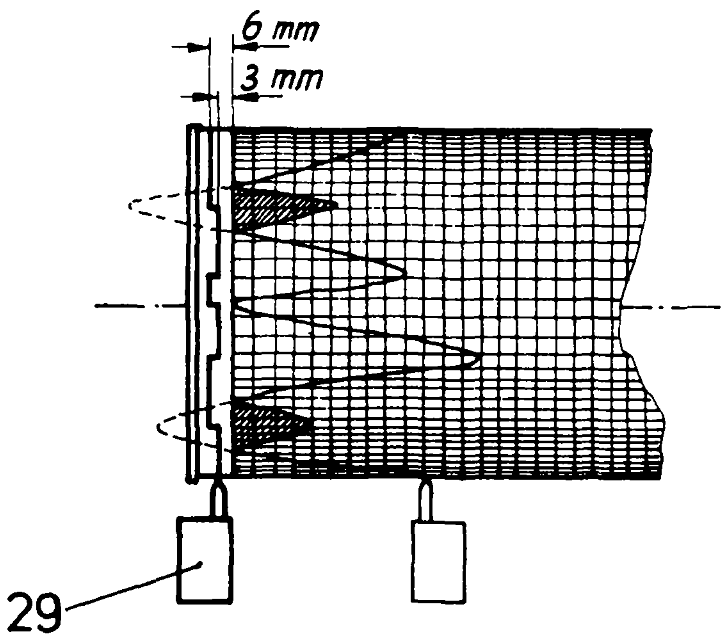
The reduction ratio can be varied by exchanging the float pulley. Proceed as indicated in the illustration.



Reversal indicator or base pen (optional accessories)

The illustration shows a recording in which the peaks would fall beyond the left or right-hand edge of the paper. On account of the reversing spindle, these peaks appear "folded back" on the chart. The trace of the base pen 29 allows the peaks to be recognized without difficulty.

Rising water: trace about 3 mm from edge of graduation.
Falling water: trace about 6 mm from edge of graduation.



<u>General rules</u> for setting up water-level recorders:

The float should not be immersed directly in flowing or turbulent water, but accommodated in a tube or well allowing observation of fluctuations of water level without the disturbing effect of waves.

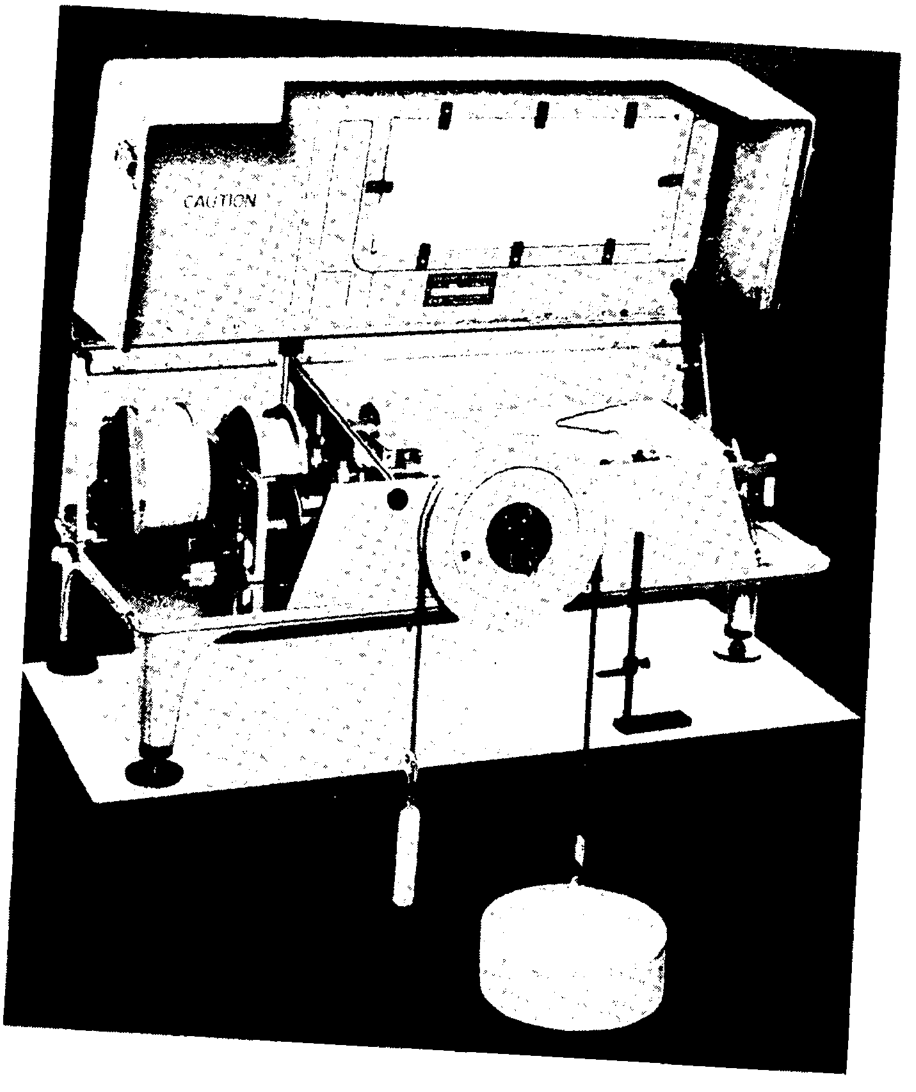
To ensure satisfactory attenuation, the cross section of the entrance to the float tube or well should not exceed 1/200th of the cross section of the tube or well. The float is best protected from freezing up by pouring machine or crude oil into the well. The depth of the oil layer should be identical to the immersion depth of the float. Pouring oil on the water in the well will also prevent vapors from rising into the shelter.

7.70 Ma

APPENDIX E

ASSEMBLY AND OPERATING INSTRUCTIONS FOR LEUPOLD AND STEVENS TYPE A WATER LEVEL RECORDER

LEUPOLD AND STEVENS TYPE A MODEL 35
WATER LEVEL RECORDER



INSTRUCTIONS

STEVENS INSTRUMENTS

TYPE A
MODEL 71
RECORDER

FORM A471

LEUPOLD & STEVENS, INC.
BEAVERTON, OREGON, U.S.A.

ILLUSTRATIONS

TABLES

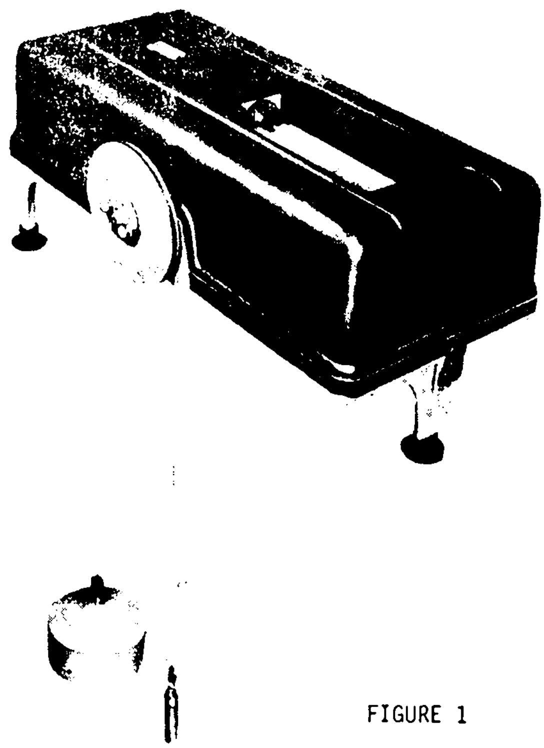


FIGURE 1

SECTION I

INTRODUCTION

The Stevens Type A is a float operated recorder that provides a permanent, continuous, long term graphic record of water level fluctuations. A clock movement controls the rate at which a strip chart is advanced. The rise and fall of the float moves a marking stylus laterally across the chart. The stylus will reverse at each margin so that any range of water level can be accommodated.

SECTION II

INSTALLATION

2.1 Remove all shipping tie-down strings, cardboard packing pieces, etc. Several parts and accessories are individually wrapped. Check the packing list to ensure all items are accounted for before disposing of packing material.

2.2 Mount the recorder on a level surface. Make holes in the surface through which the float line and clock weight cable (if required) can pass. Use the base template for spotting the holes. Mount the float pulley on the recorder. Tighten the pulley clamp assembly against the shaft shoulder. Tighten the nut against the clamp. Lightly tighten the clamp screws. (One has left hand thread, the other right).

2.3 The Float Line

2.3.1 Two adjustable hooks are provided for attaching the float line to the float and to the counterweight. The length of the float line should be such that the counterweight will not run into the shelf or pulley when the float is at low stage or strike the bottom of the float well when the float is at its highest stage. Float and counterweight should pass each other freely and should not touch the sides of the float well or be subjected to any other interference.

2.3.2 When a tape is used the extra length may be broken off. If a beaded line is supplied it should be cut about 1/4 inch past a bead to prevent fraying. If unbeaded cable is to be cut, it is best to anneal the area about 3 inches on each side of the cut by heating to a red heat before cutting.

2.3.3 Attach the float line to the float and lower it to the water. Pass the float line over the pulley making sure that the cable beads (or tape perforations) engage their respective recesses (or spines) on the pulley. Attach the counterweight and lower it into position.

2.4 Positioning the Pen

2.4.1 Turn the float pulley to raise the float a short distance. Check that the pen moves in the desired direction. If not, disengage the float line or tape from the float pulley and rotate

SPECIFICATIONS

Serial Number(s) ____________________

Chart Width [] 10 in., [] 20 in., [] 25 cm, [] 50 cm

Chart Drive:
- [] Chelsea clock, 4-1/2 months negator spring.
- [] Chelsea clock, 6 months negator spring.
- [] Chelsea clock, weight drive, ______ lb. clock weight.

Clockweight will drop ________ ft. per month.

Number of Sheaves __________ (see Table 7).

Above clock [] with dial, [] without dial.

[] Synchronous motor

__________ volts, __________ Hz. __________ RPD

[] Other ____________________

Time Scale __________ inches per day.

Chart No. A __________ will last __________.

Gage Scale(s) __________ [] English [] metric

Float pulley(s) circumference __________ for [] Tape, [] Cable

Base mounting template for [] Type A English, 2-19162, [] Type A metric, 2-19163
[] 2A-35 English or metric, 3-19560 [] Other ______

Accessories:
- [] auxiliary pencil:
- [] reversal indicator with pen;
- [] time marker with pen;
- [] counter indicator, ______ digits reading to ______;
- [] thermograph accessory reading ______ with ______ ft. of tubing;
- [] tilting bucket precipitation recording accessory with solenoid pen assembly. Bucket capacity ______.
- [] mechanical precipitation recording accessory
- [] other: ____________________

____

____

INDEX

the pulley until the pen moves in the proper direction.

2.4.2 Loosen the knurled clamp screws. Move the pen carriage until the pen indicates the correct head. (Do not go through reversal). While holding the pen in this position, tighten the clamp screws evenly to secure the float pulley.

2.5 Synchronous Motor Drive

Wire the terminals of the synchronous motor clock to a source of the voltage and frequency noted in the recorder specifications on Page 2.

SECTION III

OPERATION

3.1 Negator Spring Drive

To Start the Clock. With the clock in position, screw the crank handle counterclockwise (left hand thread) into the end of the winding shaft. Push the winding shaft in until the crank gears engage, and wind until the STOP-STOP sticker appears on the spring (minimum of one wrap remaining on the smaller drum). When winding, the safety pawl to the left of the clock, moves up and down. Stop winding when the pawl is in the "UP" position. The clock will begin to run as the crank is released and the winding shaft gear should spring out of engagement. Check the clock's escapement window to be sure the clock is running.

3.2 Weight Drive

Attach the weight to the clock weight cable. Wind up the clock weight cable using the crank handle. Procedure is otherwise similar to that described above for the negator spring clock drive.

3.3 The Chart

TABLE 1

STRIP CHARTS FOR STEVENS CONTINUOUS RECORDERS

STRIP CHART	UNIT SYSTEM	CHART WIDTH	MINOR DIVISION
A10	English	10 in.	0.1 in.
A25	metric	25 cm.	2.0 mm
A20	English	20 in.	0.1 in.
A50	metric	50 cm.	2.0 mm

3.3.1 To Remove a Chart

3.3.1.1 Note the knurled disc and shaft on the right side of the recorder just beneath the knurled knob of the supply cylinder. Pull the knurled disc out to the right, and rotate it to free the chart drive friction rollers. Rotation in one direction lifts the rollers slightly to assist in chart adjustment. Rotation in the other direction raises the rollers for chart replacement.

3.3.1.2 Run the chart forward by turning the knurled disc on the take-up cylinder, until the graphic record is just beyond the back edge of the writing plate (i.e. the flat plate between the chart drive cylinder and take-up cylinder). Using the edge of the writing plate as a guide, cut the chart with a knife. Lift the take-up cylinder out of its bearings. Pull the take-up cylinder out of the chart and then pull or shake out the chart clamp. To reattach the remaining chart paper to the take-up cylinder, follow paragraphs 3.3.2.3 and 3.3.2.4.

3.3.2 To Install Chart

3.3.2.1 Remove the writing plate between the chart drive and take-up cylinder. Remove the supply cylinder from the recorder, and remove the large knurled washer nut from the end. Remove the old chart core. Observe that the core of the new chart is flush with one end and protrudes from the other. Slip the new chart onto the supply cylinder, flush end toward the flange, and tighten the knurled washer nut firmly. Place the supply cylinder in its bearings, flange to the left.

3.3.2.2 Check that the knurled disc at the right end of the recorder is holding the friction rollers in the raised position. (For description of this disc see, "To Remove a Chart").

3.3.2.3 Crease the paper about 3/4 inch from the end so that it stands out radially from the supply roll. Thread the creased edge down between the chart drive cylinder and the friction rollers. Replace the writing plate and pull the chart up around and over the drive cylinder and writing plate.

3.3.2.4 Pull the chart until it is about 1 inch beyond the take-up cylinder with the left edge against and square with its flange. Install the chart clamp. To adjust the paper on the take-up cylinder so that it will run true, hold the chart supply cylinder shaft and rotate the knurled flange of the take-up cylinder away from you. Allow the chart paper to slip between the take-up cylinder and the chart clamp approximately three of the smallest divisions. While keeping the paper taut by lightly restraining the supply cylinder shaft, rotate the take-up cylinder until it has at least one full turn on the cylinder.

Push the knurled disc to the left, returning the friction rollers to their drive position.

3.3.2.5 Amount of Chart Remaining. The A-10 (English) and the A-25 (metric) strip charts have a diagonal blue line marked on the end of the chart fastened to the core. When this line appears during use, the remaining days of supply may be calculated. On the A-10 chart, count the number of small divisions (0.1 inches) between the left margin and the blue line. Similarly, on the A-25 chart count the number of centimeter divisions between the left margin and the blue line. The number of days of chart remaining is equal to the number of divisions counted, times a multiplier obtained from the following table:

TABLE 2

Time Scale (inches per day)	Multiplier A-10	Multiplier A-25
1.2	2	8
2.4	1	4
4.8	0.5	2
7.2	0.33	1.33
9.6	0.25	1

3.4 The Stylus

3.4.1 Pens and pencils are interchangeable. To change the pen to pencil or vice versa, loosen one of the pivot screws in the stylus carriage and interchange the stylus arms. Set the pivot so that it does not bind or shake.

3.4.2 The stylus may be adjusted to make the reversals coincide with the chart margin. The reversals occur exactly 10 inches (25 cm) apart. If they do not coincide with the chart margins, the paper has expanded or contracted due to changes in humidity. It is best to adjust the stylus for reversal on the left margin line.

3.4.3 The capillary pen ink reservoir should be filled to within 1/16 inch (2 mm) of the top of the barrel. To prime, close the air hole with one finger. With a second finger, press repeatedly on the filling tube to create a pumping action until ink appears on the chart. The plastic bottle nozzle may also be used to prime the pen. Cut about 1/16 inch off the nozzle tip. Fill the reservoir approximately 2/3 full. Press the nozzle tightly against the fill tube. Close the air hole with one finger, and gently squeeze the bottle until ink flows from the pen tip. Complete filling the reservoir as above.

3.5 Gage Scales

3.5.1 Gage scales may be changed by changing either the float pulley size or the float pulley standard. (Table 3). Float pulleys have an 18 inch or 375 mm pitch circumference. Float pulley ring attachments are available that double this circumference, thereby reducing the scale; for example, a 1:6 gage scale becomes a 1:12.

3.5.2 Standards for gage scales of 1:6 and 1:12 English, and 1:5 and 1:10 metric have a single shaft on the left side of the standard. Standards for other gage scales have two shafts with gearing. Changing to a geared float pulley standard moves the location of the float pulley 1.88 inches to the right. To change standards move the carriage to the right and remove the sprocket chain from the drive sprocket. Deflect the right hand sprocket assembly slightly to gain the necessary slack. Unscrew the wing nut and remove the standard.

3.6 Operation Time

A fully wound negator spring or clock weight cable will drive the recorder a minimum of 4 1/2 months. Recorders can be ordered with a longer clock weight cable or 6 months negator spring if extended operation is desired. A 12 lb. clock weight (24 ft. max. drop in 4 1/2 mo.) is sufficient for the time scales listed in table 4A; however, if a combination of sheaves is used to reduce the weight drop, the weight must be increased accordingly. Refer to table 7.

TABLE 3 STANDARD GAGE SCALES

Gage Scale	Float Pulley Pitch Circumference	Water Level Change for One Traverse of Stylus Across Chart: 10 in. Chart	20 in. Chart	Graph Change Per foot of Water Change	Value of Minor Chart Division	Geared Float Pulley Standard
10:12	18 in.	1 ft.	2 ft.	10.0 in.	0.01 ft.	YES
5:12	36 in.	2 ft.	4 ft.	5.0 in.	0.02 ft.	YES
1:6	18 in.	5 ft.	10 ft.	2.0 in.	0.05 ft.	NO
1:12	36 in.	10 ft.	20 ft.	1.0 in.	0.10 ft.	NO
1:12	18 in.	10 ft.	20 ft.	1.0 in.	0.10 ft.	YES
1:24	36 in.	20 ft.	40 ft.	0.5 in.	0.20 ft.	YES
1:30	18 in.	25 ft.	50 ft.	0.4 in.	0.25 ft.	YES
1:60	36 in.	50 ft.	100 ft.	0.2 in.	0.50 ft.	YES
		25 cm Chart	50 cm Chart	Graph Change Per meter of Water Change		
1:1	375 mm	0.25 m	0.5 m	1000 mm	02 mm	YES
1:2	750 mm	0.50 m	1.0 m	500 mm	04 mm	YES
1:5	375 mm	1.25 m	2.5 m	200 mm	10 mm	NO
1:10	750 mm	2.50 m	5.0 m	100 mm	20 mm	NO
1:10	375 mm	2.50 m	5.0 m	100 mm	20 mm	YES
1:20	750 mm	5.00 m	10.0 m	50 mm	40 mm	YES
1:25	375 mm	6.25 m	12.5 m	40 mm	50 mm	YES
1:50	750 mm	12.50 m	25.0 m	20 mm	100 mm	YES

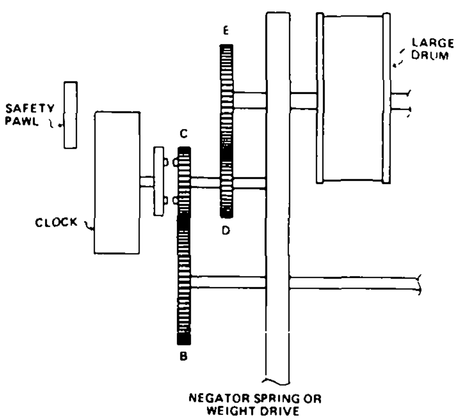


FIGURE 2

NOTE: C & D gears are supplied on a common hub.

TABLE 4A

STANDARD TIME SCALES WITH CHELSEA CLOCK

(Negator Spring and Weight Driven)

Scale Designation (inches/day)	Value of Chart Divisions: Major (1.2 in.)	Minor (0.1 in.)	25 yard Strip Chart Lasts	Gear Teeth (see Fig. 2): B	C	D	E
1.2	24 hr.	2 hr.	2 yr.	85	29	17	89
2.4	12 hr.	1 hr.	1 yr.	66	45	17	89
4.8	6 hr.	30 min.	6 mo.	66	90	14	65
*7.2	4 hr.	20 min.	4 mo.	45	92	15	63
*9.6	3 hr.	15 min.	3 mo.	44	120	15	63

*Weight Driven Only.

TABLE 4B

STANDARD TIME SCALES WITH TELECHRON SYNCHRONOUS MOTOR CLOCK

Scale Designation (inches/day)	Value of Chart Divisions Major (1.2 in.)	Value of Chart Divisions Minor (0.1 in.)	25 yard Strip Chart Lasts	Gear Teeth (see Fig. 3) A	Gear Teeth (see Fig. 3) B	A.C. Clock Speed
1.2	24 hr.	2 hr.	2 yr.	13	130	3 RPD
2.4	12 hr.	1 hr.	1 yr.	24	120	3 RPD
4.8	6 hr.	30 min.	6 mo.	40	100	3 RPD
7.2	4 hr.	20 min.	4 mo.	54	90	3 RPD
9.6	3 hr.	15 min.	3 mo.	64	80	3 RPD
9.6	3 hr.	15 min.	3 mo.	13	130	24 RPD
14.4	2 hr.	10 min.	2 mo.	78	65	3 RPD
14.4	2 hr.	10 min.	2 mo.	18	120	24 RPD
28.8	1 hr.	5 min.	1 mo.	33	110	24 RPD
57.6	30 min.	2.5 min.	15 days	54	90	24 RPD
144.0	12 min.	1 min.	150 hr.	84	56	24 RPD
144.0	12 min.	1 min.	150 hr.	21	84	144 RPD
288.0	6 min.	30 sec.	75 hr.	35	70	144 RPD
432.0	4 min.	20 sec.	50 hr.	45	60	144 RPD
864.0	2 min.	10 sec.	25 hr.	63	42	144 RPD

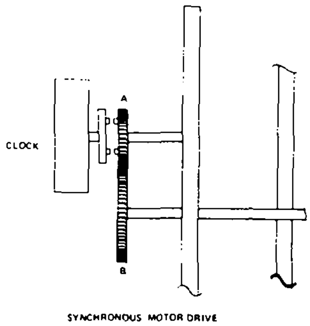


FIGURE 3

3.7 Instrument Accuracy

Standard float systems are subject to small errors due to float lag and line shift. These errors can be minimized by selecting proper floats and counterweights. Tables 5 and 6 show line shift errors and float lag where standard float systems are used. (Line shift errors can be eliminated by using a special continuous loop line float system if higher accuracy is desired).

Beaded Float Line - Standard .040 inch dia. stainless steel cable is beaded to match recessed grooves in the float pulley. This slip-proof, exceptionally strong, lightweight line minimizes possible line shift errors over long ranges.

Float Tape - Stainless steel tapes are perforated to match float pulley spines. Tapes are available plain or graduated in feet, tenths and hundredths for the English system or meters, decimeters and centimeters. A separate mounting bracket with adjustable index pointer which indicates correct water level on the tape is available.

TABLE 5

LINE SHIFT ERROR (FEET)

Float Diameter (inches)	Range in Stage (feet) 5	10	20	50	100
Beaded Float Line (6 1/2 oz. per 100 feet)					
3	.013	.027	.053	.134	.267
4	.007	.015	.030	.075	.150
5	.005	.010	.019	.048	.096
6	.003	.007	.013	.033	.067
8	.002	.004	.008	.019	.038
10	.001	.002	.005	.012	.024
12	.001	.002	.003	.008	.017
14	.001	.001	.002	.006	.012
16	.000	.001	.002	.005	.009
Float Tape (16 oz. per 100 feet					
3	.033	.066	.131	.329	.657
4	.018	.037	.074	.185	.370
5	.012	.024	.047	.118	.237
6	.008	.016	.033	.082	.164
8	.005	.009	.018	.046	.092
10	.003	.006	.012	.030	.059
12	.002	.004	.008	.021	.041
14	.002	.003	.006	.015	.030
16	.001	.002	.005	.012	.023

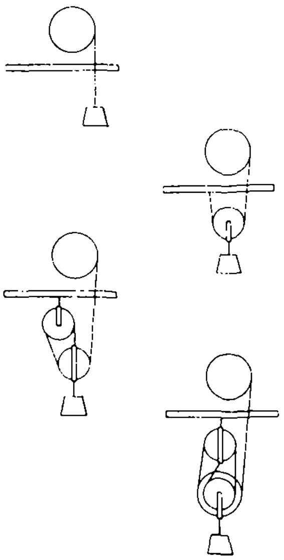
TABLE 6

FLOAT LAG ERROR IN FEET DUE TO FRICTION

Gage Scale	Pulley Circ.	FLOAT DIAMETER 3 in.	4 in.	5 in.	6 in.	8 in.	10 in.	12 in.	14 in.	16 in.
English										
10:12	18 in.	.113	.063	.041	.028	.016	.010	.007	.005	.004
5:12	36 in.	.056	.032	.020	.014	.008	.005	.004	.003	.002
1:6	18 in.	.012	.006	.004	.003	.002	.001	.001	.001	.000
1:12	36 in.	.006	.003	.002	.001	.001	.001	.000	.000	.000
1:12	18 in.	.012	.006	.004	.003	.002	.001	.001	.001	.000
1:24	36 in.	.006	.003	.002	.001	.001	.001	.000	.000	.000
1:30	18 in.	.009	.005	.003	.002	.001	.001	.001	.000	.000
1:60	36 in.	.005	.003	.002	.001	.001	.000	.000	.000	.000
metric										
1:1	375 mm	.090	.050	.032	.022	.013	.008	.006	.004	.003
1:2	750 mm	.045	.025	.016	.011	.006	.004	.003	.002	.002
1:5	375 mm	.012	.006	.004	.003	.002	.001	.001	.001	.000
1:10	750 mm	.006	.003	.002	.001	.001	.000	.000	.000	.000
1:10	375 mm	.012	.006	.004	.003	.002	.001	.001	.001	.000
1:20	750 mm	.006	.003	.002	.001	.001	.001	.000	.000	.000
1:25	375 mm	.009	.005	.003	.002	.001	.001	.001	.000	.000
1:50	750 mm	.005	.003	.002	.001	.001	.000	.000	.000	.000
Recommended Counterweight		3 oz.	4 oz.	6 oz.	8 oz.	10 oz.	12 oz.	16 oz.	16 oz.	20 oz.

TABLE 7

SHEAVE AND WEIGHT COMBINATIONS

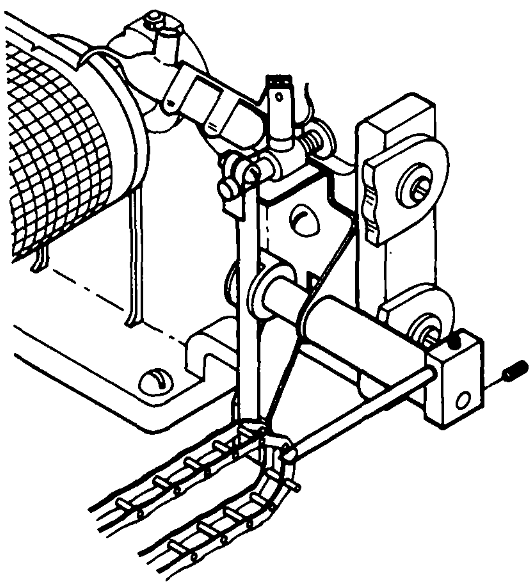


Time Scale (inches of chart travel per day)		1.2	2.4	4.8	7.2	9.6
No. of Sheaves	Weight	Distance Weight drops feet per month for above time scales				
0	12#	4.22	4.22	4.76	5.26	5.26
1	25#	2.11	2.11	2.38	2.63	2.63
2	38#	1.41	1.41	1.59	1.75	1.75
3	52#	1.06	1.06	1.19	1.32	1.32

Additional sheaves can be used on special orders. Outline your requirements or write for additional information.

SECTION IV

ACCESSORIES



REVERSAL INDICATOR

FIGURE 4

4.1 Reversal Indicator. This accessory eliminates possible confusion in interpreting graphs with reversals at the margin. The indicator makes a continuous pen line in the right margin of the chart. When stylus reversal occurs (stage still changing in the same direction) a jog is made in the line which distinguishes this reversal from a stage reversal. Short jogs are made when the sprocket rotates clockwise, long jogs for counterclockwise.

The reversal indicator can be purchased as a loose accessory for installation in the field. It mounts on the right standard just to the rear of the tracks (see Fig. 4). It is positioned by a pin and held by a screw and nut. Relative lengths of the jogs may be adjusted by loosening the lower setscrew on the tripper arm hub and rotating the hub slightly. The chain must have three operating pins, one for the stylus carriage and two for the reversal indicator. On recorders prior to January 1969 it will be necessary to purchase a new chain with the three operating pins.

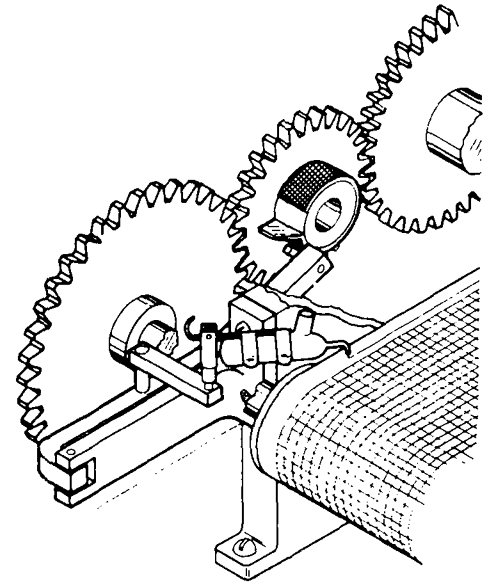


FIGURE 5

4.2 Time Marker. With this accessory an auxiliary pen marking in the left margin of the chart makes a jog at certain elapsed time intervals. The action is controlled by the clock so that the jogs correspond to clock time and not to time divisions on the chart. These jogs serve as a basis for applying corrections to the graph for possible errors due to humidity effects. Under standard humidity conditions these jogs are at 2.4 inch intervals. An adjustable actuating ring allows initial synchronization of the jogs with the major chart divisions.

The Time Marker accessory can be purchased as a loose accessory for installation in the field (see Fig. 5). It mounts on the front of the left writing plate standard and is held by one screw and positioned by a pin. The actuator ring fits over the hub of the idler gear with the slanted portion of the actuating tab on the side toward the chart.

4.3 Counter Indicator. Adjust the counter to indicate water level after the recording stylus has been set. Loosen the knurled screw (underneath the counter) which holds the counter housing and disengage the gears. Rotate the counter wheel until all are correctly set. Re-engage the counter gear with its companion gear.

NOTE: Refer to supplemental instructions for thermograph accessory, precipitation recording accessory, etc.

SECTION V

MAINTENANCE

5.1 Care of Clocks. Recorder clocks should be oiled by one thoroughly familiar with servicing clocks (over oiling can cause problems). Clocks should be cleaned and oiled once a year under normal conditions, oftener for more severe environments.

Leupold and Stevens, Inc. maintains a clock repair department at the factory. Stevens Recorder clocks sent in for service receive prompt and competent handling.

5.1.1 To Remove the Clock. Screw the crank handle into position, push in the winding shaft and wind until the safety pawl to the left of the clock cover drops down. This locks the shaft and spring drum preventing a hazardous spring unwind. Remove the large, knurled screw which secures the clock to the recorder base. Lift out the clock, being careful not to disturb the safety pawl.

5.1.2 *DO NOT ATTEMPT TO TURN THE CRANK WHEN THE CLOCK IS REMOVED - Turning the crank forces the safety pawl out of its notch. This allows the spring loaded wind-up gear to slip out of engagement, resulting in a hazardous (and often damaging) spring unwind.*

5.1.3 If, for any reason, it is necessary to unwind the negator spring the following procedure should be carefully followed. Remove the chart from the take-up cylinder. Remove the writing plate and the chart supply cylinder. Grasp the chart drive cylinder (the larger cylinder in front) firmly with the right hand. Rotate the top of the cylinder toward you slightly to relieve the tension on the safety pawl. Hold the cylinder with the right hand while releasing the safety pawl with the left hand. The crankshaft gear will spring out of engagement. Allow the spring to unwind slowly using your hand as a brake on the chart drive cylinder.

5.1.4 To Remount the Clock. Slip the clock base over the stud located on the recorder base. Turn the recorder's time gear until its pins line up with the clock drive bar slots. Install the large knurled clock screw. Follow the procedure "To Start the Clock".

5.1.5 To Regulate the Clock. Screw the crank handle into position and wind until the safety pawl to the left of the clock drops into the "DOWN" position. Unscrew the clock cover to expose the time adjusting nut. Rotating the knurled nut to the left one quarter turn will slow the clock approximately 30 seconds per day.

5.2 Cleaning Pens. Use only water when cleaning the reservoir and capillary tube. Water usually can be forced through the tube in the same manner as in priming the pen with ink. However, if the capillary tube is completely plugged with dried ink, use the pen cleaning wires furnished with each recorder.

5.3 Lubrication. Clean away any oil and dirt residue and apply one or two drops of oil with a toothpick once a year (oftner in extremely dusty atmospheres). A small oil hole is provided in the hub between the chart take-up clutch and its corresponding gear. This oils the clutch bearing. Avoid excessive oiling which could run into the clutch. Oil should not be applied to any of the gear teeth. Oiled gears collect dust and dirt, which in the long run does more harm than good. Ball bearings and Teflon impregnated sleeve bearings are factory lubricated for the life of the instrument.

5.4 *Parts and supplies can be ordered direct from the factory. Be sure to include the recorder serial number with all orders for parts.*

PARTS LIST

ITEM NO. (See Figure 6)	DESCRIPTION	PART NO.
1a	Arm with holder for Lucite reservoir pen	1-10220
1b	Arm with holder and weight for wood encased pencil	1-10901
	Ball bearing for float pulley shaft (2 or 4 req'd) (Not Shown)	1-20518
3	Cable, stainless steel clock weight, .040 in. dia. x 28 ft.	1-10275
	Chart A-10, English, 10 inch wide x 25 yards long	1-14945
	Chart A-25, metric, 25 cm wide x 25 yards long	1-14947
4	Clamp for chart on take-up cylinder	1-10130
	Clip, holder for glass pen on reversal indicator or time marker pens. (Not Shown)	1-10223
6a	Clock, Chelsea, mounted, without dial, with drive bar	1-19085
6b	Clock, Chelsea, mounted, with dial, with drive bar	1-19086
6c	Clock, synchronous motor, mounted (customer to specify type, rev/day, voltage and frequency)	
7	Clutch assembly with 60 tooth gear	1-10748
	Cover, Neoprene plastic Type A, Model 71 Instrument	3-10916
8	Crank for cable/negator spring drum (left hand thread)	1-10597
9	Drive Bar, with screw, Chelsea clock	1-10277
10	Drum only, for negator spring or cable	4-10895
11	End hook assembly	1-15147
13	Float pulley clamp assembly with nut	1-10749
14	Float pulley standards	
	English	
	Gage scale 10:12 & 5:12, (geared)	1-10675
	Gage scale 1:6 & 1:12 (single shaft)	1-10676
	Gage scale 1:12 & 1:24 (geared)	1-10677
	Gage scale 1:30 & 1:60 (geared)	1-10678
	Metric	
	Gage scale 1:1 & 1:2 (geared)	1-10683
	Gage scale 1:5 & 1:10 (single shaft)	1-10684
	Gage scale 1:10 & 1:20 (geared)	1-10685
	Gage scale 1:25 & 1:50 (geared)	1-10686

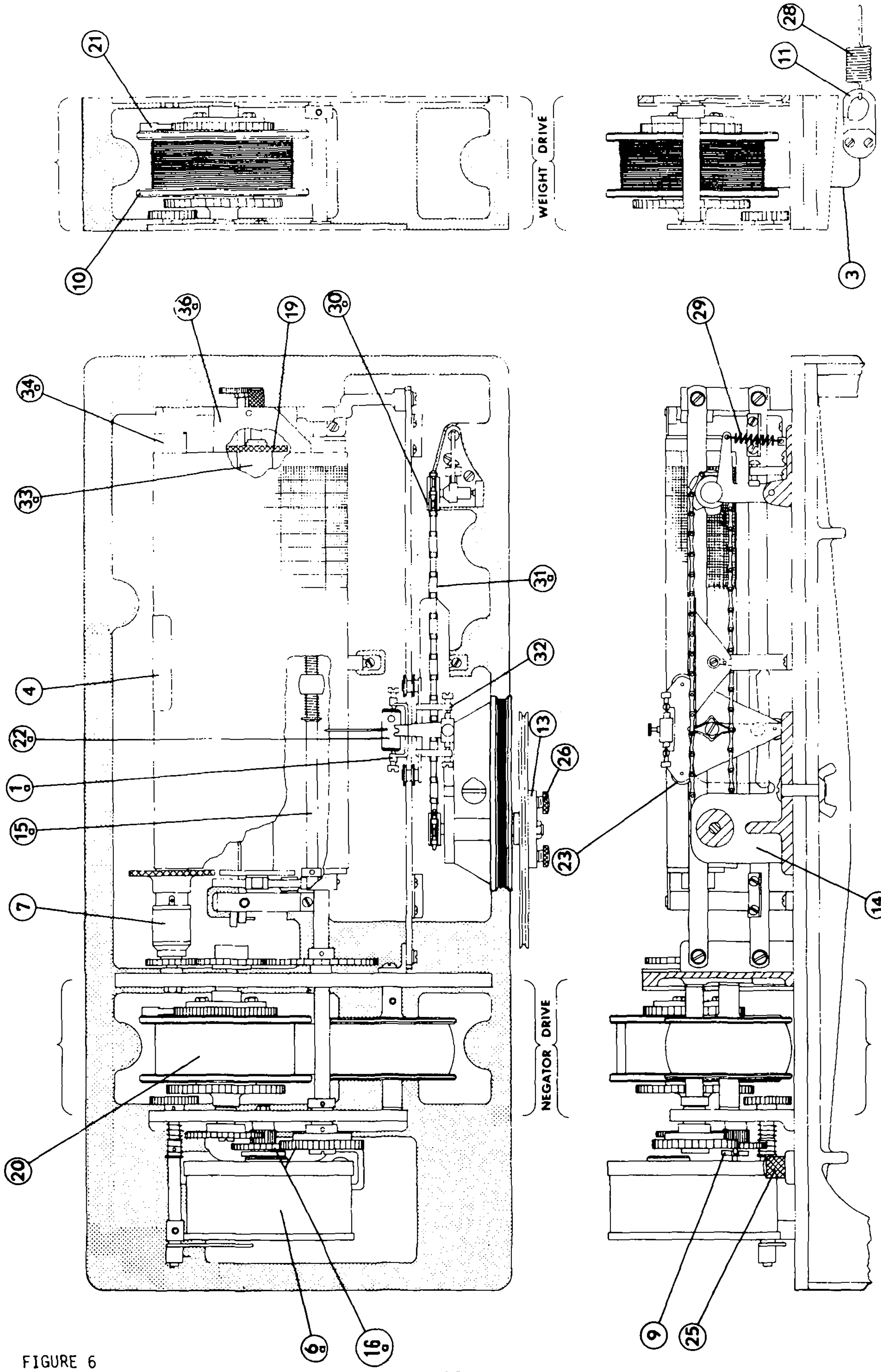


FIGURE 6

ITEM NO. (See Figure 6)	DESCRIPTION	PART NO.
15a	Friction roller assembly 10 in. or 25 cm model	1-10109
15b	Friction roller assembly 20 in. or 50 cm model	4-10111
16a	Gears time scale, Chelsea, negator or weight driven (customer to specify time scale and serial number of recorder	Refer to Table 4A & Fig. 2
16b	Gears, time scale, a.c. operated recorder (customer to specify time scale, clock type, rev/day and serial number of recorder) (Not shown)	Refer to Table 4B & Fig. 4
	Glass for cover-20 in. model (Not shown)	1-10042
	Leveling screw leg assembly (Not shown)	1-27474
19	Nut for supply cylinder shaft	1-10120
20	Negator spring, 4 1/2 mo.	1-10870
21	Pawl for cable/negator spring drum	1-10058
22a	Pen, capillary, with Lucite reservoir	1-10212
22b	Pen, capillary, with glass reservoir for reversal indicator or time marker pen (Not shown)	1-10222
23	Roller for stylus carriage	1-10175
	Screw, Pawl (Not shown)	1-10890
25	Screw, clock mounting (one req'd)	1-10294
26	Screws, set of 2, for float pulley clamp, "L" & "R"	1-10765
	Spring, cable negator drum pawl (Not shown)	1-10061
28	Spring for clock weight	1-10267
29	Spring, tension, chain sprocket	1-10202
30a	Sprocket assembly (right) with bearing (English)	1-10197
30b	Sprocket assembly (right) with bearing (metric)	1-10199
31a	Sprocket chain assembly for stylus carriage 10 in. model	4-10186
31b	Sprocket chain assembly for stylus carriage 25 cm model (metric)	4-10187
31c	Sprocket chain assembly for stylus carriage 20 in. model (English) (Not shown)	4-10763
31d	Sprocket chain assembly for stylus carriage 50 cm model (metric) (Not shown)	4-18816
	NOTE: All sprocket chains contain pins for actuating the reversal indicator accessory.	
32	Stylus carriage assembly without stylus or stylus arm	1-10169
33a	Supply cylinder with nut 10 in. or 25 cm model	1-10772
33b	Supply cylinder with nut 20 in. or 50 cm model (Not shown)	1-10773
34a	Take-up cylinder assembly 10 in. or 25 cm model	1-10124
34b	Take-up cylinder assembly 20 in. or 50 cm model (Not shown)	1-10128
	Template for mounting thermograph accessory (Not shown)	1-10767
36a	Writing plate - 10 in. model	1-10134
36b	Writing plate - 20 in. model (Not shown)	1-10135

13

VOCABULARY

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

BANK, RIGHT or LEFT. The margin of a channel as viewed facing downstream. The expression right or left applies similarly to right or left abutments, cableway towers, etc.

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

CUBIC METRES PER SECOND. A unit expressing rate of discharge. One m^3/s is equal to one cubic m of water flowing past a particular point in one second.

DAILY MEAN GAUGE HEIGHT. The mean gauge height for a particular day. Note that *mean daily gauge height* has a different definition, that is, for any given day, say June 10, it is the arithmetic mean of the daily mean gauge heights for all of these individual days in a period of record. The same distinction is applied to daily mean discharge and mean daily discharge.

DISCHARGE. Flow; it is expressed in terms of volume with reference to time (cubic metres per second, million cubic metres per year).

DISCHARGE MEASUREMENT. The determination of the rate of discharge at a gauging station on a stream; an observation of no flow is classed as a discharge measurement.

DRAINAGE AREA. That area enclosed by a topographic divide such that surface runoff would drain by gravity into the stream above the station.

GAUGE CORRECTION. Any correction that must be applied to the gauge observation or gauge reading to obtain the correct gauge height.

GAUGE DATUM. The permanent horizontal plane to which gauge heights are referred. This plane may in turn be referred to a Geodetic Survey bench mark or to a bench mark with an assumed elevation.

GAUGE HEIGHT. The water-surface elevation referred to the gauge datum. Gauge height is often used interchangeably with the more general term stage although gauge height is more appropriate when used with a reading on a gauge.

GAUGE OBSERVATION or GAUGE READING. An actual notation of the height of the water surface as indicated by a gauge, it is the same as a gauge height only when the 0.00 m mark of the gauge is set at the gauge datum.

GAUGING STATION. A particular site on a stream, canal, lake, or reservoir where systematic observations of stage or stage and discharge are obtained. This is also referred to as a Hydrometric station.

FLOAT-TAPE GAUGE. Consists of a float, a graduated tape, a pulley and a counterweight. Vertical motion of the float riding on the water surface results in movement of the tape over the pulley in response to the pull of the counterweight. Stage is read on the tape opposite a pointer attached to the pulley support.

HYDROGRAPH. Graph showing gauge height, discharge or some other property of water in relation to time.

MANUAL GAUGE. A non-recording type of a gauge from which observations of stage are obtained.

RECORDING GAUGE. An instrument which produces a continuous record of stage.

RECORDS. A systematic tabulation of observed hydrological characteristics, such as gauge heights and discharges at a gauging station.

RUNOFF. That part of the precipitation that appears in surface streams; is the same as natural flow. It is expressed in terms of volume, e.g., directly as m^3 or indirectly as depth in mm on the drainage area, with either a stated or implied reference to time.

SHIFT. A change in the stream control which alters the stage-discharge relation.

STAFF GAUGE. A graduated scale used to indicate the height of the water surface in a stream, canal, lake, or reservoir.

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

STAGE-DISCHARGE RELATION. The relationship between the stage and the discharge at a gauging station.

STREAMFLOW. The discharge that occurs in a natural channel.

WATER ELEVATION. The height of the water surface as referred to a Geodetic Survey or other standard datum.

WATER LEVEL. See gauge height.