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A PRELIMINARY REPORT UPON TESTS OF THE FISCHER AND PORTER TIDE GAUGE CONDUCTED AT BIRKENHEAD

BY

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1965

institute of coastal oceanography and tides

NATURAL ENVIRONMENT RESEARCH COUNCIL

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This Report was prepared before the Tidal Institute became the Institute of Coastal Oceanography and Tides

Brief description

It is not possible to provide a complete description of the instrument within this report. This is best obtained by reference to the Fischer and Porter Instruction Bulletin Reference 35-1540-1. The following points can however be made.

The instrument is in fact a shaft-encoder, that is, it records the rotation of a shaft with an accuracy of one hundreth part of a revolution up to a maximum of one hundred revolutions. The manufacturers suggest that it may be applied as a gas flow meter, or traffic counter or as a rain gauge in addition to its use as a liquid level recorder, in fact it is an instrument for the recording of any phenomenon which can be made to rotate a shaft.

As a tide gauge, the shaft is fitted with a pulley of exactly one foot circumference and with 5 sprockets in its rim. A stainless steel tape containing sprocket holes punched at 0.2 ft. intervals is passed over this pulley engaging the sprockets previously mentioned. A float is attached to one end of the tape and a lead counterweight to the other. Both ends of the tape are allowed to hang within the tide gauge well. With this system the aim is to record movements of the float with an accuracy of 0.01 ft. in a range 0 to 99.99 ft.

At the opposite end of the pulley shaft is fitted an alloy disc which performs two functions. A graduated dial fitted to this disc enables the part revolutions of the shaft (or decimals of a foot) to be read against a pointer. The disc also contains a pattern in relief which is used to control the punching of the two digits representing the decimals of a foot in sea level.

Through a worm drive fitted to the above shaft a train of gears drives a second alloy disc which in a similar manner contains a dial and a relief pattern referring to the two digits representing integral feet.

A complex linking device is employed to hold the decimal disc fixed at the nearest 0.01 ft. position during punching and also at the same time to rotate the foot disc to the nearest lower integral value of feet. Mechanical safeguards are provided against error at the critical points near to the integral feet. The system is quite clever and in our experience very effective, and reliable.

The record is made upon a paper tape just over 2 inches wide, each of the four possible digits being represented by a maximum of four punch holes in a simple binary system which can be read quite easily, after a little experience, by an observer of average intelligence. Three other punch hole channels are present upon the tape in addition to the 16 referred to above. One of these contains the pre-punched sprocket holes used in the drive of the tape through the recorder. The other two channels are punched upon each occasion when a digital recording is made. These are therefore correctly aligned with the holes representing the tidal elevation and are used for registration during subsequent translation. The printed format of the tape varies with the punch time interval selected for the record but is clearly marked according to time of day and an interpretation of the binary code to assist the reading of the digital records. As has been suggested the recording interval is a matter of choice but $\frac{1}{4}$ hour is recommended for tidal use. See figure 1. The record is not designed for immediate acceptance by computer but must first be translated. A continuous record over one year is theoretically possible at the $\frac{1}{4}$ hour sensing interval.

The timing device is a good quality balance wheel clock which is electrically wound and self-starting when the power supply is attached. The clockwork movement is made to rotate a cam, clearly marked in minutes and the time is read against the arm of a microswitch which initiates the recording process at the required interval.

The recording process is performed through an electric motor which operates off the single power supply. The latter can conveniently take the form of a small dry battery.

It is possible to initiate a punch by hand, irrespective of the timing device, by depressing a button on the face of the instrument.

Diary

When the tide gauge was first recieved at the Tidal Institute on December 15th, 1964, a float tape of insufficient length to cope with the Mersey tides was provided. Some delay was therefore occasioned initially. Thereafter the order of events was as follows.

Friday, January 15th 1965	:	50 foot float tape recieved.
Monday, January 18th 1965	:	Tide gauge installed at Alfred Dock alongside Tidal Institute gauge.
Tuesday, January 19th 1965	:	Van de Casteele test conducted over a spring tide range, soundings being taken in groups of 5 at 15 minute intervals over 13 hours.
January 19th - February 11th	:	Tide gauge in continuous operation and checked against well soundings on two occasions each week.
February 11th	:	An electrical fault interrupted the record. The advice of Mr. Noble was requested as to whether we should find this fault for ourselves or alternatively request service from Fischer and Porter. It was decided to test Fischer and Porter maintenance arrangements.
February 12th - February 27th	:	The gauge ran intermittently giving no useful record.
February 27th	:	An engineer arrived from Stockton on Tees and found a faulty diode.
March 2nd	:	A replacement diode was recieved by post and fitted by Tidal Institute staff. The record was restarted.
March 23rd	:	The sounding tests, which had previously shown a remarkable stability and accuracy in the performance of the gauge, showed an apparent error for the first time. The gauge was reading 0.2 ft. low.
April 20th	:	A further error became apparent, the gauge now reads 0.4 ft. low.
April 27th	:	The gauge now reads 0.6 ft. low.

Installation

Upon the arrival of the instrument it was noted that the punched record was not in correct registration with the ¼ hour lines of the record strip. An adjustment was effected to the length of the "paper tape advancement lever," so as to correct this condition. This adjustment is rather tricky. However, it should be noted that a small error in registration is not a serious matter in view of the presence of translator alignment holes mentioned earlier.

The arrangement of the float tape, in such a manner that the counterweight falls into the tide gauge well, requires the performance of rather elaborate initial calculations and well-soundings so as to determine the limits imposed on tape length. Figure 2 illustrates this point. It can be seen that the tape length is critical if maximum and minimum levels are to be recorded accurately. It so happened that the length of tape provided by Fischer and Porter was 4 ft. in excess of the nominal 50 ft. requested. If in fact the tape had been a bare 50 ft. in length, then some trouble may have been occasioned in satisfying the conditions demanded by the system.

The float pulley, in operation, is locked to flange mounted on the main shaft by the pressure of two thumb screws. There is no device for fine adjustment. When it is considered that the pulley must be adjusted correct to one hundreth part of a revolution as the level is changing with the tidal movements, it will be realised that this is no easy matter and can only be achieved by a prolonged process of trial and error. Once achieved however it is our experience that the instrument is stable so that no further adjustment is required.

It will be noted that the instrument is incapable of recording a negative value, whereas if a tide gauge zero approximating to chart datum is desired, as is quite common, then negative values are inevitable. At Birkenhead we have avoided this difficulty by adopting a tide gauge zero 10 feet below chart datum. Another possibility would be to retain the coincidence of chart datum with tide gauge zero, so that a level of -0.5 ft. for example would be punched as 99.95 ft. It would then be necessary to program the interpretation of such levels during subsequent computer processes.

The Van de Casteele Test

The results of the Van de Casteele Test conducted on January 19th are shown in figure 3. These are of a high quality and vastly superior to any comparable set of results from a conventional gauge. In particular there is no suggestion of the familiar friction and backlash troubles of the more common types of tide gauge which displace that part of the diagram produced by observations on the rising tide from that part dependent upon the falling tide. This feature results from the design of the Fischer and Porter gauge in that the mechanism which gives the decimals of feet uses simply the rotation of the main shaft without the need to translate this movement through a train of gears.

It will, however, be noted that the plotted points indicate that the gauge does not give a truly linear response. In fact the plots representing low water are displaced by an amount equivalent to 0.05 ft. with respect to those representing high water. This condition was examined in some detail and the following possibilities were considered:

(a) The coefficient of expansion, with temperature, of the float tape might have an effect. Perhaps, for example, the sprocket holes in the float tape were punched at 0.2 ft. intervals under factory conditions of, say 65°F (18°C) whereas the Van de Casteele test was performed on a January day at a known temperature of approximately 40°F (4.5°C). The error thereby induced in a stainless steel tape of 50 ft. length can be calculated to be 0.00675 ft. The error is of the correct sign to explain the form of the Van de Casteele diagram but it is clearly of too small a magnitude to be the explanation.

(b) The float tape was received tightly rolled and highly tempered. With the tape in position on the instrument, the counterweight was clearly insufficient to completely remove the residual kinks in the tape. Since the instrument is effectively measuring the length of tape between the float and the pulley it follows that the error due to kinks is likely to increase progressively, the lower the level to be recorded. The error again is of the correct sign. It is however impossible to estimate the magnitude of the error but with time it is likely that the kinks will become less prominent so that a subsequent test will possibly show an improved situation.

(c) The float tape itself represents a significant weight. Again a consideration of its arrangement in operation shows that the simple counterbalance system cannot maintain a constant tension on the critical part of the tape, namely that part which lies between the float and the pulley. If the weight of 50 ft. of float tape is W and the weight of the counterweight is C, then at high water the upward tension on the measured part of the tape is approximately C + W whereas at low water the tension approximates to C - W. In one respect this argument affects the influence of kinks, see (b) above, but also this must affect the level at which the float rests in the water.

Again the error is of the correct sign to explain the anomalies of figure 3.

It is considered that a combination of (b) and (c) can account for the 0.05 ft. anomaly shown in the Van de Casteele test.

Clock Tests

During the 13 hours of tests conducted on January 19th, the clock received careful attention. No systematic error was discernable. It should be noted that the timing device depends only upon the hourly rotation of a cam which is far less serious from a tidal point of view than the conventional tide gauge system depending upon the daily rotation of a drum which may be slightly eccentric, not of truly circular cross-section, and perhaps more important, not truly aligned with the pen guides.

Spot checks upon clock accuracy have been taken during routine visits. The results of the 20 most recent checks at the time of writing are as follows:-

Clock Conditions after 3 or 4 days	Occasions
90 secs. fast	1
75 secs. fast	0
60 secs. fast	2
45 secs. fast	1
30 secs. fast	2
15 secs. fast	1
Clock correct	8
15 secs. slow	1
30 secs. slow	2
45 secs. slow	0
60 secs. slow	2
75 secs. slow	0
90 secs. slow	0

The above results are considered to be quite satisfactory.

It should be noted that with a digital record, great reliance must be placed upon the clock since it is not possible to make time adjustments to the record before processing. The only opportunity of correcting errors in the timing of the record is to program such an adjustment to the record within the computer. Even so, if clock errors are frequent and of significant magnitude, even this solution must require the manual punching of correction data which the system of a digital recorder is specifically designed to avoid. Note that the recording strip is advanced by a ratchet and pawl movement during each punching operation and this has proved to be an efficient and positive device.

Accuracy of Punching

It is clearly important to ensure that the binary digits punched upon the tape are a correct representation of the tidal height showing upon the dials at the time of punching. Since there are in fact 10,000 possible combinations of dial positions for the initiation of a punching code this represents a formidable task. However, during the tests of January 19th some 260 codes were checked against the dial readings and no cause for concern in this respect was occasioned. Furthermore the mechanism of coding has been carefully inspected and this had been found to be of high quality. It is felt that any errors which are likely to occur here will be caused by wear during operation or possibly by the choking of the punching mechanism by the abundance of confetti produced. Consequently it is proposed to examine the mechanism in greater detail at the conclusion of the exercise.

Power Supply

As has been stated the recommended power supply is a dry battery of $7\frac{1}{2}$ volts. Clearly where a mains supply is available, power could more conveniently be provided through an accumulator on trickle charge. Since it is our desire to simulate in every way the attention likely to be given by an average tide gauge user, we have operated the instrument using dry batteries. We were surprised to find how modest were the demands of the instrument. The most readily available $7\frac{1}{2}$ volt dry battery is one designed for use with transistor radios. In fact the type used at Birkenhead is an Ever Ready AD38 costing 2s. 6d. This battery we find is most convenient to use particularly since its life can be assumed to be one calendar month. For example an AD38 was installed on the Birkenhead equipment on March 18th. Thirty-three days later on April 20th its voltage had dropped to 6.7 volts and it was replaced, although the mechanism was still functioning perfectly. It is important to note that the efficiency of operation of the equipment is not impaired by a small reduction of voltage. In particular, the clock is unaffected since this depends upon a normal balance-wheel escapement and is tolerant of battery voltage as long as this is sufficient to wind the mechanism at intervals of 3 hours or so.

General comments upon the Fischer and Porter tide gauge.

1. Criticisms

(a) The main criticism of the instrument lies in the arrangement of the float tape and its counterweight. Apart from the points mentioned hitherto, there is a significant disadvantage in an arrangement whereby the counterweighted end of the tape passes into the well as the float rises. Clearly the manufacturers are unaware of the properties of the aqua-vitae which flow in the Mersey. On a falling tide the wetted tape end passes over the float pulley and an idler pulley, bringing with it oil film and silt which is at present building up on these components. Some corrosion is now also apparent. The build up of film on the pulley wheel does not seriously alter its effective diameter since the operation of the instrument depends upon the engagement of the pulley sprockets with the tape holes, but what is clear is that the engagement of the sprockets is now much less secure. It is to this fact that we attribute the three discontinuities of 0.2 ft. noted on March 23rd, April 20th and April 27th. It is though that, at a time of surging in the well, the tape became disengaged from the sprockets and after some time interval fell into registration once again, but one hole spacing (0.2 ft) in error. It is also felt that there may be some less obvious effect on calibration here and this it is proposed to check by a subsequent Van de Casteele test. Purposely no attempt has been made to clean up the faces of the pulley or the tape so that this fault may be investigated at its worst.

It should not be too difficult to improve the system and one suggestion is given in figure 4. This suggestion also affects some slight improvement in the condition duscussed earlier in connection with the variable tension in the float tape. Consider for example the separate counterweight suspension shown in figure 4 to be tape. Now at low water the effective diameter of the take up pulley is reduced and the effective diameter of the counterweight pulley is increased so that in consequence the tensioning force is increased to counterbalance the additional weight of float tape between pulley and float. The reverse argument can be applied to fit the conditions at high water. It is possible that optimum diameter sizes of these two pulleys could be selected so as to achieve a constant tension is the float tape. A second suggestion is given in figure 4a.

(b) Without a graphical record there is no visible indication given of the performance of the well nor the gauge itself. This inevitably places greater weight upon adequate maintenance of the installation and effective checks, preferably by soundings. Perhaps of greater significance from a tidal point of view is the fact that it is not possible to obtain times and heights of high and low waters from a digital record at $\frac{1}{4}$ hour intervals. Using a digital record it will always be necessary to compute the turning points unless the recording interval is significantly reduced, say, to one minute. The maximum recording interval to be tolerated if the sensing of turning points is to rely upon computation must depend to some extent upon the tidal characteristics experienced at the port in question. A 5 minute recording interval, however, would seem to be a more reasonable choice.

(c) The button provided for the manual initiation of a digital record was found to be superfluous and in fact dangerous. If for example a punch is initiated by accident then there is no recourse other than to remove the recording strip, curtail the strip in advance of the offending record and to restart the record at a new point on the strip.

Without the button it is still a simple matter to manually initiate a punch should this be required by turning the timing cam to the nearest step by hand.

(d) When the record fails due to an intermittent fault, as indeed occurred at Birkenhead, then the previous record has no meaning without elaborate analysis. We would prefer the clock not to be self-starting so that in the event of failure, however temporary, the observer could be assured that the record is valid upto the break.

(e) A minor point of criticism, the coding discs and the current record are clearly visible through a glass panel on the face of the instrument. It is possible to read the dials showing water elevation and to inspect the record over the last 4 hours or so without opening the case. The timing cam however is not visible so that it is not possible to apply a timing check without opening up the case. A simple glass panel over the timing cam would be an improvement but the re-siting of the clock mechanism so that it could be read on the face of the instrument would be better.

(f) Electrical wiring, electric motors and electronic components do introduce the possibility of faults to which the tide gauge operator is unaccustomed. The circuit of the Fischer and Porter gauge is not too complicated however and, in spite of our experience of an intermittent fault early in our trials, we have no reason to suspect that this was other than a minor teething trouble which is unlikely to recur.

II Plaudits

(a) The instrument is well made and well designed, with the obvious reservations referred to earlier. Simple modifications would greatly improve the device and produce a first class instrument.

(b) Its performance shows a considerable improvement over the conventional tide gauge and it is considered that with a little care, a tidal record could be obtained giving discrete observations of tidal elevations correct to say, 0.03 ft. and 30 secs. in time. This achievement is made possible by the absence of many of the trouble spots with which the user of a conventional gauge is only too familiar. Backlash is eliminated in the recording of decimals of feet since the float tape drives the appropriate coding disc directly without intervening gear trains. Possibilities of friction are reduced to the two bearings of the main shaft, and the single bearing of the idler pulley. The only load imposed upon this mechanism is the driving of the gears connecting the second coding disc to the main shaft and since the first stage of this train takes the form of a worm gear reduction this load is infinitesimal. The familiar cyclic errors due to eccentricities of rotating objects do not apply. Only one such possibility exists and this is in the timing cam. Any error here would have a period of one hour and so would be unimportant from a tidal point of view, but in fact we have no reason to suspect such an error. Again the mechanism is such that the customary problems associated with riding turns cannot occur, and finally the instability of the recording paper strip from the point of view of humidity does not affect the accuracy of the record.

(c) The general stability of the Fischer and Porter gauge in recorded elevation is vastly superior to that of a conventional gauge. Figure 5 shows the results of the regular tests upon elevation made by well-soundings for both the digital gauge and the Légé gauge installed in the same well. Two discontinuities in the Fischer and Porter results are clearly marked and as has been mentioned previously it is considered that these are caused by the accidental disengagement of the sprockets from the tape. Corrections of 0.2 ft. and 0.4 ft. respectively to the appropriate observed quantities produce a pattern of errors which would have been observed if these disengagement faults had been avoided. It will be noted that apart from a small scatter due to observational errors, the Fischer and Porter results are remarkably consistent and show only a small trend to a level of about -0.02 ft. This trend may be explained by the tendency for the tape kinks to become less pronounced with use.

Translation of Record

Preliminary arrangements have been made, through Mr. Noble, to have the records from the Fischer and Porter gauge translated using equipment ordered for the Water Resources Board. Apart from an examination of the specifications of this equipment so as to ensure that it is likely to satisfy our requirements, it has not yet been possible to proceed with any translation tests since delivery of the equipment was made in late April. A thorough test of the translation service and its facilities for correction of records is now being made.

Experience elsewhere

The opportunity was taken at the Tide Gauge Symposium in Paris, May 1965, to discuss the potentialities of this instrument with other users who had had longer experience with the system.

(a) It was learned that the USC & GS had several Fischer and Porter gauges in use which were of a radically different design to that installed at Birkenhead. These instruments use a float wire rather than a tape, which is taken up on a drum containing a spiral groove. The drum is of 2 ft. circumference and the float wire is tensioned by a band spring which operates upon the axle of the drum shaft.

Although this design removes some of the difficulties which have been found in the Birkenhead gauge, notably the immersion of counterweighting systems in the well, it is felt that it is likely to introduce other undesirable features. In particular the insertion of a reduction gear in the main shaft drive is significant and will clearly introduce backlash problems of which the instrument at Birkenhead is remarkably free. Again it is not felt that a band spring system will retain ideally constant tension of the float wire at all stages of a tidal cycle. Again the spiral drum system prohibits the locking of the system during punching so that the coding discs cannot be fixed with reference to the float drum in case the suspension wire is jolted out of the groove upon release.

(b) A comparison of Fischer and Porter records with conventional analogue instruments in the Netherlands has shown occasional anomalous readings given by the Fischer and Porter gauge. This phenomenon has also been experienced in the USA. It is attributed to the occasional failure of the punching mechanism of the instrument so that one or more holes are missed from the digital record. At Birkenhead we have not yet had the opportunity to examine the translated record from the Fischer and Porter gauge and in any case such faults are unlikely to have been experienced in a new instrument as has been suggested earlier. The possibility that such errors might occur are regarded as most serious however, particularly since all such errors must have a negative sign and therefore they must be of a systematic character. It it is possible for one of the 16 channels in the punch mechanism to fail, then presumably it is possible for more than one to fail, so that we may be faced with the conclusion that at any time the tidal elevation may be equal to or greater than the digitally recorded height. No computer or manual checking technique can be expected to overcome this difficulty. This feature is regarded as sufficient to damn the instrument from the point of view of large scale introduction.

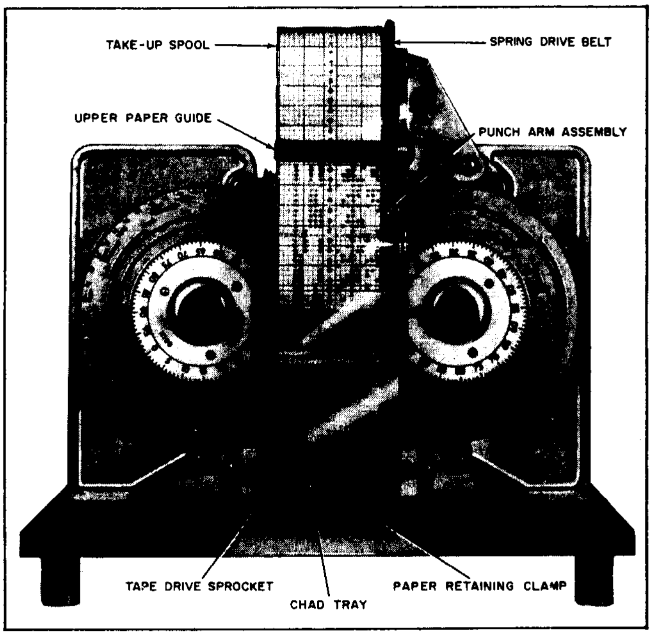
The incorporation of parity channels in the digital record may be a possible but a partial solution to this problem and this will necessarily involve major modification to the punching mechanism and coding discs. At present each of the 4 decimal digits which make up a single record is represented by 4 channels on the recording strip. This number could be increased to 5 and the coding discs redesigned so that, for example, the fifth channel is punched whenever an odd number of holes would otherwise be required to define the digit. A more sophisticated translator could then check that, in all cases, the punched code representing a digit is always defined by an even number of holes.

This system would be a means of error detection rather than correction and would necessarily assume that the likelihood of more than one failure in a group of 5 punch channels is remote.

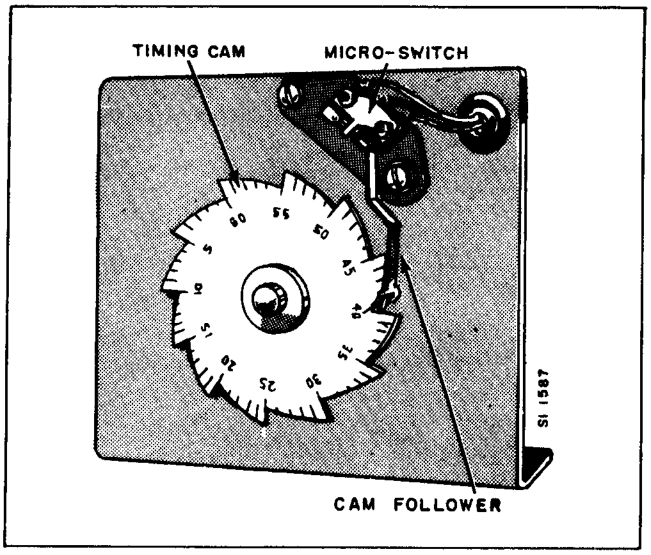
(c) Much discussion was occasioned at Paris on the subject of stilling-well response functions and their relationship with the recording interval of digital tide gauges. It had previously been felt that a $\frac{1}{4}$ hour interval was too long in view of the systematic errors which may be involved in the presence of seiches. The present climate of opinion suggests that no digital record should be devised which might severely limit the use to which the record may be put at some later date. The recording interval should match the response function. If the stilling-well merely damps out waves with periods upto, say, 15 secs. we should perhaps be interested in all phenomena with periods in excess of 30 secs. Recording at periods of half the frequency response of the installation would therefore involve a recording interval of approximately 15 secs. If accepted, this argument would impose serious problems for the present Fischer and Porter system which has a mechanical punching cycle in excess of this interval.

Conclusions

While acknowledging that the Fischer and Porter gauge is in many ways superior to the conventional tide gauge it is clear that severe shortcomings have been recognised of significant gravity. It is then necessary to suggest that we shall never be satisfied with the instrument in its present form. This being so, the future of the testing program must be considered. It would seem to be advisable at this stage, either to continue the search for a more precise instrument or to request Fischer and Porter to consider the objections and suggestions made in this paper.



INSTALLATION OF DATA TAPE



TIMER UNIT, DC TYPE

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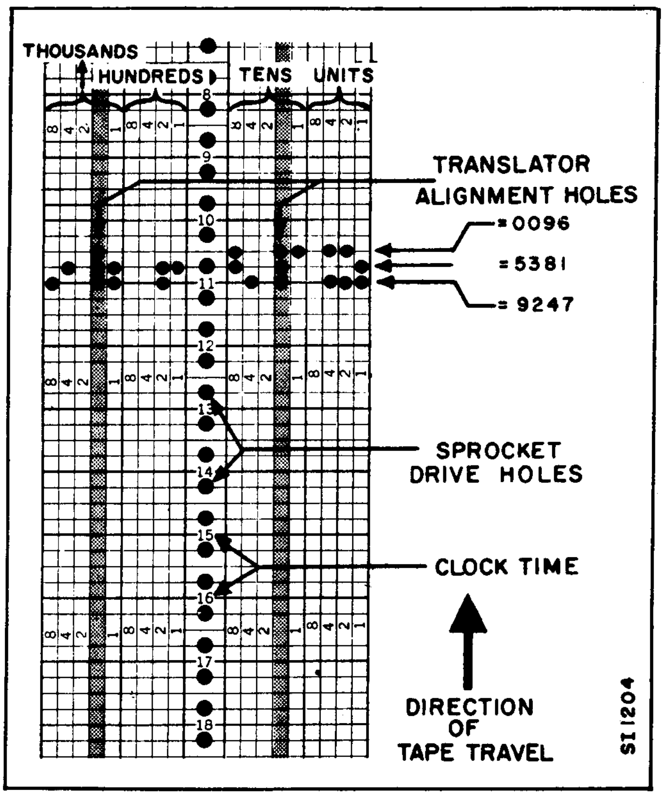
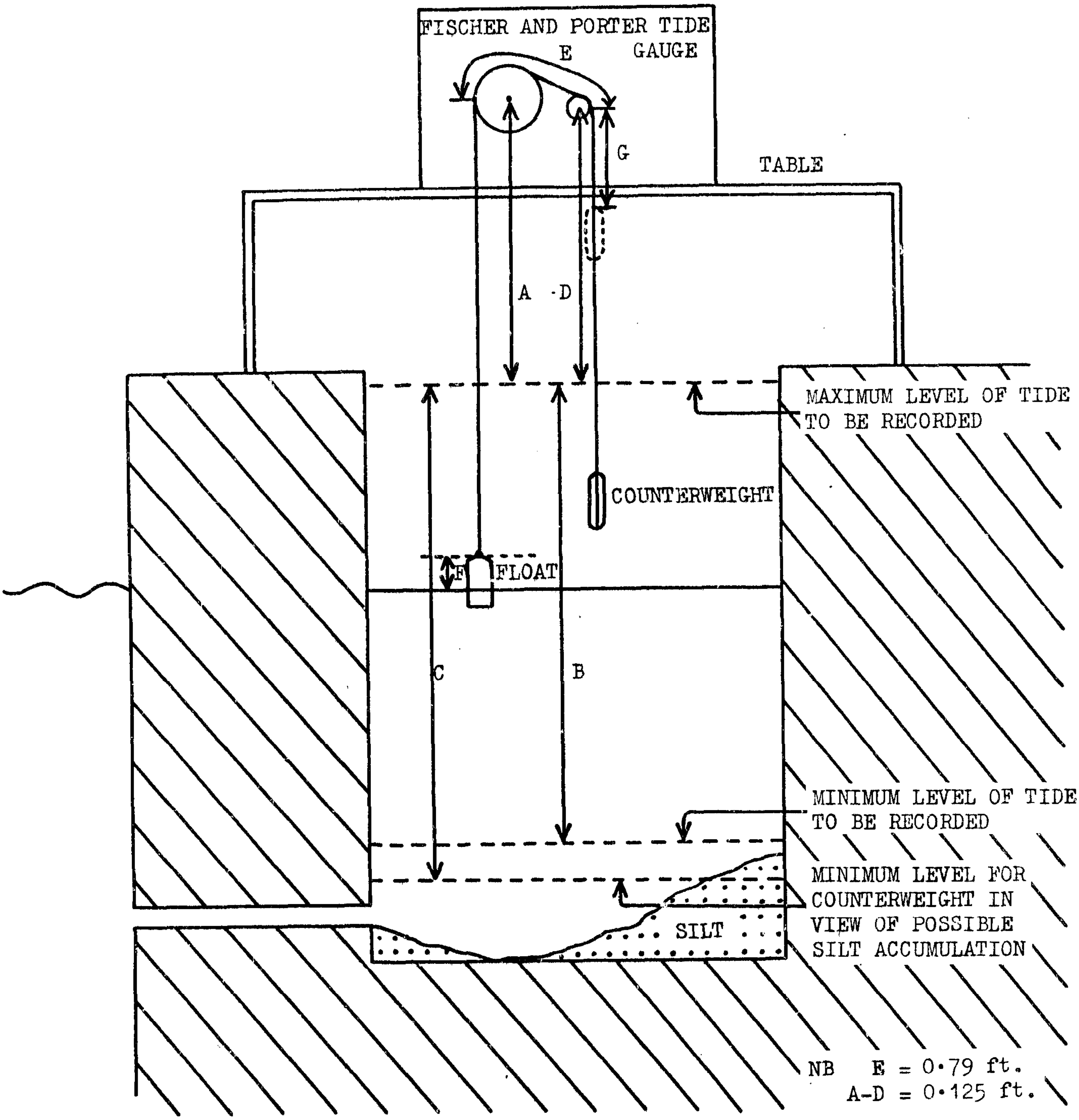


FIGURE I FACSIMILE OF DATA RECORDING TAPE

FIG. 2



MAXIMUM LENGTH OF TAPE GOVERNED BY CONDITIONS OF MAXIMUM LEVEL TO BE RECORDED

MAXIMUM LENGTH = A-F+E+D+C

MINIMUM LENGTH OF TAPE GOVERNED BY CONDITIONS OF MINIMUM LEVEL TO BE RECORDED

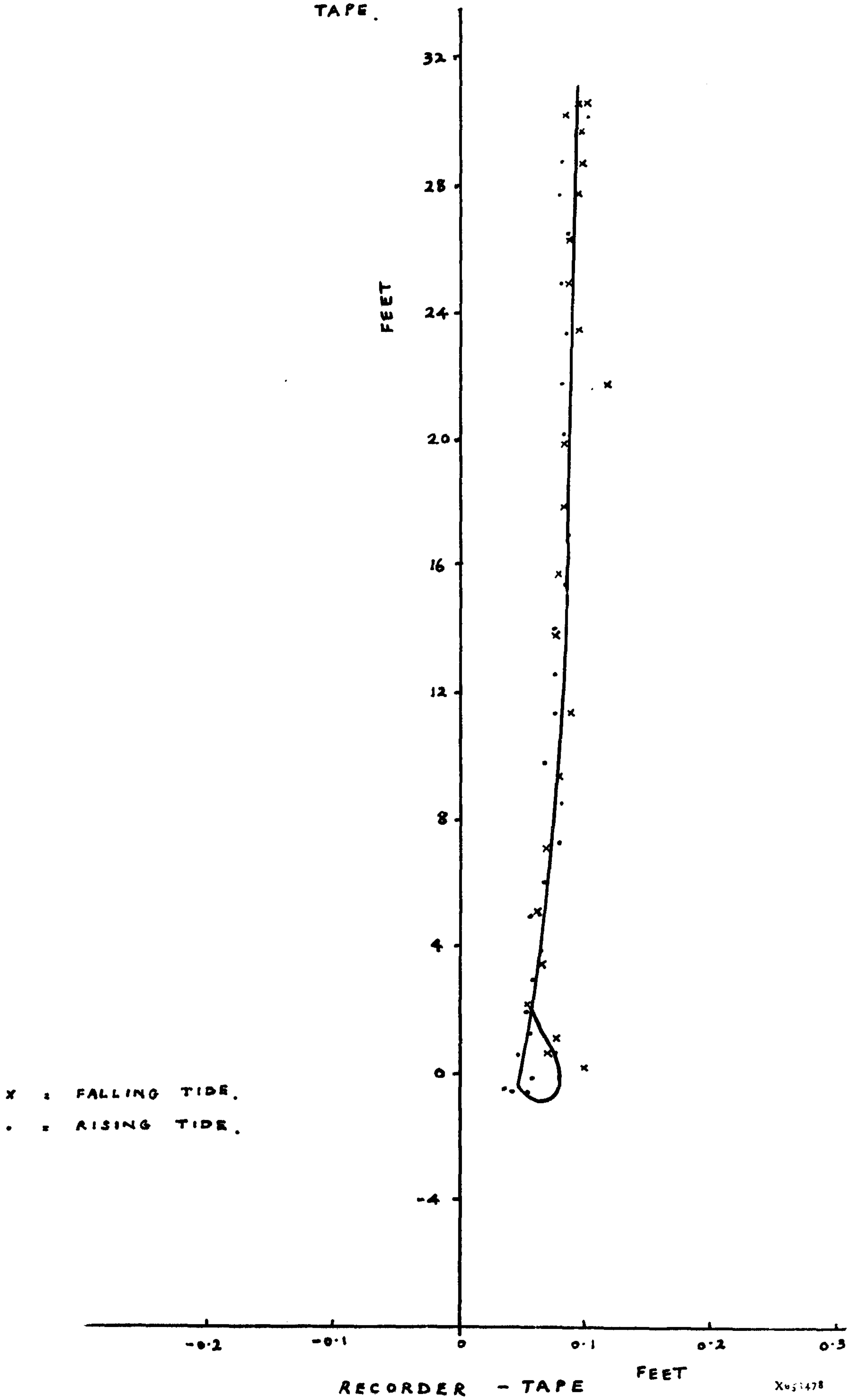
MINIMUM LENGTH = B-F+A+E+G (WHERE G = MARGIN ALLOWED TO AVOID CONTACT BETWEEN COUNTERWEIGHT AND TABLE (OR PULLEY))

AT BIRKENHEAD TOLERANCE (D+C-B-G) = 4 FEET ONLY

X652478

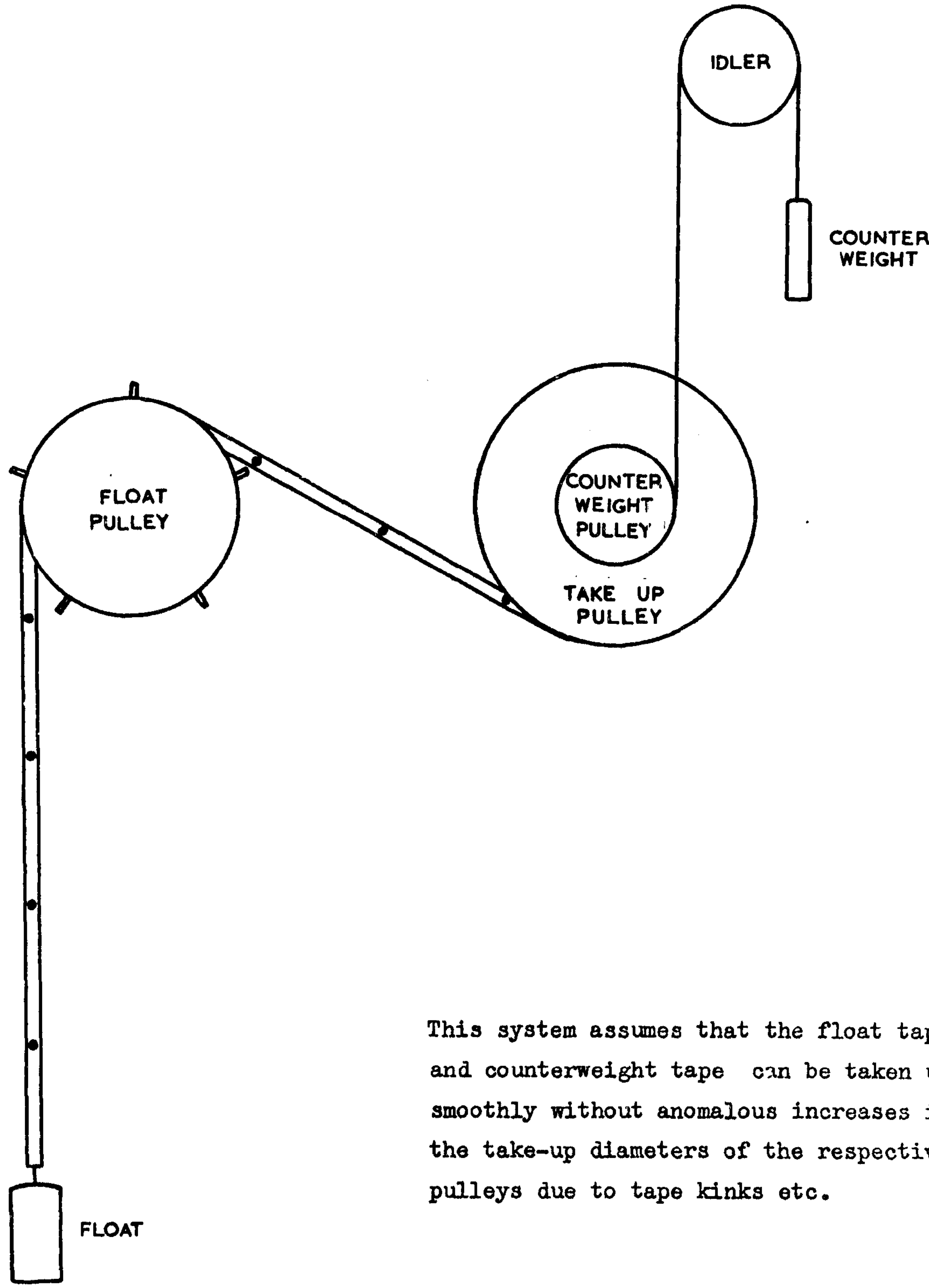
FIG. 3

FISCHER AND PORTER
(19-1-65).



X65478

FIG. 4



This system assumes that the float tape and counterweight tape can be taken up smoothly without anomalous increases in the take-up diameters of the respective pulleys due to tape kinks etc.

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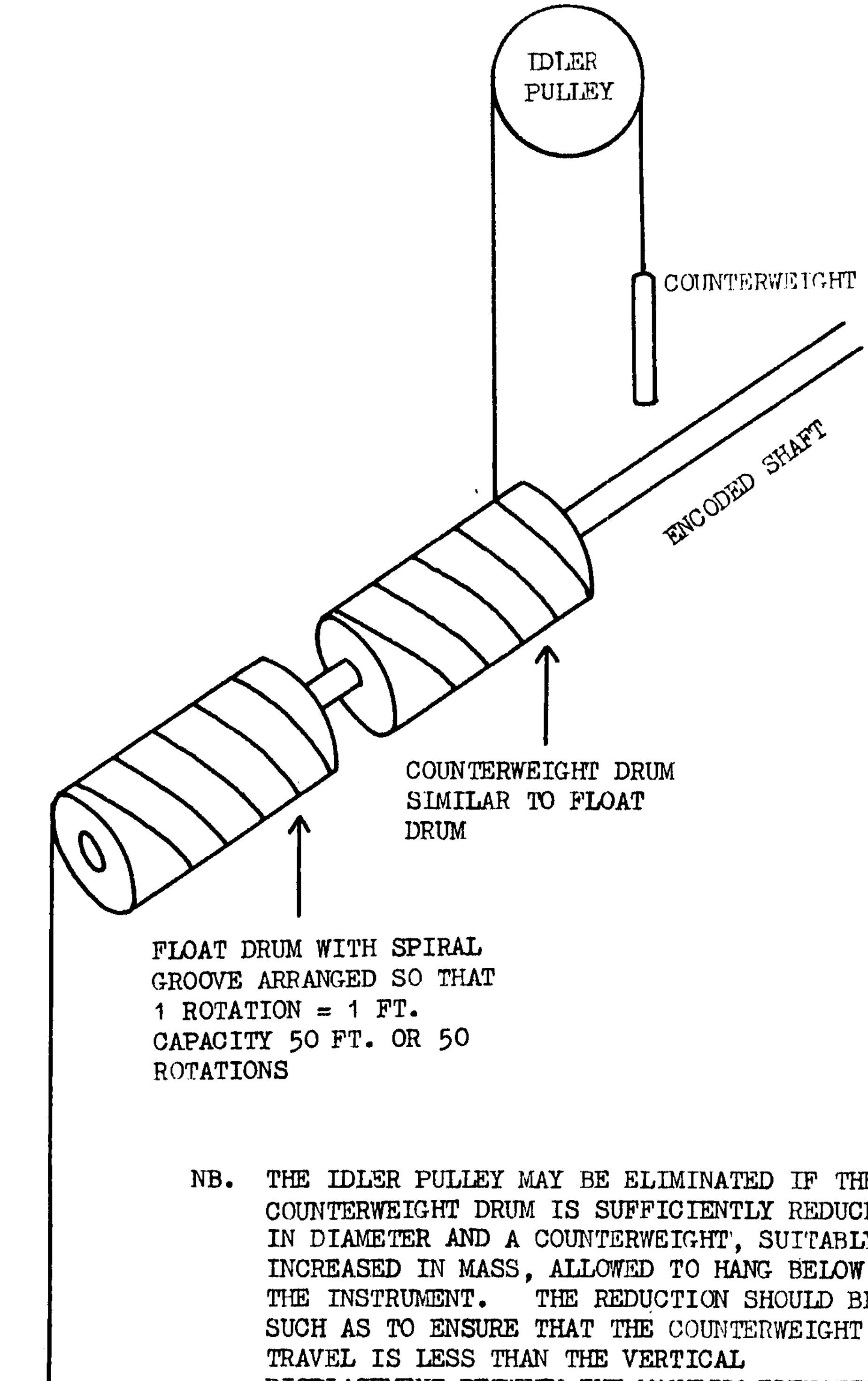
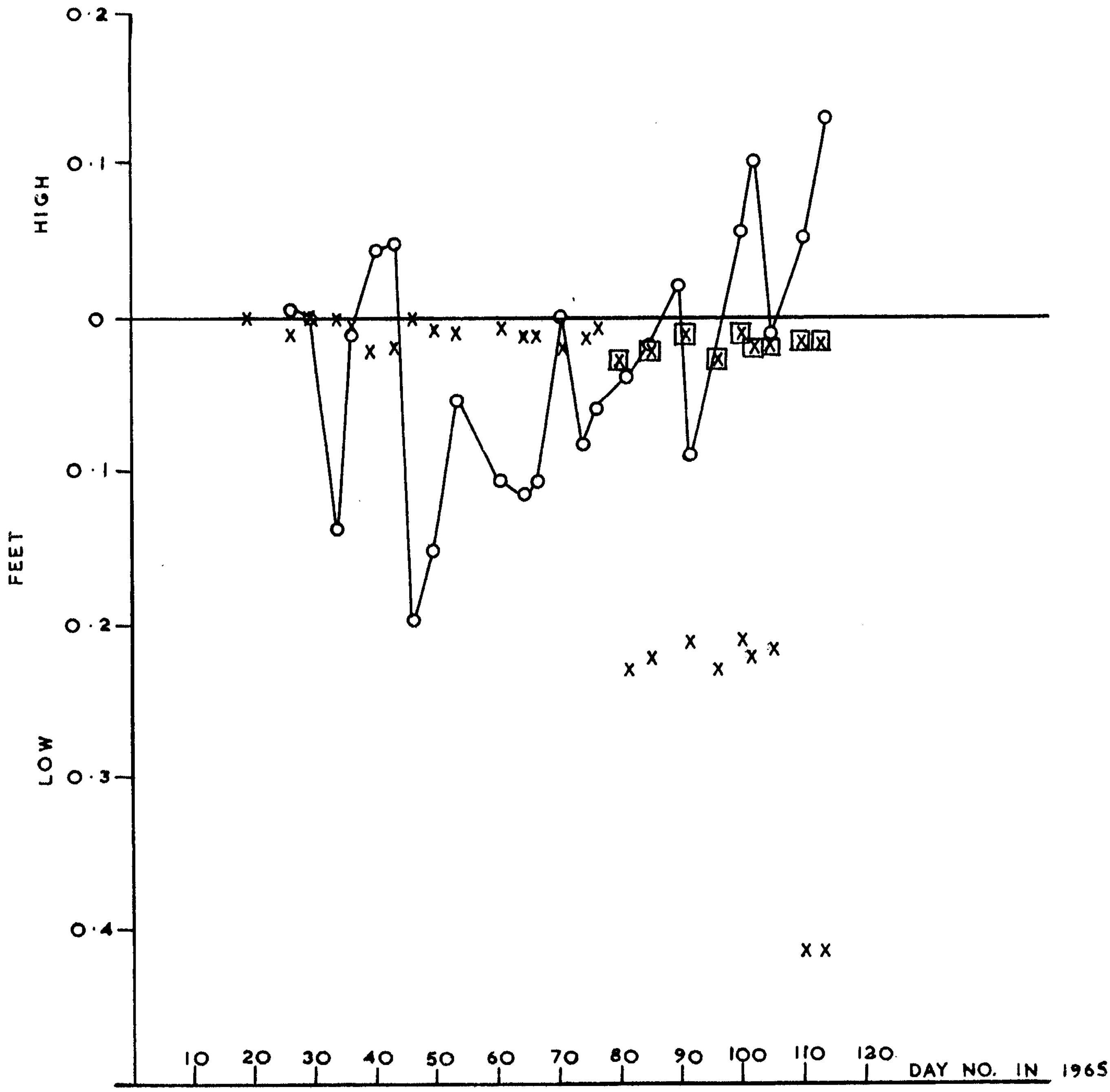
FIG. 4A



NB. THE IDLER PULLEY MAY BE ELIMINATED IF THE COUNTERWEIGHT DRUM IS SUFFICIENTLY REDUCED IN DIAMETER AND A COUNTERWEIGHT, SUITABLY INCREASED IN MASS, ALLOWED TO HANG BELOW THE INSTRUMENT. THE REDUCTION SHOULD BE SUCH AS TO ENSURE THAT THE COUNTERWEIGHT TRAVEL IS LESS THAN THE VERTICAL DISPLACEMENT BETWEEN THE MAXIMUM ELEVATION OF THE TIDE AND THE ELEVATION OF THE ENCODED SHAFT.

FIG. 5

STABILITY OF FISCHER AND PORTER TIDE GAUGE IN RECORDED ELEVATION COMPARED WITH A LÉGÉ GAUGE.
ERRORS DETERMINED BY WELL SOUNDINGS.



X FISCHER AND PORTER ERRORS IN HEIGHT

O LÉGÉ ERRORS IN HEIGHT

☒ FISCHER AND PORTER ERRORS ADJUSTED FOR ASSUMED SPROCKET SLIPS

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