CHAPTER 10

A LOW-COST INSHORE WAVE DIRECTION INDICATOR

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ABSTRACT

Although many attempts have been made in the past to measure the direction of propogation of ocean waves, a need for a simple, reliable solution to the problem has remained. The technique described here, intended for near-shore usage, makes use of a simple bottom-mounted flow direction indicator. The influence of rip and longshore currents on wave direction recordings is identified and a means of reducing these steady state current effects by a reduction in gauge sensitivity is presented, along with various possible recording and analysis techniques. Usefulness of the gauge is established as a simple engineering tool with certain limitations and examples are given of wave direction recordings related to meteorological data. A possible usage of the gauge as an approximate sediment transport indicator is also proposed.

INTRODUCTION

Situations very often arise in Coastal Engineering where a theoretical prediction of swell direction is not feasible for various reasons and the direct measurement of the directional properties of swell approaching a coastline is required. This need for measured directional spectra is well illustrated by the many ingenious ways proposed in the past (refs. (1) to (4)) to solve the problem and to solve it especially for storm conditions when optical techniques become ineffective.

Wave direction can be measured either remotely by optical or radar techniques, by the measurement of phase difference in signals from surface or submerged wave gauge arrays, or by an analysis of internal orbital wave motion or surface geometry.

The primary function of the instrument described here was the measurement of dominant swell directions in harbour development studies, where boat traffic excluded the use of surface measurement techniques. A simple, robust system was required which would lend itself to automatic analysis and which was not dependent on specific weather conditions such as a choppy sea surface, required for radar techniques.

The underwater approach was therefore chosen, but because of the fundamental problem that underwater monitoring must automatically include longshore and rip current effects which cannot be readily removed from the flow recordings, the more sophisticated methods of cross-spectral analysis of components of orbital motion did not seem warranted. Instead a completely non-spectral approach was adopted where the mean direction of the horizontal component of the forwards and backwards motion of each wave is recorded directly in a method based on Nagata's approach (ref. (5)) of identifying individual waves displaying longcrestedness. It has since been found that the backwards or return component of oscillatory wave motion appears either to tend towards the direction of bed slope at a site or to be more influenced by rip and longshore currents than the forwards or incident component. The fundamental difference then between this instrument and previous simple monitoring techniques is that these incident and return components of oscillatory motion of each wave have been separated and rip current and topographical effects have to some extent been isolated. By reducing the sensitivity of the gauge, as explained later, the bias due to longshore currents has been further reduced. Significant wave periods have been extracted from the records by Thompson's group period method (ref. (8)).

This individual-wave type of analysis does not give the more academic and complete energy-frequency-direction solutions of the spectral techniques (refs. (6) and (7)). It is also only suited to swell and not locally-generated wind-wave conditions, and is obviously limited to water depths at which the sensor can still "feel" the orbital motion of waves. However, the instrument is simple and easy to use and has produced results which should be useful for engineering purposes.

GAUGE - PRINCIPLE OF OPERATION

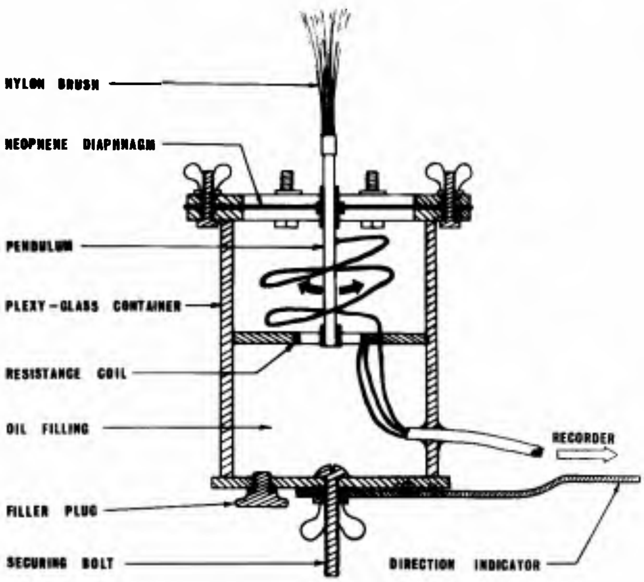
Fig. 1(a) shows one of the first prototype models of the sensor, which is known as the DOSO - Direction of Swell Orthogonals - Gauge. Basic components of the sensing head are shown schematically in fig. 1(c).

The forwards and backwards components of orbital motion or, as referred to above, the incident and return motions of each wave passing the sensor cause the brush to tilt the pendulum, which is freely mounted in the neoprene diaphragm, until contact is made with the annular resistance coil. The coil has linear characteristics and the voltages recorded at pendulum contact are proportional to flow direction. The container is filled with oil to balance pressure on the diaphragm and to insulate the circuitry and lubricate the contact point. A brush is used as resistance head to eliminate vortex oscillation effects which were encountered during flume testing.

The sensor thus registers direction of flow but not velocity and can be used separately from the recorder (fig. 1(a)) or mounted directly on the recorder container (fig. 1(b)) which in

a) Remote Mounting

b) Recorder Mounting



c) Construction Details

Fig. 1 DOSO Sensing Head

turn is clamped in a tripod on the seabed. Separate shore-based recording was used during the development of the sensor when its action was also monitored remotely by U.W.T.V. Later models have been incorporated with a self-contained recorder operating for one month unattended.

Four types of recording have been attempted. Firstly, direct analogue recording of signals shown on the left of fig. 2. Due to slow recorder response and clutter of vertical lines on the record, this technique was replaced with a pulse-actuated hammer recorder, activated by half-second integrals of direction record. The two charts show extracts of records from a simple unidirectional wave system on the right and a double system in the middle. Each dot represents a half-second of record and in this case the incident motion of each wave is on the upper side of the record and the return flow on the lower side, approximately 180° apart. To the right of each chart extract is a summation of half-second integrals over half-an-hour in histogram form. It can be seen that the mean swell direction in the righthand recording could have been estimated merely by inspection of the chart record, whereas in the double system the histogram is needed to define the two swells clearly. The slightly narrower return spectrum is the typically subdued image of the more sensitive and more accurate incident spectrum. To handle the data automatically, the half-second integrals of record were also digitised and recorded on magnetic tape. A fourth technique, which promises to be the most economical in cost and power consumption, is the conversion of voltage records to low-frequency audio tones which can then be recorded on a slow-playing audio tape recorder. This produces a complete, self-contained sensor/recorder system at a cost of under a few hundred dollars.

The system used at present is shown diagrammatically in fig. 3. The signal from the recorder is amplified, split up into half-second increments (less than half-second records are ignored) and then transmitted to the pulse-actuated chart recorder, in addition to being converted to a digital format for recording on magnetic tape cassettes. The chart record is then used for inspection purposes and the cassettes are used for computer processing.

TEST RESULTS

Tests on the DCSO have thus far been carried out at two sites near Cape Town shown in fig. 4. Station 1 near Gordon's Bay was chosen because of the double refraction of swell entering the larger bay and then finally the smaller Gordon's Bay, causing the waves to be well filtered, with a very narrow band width and displaying longcrestedness. Station 2, on the other hand, is directly exposed to the South Atlantic Ocean and is also prone to rip and longshore currents. The latter site is under investigation for a proposed nuclear power station coolant outfall and back-up data were thus readily available.

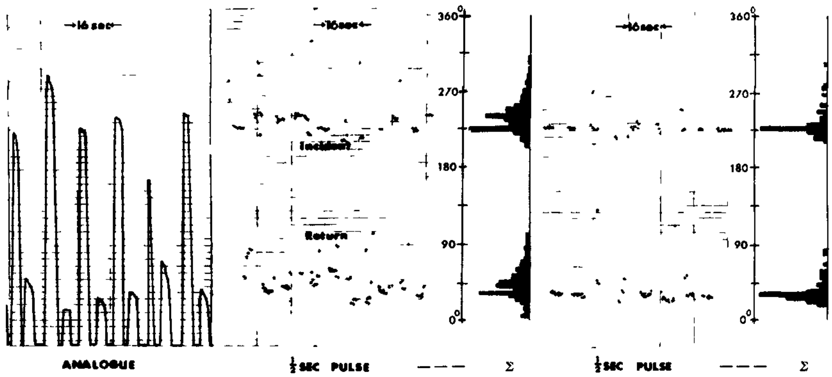


Fig. 2 Data Presentation

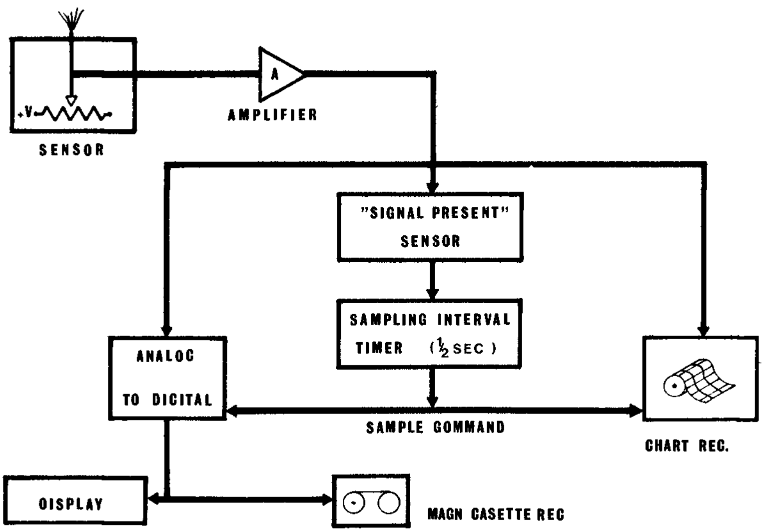


Fig. 3 Recording Technique

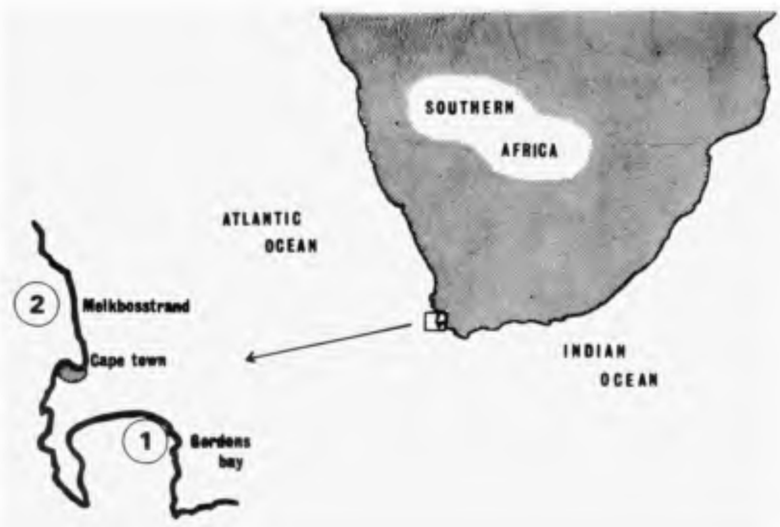


Fig. 4 DOSO Test Sites

After laboratory flume testing the sensor was installed at Station 1, orientated by a diver using a sighting compass held at the end of a string attached to the resistance brush. This technique was used for calibration checks before and after each recording and was checked later against a geodetically fixed base line on the seabed at Station 2. Results of the two orientation techniques were identical within sighting accuracy of 1° azimuth.

After a series of repeatability tests at Station 1 which produced very satisfactory results, a directional check was made in 6,5m water for a significant wave of 0,7m amplitude and 14 sec period. By varying the lever arm length of the resistance brush the sensitivity of the sensor can be varied. For this test contact velocity was set at 0,1 m/sec. Wave fronts traced from an aerial photograph are shown as dotted lines in fig. 5. The incident spectrum is on the righthand side of the degree circle and the orthogonal to the wave front passing through the recording position is shown as an arrow. Because of the absence of any noteworthy steady state currents during the test and because the wave orthogonals approximately parallel the direction of bed slope at the site, the incident and return spectra can be seen to be within about 1° of 180° apart.

Further tests were carried out in the Gordon's Bay area

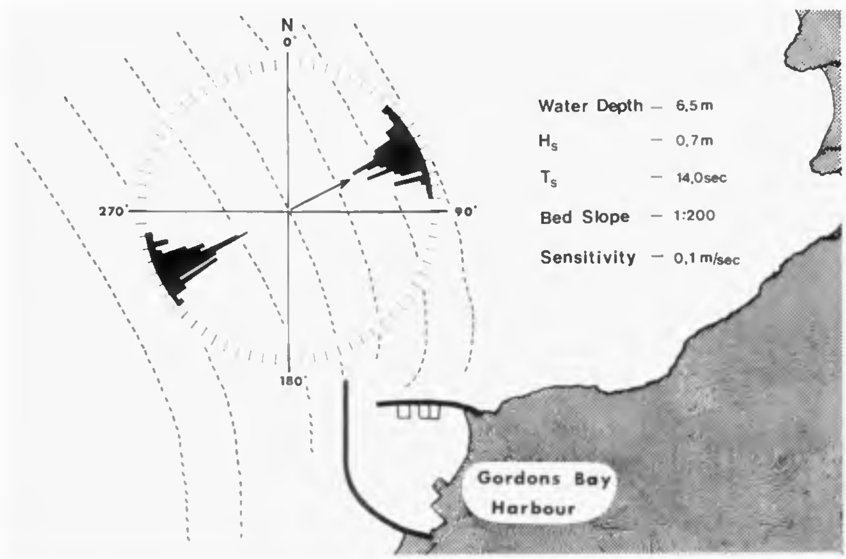


Fig. 5 DOSO Calibration - Station 1

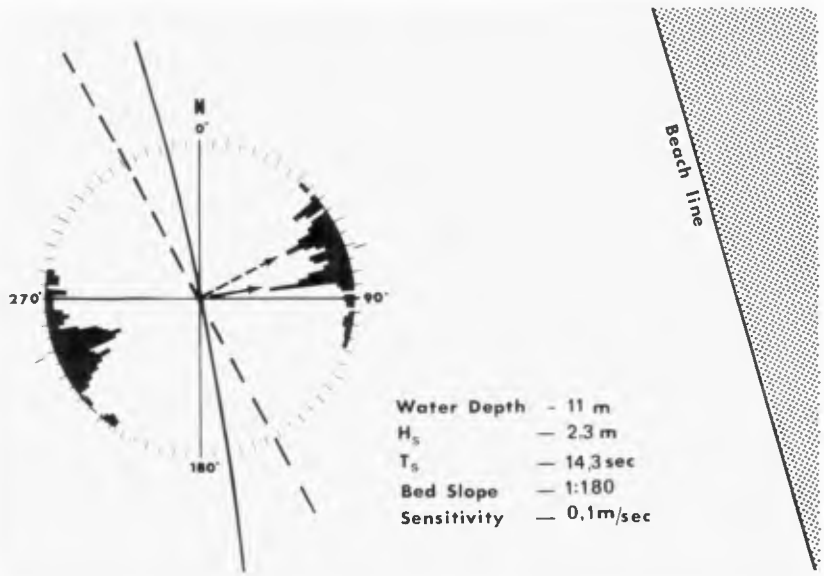


Fig. 6 DOSO Calibration - Station 2

at different water depths and a set of tables was then drawn up indicating approximate minimum wave heights and periods which will be recorded for various gauge sensitivity values, and the unit has been tested down to 30m water depth where all waves greater than 0,65m amplitude with a 12 sec average period registered on the recorder. The width of the spectrum in this case was a mere 6°.

Attention was then turned to Station 2, which is, as mentioned above, exposed to wider deepsea spectra and current effects. Sensitivity of the gauge was changed to 0,3 m/sec contact velocity which is the order of the maximum longshore current velocities measured at the site. In this way background clutter would hopefully be removed from the recording and as only the higher velocity component of oscillatory motion would be recorded, the resultant vector of wave and current velocities combined would be less influenced by the longshore current component. The gauge was installed in 11m of water about 1km offshore and fig. 6 shows a double wave front traced from aerial photographs superimposed on the incident and return histograms. Orthogonals to the wave fronts are again shown and coincide with the incident peaks. The return spectrum can again be seen to be a subdued version of the incident spectrum. This same record is shown on the lower half of fig. 7 with a Station 1 record above for comparison purposes.

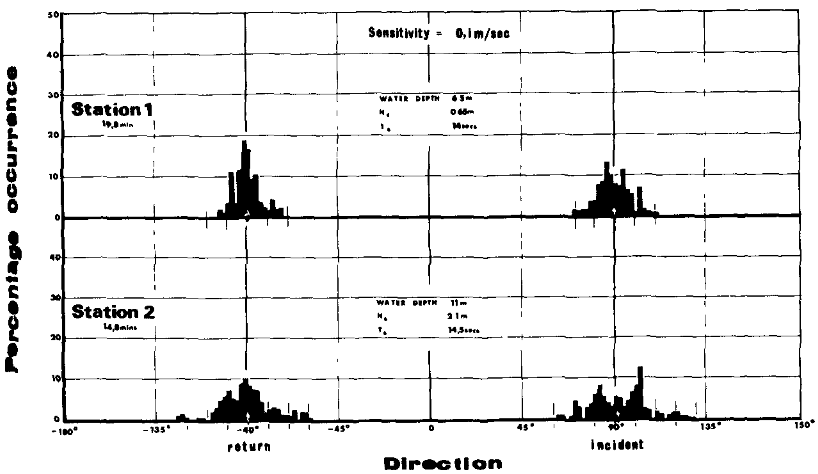
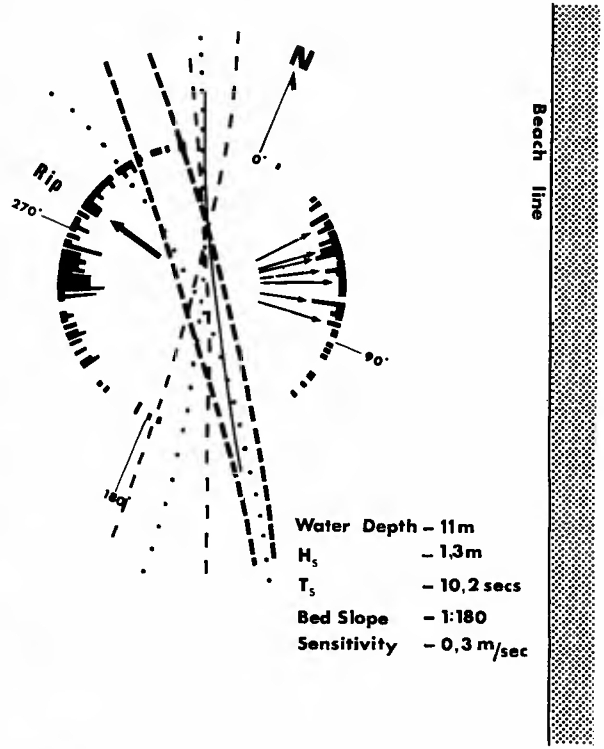


Fig. 7 Comparison of Direction Spectra from the two test sites



a) Aerial Photo Test Site

b) Wave Traces and Direction Histograms

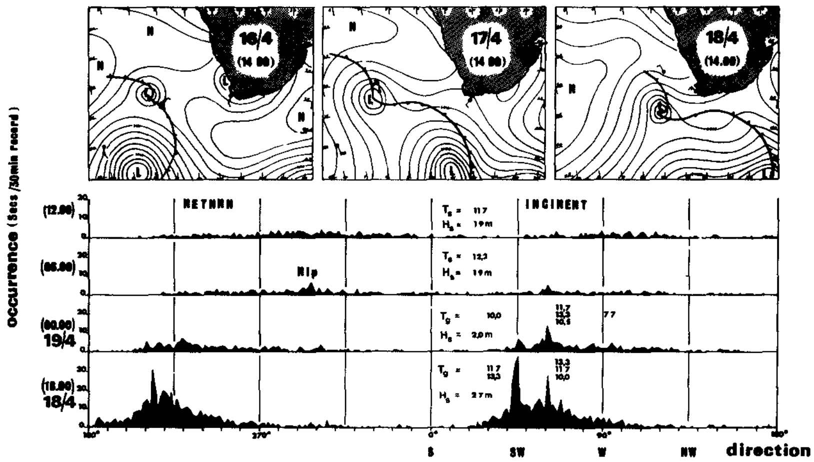
Fig. 8 Calibration during Complex Wave and Current Conditions

To investigate the effects of rip currents on records, a survey was made during very mixed sea conditions following a storm. Fig. 8(a) is an aerial photograph of Station 2 showing the DOSO position 1km offshore, and a large rip current with an estimated average velocity of about 0,3 m/sec passing through the DOSO position. A series of 18 aerial photographs taken over a ten-minute period were used to try to reproduce the full width of the directional spectrum and traces from the photographs, along with attendant orthogonal arrows, are shown superimposed on the DOSO histograms in fig. 8(b). It can be seen that the return histogram on the left does not reflect the directional spectrum at all and the effect of the rip current is clearly noticeable.

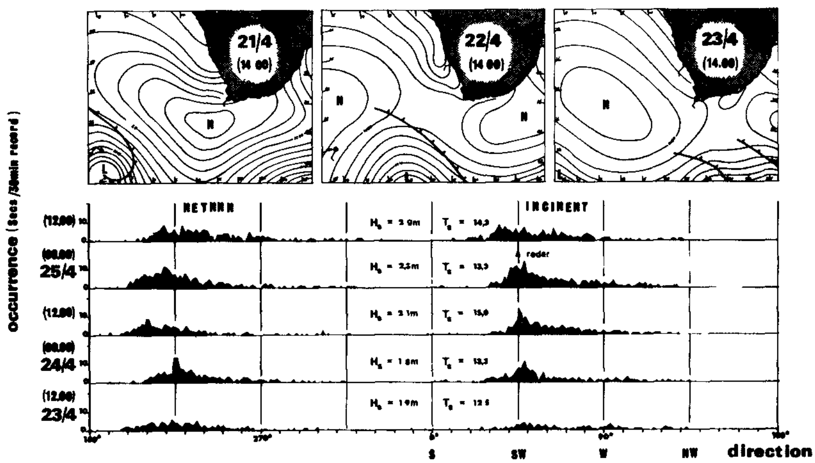
To carry the study one step further, several weather systems were analysed in conjunction with DOSO records. Fig. 9(a) shows in the top lefthand square a double low-pressure system developing to the south-west on the 16th of the month. On the 17th the southerly low had migrated eastwards until it disappeared to the east on the 18th. The northerly low-pressure system remained stationary on the 17th and approached Station 2 from the west on the 18th. The direction spectra plotted at 6-hourly intervals are shown not as percentage occurrence here but as total time recorded over a 30 min period. Incident spectra are again on the right. Recording resolution was 1,5°. Degrees of direction on the horizontal axis reflect the actual recorded direction of water motion; the capital letters below show these directions in terms of source direction of the swell. Spectral analysis of wave height records measured separately produced component frequencies which could be related to the group periods read off the DOSO records. Reading the histograms from the bottom upwards, the large south-westerly peak at 18.00 on the 18th generated by the southerly low-pressure system can be seen to decay at 00.00 on the 19th and disappear altogether shortly afterwards at 06.00. The west/south-westerly peak, i.e., the one on the right, remained longer till 06.00 on the 19th and then degenerated into a mixed westerly sea as the front approached the coast. Rip currents can be seen at 06.00 on the 19th. Significant height ranged from 2,7m to 1,9m during this period and wave periods were from 10 to 13 seconds.

Fig. 9(b) shows the development and decay of a single south-westerly low-pressure system passing eastwards, reflected once again by a two-day delay in records. The histograms at 12-hour intervals indicate a slight drift of about 5° to south as the front passes, with once again a degeneration into a wide band at 12.00 on the 25th. A shore-based radar sighting of wave direction on the morning of the 25th is shown arrowed. Note the variations in direction of the return spectra as opposed to the relative constancy of the incident spectra. Significant wave heights varied from 1,9m to 2,3m, periods from 12 to 15 sec.

As an indicator of sediment transport patterns in the



a) Double System



b) Single System

Fig. 9 Wave Direction Spectra at Station 2 related to Weather Systems near-shore zone, the sensitivity of the gauge can be set at the predicted entrainment velocity of the average sediment particle size at a site. In this case, for illustration purposes the gauge was already set at 0,3 m/sec contact velocity. This could correspond to the linear flow entrainment velocity of say a particle of about 0,8mm diameter. By plotting directly the actual direction occurrence data from the DOSO in arbitrary time units, one can draw an approximate vector history at a point of sediment transport patterns - fig. 10. The beach is shown here merely for

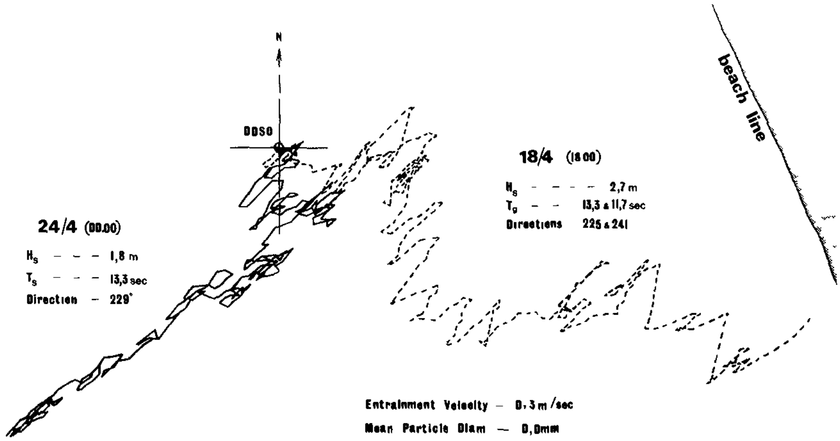


Fig. 10 Representation of littoral transport from DOSO recordings

reference purposes, the scale is meaningless. One has incorrectly assumed that the velocities acting on the sediment are constant above the threshold velocity, thus the picture indicates merely a trend, but is nevertheless an easily obtainable control for, say, sediment tracking operations. The examples here, originating at the DOSO point, are extracts from the spectra in the two previous diagrams - the double-peaked system is on the right and the single system on the left.

CONCLUSION

There is a need for a simple and reliable means of measuring the direction of waves approaching a coastline. Within the limitations described above, the technique proposed appears to fulfil this need by providing the engineer with an instrument which is simple and easy to use and which has produced results which can be directly understood and interpreted in terms of the dominant swell affecting coastal engineering works.

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