Open Ocean Tide Gauges

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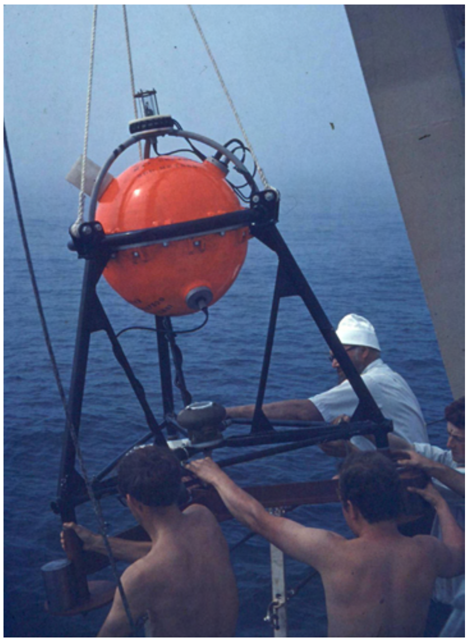
In the late 1960s David Cartwright's work on the theory of oceanic tides had reached the point at which there was a need for tidal measurements from the open sea. Continuous measurements have been made using shore-based tide gauges over many years. However, the shelf seas around the UK are extensive and relatively shallow and the non-linearity inherent in shallow water tide propagation leads to substantial distortion of the deep water tide at the coast. This, and susceptibility to local influences, renders data from shore based gauges of limited relevance in the study of oceanic tides. So it was decided to develop a seabed hydrostatic pressure-recording gauge which could be deployed for minimum periods of 29 days around the edge of the continental shelf. (This length of record is the minimum needed to provide adequate resolution of principal solar and lunar constituents in the tidal spectrum).

The prototype instrument was constructed and deployed in 1969. There followed a series of deployments round the shelf edge – and one on Rockall Bank. In 1973 the formation of IOS led to the concentration of UK tide research at Bidston on Merseyside.

In following years the team at Bidston built on the experience gained at NIO, making use of advances in microprocessor and data storage technology to develop successful deep ocean gauges with greatly increased endurance and capable of recording not only deep-sea tides but also long-term changes in ocean bottom pressure.

Shelf edge tide gauge deployments 1969-1973



First deployment of the prototype tide gauge in the Hurd Deep in the English Channel, July 1969.

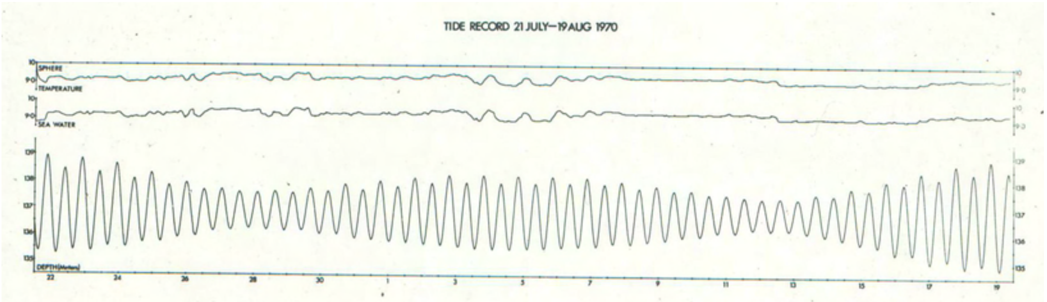
Background and technical issues

In 1968 no instrument suitable for use on the continental shelf was available elsewhere, although Frank Snodgrass at Scripps Institution in the USA had recently tested a gauge intended for use at oceanic depths and developments were underway also in France by Marc Eyries. The NIO development was initiated by Tom Tucker with a view to providing an instrument which would measure the tidal pressure range at the shelf edge to within ~ 1%. New arrivals at NIO, Peter Collar, Bob Spencer and, later, Pat Gwilliam, designed and constructed the measurement systems, while Dennis Gaunt, assisted by Dave Grohmann, was responsible for the mechanical design and deployment and recovery techniques. Deployment and recovery of the instrument, usually in water depths of around 200 metres, relied on the newly developed NIO **acoustic command system** for seabed location. It also provided the means to shed a heavy ballast frame, enabling the, then, positively buoyant capsule to rise on command to the sea surface at the end of the deployment.

There were essentially two problems to solve. The first was to select a pressure sensor with appropriate stability over the approximately one month deployment period, the second was to find a suitable data storage system. The pressure sensor chosen was one that had originally been designed by NIO for shore-based wave recording. It used the flexure of a beryllium-copper encastre diaphragm under pressure to vary the gap of a parallel-plate tuning capacitor in an oscillator circuit. The output frequency of the oscillator varied from ~60kHz at atmospheric pressure to ~105kHz at 200 metres depth. The average frequency measured in each successive 890 second interval was recorded on a commercially manufactured tape recorder (made by

Normalair Garrett – an offshoot of Westland Helicopters) together with time and temperature measurements. The averaging provided adequate suppression of any residual pressure fluctuations resulting from longer period surface waves. Temperature was also recorded, together with a coarse 2 hour 'sawtooth' time signal derived from a potentiometer driven by a mechanical clock. This was to allow any missing scans to be identified in the tidal record. Fortunately this proved to be a rare occurrence. The entire system was housed in a 0.56 m. diameter aluminium sphere of wall thickness 0.0127 m. mounted in a tubular frame.

Data storage and energy consumption presented particular challenges in the early instruments since it was necessary to power the timing and measurement systems continuously. Integrated semiconductor technology of the time was too power hungry to allow its use and low power CMOS technology was barely in its infancy. To minimise power requirements a relatively low frequency (102.4 kHz) was chosen for the master timing oscillator. Incorporated in a Meacham bridge configuration this allowed division by the newly available 10-stage CMOS binary divider. Further division to achieve the 15 minute sampling period was made using decade dividers. In the first two or three instruments discrete transistor circuits were designed for this purpose, before CMOS decade divider chips became available. The data storage requirement was also at the limit of contemporary capability. But, by using mercury oxide batteries (now banned), and with careful attention to design, it proved possible to achieve tide recording of a month's duration, with a small margin to spare.



Early records obtained using the capacitance plate transducer, when filtered to remove tides, exhibited an unrealistic drift equivalent to depth change of several centimetres per week. Low power sensors using commercially available strain gauges were then **developed** at NIO and these resulted in greatly reduced instrumental drift, to the point where the tide gauge could be used with confidence to measure seabed pressure fluctuations with periodicity of up to two or three days. The availability of quartz pressure transducers in later years permitted accurate measurement of much longer term changes.

When NIO became the Institute of Oceanographic Sciences in 1973 the development and operation of offshore tide recorders transferred to the Bidston Laboratory on the Wirral, to which Bob Spencer moved. The story of subsequent developments is told **here**. This has resulted in the collection of **large numbers of records** that have improved our ability to predict oceanic tides and also more recently to study long term changes in ocean circulation

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