A Tension Recorder for Deep-sea Dredging and Coring[1]

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The use of a tension meter or dynamometer for deep-sea dredging and coring is common practice on oceanographic vessels (Sigsbee 1880: 159–160, Thomson and Murray 1885: 61–63, Soule 1949: 49–50, Kullenberg 1955). However, in deep water, variations in wire tension that indicate bottom contact are frequently masked by the "background" of tension fluctuations due to the ship's motion. Even in moderate seas, the level of this background is often higher than the significant signal. Changes in tension due to the ship's motion, when plotted against time, produce a sinusoidal wave varying in amplitude but having a fairly uniform period. Since changes in tension due to bottom contact are characterized by an irregular wave form when plotted against time, a simple means is available for distinguishing these signals, if they are recorded.

Accordingly, a tension-recording system was built to take advantage of this effect. It was designed to be as simple and rugged as possible but with a short response time for differentiating the various signals. For this reason the hydraulic and hydraulic-electric tension-measuring devices commonly found on oceanographic winches were not considered. The hysteresis and damping inherent in many of these systems would probably obscure some of the pertinent signals.

Fig. 1 shows a block diagram of the tension recorder and its relation to the winching gear. The tension sensor (z) is a Baldwin-Lima-Hamilton 20,000 lb. capacity, type U1 load cell, waterproofed for exterior use. An ordinary 6-volt storage battery (y) provides the input voltage for the load cell. Output of the sensor is about 2 mv per input volt, full scale, and is linear over the entire range. A Leeds and Northrup Speedomax H Recorder (x) constitutes the read-out. This instrument is used with a 0 to 10 mv range and alternative chart speeds of 1 and 6 in./min. It is desirable that each tension change due to the ship's motion be resolved on the chart. Hence, the period of the ship's roll should determine the selection of the slower chart speed. The recorder is mounted

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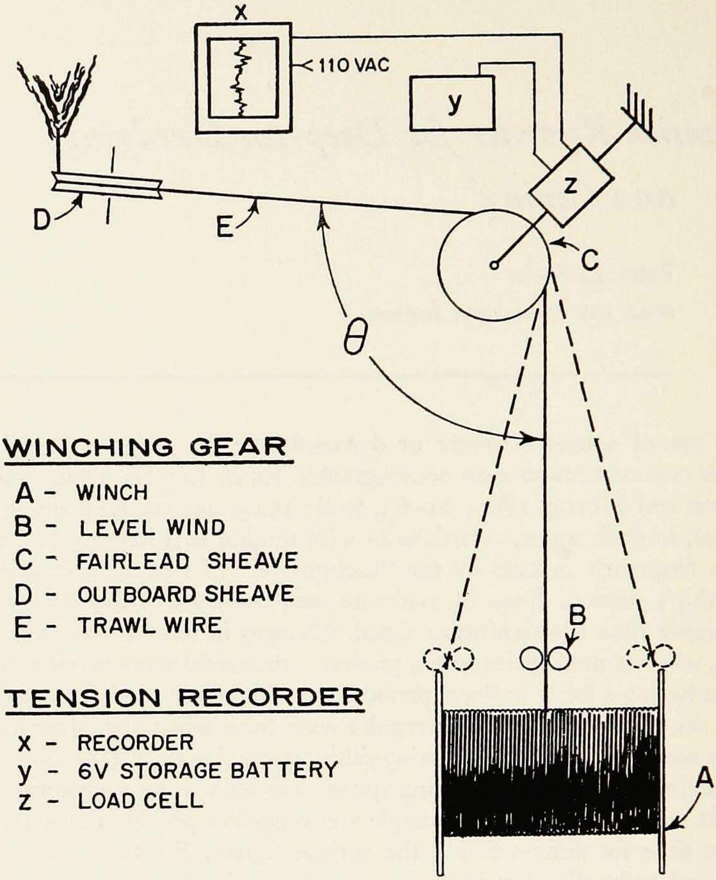

Figure 1. Block diagram of the tension recorder and its relation to the winching gear.

on deck in a weatherproof case near the winch controls. The three units of the system are interconnected with waterproof cable and connectors.

The system is calibrated for the angle θ formed by the trawl wire between level wind (B), fairlead (C), and outboard sheave (D), as shown in Fig. 1. As this angle changes with the level winding of the wire on or off the winch, an apparent change in tension is produced. This is discernible on the record as a low-frequency sinusoidal oscillation of the trace that can easily be averaged out. About one-half cycle appears on the first five minutes of the record shown in Fig. 3. On the installation employed, this apparent change results in an error ranging from $+9\%$ to -9% of the calibration for a given tension. In planning the system discussed here, the changes in tension were considered more relevant than accurate measurements of absolute tension. Two fixed fairleads should be mounted on either side of sheave (C) if greater absolute accuracy is required.

Fig. 2, part of a tension record obtained during rock dredging at a depth of 3.5 km, illustrates the characteristic variations in tension. The portion of the record marked *a* shows tension changes due to ship motion in sea state 1 and swell 2. At point *x* the dredge began dragging on rocky bottom, and although the amplitude of the signal did not change appreciably, the part of the record marked *b*, characterized by a typically irregular wave form, indicates successful rock dredging.

Ideally, the time base of the tension recorder is keyed to that of the ship's echo-sounding equipment. This is useful if a long dredge traverse through a considerable depth range is made, since it allows a closer approximation of the location of rock outcrops. When used in conjunction with a pinger on the trawl wire near the dredge (Nalwalk et al. 1962), marked tension changes can often be correlated with a sudden increase in distance between pinger and bottom as the wire straightens under tension. Usually this serves to determine the depth of an outcrop to within $\pm 10\%$. Discussion of a more complex instrumental method for precise locating of deep-towed instruments is presented by Baxter (1964).

The tension recorder has proved very useful for piston coring as well, both as a back-up if the pinger should fail, and as contributor of additional information about the coring process. The record shown in Fig. 3 presents the tension record before, during, and after bottom penetration by a 12-m piston corer at a depth of 4.2 km. When the core rig was a few tens of meters off the bottom, the recorder chart speed was increased from 1 in./min. to 6 in./min. (point o). The corer, when 3 m off the bottom (point *x*), was released by means of a pilot weight. When three seconds had elapsed, the corer had penetrated the bottom and had come to rest (point *y*). The rate of deceleration should permit an approximate estimate of the shear strength of the sediment cored. The sudden change in slope, signaling release of the corer (*x*), was noted on deck before the sound pulse from the pinger indicating the same event arrived at the surface. This is because the pulse initiated by the sudden release of a heavy weight from the end of a long wire propagates faster in the denser medium of the wire than does a sound pulse in water. The increase in tension (*z*) indicates friction of the sediment on the outside of the core tube as the latter was withdrawn from the bottom. At (*p*) the chart speed of the recorder was again decreased to conserve paper.

The system described here proved useful and reliable during an extensive ten-week sediment-sampling program aboard the Woods Hole Oceanographic Institution's R. V. Chain.

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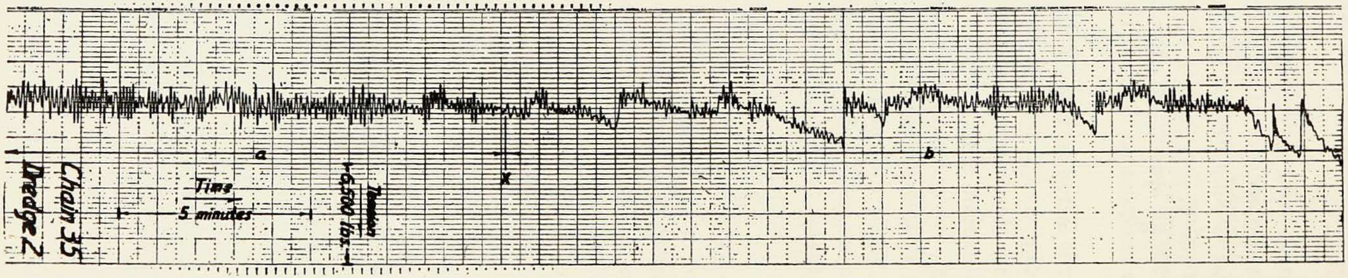

Figure 2. Part of a tension record obtained during rock dredging at a depth of 3.5 km. Letters refer to text.

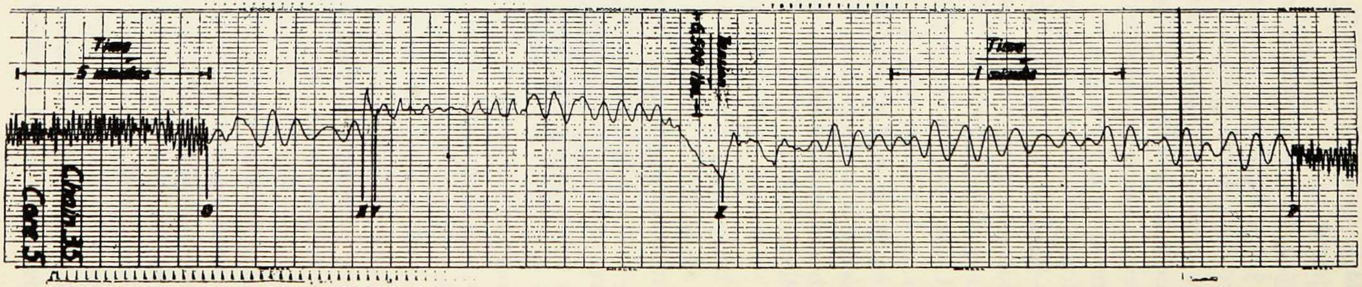

Figure 3. Tension record obtained before, during, and after bottom penetration by a 12-m piston corer at a depth of 4.2 km. Letters refer to text.

who made valuable suggestions on its installation on the ship. Drs. K. O. Emery and J. B. Hersey reviewed the manuscript. The work was supported by The National Science Foundation under grants G-12178 and GP1599 with the Woods Hole Oceanographic Institution. Ship time for the testing of the device was provided, as a part of the Equalant program, by the U. S. Office of Naval Research under contract NONR-2196 and by the U. S. Atomic Energy Commission under contract AT(30-1)-3010.

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The Jet Net, a New High-speed Plankton Sampler

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The Jet Net was developed to overcome some of the operational problems associated with conventional plankton-collecting gear and to improve upon the hydrodynamic performance of existing high-speed samplers. A device was wanted that (i) could be towed at cruising speeds, (ii) would produce a minimum of specimen damage, and (iii) would be small and easy to handle.

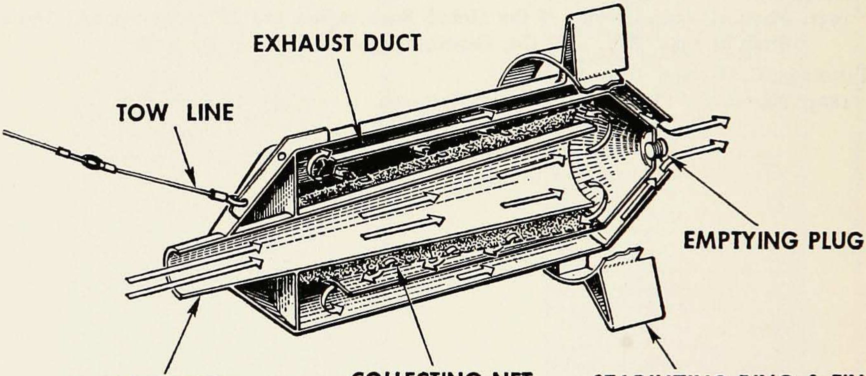

Figure 1. Cutaway of Jet Net showing construction and flow pattern of water.

The Jet Net (Fig. 1) is an encased net like the Gulf III (Gehringer 1952), but differs in that it slows the rate of flow through the net by gradually increasing the cross section of the water column entering the sampler. Energy losses from turbulent flow inside the sampler are minimized by keeping the included wall angle of the intake pipe under 7° and that of the net chamber under 3.5°. This arrangement improves the acceptance of water by the intake port while the low speed of flow in the net chamber lessens specimen damage and increases the net's filtering efficiency.

Water enters the sampler through the intake pipe (Fig. 1), which doubles in diameter from front to rear, thereby reducing the speed of the water leaving the pipe to one-quarter of the intake velocity. The water then reverses direction in the space behind the intake pipe and enters the net chamber, where it is slowed further by the expanding cross section of the chamber. The mean calculated velocity in the net chamber is 6.4 times less than the speed of the sampler through the water. Thus, at a towing speed of 5.2 m/sec. (10 knots), water flow in the net chamber is only 0.8 m/sec. (1.6 knots). After the water has passed through the net, it flows into a space between the net chamber and the external wall of the sampler, and leaves through an opening in the rear of the device. Again, to reduce energy losses, the intake and exhaust openings are sized so that water enters and leaves the sampler at essentially the same speed that the sampler travels through the water.

The folded construction used in the Jet Net has permitted a substantial reduction in the length of the sampler. It is half the size of the Gulf III and much easier to launch and retrieve. A linear arrangement of the different sections would have made the sampler twice as long. The sampler is constructed of fiber glass and weighs 50.5 kg. The weight could be halved by building it out of titanium and stainless steel. The dimensions of this device are given in Table I.

TABLE I. DIMENSIONS OF THE JET NET.

Over-all Length	125.0 cm	Length of Net Chamber	66.5 cm
Outer Diameter of Body	47.0 cm	Diameter of Net, Rear	36.0 cm
Cross-Sectional Area of Body	1730.0 cm^2	Diameter of Net, Front	28.0 cm
Diameter of Intake Pipe, Front	12.0 cm	Length of Net	66.5 cm
Diameter of Intake Pipe, Rear	24.0 cm	Diameter of Stabilizing Ring	56.0 cm
Length of Intake Pipe	102.5 cm	Height of Stabilizing Fins	15.5 cm
Diameter of Net Chamber	36.0 cm		

The Jet Net appears to fish quite efficiently. At a towing speed of 2.7 m/sec. (5.5 knots), its plankton catches are equal in quantity to those taken by a Gulf III at the same speed and for the same length of tow, even though its intake opening is about one-quarter of the cross-sectional area of the Gulf III's intake. (The 20 cm or 8 in. intake-opening nose cone was used on the Gulf III during these comparative tests.) At a speed of 4.4 m/sec. (8.5 knots), the Jet Net catches more plankton for the same length of tow than the Gulf III does at this speed. These surprising results are explained in part by the fact that the Gulf III apparently does not handle water efficiently at high speeds; the flow meter in the rear of this sampler makes substantially fewer revolutions per unit distance at high speeds than at low speeds, which would indicate that it is not accepting as much water in the former case. No flow meter was used with the Jet Net during these tests, since it was not equipped for mounting such a device. However, the fact that it caught more plankton, both large and small, than the Gulf III at high speed, with a smaller intake opening, would indicate that it is handling the flow of water much more efficiently. The design concept of minimizing turbulent flow and of reducing filtration speeds in the net chamber is probably responsible for the higher catching efficiency of the Jet Net. Another factor that may contribute to these catch differences is that in the Gulf III only a portion of the net filters water at any given time during the towing period. This is demonstrated by the fact that plankton is gradually deposited on the rear sections of the net first. In the case of the Jet Net, plankton is deposited evenly over the whole surface of the net, indicating that all of the net is filtering water.

A nitex netting, having approximately 16 meshes per centimeter and an opening of 0.44 mm between meshes, was used in the Jet Net during the comparative tests conducted with the Gulf III. Despite the fact that the Gulf III was equipped with a slightly finer meshed net having an opening of 0.38 mm between meshes, the Jet Net consistently retained many more of the smaller plankters, particularly at the higher speeds. This was probably due to the low filtration speeds in the net chamber. The Gulf III samples showed considerable evidence of specimen damage from flow forces at the net surface, and it appears that many of the smaller organisms were extruded through the net. The condition of the plankton collected by the Jet Net was better in all cases than that of the Gulf III. Fish larvae are excellent indicators of specimen damage, and those taken with the Jet Net were not badly skinned, as in the case of the Gulf III; even at the highest towing speeds a large percentage of the larvae retained their eyes. These last-mentioned structures are very susceptible to damage and are soon lost if there is any attrition in the net from flow forces. Other delicate organisms, such as small medusae and oikopleurans, were taken in much better condition in the Jet Net; also, copepods and euphausiids showed less appendage damage.

The plankton catch is removed from the Jet Net without taking it apart. Five ports in the front part of the sampler body permit the net to be washed down with a spray of water from a hose. These ports are covered with a metal band when the device is in use. The accumulated plankton is emptied from the sampler by removing a threaded plug from the after end and allowing the contents to pour out into a bucket.

The net can be replaced by removing five bolts from the forward part of the body. This allows the after section which holds the net to be removed from the forward section of the sampler. The whole operation is very simple and can be done in less than five minutes.

The Jet Net is towed from a point just behind the juncture of the intake pipe and the main body of the sampler. It has been tested and visually observed to tow stably at speeds up to 5.4 m/sec. (10.5 knots), using either a lead weight or a small Isaacs-Kidd kite depressor to attain depth. The towing characteristics of this sampler are very similar to those of the Gulf III. When used with a small Isaacs-Kidd kite depressor, it requires essentially the same amount of wire as a Gulf III using this depressor to reach an equal depth. To attain a depth of 50 m at a speed of 2.7 m/sec. (5.5 knots) requires approximately 225 m of wire when using 11-mm diameter wire. To reach the same depth at a speed of 4.4 m/sec. (8.5 knots) requires approximately 360 m of the same wire. The greatest difference in the towing characteristics of the Jet Net and the Gulf III is found in the amount of drag produced. The drag of the Jet Net is, depending on speed, 30% to 50% less than that of the Gulf III. Because of this low drag, the Jet Net can be operated safely from hydrographic wire.

The advantages of this design over conventional designs are that the device allows sampling to be conducted at high speeds without greatly increasing specimen damage. The use of hydrodynamic principles has permitted an efficient flow of water through the sampler and made it possible to catch a larger plankton sample with a smaller, more easily handled device. Preliminary field testing of the Jet Net with the Gulf III and Bary High-speed Plankton Catcher (Bary et al. 1958) has indicated that the Jet Net catches as much or more plankton in better condition for the same length of tow and speed. The results of this comparative study will appear in a paper by Clarke, Bary, and Ahlstrom. High towing speeds permit substantial savings in ship time. If the Jet Net were used instead of the one-meter ring net, it would be possible to conduct sampling while cruising between stations, thus making use of time that would be lost otherwise. For surveys, there is an additional advantage in that this device takes its sample over a greater distance, thereby reducing the effects of plankton patchiness. The better condition of the specimens taken with this device when compared with other high-speed samplers offers obvious advantages to programs concerned with distributional studies of larval fish and other delicate planktonic organisms.

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