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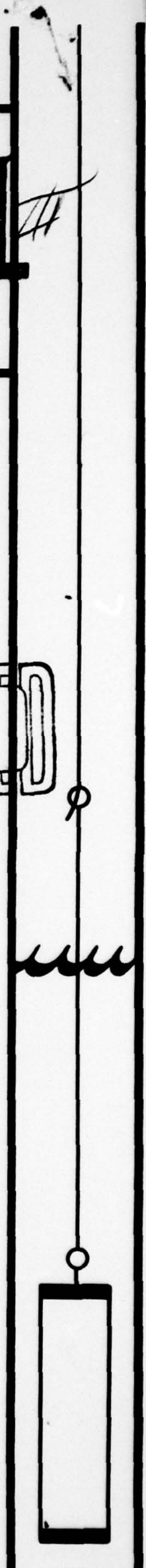
EXPOSURE LEVEL

vol. 7 no. 2 a newsletter for ocean technologists

The Effects Of Fouling On Electromagnetic Current Meters



Introduction

Conventional Savonius rotor and propeller type ocean current meters, when exposed to biologically active shallow water environments, often foul, in a matter of weeks, to the point where propeller or rotor movement is impeded and the worth of current speed data becomes questionable. Under such conditions, little long-term data can be obtained without frequent cleanings and/or reapplication of antifouling material.

The inaccuracies of ocean current data caused by fouling, along with the other numerous problems resulting from the immersion of mechanical devices under the sea, led to the development of current meters with no moving parts. Two major designs of these meters have emerged. The acoustic variety, which can be based on a number of different sound propagation techniques, is only now beginning to be produced in any numbers. The electromagnetic current meter (EMCM), on the other hand, is enjoying wide usage, and is often thought to be less prone to fouling problems than conventional meters (Thorpe, et al, 1973; NOIC, 1974).

Despite the fact that electromagnetic current meters have been in commercial production for a number of years, there is little information available relating the fouling of specific EM sensors to reduction in accuracy.

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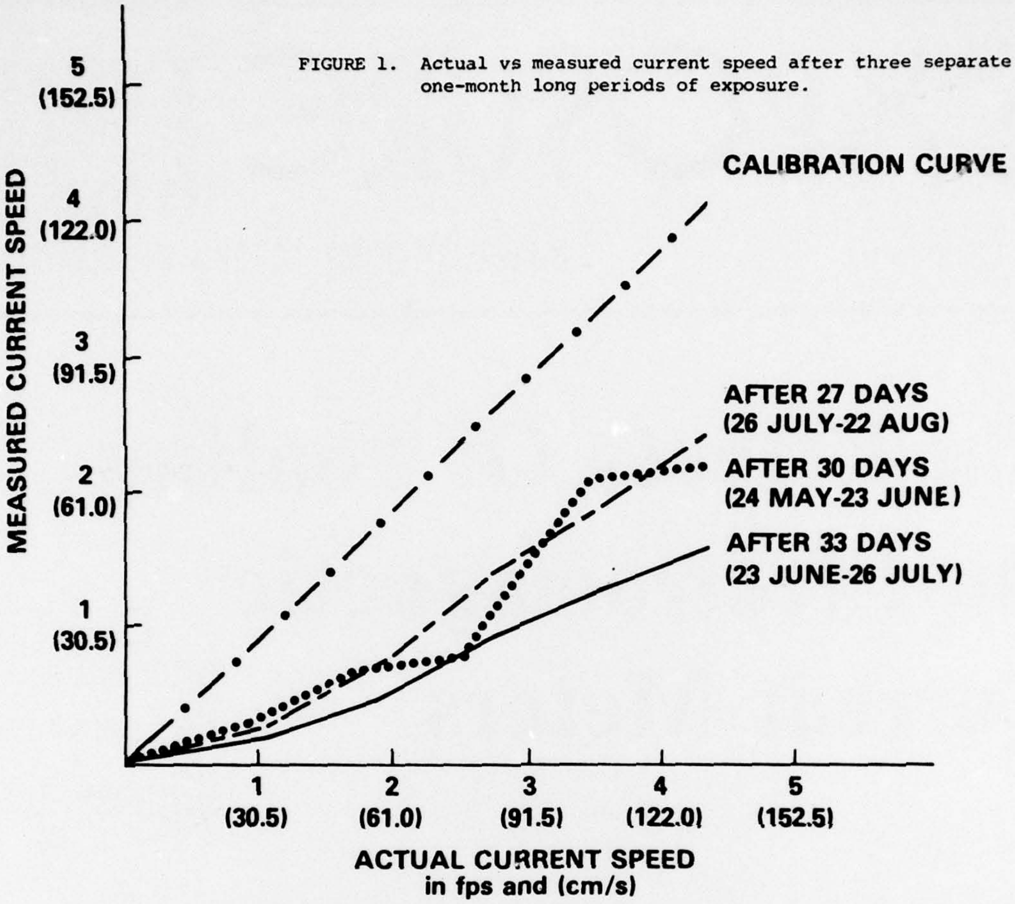

FIGURE 1. Actual vs measured current speed after three separate one-month long periods of exposure.

Methods

An EMCM* was obtained and then calibrated at the United States Naval Academy's 120 ft. (36.6 m) flow tank in Annapolis, Maryland (See Figures 1 and 2). Since each channel operates independently, it was decided to concentrate test efforts on only one channel. The y channel was selected because it came closest to meeting the published manufacturer's specifications. The decision to concentrate on one channel did not in any way adversely affect test results; in fact, it allowed more data points to be taken in the time available, and insured that sensor orientation was exactly the same for each flow tank test. The sensor was immersed near the mouth of the Severn River in Annapolis, MD, for exposure to fouling organisms. For reasons of both security and convenience, the sensor was suspended, free swinging, approximately 2 ft (.6 m) below the surface, underneath a pier laboratory. There was no exposure to direct sunlight at this location and currents are minimal (.25 fps - 7.6 cm/s). Periodically, after time intervals varying from 6 days to slightly over a month, the sensor was removed from its mooring and tested in the flow tank. After each one-month test period, the fouling organisms were removed, and the instrument was recalibrated. Recalibration curves showed excellent agreement with original calibration.

*Marsh-McBirney, model 711, current meter, manufactured in 1972, was used. Although sensor was not protected against fouling, a no-foul rubber covering is available for most models.

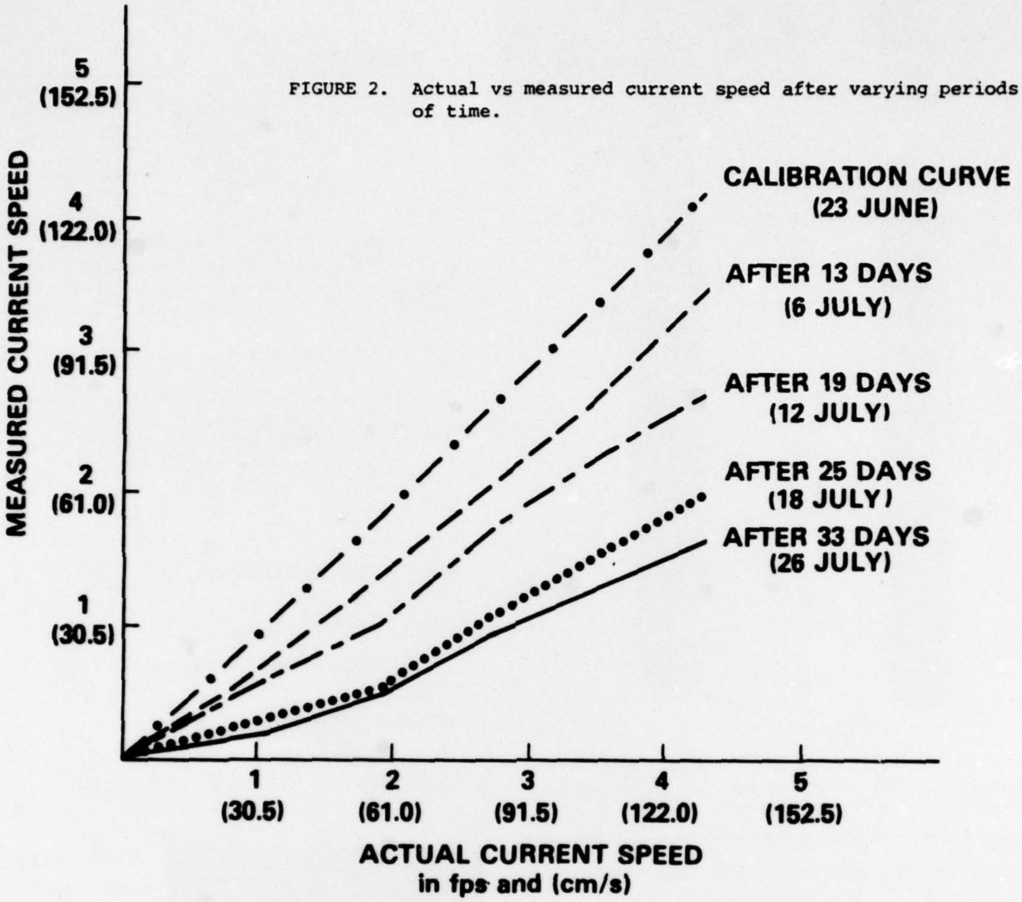

FIGURE 2. Actual vs measured current speed after varying periods of time.

Results

The dimensions and cylindrical shape of the probe and probe mounting gave rise to the phenomenon of alternate vortex shedding, which resulted in some rather large inaccuracies at speeds above 4.5 fps (137.2 cm/s). All test runs above this value were, therefore, disregarded in formulating test results.

The types of fouling organisms present on the probe were quite variable depending on the particular season of immersion. Barnacles were the prime offenders for the period 24 May to 23 June, while brown algae were predominant for the remainder of the tests. Bryozoa were quite abundant during the last period, 26 May to 22 August. All tests were run during the May-August period because, for the particular environment where the sensor was submerged, very little fouling occurs during the remainder of the year (Shaw, 1967). Figure 3 shows how the sensor looked unfouled and after it had been exposed to fouling organisms for 27 days (26 July to 22 August). No attempt was made to quantitatively determine the extent of fouling of the probe after any of the periods.

Figure 1 shows that large inaccuracies occurred after all three long periods of exposure. The differences in the three curves shown are probably due to the amount and type of organisms that were present during the period in question. Figure 2 clearly shows the increase in error of the meter as a function

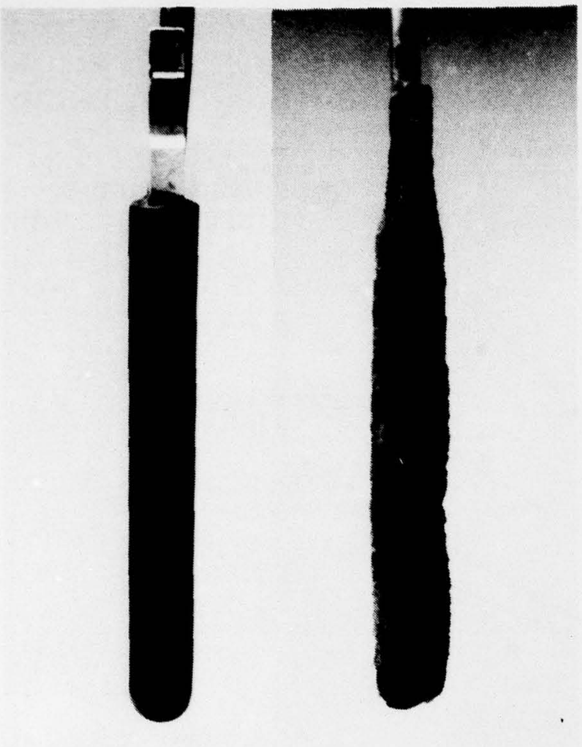

FIGURE 3. A comparison of the electromagnetic sensor before and after 27 days of exposure to fouling organisms.

of the amount of time of exposure of the sensor to the fouling environment. It is significant to note that errors of as high as 31 percent below true current speed can be noted after only 13 days of exposure.

Conclusions

As shown in Figures 1 and 2, unprotected sensors exposed for only a few days may exhibit errors of a magnitude sufficient to make measurements unacceptable for many purposes. Longer exposures can result in inaccuracies large enough to make data collected from fouled instruments completely useless. Any EMCM which will be deployed in a biologically active environment for more than a few hours must be equipped with an effective anti-fouling system which provides protection to the entire sensor as well as the electrodes themselves.

REFERENCES:

National Oceanographic Instrumentation Center (1974) Electromagnetic current meter evaluation. Technical Bulletin RN-1009, 11 pp.

Shaw, W. (1967) Seasonal fouling and oyster setting on asbestos plates in Broad Creek, Chesapeake Science, 8(4), 228-236.

Thorpe, S. A., Collins, E. P., and Gaunt, D. I. (1973) An electromagnetic current meter to measure turbulent fluctuations near the ocean floor. Deep Sea Research and Oceanic Abstracts, 20(10), 933-942.

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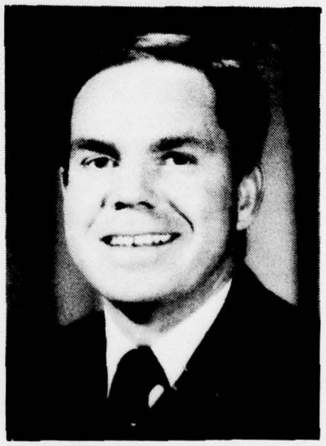

John Simpson received his undergraduate degree from Colgate University and his M.S. (Oceanography) from the Naval Postgraduate School in 1972. He is currently an instructor in the Oceanography Department of the U.S. Naval Academy. Prior to joining the department, he was stationed in Denmark as an exchange officer with the Royal Danish Navy, and as such was instrumental in setting up a marine data collection system to aid in the safe navigation of large ships through Danish waters. His next assignment will be with the staff of the Oceanographer of the Navy in Washington, D.C.

A Magnetodiode Rotor Sensor

As part of the development of the Davis-Weller Vector Measuring Current Meter (VMCM), the Sony MD230A* magnetodiode pair was selected as the rotor sensing element. There were many reasons for this choice. First, by using a magnetic sensor we could avoid the knotty problem of biological fouling attendant to optical systems. Second, the magnetodiode as a device offers small size, sturdy construction, and a reasonably high output level which is independent of rate of change of field. Third, the MD230A is a matched pair which can be wired to cancel the unacceptably large temperature coefficients of the individual diodes. The drawback of this device is that it draws a fair amount of current (1.5 mA at 6V) and still has a noticeable residual temperature coefficient. This meant that the sensor circuit had to be designed to operate in a power-up/power-down mode, and that sufficient testing had to be conducted to determine, with reasonable confidence, the effect of temperature variations on working sensors. This has been done, and today we are satisfied that these units will perform reliably.

Each rotor housing of the VMCM contains two magnetodiode pairs. Four magnets are mounted in a plastic carrier which turns with the propeller shaft. As the propeller turns, the varying magnetic field is sensed by the magnetodiodes, whose outputs are converted to logic levels which are then processed to determine rotation rate and direction.

Figure 1 depicts the circuitry used to convert the magnetodiode output to a CMOS-compatible logic level. This consists of a power-up circuit, bridge, comparator, and flip-flop storage buffer.

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*Available from Shigma, Inc., 2471 Bayshore, Suite 501, Palo Alto, CA., 94303, Tel. (415) 328-3351.

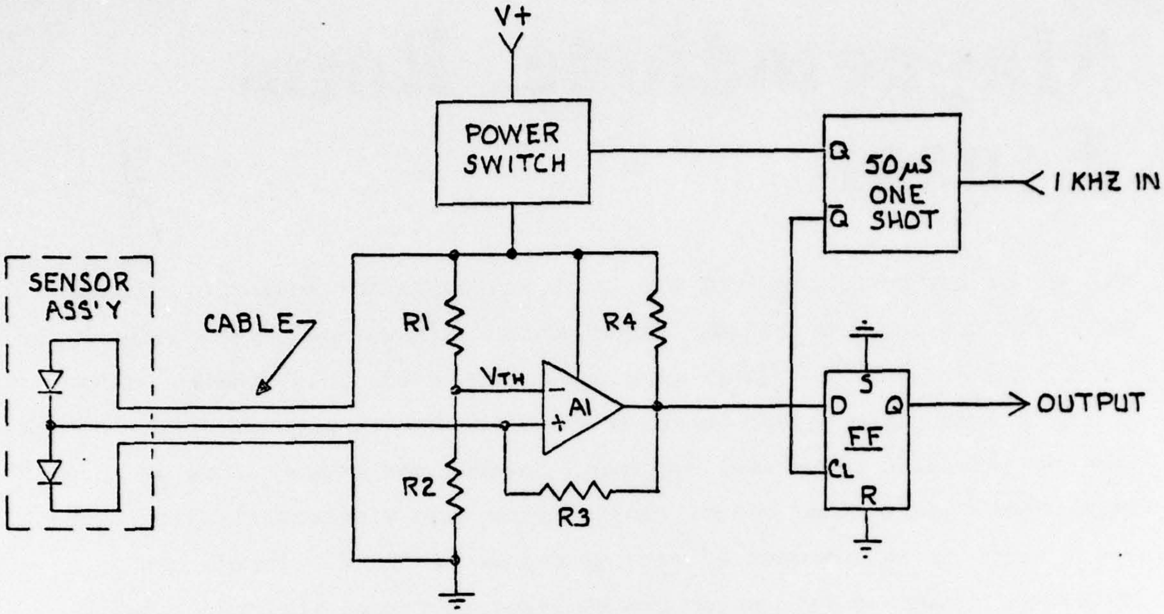

FIGURE 1.

Power-up is accomplished by triggering a 50 µs one shot which turns on a transistor power switch. The repetition rate (1 KHz for our application) is determined by the resolution required at the highest expected rotor speed. The 50 µs on-time was found empirically to be the minimum which would allow our cable/sensor combination to reliably come up to a stable level. The cable plays a part in this determination because its capacitance contributes significantly to the total turn-on delay. One fringe benefit of powering up and down in this fashion is that we can run the magnetodiodes at twice rated voltage without exceeding their maximum power dissipation rating, thereby approximately doubling the output voltage swing.

The bridge circuit consists of R1, R2 and the two magnetodiodes. R1 and R2 provide the threshold voltage (V_{TH}) against which the comparator makes its decision. Production variations in magnetodiode output require that V_{TH} be matched with its particular sensor, either by trimming R1 and R2 or by selecting the magnetodiodes. In the VMCM we use a combination of these two methods, grouping magnetodiodes in each meter by output, then settling V_{TH} to match this output.

The comparator circuit consists of A1 (1/4 of a LM339 quad comparator), R3 and R4. R3 provides positive feedback for noise rejection and comparator stability. R4 is a pull-up resistor for the open collector output of the comparator.

The output of the comparator is clocked into the storage flip-flop at the fall of the power-on pulse, which allows the circuit maximum time

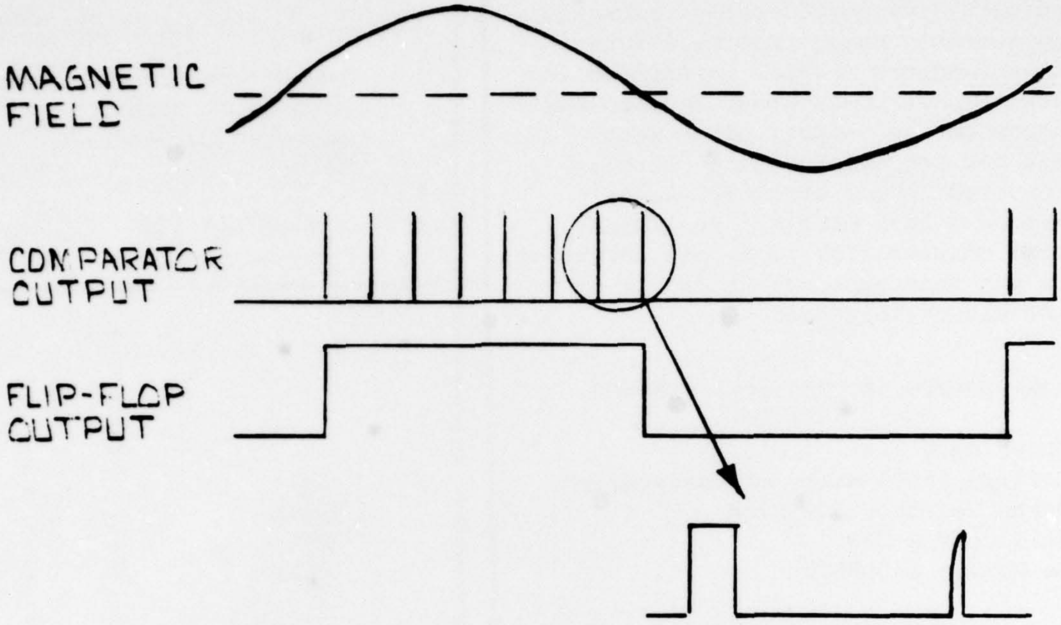

FIGURE 2.

to stabilize. It might seem that a race condition exists, but in fact the comparator output remains present for plenty of time after powering down.

So, in essence, we periodically sample the magnetodiode sensor, determine whether or not the magnetic field exceeds a certain value, and store the information. In principal, the flip-flop output produces one pulse-out for the passage of each magnet. This is illustrated in Figure 2, which shows the output for a constant rotor speed condition. The detail drawn for the comparator output underlines a fact one should be aware of. The thin pulse shown occurs when the comparator makes a decision very close to V_{TH}. In this condition a few millivolts noise could have resulted in a zero output. This is not a problem when the rotor is continuously turning, but if it is stalled or moving very slowly through the decision point, noise can produce alternating ones and zeroes at the flip-flop output. Careful design will minimize the rotational angle through which this will occur, but it cannot be entirely eliminated. This problem must be dealt with by the logic following the output; how it is done depends on the particular logic design.

To quantify things a bit, we get an output of approximately 0.9 V peak-to-peak from the magnetodiode using a Hitachi 90C90A# magnet (8200 Gauss) at a nominal spacing of 0.160 inch with a 12 V supply. When one takes into account diode production variations, temperature effects, and assembly tolerances, this output

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\# Available from Permag Corp.,
5441 W. 104th St., Los Angeles,
CA., 90045
Tel. (213) 776-5656.

gives a reasonable operational margin if the magnetodiode outputs are individually trimmed during instrument checkout and periodically rechecked. We recently began testing a system using magnets mounted in alternating directions. This about doubles the magnetodiode output, which much reduces the checkout and trimming required, while still leaving a larger safety margin. Preliminary test results look good, and we expect to put this improvement in all of our meters this year.

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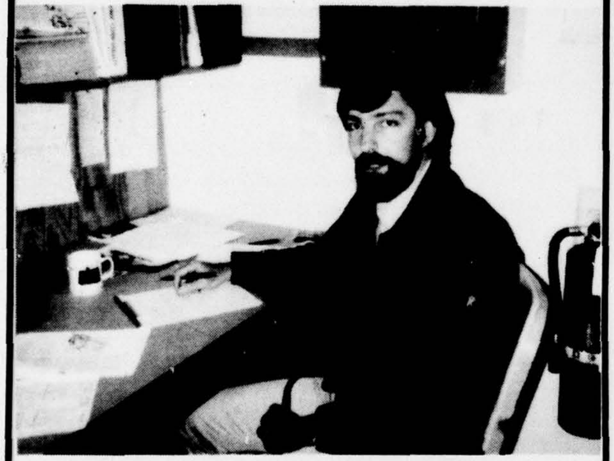

Mr. Wald received a B.S. degree in physics from the Riverside campus of the University of California in 1970. Since graduation, with the exception of working in private industry for a short time, in the field of air pollution monitoring equipment, he has been employed in the development of deepwater surface moorings, and coastal wave measurement equipment at Scripps Institution of Oceanography.

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