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An ultrasonic current meter

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Disadvantages with conventional current meters

Current meters that are based on rotating sensors (rotors, propellers) have several disadvantages. The most serious ones are:

- Low sensitivity (usually unreliable at currents smaller than about 5 cm/sec.
- Slow response (unable to detect rapid changes in current values).
- Poor directional sensitivity.
- High risk for instrument derangement from impurities and algae growth in the water.

To obtain better current measurements a team from the Norwegian Institute of Marine Research and Chr. Michelsen Institute - both in Bergen, Norway - has developed an ultrasonic current meter with no moving parts.

Principle of operation

Figure 1 shows the principle of operation. The sensor consists of two piezoelectric discs with a diameter of 10 mm and a resonant frequency of 3 MHz. The sensors are spaced 10-20 cm apart and emit short bursts of ultrasound towards each other 500-1000 times per second. If a current component with velocity v(x) flows in the direction of the sound, the sound propagandation time over the distance dx equals

$$\frac{dx}{c \pm v(x)}$$

where c is the velocity of sound in the water, and the $\pm$ sign depends on whether the sound moves with or against the current.
The transit time over the distance ℓ between the sensors will be (Assume $\frac{v(x)}{c} << 1$)

$$T = \int_0^{\ell} \frac{dx}{c \pm v(x)} = \tag{1}$$

$$= \frac{1}{c} \int_0^{\ell} (1 \pm \frac{v(x)}{c} \quad dx = \frac{\ell}{c} \pm \frac{1}{c^2} \int_0^{\ell} v(x)dx \tag{2}$$

$$T_1 - T_2 = \Delta T = \frac{2}{c^2} \int_0^{\ell} v(x)dx = \frac{2\ell}{c^2} \bar{v} \qquad (3)$$

The mean velocity over the sound path

$$\bar{v} = \frac{\Delta T \ c^2}{2\ell} \qquad (4)$$

In order to compensate for variations in the sound velocity, the sum of

$T_1 + T_2 \approx 2T_1 = \frac{2\ell}{c}$ can be measured.

This gives

$$\bar{v} = \frac{\Delta T \quad \ell^2}{2\ell \ T_1{}^2} = \frac{\ell}{2T_1{}^2} \ \Delta T \qquad (5)$$

which shows that current can be measured completely independent of the sound transmission properties of the water.

To obtain an output signal T_1 and T_2 are converted to analogue voltages and their difference is amplified. Use of high speed logic sircuits permits measurements of time differences in the subnanosecond range allowing a recording of currents down to 1 mm/sec. to be easily measured. As this instrument has no moving parts it can be given a rugged design making it insensible for algae growth around the sensors.

Practical results

A prototype current meter is shown on figure 2. The meter has been tested for several weeks to control the currents flowing in and out from a fish farming inlet.

Figure 3 shows a recorded section from an experiment on improving the natural water exchange in the inlet by setting up artificial currents with propellers. In this experiment conventional rotating sensors failed to work in a short time because of intense algae growth.

Further development

The present instrument has been made to measure one dimentional current. Planned prototypes will be designed tp measure current components in the x, y and z-directions referred to magnetic north and true vertical direction.

To obtain a continuous recording of the instrument orientation an ultra-sonic compass that utilizes the same electronic circuits as the current meter that has bee deviced. It consists mainly of an ordinary magnetic compass and obtains its output signal by measuring the compass needle orientation acoustically.

Prototype specifications

Measuring range:	Adjustable in steps from 10^{-3} - 10^{2} m/sec.
Output signal:	Analogue $\pm$ 10 V
Linearity:	Better than 1%
Band width:	0 - 200 Hz
Zero drift:	Less than 0, V/week (can be eliminated by including automatic zeroing)
Power consumption:	W

Discussion

Ultrasonic current meters are first of all superior to rotating meters when concerning sensitivity and response time. They need however more complicated electronic circuitry, more power and more skill in adjustment and servicing.

In order to obtain better measurements more complicated instruments will be necessary, and it is very probable that ultrasonic current meters will play a very important role in future current instrumentation systems.

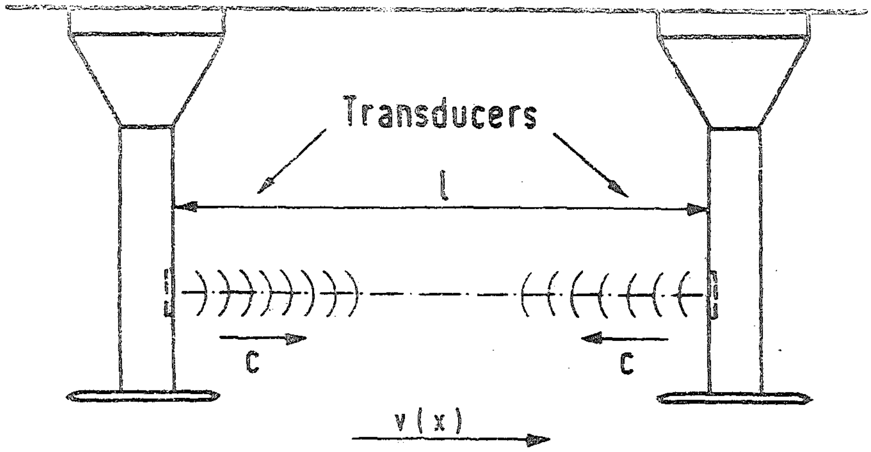

Figure 1
Principle of operation.

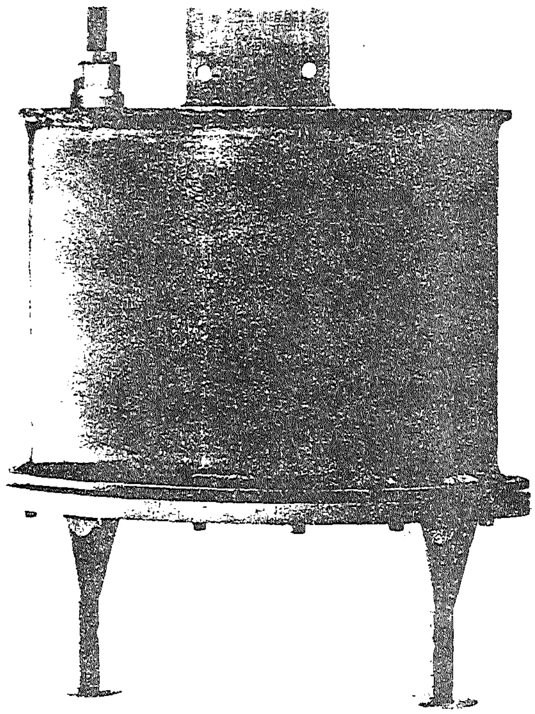

Figure 2
Prototype current meter.

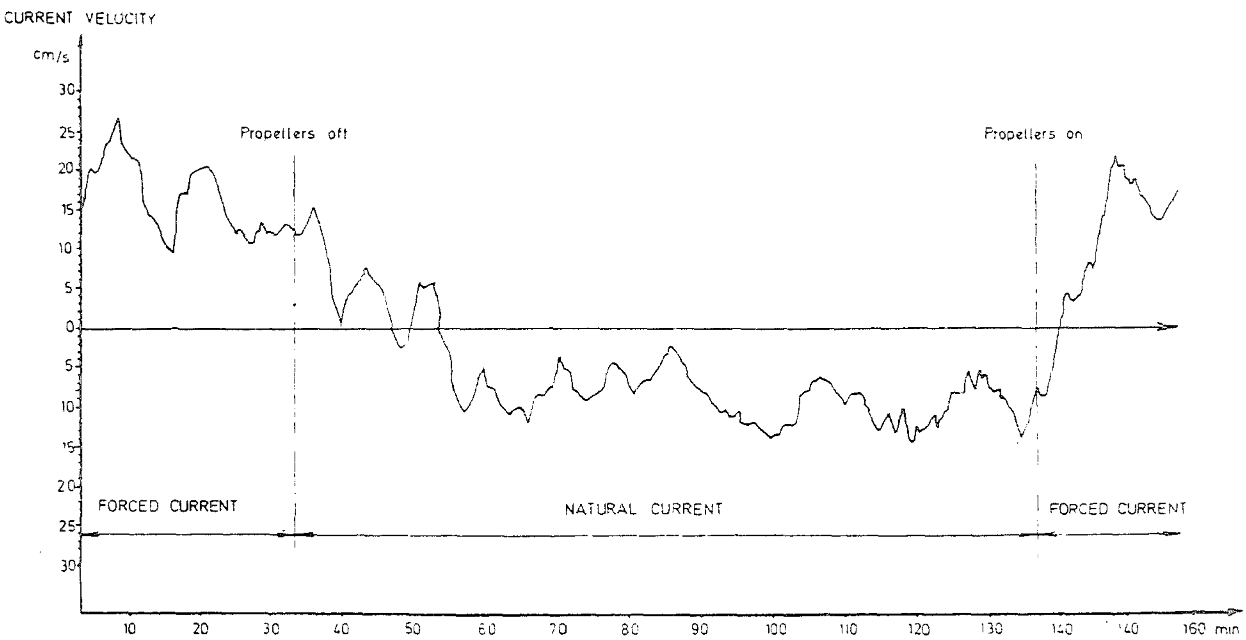

Figure 3 Recorded currents from prototype instrument.