

**A TECHNIQUE FOR DETECTION OF SAVONIUS ROTOR OSCILLATION**

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**ABSTRACT**

*Laboratory and field experiments by many investigators have shown that an effect of oscillatory flows on a Savonius rotor current meter is over-speed registration during flow lag. The exact reason for this phenomenon appears to be unknown. It has been suggested that one possible reason may be the oscillation of the rotor, instead of the expected unidirectional rotation. In this paper a technique to detect and tag rotor oscillations is presented.*

**INTRODUCTION**

Ocean currents have traditionally been measured using mechanical sensors, and rotor current meters were the "workhorses" of ocean flow measurements in the past. Measurements of currents using a mechanical sensor, such as rotor, are based on the mechanism of physical rotation of the rotor in response to the drag force experienced by it from the moving water in a flow field. For steady flows the average rotational frequency of the rotor is closely related to the speed of the surrounding water.

Since rotor current meters were in wide use the rotor has been probably, the most widely evaluated flow sensor. Consequently, some problems associated with the Savonius rotor have been reported. It has been observed that the Savonius rotor's accuracy for measurements of low flow speeds is related to the sea-state and the degree of unsteadiness of flow. For example, it has been pointed out by Paquette (1962) that a rotor type current meter exhibited over-registration when the mean flow was weak. Pollard (1973) reported that error currents as large as 20 cm/sec could be recorded by surface-moored rotor current meters in severe wave conditions. Kalvaitis (1974) observed that Savonius rotor vector-averaging current meter yielded small over-estimates of low-frequency flow in the presence of intense high-frequency oscillatory flows. Field experiments by Halpern et al (1976) and Halpern et al (1981) revealed that the rotor type current meter exhibit over-registration when mean flow is small and oscillatory flows are large. Field intercomparison studies by Johnson et al (1986) indicated that speed records from surface-moored rotor type current meters are influenced by rotor over-speed registration. This effect was manifested by the presence of "holes" in the current velocity distribution at low speeds (less than 50 cm/sec). This meant absence of low speeds at rough sea conditions. With reduced wave activity the size of these "holes" also reduced and finally vanished in calm sea conditions. Sherwin (1988) observed a mean speed over-estimation of 66% by the Savonius rotor type current meter when flow speeds were less than 10 cm/sec, and waves and swells were large. These effects indicated that the Savonius rotor failed to record small mean horizontal velocities at high sea-states when other types of sensors recorded low velocities under similar sea-states.

In an attempt to unravel the mysteries that shroud the motion of a Savonius rotor in an unsteady flow, various investigators have performed numerous laboratory experiments. A series of independent experiments by Fofonoff et al (1967) and Saunders (1980) in wave tanks provided contradictory results as to the response of the rotor in accelerating and decelerating flows. Karweit (1974) subjected a Savonius rotor to an oscillatory flow having a mean value. A comparison between the rotor rotation rate in the oscillatory flow and its rotation rate in a steady flow yielded systematic positive errors in rotor velocities as inferred from steady-state calibrations.

There are many speculations as to the cause of over-speed registration by Savonius rotor. Paquette (1962) opined that when the rotor current meter undergoes short rapid pendulous motions, there is possibility for over-registration to occur when an electrically registering rotor fails to keep going as a result of insufficient flow speed, and is thereby stalled or almost stalled on the contact. If this speculation is true, rotor over-speeding may not be the sole cause for over-registration of flow speed by a Savonius rotor.

Another school of thought attributes flow speed over-registration by Savonius rotor to the two end plates supporting the curved blades of the rotor. The argument often put forward is that, in this configuration, the rotor is likely to "trap" a certain amount of water during its rotation and, therefore, increases its inertia. In an attempt to improve the rotor current meter performance, a new version of Savonius rotor has recently been introduced by M/s. Anderaa of Norway. This new version removes the end plates. Since the two ends are "open" in this configuration, the problem of increase in inertia is expected to be minimal. To our knowledge no evaluation on the performance of this new rotor vis-a-vis the old version of the rotor has been reported. The fact that cup anemometer with no end-plates also exhibits over-speed registration in turbulent wind field (Busch et al 1976) is probably an indication that removal of end-plates of the Savonius rotor may not be a remedy for over-speed registration by the Savonius rotor. In any case, there appears to be no authentic experimental evidence as to the cause of over-speed

registration by Savonius rotor, and it may be premature to attribute 'over-speed registration' to 'rotor over-speeding'.

## PRESENT WORK

Looking at the problem from a purely instrumentation angle, the argument put forward by Paquette et al sounds reasonable. One of the reasons for over-speed registration at low flow speeds by rotor current meters which are surface-moored in a wave field can be the oscillation i.e., back and forth motion of the rotor, instead of unidirectional rotation. When the mean horizontal flow is small, and the meter moves up and down under the influence of mooring line motion in an oscillatory flow the rotor may tend to oscillate because the horizontal drag force, which makes the rotor rotate unidirectionally, is a minimum at low mean flows. If the rotor oscillates in the vicinity of the flow detecting reed-relay, the relay can close and open whenever the rotor oscillates in the vicinity of the relay.

## Configuration of Relays

The flow sensing Savonius rotor is meant for counter-clockwise rotations in a steady flow field. The rotor motion is detected by magnetically coupling it to three reed-relays. A rotor following magnet, free to rotate about the axis of a ball-bearing and to freely sweep over the reed-relays is so positioned that only one pole of the magnet can effect a closure of the relay. Thus, one full revolution of the rotor in the same sense will result in serial closures of all the three relays, thereby generating three voltage pulses during a full revolution of the rotor. In order to balance the rotor following magnet which is located off-centered with respect to the axis of the ball-bearing, a brass dead weight is attached to one end of the magnet.

## Description of the Circuit

A block schematic of the circuit is shown in Figure 1. The circuit enables counting the rotor-generated pulses in a form which permits detection of error counts produced by the rotor's flow un-related oscillations in an oscillatory flow field. The circuit works as follows: As the rotor magnet comes in the vicinity of a reed-relay a closure occurs resulting in the generation of a voltage pulse. The pulse is bounce-corrected using a Schmitt trigger and an edge-triggered monostable. The monostable gives a voltage pulse of a defined ON-time, irrespective of the speed of rotation of the rotor. Such pulses k1, k2 and k3 have originated from reed-relays 1, 2 and 3 respectively. Signals k1, k2 and k3 are then AND-gated with clk1, clk2 and clk3 pulse streams respectively. The AND-gated pulse streams of differing frequencies are then OR-gated to obtain a frequency-shift-keyed (FSK) signal, P. Signals k1, k2 and k3 are also OR-gated, and the resulting signal R is input to one port line (D14) of a Tattle-tale data logger. The number of positive pulses within the signal R for a specified time duration (determined by calibration) gives the flow speed. Enhancement in temporal resolution and sensitivity in flow measurement by 1.5 times is an added advantage of the three-relay system presented here. Whenever the signal R is

high, the data logger determines the period of the bunch of pulses contained in the FSK signal P (See Figure 2). The period of the bunch of pulses (input to port line D13 of the data logger) during the closure of a particular relay is an 'identifier' of that relay. From the sequence of the period of the received FSK signal P, the data logger recognises the sequence in which relay closure occurred within the specified time interval of relay closure counting. If the rotor has rotated in the sequence shown in Figure 2 throughout this time interval, it means that there was no rotor oscillation, and the total number of relay closures within this time interval is, therefore, an indication of the flow speed. If there is no oscillation, the data logger registers a zero in the 'oscillation counter'. Whenever there is a deviation from the sequence shown in Figure 2 the oscillation counter adds a 1 to its content. At the end of the count interval the number registered in the oscillation counter is divided by 2 and the result is stored as the number of oscillations (back and forth motion) of the rotor during a given pulse-count interval. The data logger also stores the number of closures by each relay. This permits the identification of the relay or relays over which the rotor made back and forth motions.

## CONCLUSION AND FUTURE PLANS

The technique presented here has been tested in the laboratory. It was observed that if the rotor is unidirectionally rotating in the correct sense i.e., if there is a steady flow, the circuit registers the correct number of counts during the flow speed measurement interval. Similarly, if there is no flow, no count is registered. If, however, the rotor oscillates about its axis (i.e., the movement of the rotor is not due to a steady flow), the number of such flow un-related oscillations during the flow speed measurement interval is also registered. In this way, the algorithm prevents attribution of an erroneous higher value for flow speed whilst the mean flow is actually very low or absent. The algorithm implemented here also permits one to identify the nature of oscillation, such as the number of relays over which oscillations have taken place. This will provide an indication of the angle swept by the rotor during its oscillation. This information may, perhaps, permit one to relate the nature of rotor oscillations to the sea-state and/or the type of mooring adopted and may also provide a clue as to the effectiveness of a particular mooring or mounting method.

The technique has been incorporated in a recording current meter presently being developed at NIO, Goa. In order to confirm the truth or otherwise of the speculation regarding rotor oscillation, it is planned to initially deploy two current meters, one having a Savonius rotor without end plates and the other with a rotor having end plates, in an artificial wave flume created by a random wave generator, where the mean steady flow is small compared to the oscillating flow. Since the amplitude and frequency of the wave in a flume can be controlled and recorded, the experiments can be performed in various controlled conditions. Such experiments will permit investigation of the situations under which the rotor oscillated, and also the nature of oscillations. It is hoped that such

Investigations will permit to nail down at least one confusion regarding the nature of rotor motion in the real field.

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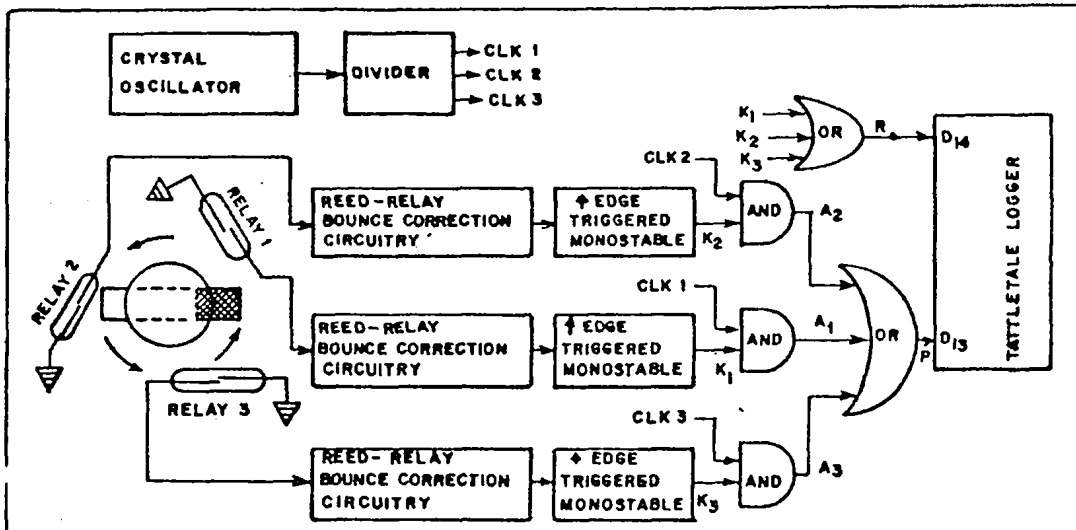


Figure 1. Flow speed sensing and rotor oscillation detection circuitry.

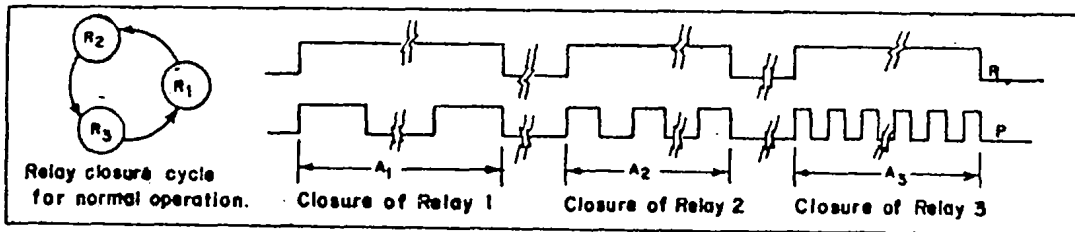


Figure 2. Sequence of pulse-stream for normal operation of rotor.