Prepublication copy: ASCE 1995
1st International Conference on Water Resources Engineering

Effects of Pulsating Flow on Current Meter Performance

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Abstract

Summarized are laboratory tests for current meter response to pulsating flows. Included are results for mechanical and electromagnetic water-current meters that are commonly used for stream gaging. Most of the vertical-axis and horizontal-axis types of mechanical meters that were tested significantly underregistered the mean flow velocity when the magnitude of the pulsating portion of the flow velocity was greater than half the mean velocity but less than the mean velocity. Errors for all meters tested were largest at the lowest mean flow velocity, 0.076 m/s.

Introduction

Current-meter measurements are the foundation for many studies of hydraulic and hydrologic phenomena. Ideally a current meter, whether it employs mechanical or electromagnetic principles, should respond instantly and consistently to changes in water velocity. Meters, however, are not perfect instruments and may not accurately register velocity in all measurement conditions encountered. Turbulent or pulsating flows can cause registration errors in meters. Previous studies have contradicted each other, finding that meters either overregistered or underregistered in unsteady flows (Jepson, 1967; Yarnell & Nagler, 1931).

This study presents data for one electromagnetic and thirteen mechanical current meters. The mechanical meters include six vertical-axis and seven horizontal-axis meters. For mechanical meters, the inertia of a meter's moving parts and the efficiency with which the meter translates linear velocity into angular velocity affects the ability of a meter to measure accurately in a pulsating flow. For electromagnetic meters, the response time of the circuitry and the probe shape affects the ability of the meter to measure accurately in pulsating flow. Tested meters herein measure one vector component of flow for a small flow volume and are listed in table 1 with rotor descriptions where applicable.

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Table 1. Description of Meters Tested (includes the rotor properties and switch type used to signal revolutions: v, vertical-axis; h, horizontal-axis; e, electromagnetic; alum., aluminum; c/w, cat-whisker; n/a, not applicable; m, meters; gm, grams).

Meter	Type	Switch	Rotor Properties			
			diameter (m)	pitch or cup (m)	weight (gm)	material
Price type-AA	v	c/w	0.127	0.051	174.8	brass
optic Price type-AA	v	optic	.127	.051	174.8	brass
Price pygmy	v	c/w	.051	.020	20.9	brass
winter Price type-AA,m	v	c/w	.127	.051	174.8	brass
winter Price type-AA,p	v	c/w	.127	.051	226.8	plastic
modified Price type-AA	v	c/w	.127	.051	104.2	plastic
Swoffer 2100[2]	h	optic	.051	.100	6.9	plastic
Valeport BFM002	h	reed	.050	.100	25.1	plastic
Valeport BFM001	h	reed	.125	.27	155.7	plastic
Ott C-31, metal	h	reed	.125	.25	458.7	brass
Ott C-31, plastic	h	reed	.125	.25	277.8	plastic
Ott C-31, A	h	reed	.100	.125	241.4	brass
Ott C-31, R	h	reed	.100	.25	214.3	alum.
Marsh McBirney 2000	e	n/a	n/a	n/a	n/a	plastic

[2]Brand names used in the report are for identification purposes only and do not constitute endorsement by the U.S. Geological Survey.

Test procedure

Testing was conducted in the tow tank at the U.S. Geological Survey Hydraulics Laboratory, Stennis Space Center, Miss. The tow cart provided the mean velocity, Uo. The sinusoidal, pulsating flow component was superimposed in the direction of Uo by a device attached to the tow cart. The device consists of a variable-speed d-c motor and motion controller attached to a drive wheel that oscillates an attached carriage back and forth on rails. The meter is attached to the carriage by a rigid rod. Both the amplitude, d, or half stroke length of the meter in the water and the frequency, p, or speed at which the drive wheel turns are adjustable. The maximum pulsating velocity component for a test is $U'=2d\pi p$. Tests for Uo of 0.076, 0.457, and 0.914 m/s at various combinations of frequency (0.03, 0.05, 0.1 and 0.2 cycles/sec) and amplitude (0.0127, 0.0635, and 0.2540 m) are presented (figs 1. and 2). Tested frequencies are considerably lower than Jepson's (1967) tests and more representative of large scale turbulence.

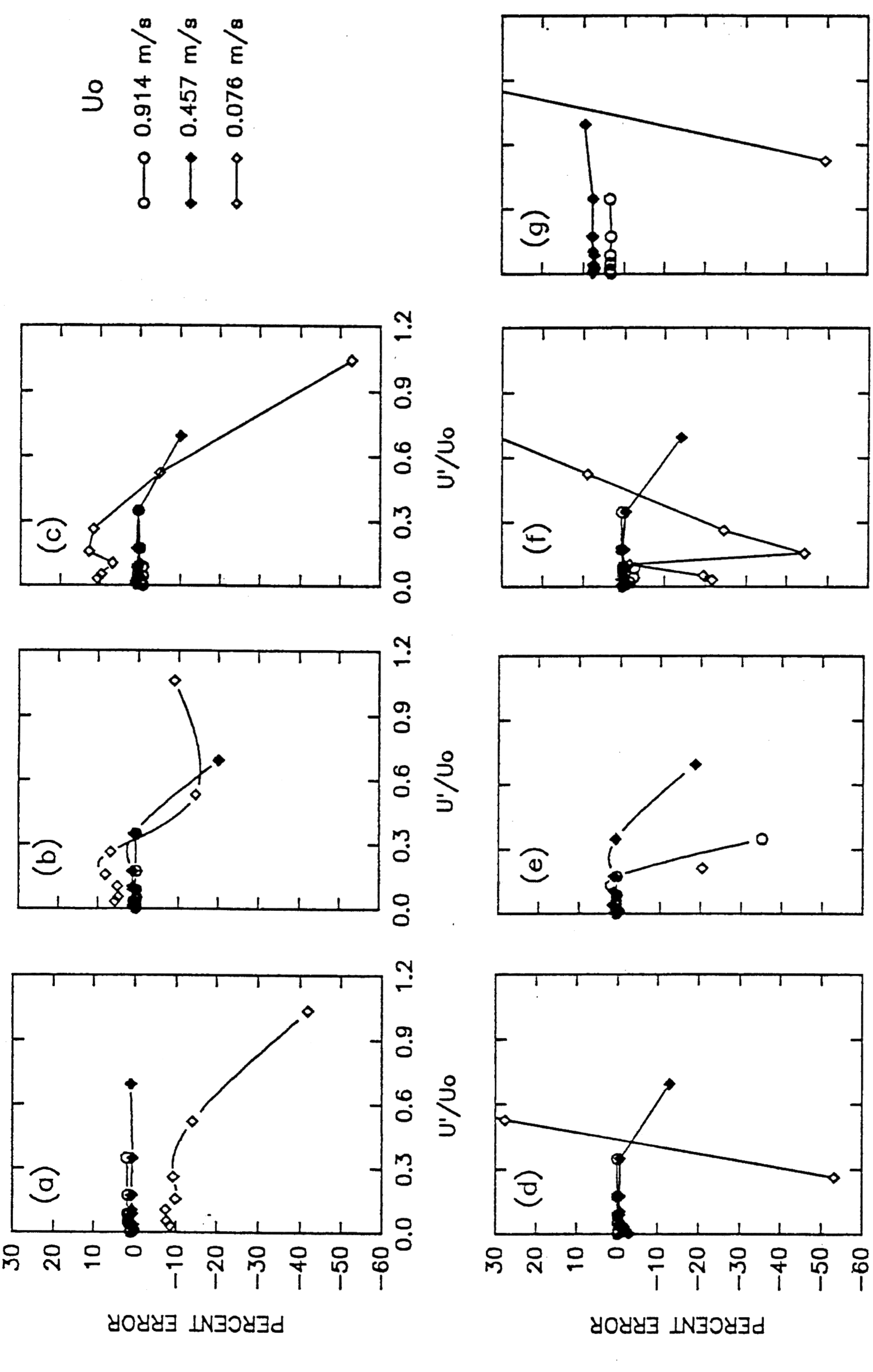

Figure 1. Flow Pulsation Effects: (a) Swoffer 2100; (b) BFM001; (c) BFM002; (d) C-31, metal; (e) C-31, plastic; (f)C-31, R; (g)C-31,A

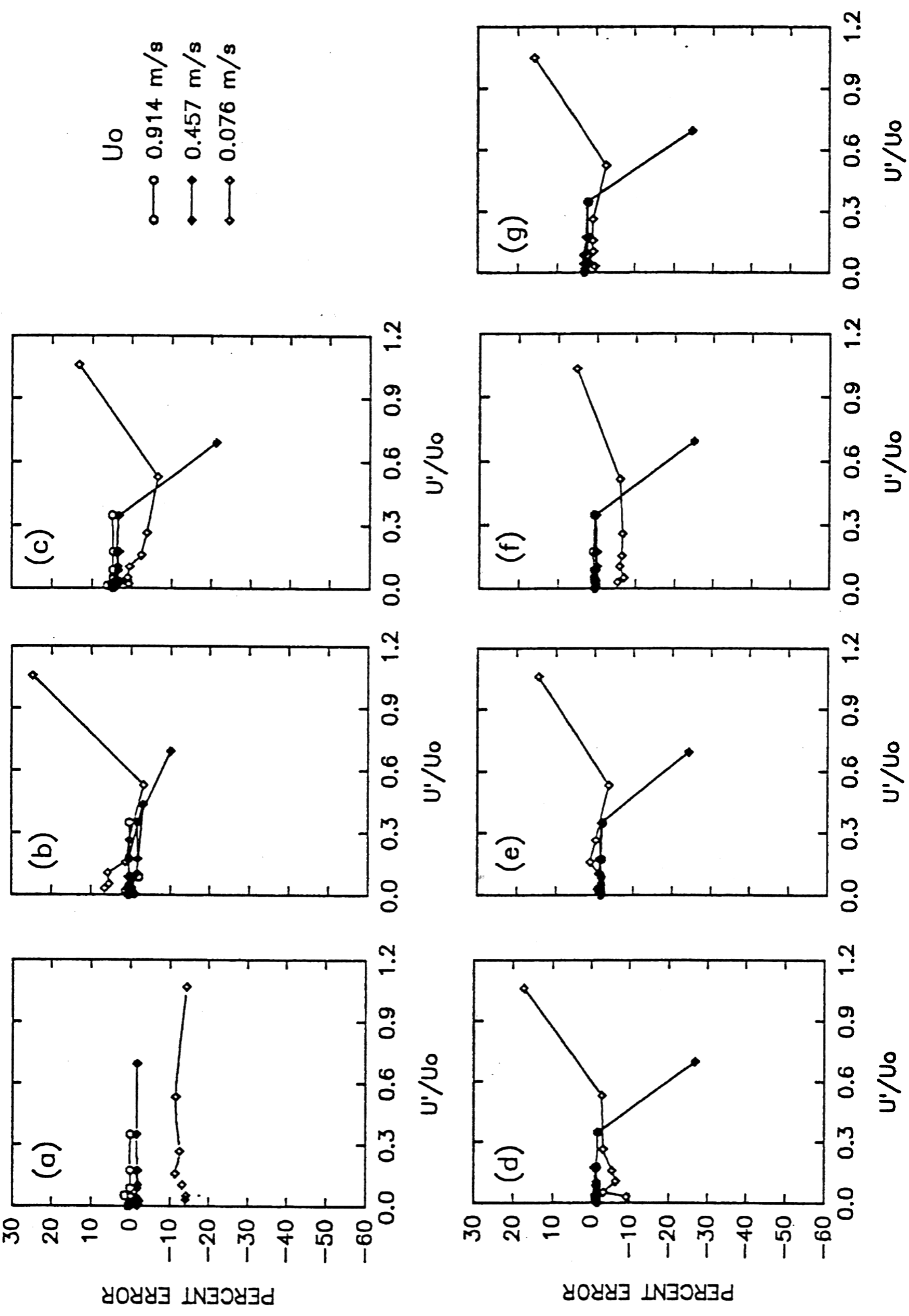

Figure 2. Flow Pulsation Effects: (a) Marsh McBirney 2000; (b) Price-pygmy, (c) winter Price type-AA, m; (d) Price type-AA; (e) optic Price type-AA; (f) modified Price type-AA; (g) winter Price type-AA, p

Test Results

Error magnitudes tended to decrease with increasing Uo for most meters tested (figs. 1 and 2). Mechanical meter error magnitudes decreased with decreasing ratios of maximum pulsating velocity component to mean velocity, U'/Uo, for Uo=0.457 m/s and Uo=0.914 m/s. The percent error, ε, in velocity registered by the mechanical meters is estimated by $\varepsilon=100(r_m-r_{est})/r_{est}$ where r_m is the meter revolutions per second (rps) measured in the sinusoidally pulsating flow and r_{est} is the rps estimated from the meter rating equation for Uo. For the electromagnetic meter, percent error is estimated by ε=100(Um-Uo)/Uo where Um is the meter registered velocity.

The poorest performance of most tested meters performed was at the lowest mean velocity, 0.076 m/s. Horizontal-axis meters, except for the BFM001, had average absolute errors >15% at Uo=0.076 m/s for all U' tested. The C-31 metal and A did not register any velocity for U'<0.040 m/s and the C-31 plastic registered only when U'/Uo>1. Vertical-axis meters average absolute errors are between 3% and 7% for Uo=0.076 m/s. The Marsh McBirney 2000 (MMB2000) error is 13% for Uo=0.076 m/s and may have been affected by noise from possible poor electrical grounding.

For the remaining mean velocities, Uo=0.457 m/s and Uo=0.914 m/s, average absolute meter errors are <10% for mechanical meters when U'/Uo<0.3 and <2% for the MMB2000 and Swoffer 2100 for all tested U'/Uo. All meters except the C-31 plastic and A have average absolute errors of <5% for Uo>0.076 m/s and U'/Uo<0.5. However, the C-31 A and Swoffer 2100 were relatively insensitive to change in U'/Uo for Uo>0.076 m/s. For U'/Uo>0.5, error magnitudes are larger for the vertical-axis than for the horizontal-axis meters. The MMB2000 was relatively insensitive to changes in U'/Uo for all Uo tested.

Conclusions

Registration errors for mechanical meters increased as the mean velocity decreased and as U'/Uo approached 1. Except for the electromagnetic meter (MMB2000), error was large for all meters when U'/Uo>1 and the meters were subjected to a flow reversal. The electromagnetic meter was insensitive to changes in U'/Uo. Registration errors decreased for all meters with increasing Uo.

References

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