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A Brief Literature Review of Open-Channel Current Meter Testing

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A Brief Literature Review of Open-Channel Current Meter Testing

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ABSTRACT

The U.S. Geological Survey (USGS) has undertaken the task of conducting an evaluation of the USGS's standard water-flow current meter, the Price type-AA current meter. The first part of the USGS's task was to conduct a comprehensive literature review to determine the extent and types of testing that has been conducted to evaluate the performance of various types of current meters used for open-channel flow measurements. The meter types included in the review were the vertical-axis mechanical type, the horizontal-axis mechanical type, the electromagnetic type, and the point-velocity acoustic (ultrasonic) type current meters. The review revealed that current meters have been systematically tested since the 1890's. The testing covered in the literature consisted of evaluating the performance of current meters subjected to various methods of standard calibration techniques, to oscillatory flow (vertical, horizontal, and axial), to oblique flow (vertical and horizontal angles of flow), proximity to boundaries, turbulence effects, and temperature effects.

INTRODUCTION

The U.S. Geological Survey (USGS) has undertaken the task of conducting an evaluation of the USGS's standard water-flow current meter, the Price type-AA current meter. The first part of the meter evaluation was to conduct a comprehensive literature review to determine the extent and types of tests that were conducted on a variety of open channel water-flow current meters in the past. The current meters of interest to the USGS are the vertical axis mechanical meters such as the Price type meter, horizontal axis mechanical

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meters such as the Ott[2], Haskell[2], Hoff[2], and Neyrpic[2] meters, electromagnetic meters such as the Marsh-McBirney[2] meters, and acoustic meters such as the EG&G[2] Smart Acoustic current meter. The literature review revealed that documented experiments have been conducted on the performance of mechanical current meters since the 1890's, while documented tests on the performance of electromagnetic and acoustic current meters has been conducted in the last fifteen years. Most of the information obtained in the early tests dealing with the performance of specific meters is of limited use because the meters used in those early studies are obsolete and no longer in use.

This paper briefly summarizes the more noteworthy and unprecedented articles and reports. This paper includes a brief description of each type of test followed by a listing of the authors of papers describing the tests and their results. A listing of the more than 100 articles and reports located and reviewed for the USGS study can be supplied upon request.

VERTICAL-AXIS METERS

Over the last 100 years the vertical axis current meter has been subjected to tests designed to evaluate the performance of the meters under conditions dealing with pulsation of flow in the direction of flow, oblique flows, proximity to boundaries, turbulence, and temperature. All of the documented tests located and reviewed by the USGS were conducted using variations of the Price type meter.

Pulsation of flow

The tests dealing with the pulsation of flow were conducted by horizontally moving a vertical axis current meter backwards and forwards in the flow. Tests by Rohwer (1933) were conducted by towing a meter through still water while the tests by Yarnell and Nagler (1931) were conducted in a flume with flowing water.

Vertical oblique flows

The results of tests dealing with vertical oblique flows on vertical axis current meters have been reported extensively in the literature. There are two methods of conducting this kind of test. The first method consists of rotating a meter in its vertical plane, locking it in place and then towing or placing the meter in a flowing flume. This method was used by the USGS (1899), Brown and Nagler (1914), and Fulford (1990). The second method consists of moving a meter in the vertical direction when it is being towed or located in a flowing flume. The second method was used by Rohwer (1933), and Kallio (1966b).

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[2] Use of trade names in this paper is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Horizontal oblique flows

Tests with horizontal oblique flows are conducted by rotating a meter in the horizontal plane, fixing it into position and towing the meter. Tests of this type were conducted by Rohwer (1933) and Engel and DeZeeuw (1978).

Proximity to boundaries

Tests to determine the behavior of vertical axis meters in proximity to boundaries have been conducted by Rohwer (1933), Pierce (1941), and Kulin (1977) and further evaluated by Engel (1983).

Turbulence

Most of the literature pertaining to turbulence tests are actually comparisons of discharge measurements taken with various current meters. This type of study was conducted by Kallio (1966a) and Fulford (1990). In contrast, Yarnell and Nagler (1931) and Schubauer and Mason (1937) attempted to create turbulent conditions in order to test meters.

Temperature

The effects of temperature on the calibration of a Price type meter was reported on by Robson (1954).

HORIZONTAL-AXIS METERS

As with the vertical axis meters, horizontal axis meters have been subject to tests designed to evaluate the performance of the various meters under conditions dealing with pulsation of flow, oblique flows, proximity to boundaries, turbulence, and temperature.

Pulsation of flow

Tests to determine the effect of the pulsation of flow on the performance of various types of horizontal axis current meters have been carried out on Hoff, Ott, and Haskell meters by Yarnell and Nagler (1931), and Rohwer (1933), and Ott meters by Jepson (1967).

Oblique flows

Oblique flow tests for horizontal axis meters were conducted on Hoff, Ott, and Haskell meters by Rohwer (1933), Ott meters by Kallio (1966b) and Jepson (1967), and Neyrpic meters by Johnson(1966).

Proximity to boundaries

Tests to determine the behavior of horizontal axis meters in close proximity to boundaries have been conducted on Hoff, Ott, and Haskell meters by Rohwer (1933), Ott meters by Pierce (1941), and Neyrpic meters by Johnson (1966).

Turbulence

As with the vertical-axis meter tests, most of the turbulence tests conducted on the horizontal axis meters were actually comparisons of discharge measurements with various meters. This comparison work was conducted with an Ott meter by Kallio (1966a). Again in contrast, the work by Yarnell and Nagler (1931) on Hoff, Ott, and Haskell meters and Ott meters reported on by Buchanan (1963) were conducted in artificial turbulence.

Temperature

Tests to determine the effects of temperature on the performance of a set of Neyrpic meters were conducted by Johnson (1966).

ELECTROMAGNETIC METERS

Very little work on the flow measuring characteristics of electromagnetic current meters (EMCM) has been reported on in the literature. Because of the small number of papers found, individual sections outlining different test types will not be given. Also, individual meter types are not given in this paper because they are not always given in the literature.

Test results covering the response of EMCMs to the pulsation in flow, vertical oblique flows, proximity to boundaries, and turbulence are given by Aubrey, and others (1984). Additional work pertaining to turbulence is outlined by Bivins (1976). The response of EMCMs to horizontal oblique flows is given by Marsh-McBirney (1988). The response of EMCMs to frazil ice conditions is given by Derecki and Quinn (1987).

ACOUSTIC METERS

Like the electromagnetic current meters, acoustic point velocity meters have little information reported in the literature as to their flow performance under adverse conditions. The paper by Appell (1978) covers oblique flows in both the vertical and horizontal directions.

CONCLUSIONS

A USGS literature review revealed that open-channel water-flow current meters have been systematically tested for more than 100 years. Although the results of the earlier studies cannot be applied directly to current meters in use at present (1991), the testing methods used in the earlier studies can be applied to the present versions of current meters in order to evaluate their flow measuring characteristics. The articles and reports that presented studies which used poor methods of testing or that presented incorrect conclusions based on the test results can also be used as references of what should be avoided when testing current meters.

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