# The Importance of Accurate Open Channel Flow Measurement

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## ABSTRACT

Effective open channel flow measurement is becoming more significant due to reducing water supplies, especially in areas like Africa and the Middle East, and the growing concerns regarding municipal water measurement, are creating a heightened demand for the accurate monitoring of open channels flows. To this end it's perhaps becoming even more important that open channel flows are metered effectively and efficiently – minimizing the overall margin of error.

***Keywords***: Parshall flume, Primary Flow Signal, PFS Halmi Parshall Flume, Open Channel Flow Metering

## 1 INTRO TO THE FLUME

An open channel is the flow of liquids that flows with a free surface, and are at some point "open" to the atmosphere. Examples include irrigation ditches, streams, water works processes, sanitary and storm water sewage systems, and industrial to municipal metering stations.

Effective open channel flow measurement is becoming more significant due to reducing water supplies, especially in areas like Africa and the Middle East, and the growing concerns regarding municipal water measurement, are creating a heightened demand for the accurate monitoring of open channels. To this end it's perhaps becoming even more important that open channel flows are metered effectively and efficiently – minimizing the overall margin of error.

The Parshall flume was, and in some cases still is, the standard measurement device for open channels, but it was not conceived as a flow measurement primary for many of the applications for which it has been used over the past 90 years.

Although Parshall flumes may appear to be standard devices, closer inspection often reveals that they are not. A truly standard device is one that has been fully described, accurately calibrated, correctly installed, and sufficiently maintained to fulfill the original requirements (Bureau of Reclamation 1967).

## 2 FLUME HISTORY

Parshall flumes were developed by Ralph L. Parshall between 1915-1921. As a research engineer with the U.S. Department of Agriculture, Parshall noticed there was a severe lack of measurement structures that could effectively monitor stream flows. Parshall's flume, when placed in a channel, measures the flow of the water as it uniquely relates to water depth.

His invention was a simple solution that used the Venturi effect to monitor the flows in irrigation projects, and it also allowed reasonable water measurement in ditches and creeks, that improved the management and distribution of water resources.

While the Parshall flume was primarily intended to meet general field conditions where extreme measurement accuracy was not required, it is accurate enough for irrigation purposes (Parshall 1936). Nevertheless, it has been used for billing and permitting purposes with anticipated accuracies within +/- 5% of actual flow. With the invention of the Parshall flume, it was possible to enforce water laws in existence at that time, but not necessarily for the contemporary laws and regulations we must deal with today.

For this paper, it is assumed that proper flume sizing based on anticipated normal and maximum flow rates have been thoroughly considered, that upstream approach conditions which promote acceptable flow conditions have been met, and that the downstream channel will not result in a backwater effect creating submergence within the flume.

### 2.1 Flume Options

As revolutionary as the Parshall flume was in terms of handling irrigation flows, there are significant weaknesses. The floor of the converging section must be constructed and installed so that the crest of the flume is level both longitudinally and laterally. Even small manufacturing or installation errors have significant measurement inaccuracies that increase as the discharge decreases.

In the past few decades, the Parshall flume has been most frequently supplied as a pre-manufactured thin walled fiberglass liner that often does not exhibit the extreme precision and tight tolerances that Parshall (1936) deemed critical to ensure accurate flow measurement. Flume liners depend on very exacting installation, execution, and an even more careful analysis of conduit geometry into which it is installed.

## 2.2 Parshall Flume Weaknesses

A flow measurement system usually consists of a primary element (flume), which is the part of the system that creates what is sensed (head or head pressure), and is measured by a secondary instrument. When a flow measurement system is in place and billing becomes a factor regarding either the amount of water delivered or received, those measurement values and metering elements must be accurate to ensure both the "sender" and the "receiver" are providing or paying for the correct amount of flow.

The initial secondary metering mechanism designed by Parshall relied on a series of pulleys or floating orbs. It is important to note that there have been significant advancements in secondary metering solutions, such as ultrasonic monitoring. The correct placement of these secondary instruments, however, is still under debate, and errors up to 60 percent can occur when the head is measured incorrectly (UWRL 2009).

The other area of concern regarding the Parshall flume is one that has also been debated for years – what is the discharge coefficient? Although most Parshall flumes are built relying on a table or calculation formula to generate flow rates, it raises the question about third-party verification and overall accuracy because it is effectively impossible to calibrate a Parshall flume in an independent testing facility since the flume liner must be field supported. It is equally impossible, except in rare cases, to perform any kind of field calibration of a Parshall flume.

Parshall flumes may appear to be standard devices, but closer inspection often reveals that they are not. A truly standard device is one which has been fully described, accurately calibrated, correctly installed, and sufficiently maintained to fulfill the original requirements (Bureau of Reclamation 1967). Manufacturers of the Parshall flume generally point to the USDA Water Measurement Manual when asked to provide accuracy, however the Manual does not describe how an installed flume's accuracy is verified. In fact, it describes the limitations of the application and use of a Parshall flume as related to line velocity limitations, upstream and downstream channel geometry, and minimum and maximum flow rate ranges.

## 2.3 Advanced Open Channel Flumes

Fortunately, there are modern solutions to effectively meter open channel liquid flows that are traceable to the U.S. National Institute of Standards and Technology, and also have a discharge coefficient, which is the ratio of actual discharge to the theoretical discharge. By using the primary principles of open channel measurement, but reengineering both how a flume is positioned and at which point flow height is measured, accuracy and verifiability increase significantly.

## 2.4 Evolving the Parshall Flume

A new, more advanced version of the open channel flume needed to be developed in order to significantly improve the verifiable accuracy of the flow rate, while also giving "senders" and "receivers" greater confidence in the actual amount of flow.

Dezsoe Halmi, founder of Primary Flow Signal, invented and commercialized the Halmi Parshall Flume, later termed the PFS-HPF. The PFS-HPF has been tested repeatedly by third party laboratories and has a certifiable discharge coefficient. The overall precision of the PFS-HPF is **+/-2.0%** of max rate and the primary device can be used with a number of secondary read-out devices, such as ultrasonic level, pressure transmitter, capacitance probe and others. Additionally, unlike the traditional Parshall flume, the PFS-HPF was designed so that the appropriate, accurate placement of secondary measurement devices is easily recognizable and verifiable. With its variable discharge feature, low flow rate conditions in an oversized channel can be effectively dealt with, therefore eliminating the excessive errors that are common in many installations.

Another benefit is flume placement and installation. Parshall flumes and other standard flumes act more as actual liners and need to be backfilled with concrete. The PFS-HPF was engineered to be self-supporting, does not require concrete work for installation, and can be used for a wider minimum to maximum flow rate range with the addition of secondary devices such as ultrasonic level, capacitance resistance, head pressure, and others to suit a wide range of application conditions. Also, because the HPF does not require concrete backfilling, it results in a simpler and less expensive installation cost – something that would be particularly helpful in areas where construction materials are scarce or economically unviable.

With laboratory flow calibration, HPF accuracy is **+/-1.0%** of maximum rate with a much lower headloss compared to the Parshall flume.

Causes for Parshall flume measurement errors are well documented, and include support structure settlement, submerged flow conditions/back-watering effects, and accumulation of debris – all of which occur commonly in real-world applications of the flume.

Less obvious deficiencies include improper entrance geometry, incorrect staff gauge or secondary instrument installation, and lack of manufacturing precision and performance testing.

The ability to receive correct, verifiable measurement is becoming increasingly important and requires expert engineers in the field. Parshall flumes can be purchased commercially or built to design specifications given by Parshall (1926). Guidance from the Water Measurement Manual tells us that if the installation conditions are not ideal (as described in the manual), there is no verifiable way to predict the installed accuracy unless all unacceptable conditions are corrected. Therefore there must be a more accurate, and traceable solution.

## 3 6.0” PARSHALL FLUME COMPARISON

Since there is no supporting data available for any firm accuracy statement for Parshall flumes and given the fact that anyone who would use a flume is seeking some level of accuracy, the manufacturers of such devices, over time, have somewhat settled on a +/-5.0 of maximum head accuracy statement. Anyone can and should question that statement since it cannot be substantiated. The technical literature that is available, and that must be considered when developing any understanding of what could be expected, is a United States Department of the Interior publication entitled "Water Measurement Manual" Second Edition 1967. As a reference tool, this manual will present some of the conditions required for any possible understanding of the expected accuracy, as well as warnings as to how best to use a Parshall flume in field applications.

If we assume that the +/-5.0% of maximum head has some credibility, the following table shows the integrated system accuracy when you add the ultra-sonic type secondary.

Assume 6.0” Parshall Flume Q = 0.30 MGD to 1.20 MGD (error sources are +/- percentage of actual flow rate)

| Q (% Max) | MGD | Ultrasonic | Parshall Accuracy | System Accuracy |
|---|---|---|---|---|
| 100 | 1.20 | +/-1.69% | +/- 8.01% | +18.09/+1.71 |
| 75 | 0.90 | 2.03 | 9.64 | +19.05/-0.65 |
| 50 | 0.60 | 2.63 | 11.25 | +17.75/-5.35 |
| 25 | 0.30 | 4.09 | 19.67 | +20.99/-19.19 |
| 10 | 0.12 | 7.33 | 35.90 | +22.64/-50.64 |

## 4 6.0” HALMI FLUME COMPARISON

The Halmi Parshall Flume is a device whose accuracy is known and substantiated by laboratory flow calibrations, resulting in a discharge coefficient being developed and proven. The accuracy of the secondary is also improved since the capacity of the flume is variable depending on the degree of end restriction that can be selected based on the minimum and maximum expected flows.

(Error sources are +/- percentage of actual flow rate)

| Q (% Max) | MGD | Ultrasonic | Halmi HPF Accuracy | System Accuracy |
|---|---|---|---|---|
| 100 | 1.20 | +/-1.69% | +/- 2.00% | +/- 2.62 |
| 75 | 0.90 | 2.03 | 2.67 | 3.35 |
| 50 | 0.60 | 2.63 | 4.00 | 4.79 |
| 25 | 0.30 | 4.09 | 8.00 | 8.98 |
| 10 | 0.12 | 7.33 | 20.00 | 21.30 |

## 5 PFS-HPF DESIGN

The PFS-HPF design can be configured to handle excessive pipe slope or velocity conditions that render the traditional Parshall flume highly inaccurate.

The basic accuracy of a Parshall flume is considered to be +/-5.0% at max rate. The basic accuracy of the PFS-HPF is +/-2.0% of max rate. The PFS-HPF can be used with a number of secondary read-out devices. Parshall Flumes have a limited number of secondary instrument read-out devices that they can be used with.

Parshall flumes and other standard flumes are liners that need to be backfilled with concrete which often times results in distortion of the flume profile that significantly affects their installed accuracy: the PFS-HPF is self supporting, does not require any concrete work, which means a less expensive installation cost, and can be used for a wider minimum to maximum flow rate range with the addition of the optional HPF restrictor package. With laboratory flow calibration, HPF accuracy is +/-1.0% of max rate which is a much lower headloss compared to the Parshall Flume.

## 6 CONCLUSION

Accurate flow measurement for open channels is becoming increasingly important due to the growing demand for water, and the decreasing resources available. The key element to note when implementing a measurement system, is that extensive sloping, sedimentation or drastic changes to geometry can negatively impact the accuracy and dependability of a traditional Parshall flume. Providing a correct measurement must be taken into consideration to select an effective solution. It is hoped that this brief analysis, clearly and reliably illustrates and explains the drastic difference between flow measurements performed by PFS-HPF and Parshall flume flow metering systems in in accuracy, head loss and reliability.