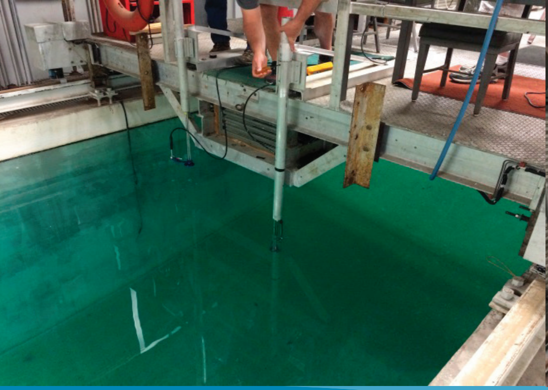

TECHNICAL PAPER:

Tow Tank Verification Report

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Version 1.0, October 6, 2016

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INTRODUCTION

The FlowTracker® Handheld ADV is an Acoustic Doppler Velocimeter (ADV®) that is designed to perform accurate point velocity measurements in flowing water. The FlowTracker offers ADV performance from a simple hand-held interface, allowing rapid data collection without the use of a computer.

Fig. 1 FlowTracker2

The FlowTracker2 was launched in 2016 with a number of hardware and software improvements. The most noticeable hardware changes were the handheld and the ADV stem. The new handheld offers color graphics and real-time data display, and the probe assembly can be detached from the handheld.

The electronics of the ADV were moved from the hand-held to the ADV itself, resulting in a slightly larger stem. This change reduces the instrument noise and allows the interchange between probes and handhelds. The FlowTracker2 Tow Tank Verification technical note gives an overview of the test facilities, reference instrumentation, test methodology, results and requirements of Tow Tanks. The verification process focused on two main aspects: Velocity Accuracy and Flow Disturbance.

TESTING FACILITY AND INSTRUMENTS

The facility chosen for the FlowTracker2 verification tests required consistent measurement conditions over a range of velocities, established operating methods and accreditation. The USGS Hydrologic Instrumentation Facility (HIF) towing tank facility was used for the verification process of FlowTracker2.

A. Towing Tank

The HIF Towing Tank facility is primarily used for the development of individual ratings or the verification of conventional current meters against a standard rating. The application of Acoustic Doppler instruments in the towing tank requires suspended particles in the water to measure the water velocity. This was achieved by seeding the tank.

Fig. 2. HIF Towing Tank

B. Reference Instrument

The Original FlowTracker was used as a reference to evaluate the velocity measurements performed by FlowTracker2 and the Towing Cart velocity. The data collected by the reference instrument were also used to evaluate aspects possibly impacting velocity accuracy, including SNR conditions, residual currents, and thermal convection currents.

METHODS

The test configurations designed for Velocity Accuracy and Flow Disturbance were based on a number of criteria to identify if there are any external factors that may influence the measurements. The following aspects were taken into consideration,

- velocity ranges,
- number of samples collected,
- travel distance of towing cart,
- reference measurement instruments,
- towing cart reference velocity.

A. Towing Cart Mounting

The mounting mechanism of the towing cart at HIF facility varied in design for each of the tests performed.

The mechanical boom on the towing cart allows the operator to lower the instruments into the water. The boom can accommodate two instruments at a time, using support rods with fixed orientation and depth for each instrument.

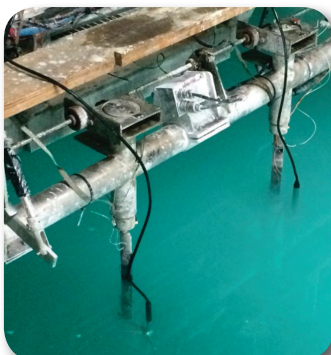
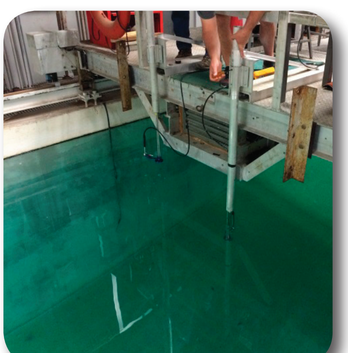


Fig. 3. Mechanical Boom



The top setting rod mount used for flow disturbance was developed by HIF to accommodate top setting rods. The alignment of the instrument and depth is user adjustable

Fig. 4. Top Setting Rod Mount

B. Data Collection

The velocity runs for both Velocity Accuracy and Flow Disturbance were performed over the maximum available length of the towing tank (about 300ft) or the maximum number of samples allowed per measurement (1000 samples), whichever came first.

The time series of velocity data during each velocity run assisted in identifying any influences on the measurement accuracy. During the initial tests the data showed changes in velocity at one end of the towing tank, shown in Figure 5. This influence was likely due to an air-conditioning duct above the towing tank.

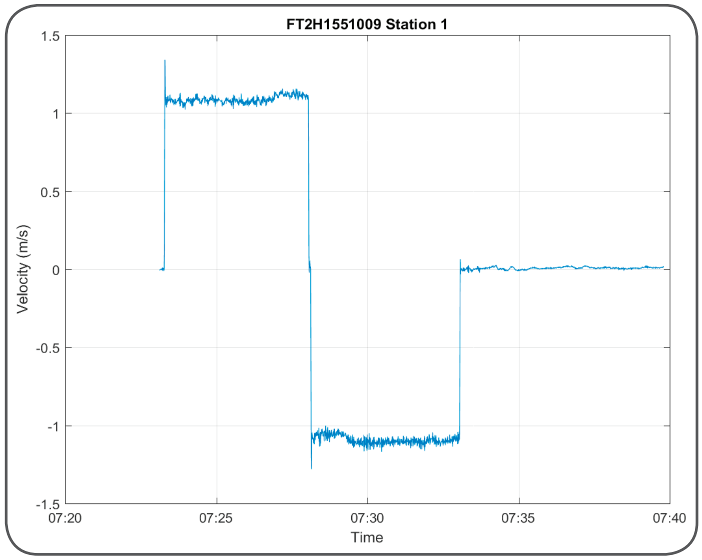


Figure 5: Tank Influences on Measurement Accuracy

Factors that are known to affect the measurement accuracy of Acoustic Doppler instruments in Towing Tanks are listed under the following points. During the testing process each of the factors were scrutinized to determine any possible influences on the velocity measurements.

- Towing tank conditions. Residual currents are created due to the movement of the mount and instrument through the water. Velocity measurements were performed at the end of each velocity run while the cart was stationary to determine the magnitude of residual currents.
- Towing cart effects. Vibration of the towing cart during slow speeds directly affects the measurement accuracy. The presence of vibration increases the noise in the data collected, resulting in higher standard error in the velocity measurements.
- Mounting fixtures. The type of mounting fixture defines the maximum velocity range that can be tested. Mounting fixtures such as Top Setting Rods start to vibrate at velocities above 3.3 ft/s, affecting the measurement accuracy.

C. Data Processing

The HIF Towing Cart data collection system recorded the mean distance and time for each complete run, producing a mean velocity over the entire run. Thus, the velocity data collected by the FlowTracker instruments must be averaged over the same time interval as the Towing Cart to be able to compare to the same Towing Cart run data.

During the FlowTracker data collection, some samples at the beginning and end of the run needed to be excluded from the averaging interval, although best efforts were made to preserve as much data as possible over a single run to match the Towing Cart time interval. A maximum of 5 samples (2.5 seconds of data) were removed from the beginning and end of each data run due to ramp up and down effects of the tow cart, causing spikes in the data.

No other manipulation or de-spiking of the data was performed, and the mean velocity was calculated over the yellow highlighted region shown in Figure 6. As mentioned earlier, the FlowTracker2 produced velocity data at 2Hz, and the Original FlowTracker, 1Hz. As shown in Figure 6, both the positive and negative runs are recorded by the FlowTracker. Only the positive runs were used in the analysis and results.

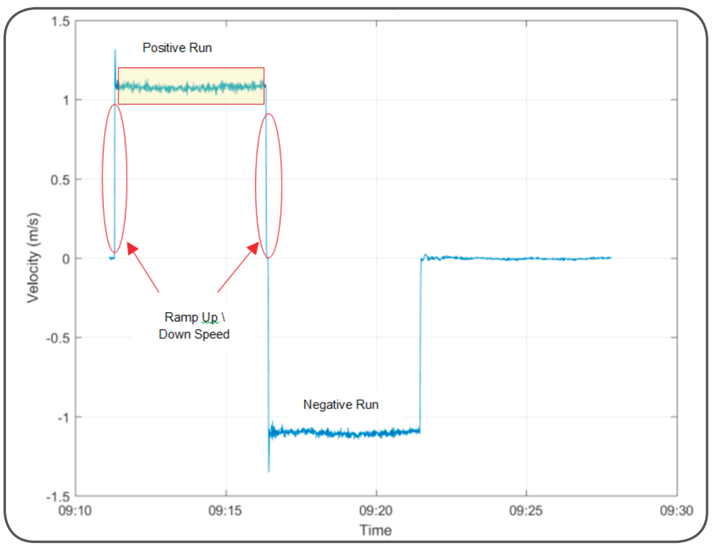


Fig. 6. Raw Data used Mean Velocity Calculation

RESULTS

The velocity data used to determine the Velocity Accuracy of the FlowTracker2 was based on the data collected using the Direct Mount on the towing cart. The measurement results obtained from each of the velocity runs listed in Table 1 were used in the evaluation of the velocity accuracy of FlowTracker2 instrument.

Table 1: Towing Cart versus FlowTracker Measured Velocity

Cart Speed (ft/s)	Original FlowTracker		FlowTracker2	
	Velocity	Difference	Velocity	Difference
0.100	0.1042	4.22%	0.1048	4.80%
0.300	0.3002	0.08%	0.2979	-0.70%
0.490	0.4921	0.44%	0.4893	-0.14%
0.490	0.5049	3.05%	0.5006	2.16%
0.7998			0.8033	0.44%
1.099	1.0975	-0.13%	1.0939	-0.46%
1.2969			1.2955	-0.11%
1.601	1.6253	1.52%	1.6143	0.83%
2.501	2.5135	0.50%	2.5089	0.32%
3.300	3.3284	0.86%	3.3087	0.26%
4.900	4.9219	0.45%	4.9146	0.30%

The velocity data collected from the FlowTracker2 shows an overall improvement of velocity accuracy over the Original FlowTracker across the entire velocity range. The two velocity ranges that showed a larger than expected difference, for both the Original FlowTracker and FlowTracker2 were at 0.1ft/s and 0.490ft/s towing cart speed. Towing Cart vibrations and residual currents were probably the source of error, resulting increased noise in the data and higher standard error.

The variability in the differences against the towing cart speed for velocity ranges up to 0.5ft/s could be associated with the factors affecting the measurement accuracy. The measurement results show a more consistent improvement during higher cart speeds, suggesting that the magnitude of external factors impacting the measurement accuracy is a small percentage during higher velocity ranges.

The small velocity deviations from the tow cart speed across the velocity range are directly related to the increased ping rate (40Hz) of FlowTracker2. The increase in the amount of data collected for calculating the average velocity during each sample improves the overall measurement uncertainty. The difference in velocity between the Tow Cart Speed and the Measured Velocity of Original FlowTracker and FlowTracker2 is plotted against the Tow Cart Speed in Figure 7. The difference between the Tow Cart speed and measured velocity is generally less in the FlowTracker2 compared to the Original FlowTracker.

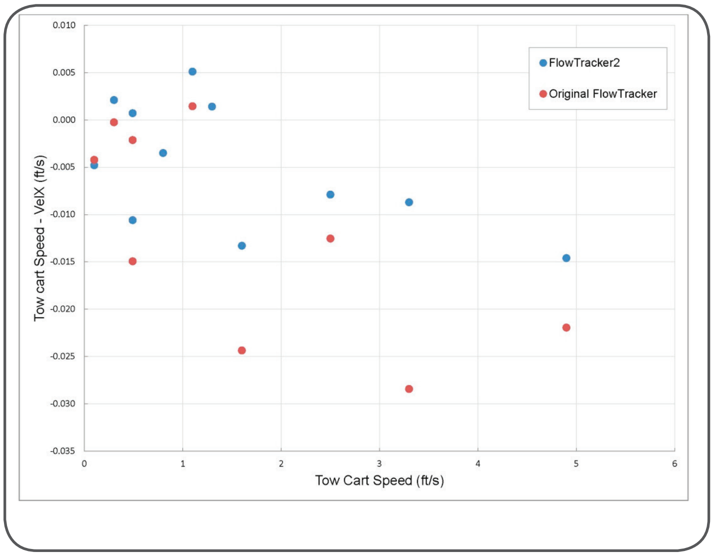


Fig. 7. Difference in Measured Velocity versus Reference

The velocity data used to determine Flow Disturbance of the FlowTracker2 were based on the data collected using both the Hex and Round Top Setting Rods on the towing cart. The measurement results obtained from each of the Top Setting Rods during the velocity runs were used in the evaluation of the impact of Flow Disturbance on velocity measurements.

The velocity data collected from FlowTracker2 using both the Hex and Round Top Setting Rods showed similar differences with the Towing Cart speeds. The overall difference between the velocity measurements performed using Hex Top Setting Rod and Towing Cart speed was 1.3141%. The difference between Round Top Setting Rod and Towing Cart speed was 1.3048%. The percentage difference in velocity between measurements performed with different Top Setting Rods and Towing Cart speed is associated with flow disturbance caused by the Top Setting Rod and J-Bracket mount.

The results obtained from the FlowTracker2 Flow Disturbance tests are very similar to previous research (SonTek/YSI Technical Note "FlowTracker and Wading Rod Flow Disturbance") performed in towing tanks. The effect of Flow Disturbance on measured velocity from previous research varied between -0.7% to -1.4% depending on the Top Setting Rod and Mounting Bracket configuration.

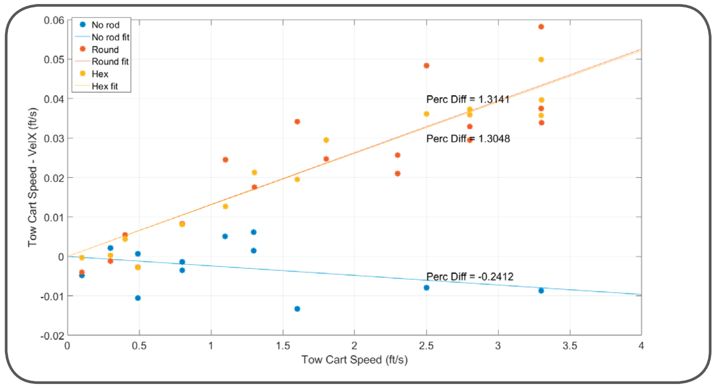


Fig. 8. Effect of Top Setting Rod on Measured Velocity

The difference in velocity between the Tow Cart Speed and the Measured Velocity of the FlowTracker2 mounted on a Round Top Setting Rod and a Hexagonal Top Setting Rod is plotted against the Tow Cart Speed in Figure 8. The slope of a linear regression (solid line) shows the percent different between the Tow Cart and measured velocities.

CONCLUSION

The results acquired from the Velocity Accuracy tests show an overall improvement of measurement uncertainty over the entire velocity range with FlowTracker2. The new sampling strategy that was implemented in FlowTracker2 provides four times higher ping rate per measurement sample. The increased number of data points that are averaged for every one second velocity sample improves the measurement uncertainty of velocity measurement over user defined sampling interval. The velocity accuracy of the FlowTracker2 is well within the published velocity specification of 1% + 0.25cm/s of the reference velocity.

The flow disturbance results obtained from the towing tank tests showed similar results between the Round Wading Rod and Hexagonal Wading Rod. The difference in velocity of 1.3141% for Hex and 1.3048% for Round Top Setting rods are slightly higher from the recommended 1% for Round and 1.2% for Hex by SonTek from previous research performed on Original FlowTracker. The slight increase in flow disturbance could be contributed to the technical difficulties experienced in aligning the ADV Probe with the mounting fixture used for the Top Setting Rods. This increase is likely negligible considering other errors introduced during the process of taking a measurement. The order of flow disturbance present during towing tank tests is very similar to what was found in previous research.

SonTek recommends that a correction factor of 1.3% is used for both the Round Top Setting Rod and Hexagonal Top Setting Rod with FlowTracker2 for correcting flow disturbance caused on velocity measurements by the Top Setting Rod and Mounting Bracket.

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Daniel started his hydrographic career in South Africa with experience in surface water and ground water monitoring. He continued with his career progression as Technical Manager of hydrographic operations overseeing all computations including stage-discharge development and data processing. He expanded his 25 years' experience in hydrographic operations by accepting Manager of Water Monitoring Systems position in Australia, responsible for the design of business process frame works and the development of operational standards, quality assurance systems and training programs. His current focus at SonTek is the improvement in the application of methodology, quality assurance and data management principles used in collecting Acoustic Doppler data with respect to International Standards and Organizational requirements. Daniel holds a B.Sc. in Water Engineering from Central University Technology and B.Sc. in Geohydrology from Free State University.

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