

Verification of acoustic doppler instruments

Introduction

If you are a single operator or part of a larger organization, it's just a matter of time before the question will arise, "should I verify my acoustic Doppler instrument?"

Acoustic Doppler instruments do not drift compared to water quality, water level, and other instruments used within Hydrometry. However, it is important that acoustic Doppler instruments are verified at scheduled intervals for the following reasons:

- Electronic instruments operated in range of environmental conditions, including water, temperature, humidity, and salinity will show signs of wear and tear over time
- Instruments exposed to high levels of movement and vibration from highly turbulent flow conditions to transport of equipment on the back of a Ute need to be checked periodically.
- All Hydrometric data is quality coded and the verification and or calibration of measurement instruments forms a key component of the overall quality assigned to the processed data.



Figure 1. ADCP Streamflow Regatta

Methods of Verification

A - Regattas

The simplest form of verification is to perform a comparison measurement between two different instruments in the field, with the results within an acceptable margin, as illustrated in Figure 1. Organizations will commonly hold yearly or bi-yearly regattas for the purpose of comparing

instruments against each other and a known flow to identify outliers. The verification is highly dependent on the site selection and methodology followed during each of the verification measurements. specifications ($\pm 0.25\%$ or $\pm 1\%$ difference).



Figure 2. SonTek RS5 in the process of being verified following USGS process at the HIF.

B - Tow Tank Verification Facilities

Larger organizations have the means and space to perform comprehensive verification tests in custom-built tow tanks. One of the largest facilities is operated by the USGS at the Hydrologic Instrumentation Facility (HIF) located in Tuscaloosa, Alabama, USA (formerly Mississippi, USA).

The USGS performs a rigorous process (outlined in Techniques and Methods 3-A22, USGS) to ensure that all their acoustic Doppler current profiler (ADCP) instruments perform within the manufacturer specifications. All ADCP instruments used by the USGS are verified at the HIF and against field comparison measurements when any of the following scenarios occur:

- New instruments purchased
- Repaired instruments (HIF or Manufacturer)
- Approved firmware change
- QA Verification Age Limit (3 Year Cycle)

The HIF QA process for ADCP instruments consists of the following:

- Inspection for physical damage
- Instrument diagnostic self-check tests
- Temperature probe check (must be within ± 2 degrees Celsius of reference)
- Distance made good using bottom track over a fixed distance must meet the manufacturer's specifications ($\pm 0.25\%$ or $\pm 1\%$ difference).

C - Using Bottom Track for Water Track Verification (Distance Made Good)

Bottom Track is the preferred parameter to use for both verification and calibration of ADCP instruments for the following reasons:

- The bottom-track processing algorithm for calculating speed over the ground functions similarly to the water-track velocity calculations. It utilizes the same beam angle transformation matrix and incorporates similar data as used in the water-track velocity calculations.
- The bottom in a tow tank does not move, regardless of facility and water conditions. This principle allows the movement of the ADCP instrument with precise speed over the ground, and or compute the cart average speed by using distance and time travelled. Normally, tow tanks for bottom track verification have a layer of gravel to facilitate the bottom signal.
- The water in the tow tank is impacted by the movement of ADCP resulting in residual currents being generated during each run. Waiting times of up to 30 minutes (tow tank dependent) is required between each run for the residual current to dissipate if water track is measured. By contrast, when using bottom track, water movement does not have an impact on bottom-track / DMG test accuracy.
- Using bottom track instead of water track eliminates unknown uncertainties due to hydrodynamic effects (wake from instrument in water reflecting off tank walls, temperature gradients causing vertical movement, etc.)
- When measuring water-track velocities, seeding material is required due to the lack of suspended particles in the water. The seeding process disturbs the water surface and settling time is required to allow the seeding material to disperse and for the disturbance to dissipate. There is also a cost associated with seeding material and clean-up process. With bottom tracking, seeding is not required.

Using bottom-track velocity to verify successful operation of an ADCP not only confirms calculations of water velocities, it also exercises many different parts of the water and bottom detection algorithm, which further confirms that the ADCP is in proper working condition. If any number of the components that go into the final DMG value has issues, the results will be outside of the acceptable manufacturer's specification.

Distance Made Good

Distance Made Good is defined as the distance travelled from the start of the measurement to the end if a straight line is drawn through the two points. This is a readily available parameter available in SonTek ADCP software (RiverSurveyor Live, RSQ) for down-looking ADCPs. It must be calculated for side- and up-looking

instruments like the SL and IQ. This parameter is calculated based on bottom-track in a tow tank verification test and used to compare to a tow tank track distance calculated independently as reference.

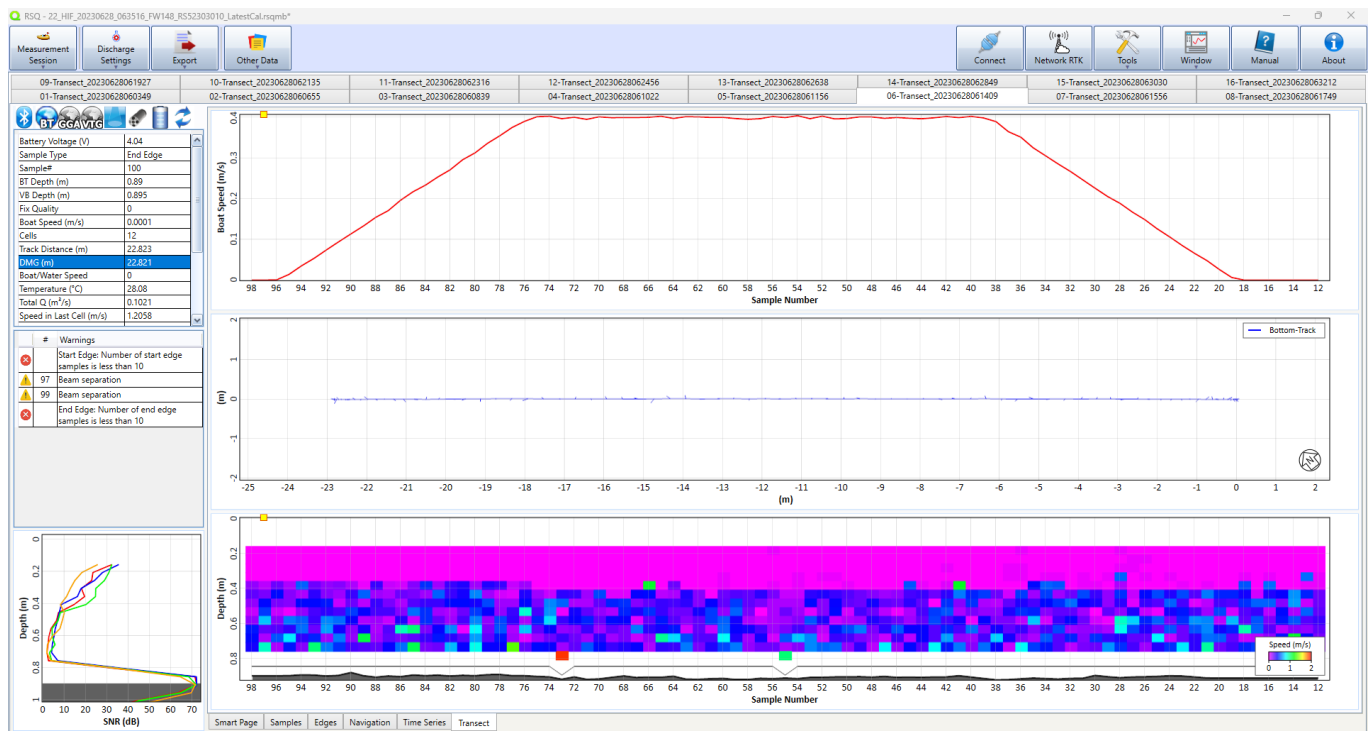


Figure 3. Data from a SonTek RS5 tow tank verification test.

Figure 3 shows a screen shot of data from a SonTek RS5 complete run through a tow tank verification test at the HIF. The final DMG value can be seen in the left tabular window. This value is compared to the track distance calculated by the cart mechanism itself.

The DMG test is conducted on each instrument, and each frequency for multi-frequency instruments. Each frequency is tested twice in both forward and backwards directions (4 tows along the tank) at four

different angles (0°, 45°, 90°, 135°) to compare different leading beams. A total of 16 tow tank runs is performed for the RS5 in the example above. For a SonTek M9, the number of runs is doubled to account for the two different frequencies. The HIF and other agencies use special settings files to force the ADCP to measure in a certain way (fixing the frequencies and disabling certain variables, like the magnetic compass).

Aligning with the Manufacturer's Calibration Process

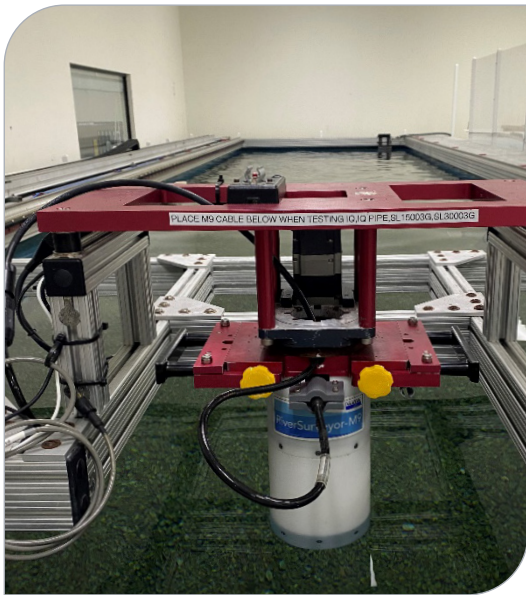


Figure 4. SonTek Beam Angle Calibration tank with a SonTek M9 undergoing calibration.

The verification process adopted by organizations for verifying the following acoustic Doppler instruments should align with the processes developed by manufacturers to remove any discrepancy in the verification results.

- acoustic Doppler Current Profiler (e.g. RiverSurveyor M9, RS5)
- acoustic Doppler Velocimeter (e.g. FlowTracker 2)
- acoustic Doppler Velocity Meter (e.g. SonTek IQ, SonTek SL)

The above process outlined by the HIF and used at other facilities mimics the process each SonTek ADCP undergoes for its own beam angle calibration. Figure 4 shows the SonTek beam angle calibration tank with a SonTek M9 undergoing the beam angle calibration process.

During the transducer potting process, micro-variations in transducer builds require each ADCP to undergo a rigorous calibration process. The M9 is rotated through multiple angles at known speeds over multiple tank runs. The result is a matrix transformation that is specific to each ADCP, an example of which is shown in Figure 5. When an ADCP undergoes a tow tank verification test, it is important that these values be used in the bottom-track velocity calculation to verify they still apply. These parameters play a critical role in the passing or failing of a DMG tow tank test to verify an ADCP is in working order.

If your agency is interested in setting up your own ADCP verification, it is important that you be in touch with the manufacturer to understand their processes. Tow tank testing is extremely sensitive to the setup, and it is critical to follow specific processes developed by manufacturers to ensure there are no false failures in tow tank testing results.

For more information, [contact SonTek's Total Care Customer Service and Technical Support Center](#)

3 MHz

1.17863	-0.00449	-1.16953	-0.00506
0.00309	1.18415	0.00461	-1.19232
-0.27830	-0.27498	-0.27288	-0.27762
0.54823	-0.55486	0.55700	-0.54749

1 MHz

0.83140	-0.83899	-0.82463	0.83134
0.84060	0.83459	-0.83466	-0.84101
-0.27912	-0.27602	-0.27262	-0.27619
0.54780	-0.55135	0.55667	-0.55209

Vertical Beam

0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000
-1.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000

Figure 5. Typical transformation matrix for a SonTek M9.

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