VALIDATION OF CSIR WIND TUNNEL CALIBRATION DATA UNDER DIFFERENT BAROMETRIC CONDITIONS USING COMPARISONS WITH A REFERENCE LABORATORY

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This paper presents the validation of the calibration data of the Council of Scientific and Industrial Research (CSIR) Calibration Wind Tunnel by evaluating its accuracy under different barometric conditions. Using a reference laboratory with established calibration standards as a benchmark, we compared the CSIR wind tunnel's measurements against those from the reference facility across a range of wind speeds. Our methodology involved a series of controlled calibration designed to assess the consistency and reliability of the wind tunnel's calibration data in different atmospheric conditions. The results demonstrated that the CSIR wind tunnel maintains a high degree of accuracy and reliability, with deviations falling within acceptable limits relative to the reference laboratory's data. This validation highlights the robustness of the CSIR wind tunnel calibration process and its capability to deliver precise wind speed measurements' calibration across different environmental conditions.

Keywords: Wind Tunnel Calibration, Calibration Accuracy, Reference Laboratory Comparison, Barometric Conditions

1. Introduction

Accurate wind speed measurements are essential for numerous applications, including environmental, aerospace and aviation research. The Council of Scientific and Industrial Research (CSIR) Calibration Wind Tunnel plays a significant role in providing the calibration of these measurements. On the other hand, maintaining the accuracy and reliability of the wind tunnel's calibration data under a range of environmental conditions is necessary to ensure the integrity of the results. Even though this calibration process is crucial, the wind tunnel's performance needs to be extensively validated to ensure its reliability. Previous measurements evaluations have frequently been narrowly focused, concentrating only on specific conditions, or lacking thorough benchmarks. To guarantee the stability and correctness of the calibration data, a comprehensive assessment of the CSIR wind tunnel's calibration data under various barometric conditions is required.

This paper provides a thorough validation of the CSIR wind tunnel calibration data by assessing its accuracy under various atmospheric conditions. We cross-referenced measurements from the CSIR wind tunnel with those from a reference laboratory that has set calibration standards, for a range of wind speeds. As part of our approach, we conducted a number of calibration experiments to evaluate the accuracy and dependability of the wind tunnel's calibration.

The outcome of the comparison shows that the CSIR wind tunnel consistently maintains high standards of accuracy and dependability, with calibration data deviations from the reference laboratory falling within reasonable limits. This validation confirms the CSIR wind tunnel calibration procedure' dependability and its capacity to provide accurate wind speed measurements in a range of environmental circumstances.

2. Calibration Methods

2.1 Calibration Setup

The validation procedure included carrying out a hotwire anemometer calibration in both the CSIR wind tunnel and the comparison laboratory. The comparison laboratory, which was equipped with high-precision calibration tools, served as a reference for comparison. In both wind tunnel, the hotwire anemometer was installed where the airflow is stable and well-characterized (Wind tunnel test section). The hotwire was aligned with the direction of the airflow to avoid inaccurate measurements due to misalignment (M. Al-Garni, 2007). The calibration included various wind speeds and local density effects were accounted for in order to validate the wind tunnel's calibration data accuracy in different atmospheric conditions.

2.2 Calibration Procedure

The hotwire anemometer was allowed to stabilize before starting the calibration. This warm-up period only ensures that temperature and electronic components have settled. Multiple measurements from both the hotwire anemometer and the wind tunnel at each wind speed (from 0.05 m/s to 25 m/s) were recorded to assess repeatability and consistency. Monitor and record Environmental conditions such as temperature and humidity were monitored, as these can affect the calibration.

Table 1.Measurements as reported by the both participating laboratories

Cal Points	Reference Laboratory				CSIR DAS ASYS CalWT			
	Act (m/s)	UUT (m/s)	Error (m/s)	UoM (m/s)	Act (m/s)	UUT (m/s)	Error (m/s)	UoM (m/s)
1	0.050	0.040	-0.010	0.010	0.067	0.017	-0.050	0.033
2	0.076	0.070	-0.006	0.011	0.087	0.060	-0.027	0.034
3	0.099	0.100	0.001	0.011	0.099	0.100	0.001	0.034
4	0.499	0.510	0.011	0.011	0.503	0.520	0.017	0.033
5	1.002	1.000	-0.002	0.011	0.998	0.980	-0.018	0.038
6	5.016	4.920	-0.096	0.015	4.988	4.950	-0.038	0.146
7	10.046	10.040	-0.006	0.025	10.023	10.050	0.027	0.324
8	15.019	15.160	0.141	0.042	14.969	15.130	0.161	0.432
9	20.030	20.230	0.200	0.039	19.960	19.940	-0.020	0.518
10	25.001	25.350	0.349	0.045	24.973	24.770	-0.203	0.610

2.3 Data Analysis

Collected calibration data was analysed in order to assess the accuracy of the measurements obtained from the CSIR calibration wind tunnel. Statistical techniques were used to assess the consistency of the recorded wind speeds and to measure variations from the data obtained from the reference laboratory. The analysis also took into account the influence of different barometric pressure (sea level and non-sea level pressure) on the accuracy of the measurements.

2.3.1 Evaluation using reported Combined Uncertainties

Calibration measurements from both participating laboratories were compared and the deviations were calculated between the two sets of measurements. The overall measurement uncertainty was determined by adding the expanded uncertainties reported by both laboratories (ISO 13528:2022).

Table 2: Calculated Calibration Deviations

REF LAB (M/S)	ERROR (M/S)	UL (M/S)	LL (M/S)
0.050	-0.023	0.043	-0.043
0.076	-0.010	0.044	-0.044
0.099	0.000	0.044	-0.044
0.499	0.010	0.044	-0.044
1.002	-0.020	0.046	-0.046
5.016	0.030	0.096	-0.096
10.046	0.010	0.355	-0.355
15.019	-0.030	0.469	-0.469
20.030	-0.290	0.561	-0.561
25.001	-0.580	0.664	-0.664

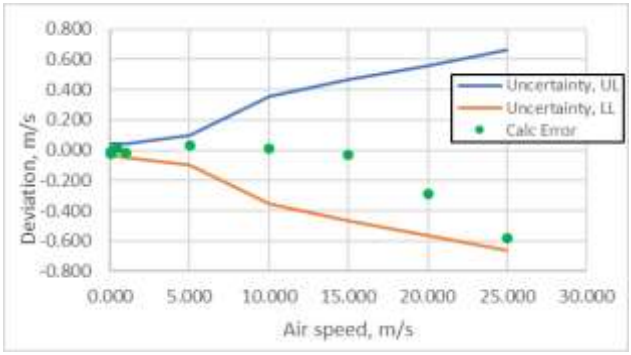

Figure 1. Graphical Presentation

2.3.2 Normalized Error Evaluations

Normalised Error (En) (Frahm and Wright, 2022, p. 10) was calculated using the measured values and their associated uncertainties of measurement, as reported by the participants.

Table 2: En Value Calculation

Ref Lab		CSIR CalWT		En
UUT (m/s)	UoM (m/s)	UUT (m/s)	UoM (m/s)	
0.040	0.010	0.017	0.033	-0.658
0.070	0.011	0.060	0.034	-0.283
0.100	0.011	0.100	0.034	0.000
0.510	0.011	0.520	0.033	0.289
1.000	0.011	0.980	0.038	-0.506
4.920	0.015	4.950	0.146	0.204
10.040	0.025	10.050	0.324	0.031
15.160	0.042	15.130	0.432	-0.069
20.230	0.039	19.940	0.518	-0.558
25.350	0.045	24.770	0.610	-0.949

3. Results and Discussions

3.1 Accuracy assessment

The results show that the measurements taken by the CSIR wind tunnel were really accurate, as the deviations from the reference laboratory's data were within acceptable limits. The calculated deviation from measurements between both participating laboratories fall within the acceptable limits defined by the combined uncertainty of measurement and the En values calculated from both results are satisfactory (En<1). The wind tunnel demonstrated consistent performance throughout the range of wind speeds from 0.05 m/s to 25 m/s.

3.2 Impact of Barometric Conditions

The uncertainty bounds claimed for the CSIR facility were not exceeded in this comparison test in spite of the difference in height above mean sea level of 1300 m between the two laboratories. This increases confidence in the density compensation procedure that is applied to hotwire calibrations performed in the CSIR facility.

3.3 Reliability of Measurements

The measurements showed high repeatability, which further proves the reliability of the CSIR wind tunnel's calibration process. The small variability in deviations between the CSIR calibration wind tunnel and the reference laboratory confirms the proficiency of the existing calibration procedures.

4. Discussion

The calibration process of the CSIR wind tunnel has been validated by this study, showcasing its strong and accurate performance. The CSIR calibration wind tunnel has proven its reliability for wind speed calibration by consistently providing precise measurements even under different barometric conditions.

5. Conclusions

The accuracy and reliability of the CSIR wind tunnel calibration process under different barometric conditions has been verified in this comparison. The wind tunnel's ability to provide accurate wind speed measurements is confirmed by its successful validation against a reference laboratory. These acceptable validation indicates that the calibration procedure used by the CSIR Calibration Wind Tunnel is reliable, the wind tunnel is functioning correctly, and the results are trustworthy for their intended application. This assurance is crucial for maintaining the accuracy and credibility of measurements, ensuring that the data produced can be confidently used in research, development, or industrial applications.

6. Recommendations

Further investigations could explore into additional differences in environmental conditions and how they affect wind tunnel measurements.

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