



UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
Gaithersburg, Maryland 20899-8361

REPORT OF CALIBRATION
FOR
AIR SPEED INSTRUMENTATION

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Submitted by
Ebtron, Inc
1663 Highway 701S
Loris, SC 29569

The calibration of the instrument described above was performed in the 1.5 m by 1.2 m rectangular test section of the NIST Dual Test Section Wind Tunnel. The airspeed was measured by the NIST Laser Doppler Anemometer (LDA). This working standard is traceable to the derived SI units of velocity via the spinning disk method.¹ The instrument under test (IUT) was supported near the center of the tunnel in a manner that presented negligible interference with the flow (see Figure 1). The LDA sensing volume was located 0.3 m upstream of the IUT so that the flow measured by the LDA was not perturbed by the presence of the IUT. The temperature, pressure, and the relative humidity were measured in the test section of the wind tunnel during the calibration. The instrument was calibrated from 0.25 m/s (50 fpm) to 40 m/s (8000 fpm).² For each airspeed setting two calibration cycles were completed with a shutdown between cycles. Each of the calibration cycles consisted of 24 airspeed set points with 5 repeated measurements at each set point. Including all calibration cycles, we measured a total of 10 repeated airspeeds at each set point.

¹ Yeh, T. T., Hall, J. M., *Air Speed Calibration Service*, NIST Special Publication 250-79, National Institute of Standards and Technology, Gaithersburg, Maryland, 2006.

² Throughout this report the acronym fpm denotes feet per minute.

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Figure 1.

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The calibration results for the instrument presented in Table 1 and in Figure 2 were calculated using the means of the 10 measurements at each speed. Both Figure 2 and Table 1 show results from the instrument under test (V_{IUT}) and from NIST primary standard (V_{NIST}) in meters per second (m/s) and feet per minute (fpm), the temperature, pressure, and relative humidity of the air at the wind tunnel test section, the air speed ratio (V_{IUT}/V_{NIST}), and the expanded uncertainty values for the air speed ratios. The uncertainties of the temperature (T), pressure (P), and relative humidity (RH) values listed in the Table 1 are 1 K, 0.1 kPa, and 5 % of relative humidity respectively.

The air speed ratio V_{IUT}/V_{NIST} is plotted in Figure 2 and the error bars in the plot represent the expanded uncertainty. The expanded uncertainty of the calibration of the instrument under test U is calculated by ^{3, 4}

$$U = k \sqrt{u_{V_{NIST}}^2 + u_{Acq}^2 + u_R^2} \quad (2)$$

where the quantity k is the coverage factor (taken to be 2) and used to convert the combined standard uncertainty at the 68% confidence level to the expanded uncertainty at an approximate 95% confidence level. The quantity $u_{V_{NIST}} = 0.21\%$ is the relative standard uncertainty of the airspeed measurements made with the LDA.⁵ The quantity u_{Acq} is the uncertainty associated with the data acquisition system and instrumentation EBTRON PROPRIETARY INFORMATION REMOVED

This standard uncertainty, u_{Acq} , is less than or equal to 0.05 % and can be considered negligible relative to other uncertainty components. To measure the reproducibility, u_R ,⁶ the standard deviation of the mean of the airspeed ratio at each of the nominal airspeeds was used to calculate the relative standard uncertainty (the standard deviation of the

³ Taylor, B. N. and Kuyatt, C. E., *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*, NIST Technical Note 1297, National Institute of Standards and Technology, January 1993.

⁴ Coleman, H. W. and Steele, W. G., *Experimentation and Uncertainty Analysis for Engineers*, 3rd ed., John Wiley and Sons, Inc., 2009.

⁵ Iosif I. Shinder, Christopher J. Crowley, B. James Filla, Michael R. Moldover, Improvements to NIST air speed calibration service, *Flow Measurements and Instrumentation*, V. 44 (2015) pp. 19-26.

⁶ Closeness of the agreement between the results of measurements of the same measurand carried out under changed conditions of measurement. Defined in the ISO, "International Vocabulary of Basic and General Terms in Metrology, 2nd ed.," International Organization of Standardization, Geneva, Switzerland, 1993. Reproducibility is herein defined as the closeness of agreement between measurements with the air speed changed and then returned to the same nominal value.

mean divided by the mean and expressed as a percentage).⁷

Table 1.

T	P_{static}	RH	ρ	V_{NIST}	V_{NIST}	V_{IUT}	V_{IUT}	$V_{\text{IUT}}/V_{\text{NIST}}$	$U, k=2$
[C]	[kPa]	[%]	[kg/m ³]	[m/s]	[ft/min]	[m/s]	[ft/min]	[-]	[%]
20.56	100.2	18	1.186	0.2450	48.22	0.2507	49.35	1.023	0.90
20.52	100.2	18	1.187	0.4964	97.73	0.4996	98.34	1.006	0.45
20.47	100.2	18	1.187	0.7532	148.3	0.7496	147.6	0.995	0.55
20.28	100.2	18	1.188	1.004	197.6	1.000	196.9	0.997	0.44
19.99	100.2	18	1.189	1.255	247.0	1.250	246.0	0.996	0.43
19.73	100.2	19	1.190	1.507	296.7	1.501	295.5	0.996	0.42
19.55	100.2	19	1.191	1.757	345.8	1.750	344.5	0.996	0.41
19.45	100.2	19	1.191	2.011	395.8	2.000	393.7	0.995	0.42
19.31	100.2	19	1.192	2.262	445.3	2.250	442.8	0.994	0.42
19.15	100.2	19	1.193	2.514	494.9	2.501	492.2	0.995	0.41
19.04	100.2	19	1.193	3.770	742.0	3.750	738.2	0.995	0.41
19.66	100.1	17	1.189	5.027	989.6	4.999	984.1	0.994	0.41
19.27	100.0	18	1.190	6.036	1188	6.000	1181	0.994	0.41
19.22	100.0	18	1.190	7.301	1437	7.250	1427	0.993	0.41
19.16	99.99	18	1.190	8.862	1744	8.801	1732	0.993	0.41
19.11	99.98	18	1.190	10.07	1983	10.00	1969	0.993	0.41
19.13	99.94	18	1.190	12.61	2482	12.51	2462	0.992	0.41
19.15	99.91	18	1.189	15.13	2978	15.00	2953	0.992	0.41
19.27	99.88	18	1.188	17.15	3375	17.01	3347	0.992	0.41
19.37	99.82	17	1.187	20.16	3969	20.01	3939	0.992	0.41
19.60	99.72	17	1.185	25.21	4962	25.02	4925	0.992	0.41
19.99	99.61	16	1.182	30.25	5954	30.03	5911	0.993	0.41
20.55	99.47	16	1.179	35.27	6943	35.05	6899	0.994	0.41
21.28	99.31	15	1.174	40.30	7934	40.07	7889	0.994	0.41

⁷ WGFF Guidelines for CMC Uncertainty and Calibration Report Uncertainty. October 21, 2013
http://www.bipm.org/en/committees/cc/ccm/working_groups.html

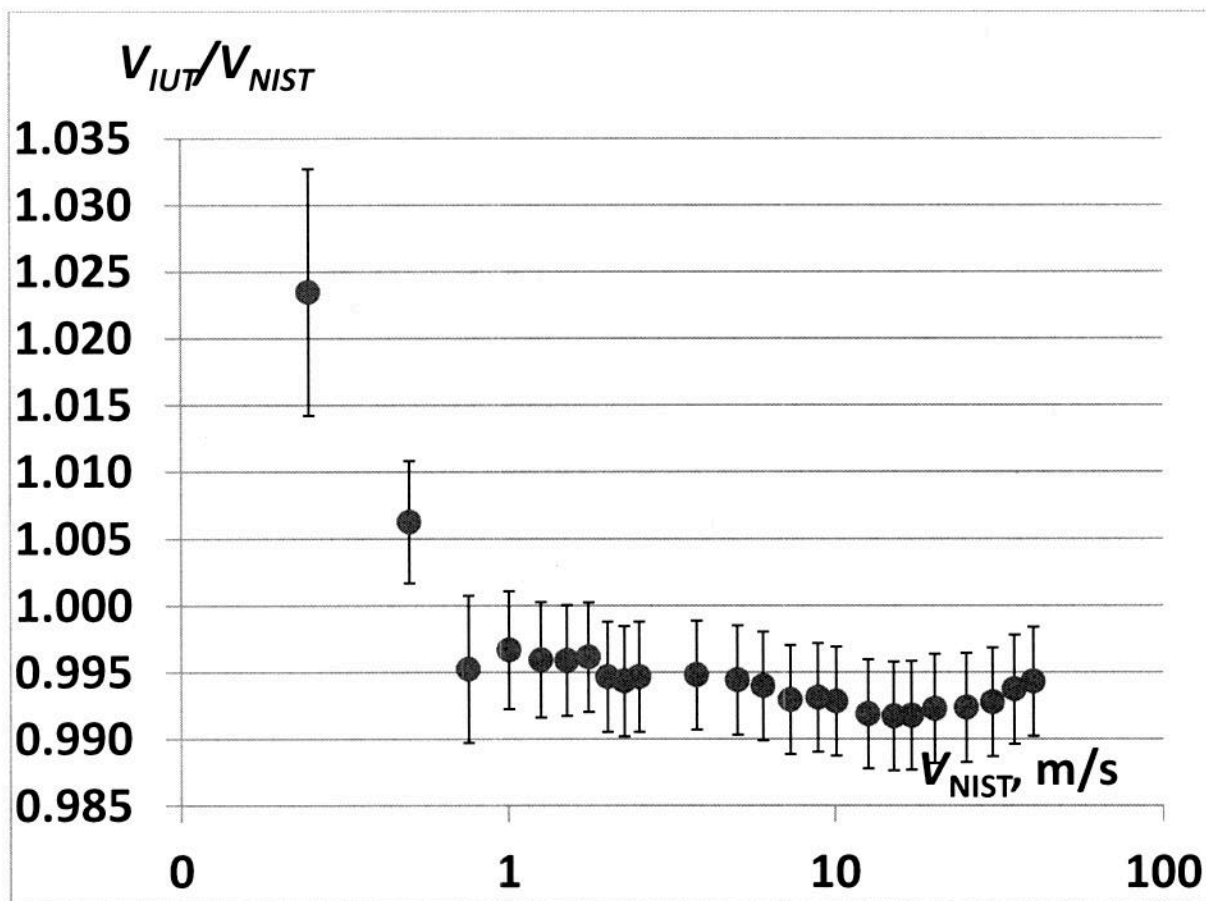
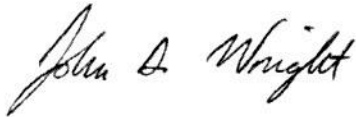


Figure 2.

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The uncertainty reported in this report is for the airspeed ratio V_{IUT}/V_{NIST} . These results apply only to the calibrated instrument under test and only over the range that it was tested. When the REMOVED is applied by the customer to measure airspeed, additional uncertainty sources beyond those included in the NIST calibration should be considered. These additional uncertainty components include: blockage effects, alignment with the flow direction, long term calibration changes, EBTRON PROPRIETARY INFORMATION REMOVED temperature, humidity, etc.

For the Director of the
National Institute of Standards and Technology



Dr. John D. Wright
Leader, Fluid Metrology Group
Sensor Science Division
Physical Measurement Laboratory
National Institute of Standards and Technology

Calibration performed by,



Dr. Iosif Shinder
Physicist, Fluid Metrology Group
Sensor Science Division
Physical Measurement Laboratory
National Institute of Standards and Technology

Calibration Reviewed by,



Dr. Aaron Johnson
Fluid Metrology Group
Sensor Science Division
Physical Measurement Laboratory
National Institute of Standards and Technology