Dynamic Pressure Equations Used at the 14- by 22-Foot Subsonic Tunnel

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Abstract

This document provides a description of equations used to calculate test section dynamic pressure in the 14- by 22-Foot Subsonic Tunnel. The equation used to calculate dynamic pressure is dependent on the test section configuration.

Introduction

The NASA Langley Research Center 14- by 22-Foot Subsonic Tunnel (14x22) is an atmospheric, closed return tunnel with a test section 14.5-ft high, 21.75-ft wide, and 50-ft long that can reach a velocity of 348 ft per sec with a dynamic pressure of 144 psf. The unit Reynolds number ranges from 0 to 2.2 x10^6 per foot. Test section airflow is produced by a 40-ft diameter, 9-bladed fan powered by a 12000-hp solid state converter with synchronous motor. This main drive motor was installed in 2001.

The tunnel (initially named the V/STOL Tunnel and later the 4- by 7-Meter Tunnel) was constructed in 1970 to provide an improved understanding of the aerodynamics of vertical/short takeoff and landing (V/STOL) aircraft configurations. This facility addresses the distortion of the tunnel flow that results from the strong downwash generated by the V/STOL model lift fans or jets and the interaction of the floor boundary layer with the vertical or forward-facing propulsion flow components from the model. Tunnel configurations include a fully closed test section, and an open test section closed only on the floor. An optional boundary layer removal system mitigates the formation of a floor boundary layer in the test section and provide a uniform vertical velocity distribution for ground-effects testing. The 14x22 is also ideally suited for low-speed tests to determine high-lift stability and control, aerodynamic performance, rotorcraft acoustics, turboprop performance, motorsports, and basic wake and flow-field surveys.

An extensive modification was completed in 1984 to improve flow and expand capabilities for both acoustic and rotorcraft testing. In 1999, the facility automation system and new model carts were added to the facility

The dynamic pressure calculations at the 14x22 relate pressure measurements in the settling chamber and at the downstream end of the contraction to a pitot-static probe measurement in the test section (ref. 1). The dynamic pressure is measured approximately 2 feet downstream of the antiturbulence screens at test section station –59.4 (59.4 ft upstream of the test section entrance plane). The probe tip is located 5.4 feet from the north wall, 11.4 feet above the settling chamber floor, or approximately 23 feet to the left of and 13.4 feet below tunnel centerline. The static pressure is measured 12 feet upstream of the test section entrance. The probe is mounted 87 inches above the test section floor at tunnel centerline elevation, and the probe tip is located 14 inches from the wall of the contraction. This dynamic pressure calibration of the 14x22 has traditionally been accomplished through use of a stand-mounted pitot-static probe positioned so that the probe orifices are located along the centerline of the test section at Sta. 17.75. See Appendix for probe and stand descriptions.

Dynamic pressure equations are determined by the test section configuration, either open or closed test section, and with and without Boundary Layer Removal System (BLRS). The equations are based on curve fits that utilize data from the pitot-static probe to calculate cprime (dynamic pressure calibration coefficient as measured by the centerline pitot-static probe). Qcode (dynamic pressure computation flag), which is set based on the test section configuration, determines which set of equations are utilized to calculate cprime. After its calculation, cprime is used to calculate dpinf (dynamic pressure uncorrected for compressibility). Additional corrections are calculated (such as compressibility effects, blockage, wall effects, and others), but are not presented in this document.

This document describes the dynamic pressure computation variables and how dpi (measured indicated difference between total and static pressure) is determined. Next, a description of the equations associated with each qcode is provided. Currently, descriptions and equations exist for qcode 0 through 6 and 11 through 13. Finally, proposed qcode descriptions are listed.

Dynamic Pressure Computation Variables

<u>Input</u>

- ccust – customer specified dynamic pressure calibration constant (default value is 0.0)
- dpi – measured indicated difference between total and static pressure (psf)
- kprcoef – dynamic pressure probe coefficient (value is 0.998)
- pitot – test section dynamic pressure as measured by pitot tube (psf)
- qcode – dynamic pressure computation flag

<u>Output</u>

- cprime – dynamic pressure calibration coefficient as measured by the centerline pitot-static probe
- dpinf – dynamic pressure uncorrected for compressibility (psf)

Qcode Descriptions and Equation

qcode	Test Section	BLRS	dpi	cprime	dpinf	pitot
0	Not applicable (NA)	NA	0.0	0.0	0.0	
1	Pitot Probe		0.0	0.0	0.0	pitot
2	Closed	Off	0.0≤dpi<46.0	$1.1381 + 0.00017194*dpi + 0.0000050536*dpi^2$	cprime*kprcoef*dpi	
			46.0≤dpi<52.5	$1.06032 + 0.00354687*dpi - 0.000031557*dpi^2$		
			dpi≥52.5	$1.1473 + 0.00023339*dpi$		
3	Closed	On	0.0≤dpi<2.5	$0.99 + 0.05929584*dpi - 0.0118592*dpi^2$	cprime*kprcoef*dpi	
			2.5≤dpi<26.0	$1.06 + 0.00169569*dpi - 0.00001914*dpi^2$		
			26.0≤dpi<52.5	$1.0947 - 0.0013401*dpi + 0.00005999*dpi^2 - 0.000000532*dpi^3$		
			dpi≥52.5	$1.08 + 0.00067836*dpi - 0.000001019*dpi^2$		
4	Open	Off	0.0≤dpi≤2.4	$1.16606 - 0.0329*dpi + 0.007*dpi^2$	cprime*kprcoef*dpi	
			2.4<dpi<35.5	$1.1256 + 0.00078*dpi - 0.0000078*dpi^2$		
			dpi>35.5	$1.13365 + 0.00033*dpi - 0.0000015*dpi^2$		
5	Open	On	0.0≤dpi<21.52	$1.09534 + 0.0020529*dpi - 0.000060503*dpi^2 + 0.00000074299*dpi^3$	cprime*kprcoef*dpi	
			dpi≥21.52	$1.10736 + 0.00059111*dpi - 0.0000025559*dpi^2$		
6	Customer Assigned				ccust * dpi	
11*	Walls Up Ceiling Down	Off	0.0≤dpi<4.4	$1.1588 - 0.01084*dpi$	cprime*kprcoef*dpi	
			4.4≤dpi≤52.5	$1.1132 + 0.00065557*dpi - 0.000003349*dpi^2$		
			dpi>52.5	1.1376		
12*	Walls Up Ceiling Down	On	0.0≤dpi<0.5	0.95	cprime*kprcoef*dpi	
			0.5≤dpi<10.0	0.98462 + 0.086044*alog10(dpi)		
			10.0≤dpi≤52.5	$1.0472 + 0.0027465*dpi - 0.000028503*dpi^2$		
			dpi>52.5	1.1128		
13*	Walls Up Ceiling Down w/Vortex Generators	Off	0.0≤dpi<40.0	$1.2882 - 0.000014382*dpi + 0.0000084863*dpi^2$	cprime*kprcoef*dpi	
			40.0≤dpi<46.2246	$1.243684 + 0.002211432*dpi - 0.0000193364*dpi^2$		
			dpi≥46.2246	$1.285 + 0.0004238*dpi$		

Proposed qcode Descriptions

qcode	=	7	(Open Test Section with Acoustic Panels)
qcode	=	14	(Walls up, Ceiling down, Boundary Layer Removal System Suction is On, Vortex Vanes(Generators) are On)
qcode	=	15	(Walls up, Ceiling down, Boundary Layer Removal System Suction is Off, Vortex Vanes(Generators) are On, Aft Bay)
qcode	=	16	(Walls up, Ceiling down, Boundary Layer Removal System Suction is On, Vortex Vanes(Generators) are On, Aft Bay)
qcode	=	17	(Open Test Section, Boundary Layer Removal System Suction is Off, Aft Bay)
qcode	=	18	(Open Test Section, Boundary Layer Removal System Suction is On, Aft Bay

***	These calibrations are out of date. New calibrations for future test(s) are required.***

References

1. Barlow, Jewel B.; Rae, William H.; and Pope, Alan: Low-Speed Wind Tunnel Testing. Third Edition. John Wiley & Sons, Inc., 1999, pp. 219 – 221.

Appendix

Description of probe and support hardware

Probe

The calibration probe is a standard "L"-shaped pitot-static probe, 13.375 inches in length, and manufactured by United Sensor Corp. It is designed to be "wall mounted" from the outside of the flow duct through use of a chuck configured with pipe threads. The probe slides within the chuck and can be positioned so the probe tip orifice is up to 9.6 inches from the mounting surface. The probe is locked in position on the shaft by a pair of set screws.

Stand support

The stand support is a vertical, streamlined steel tube post welded to a base plate, which mounts on the test section floor. The post is braced by two lateral diagonal posts and one extending diagonally downstream, all fabricated of the same streamlined tubing. The post dimensions are as follows: chord, 3.375 inches; thickness 1.375 inches; height 76.76 inches above the base plate (including probe mount fitting). The probe is mounted in a fitting that mates with the tube support and allows limited manual adjustment of the probe's pitch and yaw angles. The mount fitting has the same cross-sectional shape as the support tube, and a top face that is flat and parallel to the tunnel floor, and the probe is mounted so that the center of the pitot orifice is 9.6 inches above the top face of the support post. This support positions the probe at a fixed height above the test section floor. A photograph of the stand-mounted probe installed in the test section is presented in figure 1.

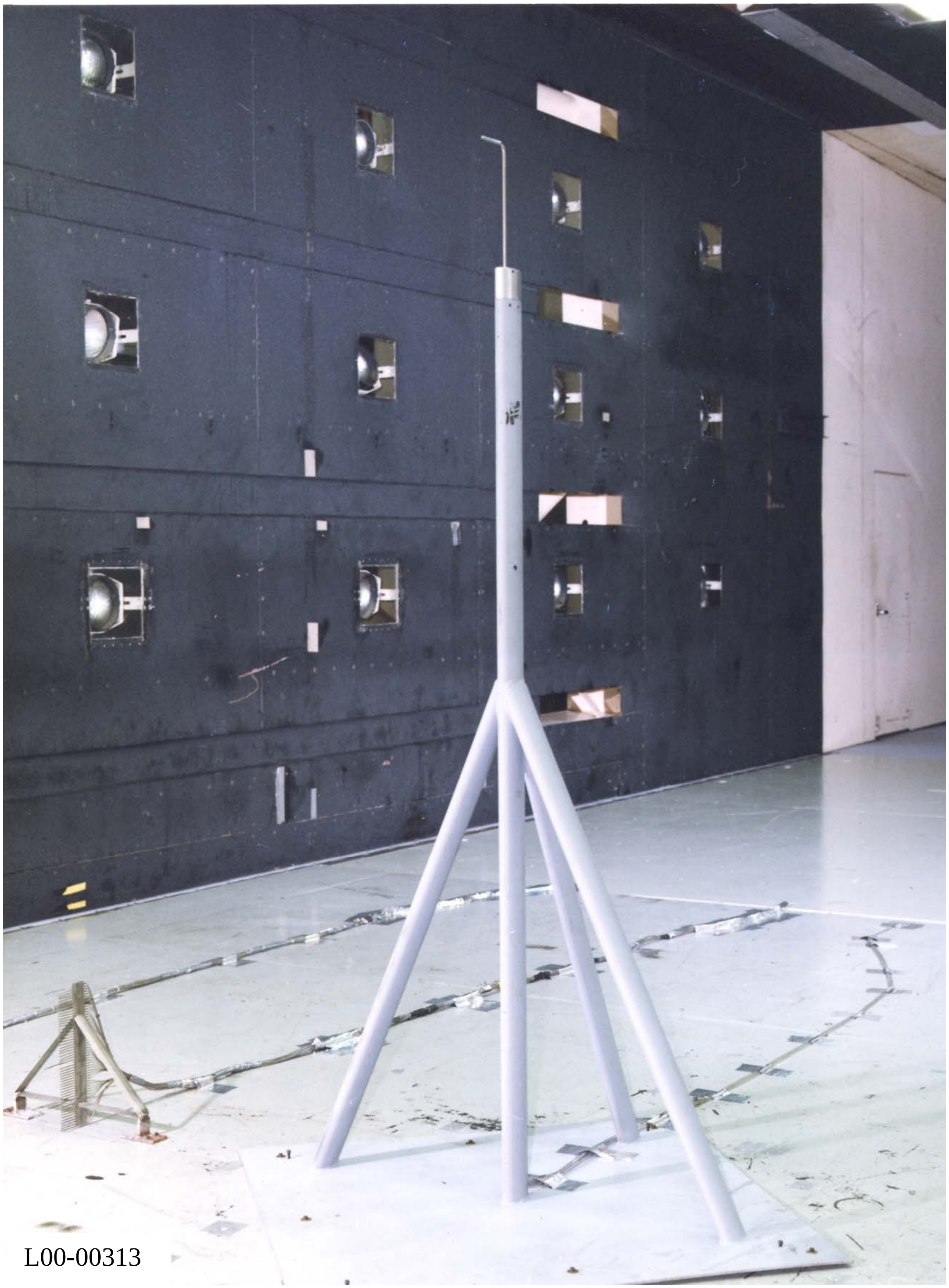

Figure 1. Calibration probe installed on support stand.

Measurements

Measurements of the calibration probe pitot-static pressure were made directly using a precision 1 psi differential pressure transducer. Measurements of the facility reference or indicated dynamic pressure (DPIHS) were also made directly with a similar pressure transducer. The facility indicated dynamic pressure is assessed using a stagnation pressure probe mounted in the tunnel settling chamber just downstream of the antiturbulence screens coupled with a static pressure probe mounted on the wall of the tunnel contraction 12 ft upstream of the test section entrance. The arrangements of measurement probes to the pressure transducers are shown in figure 2.

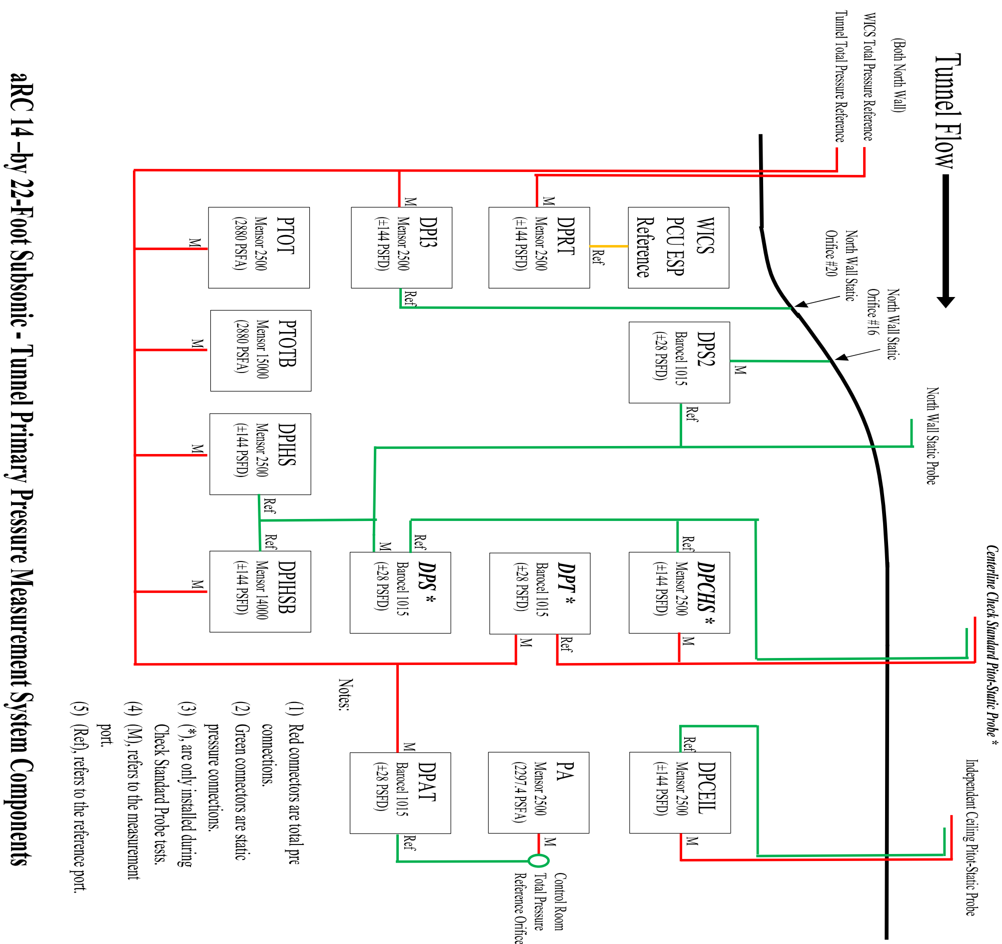

Figure 2. – Sketch of the LaRC 14- by 22-Foot Subsonic Tunnel Primary Test Section Pressure Measurement System Components.