NASA AMES
UNITARY PLAN WIND TUNNEL
BLOCKAGE RECOMMENDATIONS

Ames does not have specific criteria to which users of our facilities must adhere. However, the following suggestions are offered to users of our wind tunnels:

<u>Low-speed</u> (specifically, the 12-Foot Pressure Wind Tunnel):

$$\frac{\text{wing span}}{\text{tunnel width}} \leq 0.8 \qquad [1]$$

and

$$\frac{\text{maximum model cross-sectional area}}{\text{test section cross-sectional area}} \leq 1 - \frac{.25(3M+1)}{\left\{1 + \frac{[.25(3M+1)]^2 - 1}{6}\right\}^3} \qquad [2]$$

where M is the desired test Mach number.

Criterion [1] is a "rule of thumb" based on Ames' experience both in the analysis of test results and from calculations of solid-wall-interference corrections that are applied to all our low-speed solid-wall test results. Criterion [2] is based on the relationship of the model cross-sectional area, the test section cross-sectional area, the chocking Mach number (uncorrected for blockage [construction] effects) and the "rule of thumb" that the difference between the maximum test Mach number and the choking Mach number shall be at least one third of the difference between the choking Mach number and a Mach number of 1.0.

<u>Transonic-speeds</u> (specifically, the 11x11-Foot Transonic Wind Tunnel):

$$\frac{\text{wing span}}{\text{tunnel width}} \approx 0.5 \text{ to } 0.7 \qquad [3]$$

and

$$\frac{\text{maximum model cross-sectional area}}{\text{test section cross-sectional area}} \leq 0.005 \text{ to } 0.01 \qquad [4]$$

It should be noted that the 11x11-Foot Transonic Wind Tunnel has slotted walls with about 6 percent porosity; transonic wind tunnels with walls ventilated different from Ames' facilities may have other sizing criteria.

A list of references that may provide additional information regarding model-sizing criteria is attached. Reference 1 provides a general discussion of correction techniques for closed wind tunnels. References 2, 3 and 4 are the basis for the procedures used at Ames. References 5 and 6 provide information of a general nature regarding sizing criteria for testing at transonic speeds. These references will enable you to compute model-sizing parameters based upon your own specified drag-accuracy requirements for test results from slotted-wall wind tunnels.

Criteria [3] and [4] are in good agreement with the information found in the list of references, but the indicated values are empirically-based on Ames' testing experience and the analysis of test results both by Ames' staff and other users of our transonic facilities. Specifically, for transonic drag verification tests, the following modified criteria are recommended:

$$\frac{\text{wing span}}{\text{tunnel width}} \approx 0.5 \qquad [3a]$$

and

$$\frac{\text{maximum model cross-sectional area}}{\text{test section cross-sectional area}} \leq 0.005 \qquad [4a]$$

However, with criteria [3a] and [4a], the resulting models are generally quite small, and even at the two atmospheres of pressure operating capability of the 11x11-Foot Transonic Wind Tunnel, the test results are, typically, for fairly low Reynolds numbers. Therefore, facility users frequently design models to the following criteria:

$$\frac{\text{wing span}}{\text{tunnel width}} \approx 0.6 \qquad [3b]$$

and

$$\frac{\text{maximum model cross-sectional area}}{\text{test section cross-sectional area}} \leq 0.01 \qquad [4b]$$

It may be of interest to note that a typical "state-of-the-art" transport model designed for testing in the 11x11-Foot tunnel with a scale factor such that

$$\frac{\text{wing span}}{\text{tunnel width}} = 0.6$$

would have

$$\frac{\text{maximum model cross-sectional area}}{\text{test section cross-sectional area}} = 0.006$$

Ames would consider this model to be about the largest practical size for reliable drag verification testing in the 11-Foot Tunnel.

Frequently, other criteria size the models tested in our facilities. These considerations may include, but are probably not limited to:

1. The desirability (or requirement) to test the model in other wind tunnels of different sizes.

2. Load limitations imposed by force and moment sensing balances and support structure.

3. Geometric fidelity, which may not be attainable if models are made too small—e.g., take-off and landing geometrics are difficult to manufacture on small-scale models.

4. The need to match Reynolds number (or some other parameter, such as boundary-layer-transition location) to another set of data or test requirements.

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1984

References for Model/Wind-Tunnel Sizing

1. Pope, Alan; and Harper, John J.: Low-Speed Wind Tunnel Testing. John Wiley and Sons, 1966. Pp 300-377.

2. Sivells, James C.; and Salmi, Rachel M.: Jet Boundary Corrections for Complete and Semispan Swept Wings in Closed Circular Wind Tunnels. NACA TN 2454, 1951

3. Herriot, John G.: Blockage Corrections for Three-Dimensional-Flow Closed-Throat Wind Tunnels, with Consideration of the Effect of Compressibility. NACA TR 990, 1950

4. Maskell, E.C.: A Theory of the Blockage Effects on Bluff Bodies and Stalled Wings in a Closed Wind Tunnel. ARC R & M 3400, 1963

5. Pope, Alan; and Goin, Kenneth L.: High-Speed Wind Tunnel Testing. John Wiley and Sons, 1965. Pp 302-304.

6. Goethert, Bernhard H.: Transonic Wind Tunnel Testing. Pergamon Press, 1961. Pp 200-235

7. Steinle, Frank W., Jr.; and Pejack, Edwin R.: Toward an Improved Transonic Wind-Tunnel-Wall Geometry—A Numerical Study. AIAA-80-0442, 1980

8. Steinle, F.; and Stanewsky, E.: Wind Tunnel Flow Quality and Data Accuracy Requirements. AGARD-AR-184, 1982.

9. Steinle, Frank W., Jr.; and Mabey, Dennis G.: Computer Studies of Hybrid-Slotted Working Sections with Minimum Interference at Subsonic Speeds. NASA TM 86002, 1984