SURFACE FLOW VISUALIZATION REQUIREMENTS FOR TESTING IN NTF

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NASA/Industry panels have addressed the question of wind tunnel to flight correlation using the National Transonic Facility in both 1976 and 1980. The 1976 panel (ref. 1) recommended very strongly that users should "avoid absolute drag comparisons (model to flight) because of thrust measuring uncertainties." The 1980 panel (ref. 2) recommended in a more positive vein, "an early priority for the NTF should be the definition and conducting of an experiment or experiments to provide user confidence in tunnel-to-tunnel measurements (comparing existing facilities to the NTF)." It is just this type of experiment which is currently being developed by Boeing, comparing the Boeing Transonic Wind Tunnel (BTWT), the Calspan 8 Foot Transonic Tunnel, the NASA-Ames 11 Foot Unitary Transonic Tunnel, and the NTF using a swept-strut mounted full model of the 767.

By carefully tailoring the instrumentation package and the test program in each tunnel, this tunnel-to-tunnel correlation can be made using drag level, drag rise due to compressibility, and buffet boundary (fig. 1). At the same time, the variation of drag with Mach number and the buffet boundaries can also be correlated with full-scale in-flight measurements.

These parameters are expected to vary with Reynolds number. Figure 2 schematically indicates this expected variation of drag coefficient for two Mach numbers of interest. The effect of forced boundary layer transition as a function of Reynolds number is well known. To allow a tunnel-to-tunnel correlation, the shape of the various "tripped" boundary layer curves shown in figure 2 and the Reynolds number at which they coalesce should not be a function of the wind tunnel in which the test is run. Yet, turbulence level and distribution, local upflow distribution, test section noise, model surface deterioration, and other factors will affect boundary layer transition. Therefore it is necessary to know the untripped transition location, the shock location, and the trip effectiveness in order to be able to assure a consistent model surface flow condition in the various wind tunnels to be correlated. These are certainly factors which need to be controlled during such a tunnel correlation study.

In the past (ref. 3) very few surface flow measurement schemes have been suggested which offer the potential for application to this problem. Yet it is obvious that surface flow visualization is required at all the facilities to be correlated, including the NTF, in order to allow the following (fig. 3):

1. an understanding of the chordwise and spanwise extent of laminar flow
2. the change in shock location for various trip configurations
3. the effectiveness of the chosen boundary layer trip (since its specifications will change as a function of Reynolds number)
4. a comparison of the separation patterns at the buffet conditions.

It is not the purpose of this paper to offer a solution to this requirement, but merely to point out that it is a requirement to tunnel-to-tunnel correlation testing involving the NTF. Figure 4 is an attempt to define a specification for a surface flow visualization system to be used in the NTF. Recognition of the special limitations in the NTF including physical and visual accessibility, high operating cost, flow contamination requirements, as well as the need for on-line review of the results in order to develop the final trip configurations in a timely manner, leads to the requirements listed.

It is recommended that a high priority be given to the development of such a surface flow visualization system by NASA and all potential users.

References

1. Baals, Donald D. ed.: High Reynolds Number Research, NASA CP-2009, 1976.
2. Ayers, Theodore G.: Report of the Wind Tunnel/Flight Correlation Panel. High Reynolds Number Research - 1980, McKinney, L. Wayne; and Baals, Donald D.; eds., NASA CP-2183, 1981, pp. 249-263.
3. Bobbitt, Percy J.: Report of the Panel on Fluid Dynamics. High Reynolds Number Research - 1980, McKinney, L. Wayne; and Baals, Donald D.; eds., NASA CP-2183, 1981, pp. 169-195.

- Drag Level at "Incompressible" Mach Number
  - Comparison with other wind tunnels at a constant Reynolds Number
  - Comparison with other wind tunnels as a function of Reynolds Number
- Compressible Drag Rise
  - Comparison with other wind tunnels as a function of Reynolds Number
  - Comparison with flight at a constant Reynolds Number
- Lift & Drag Buffet Boundaries
  - Comparison with other wind tunnels as a function of Reynolds Number
  - Comparison with flight at a constant Reynolds Number

Figure 1.- Output of correlation testing at NTF for transport-type configurations.

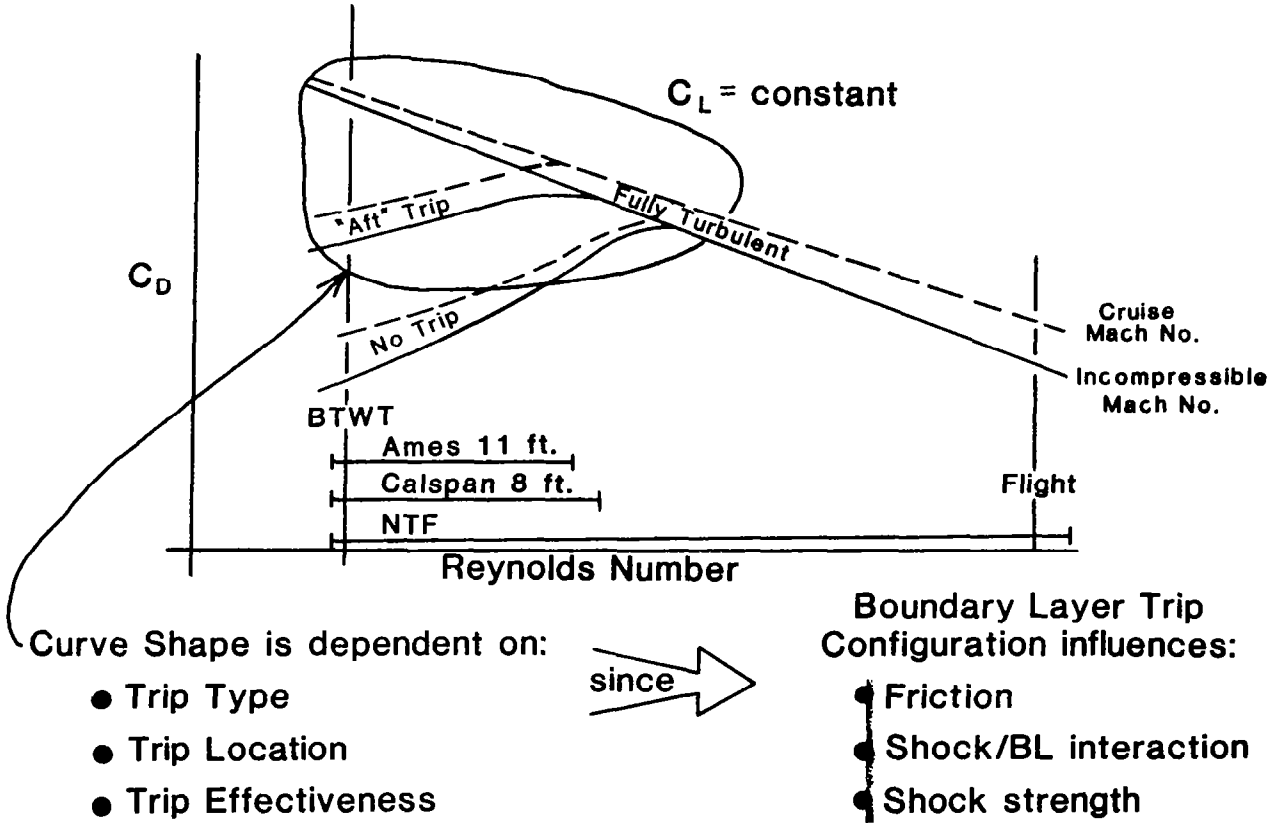

Figure 2.- Expected drag variation with Reynolds number.

- Meaningful Testing at NTF will require Surface Flow Visualization to identify:
  - Extent of Laminar Flow (Aft trip location requirements)
  - Shock Location
  - Shock/Boundary Layer Interactions
  - Trip Effectiveness
  - Separation Patterns

as a function of Mach Number and Angle of Attack

Figure 3.- Correlation testing with NTF.

- Application
  - Remote
  - Rapid
- Patterns
  - Rapid Development
  - Easily Recorded
  - Readily Interpreted
- Material
  - No measurable Impact on Flow Field
  - Non-contaminating
- Documentation
  - On-line visibility
  - Clear permanent records

Figure 4.- Surface flow visualization requirements.