Wind Tunnels

If the prototype Mach number, M, is lower than about 0.3, then subsonic wind tunnel testing may be appropriate and the primary focus should be the Reynolds number scaling. If the intention is to employ a small scale model of the device or to test the device or model at non-prototypical wind speeds then particular attention needs to be paid to the comparison of the model and prototype Reynolds numbers. Even when the model and prototype Reynolds numbers are matched other, lesser factors (apart from a Mach number effect) may cause discrepancy between the model and the prototype; examples are the effect of the turbulence in the flow entering the working section, the surface finish of the model and the effect of the nearby tunnel walls.

We begin with examples of wind tunnels designed for subsonic flows ($M < 0.3$). Though some wind

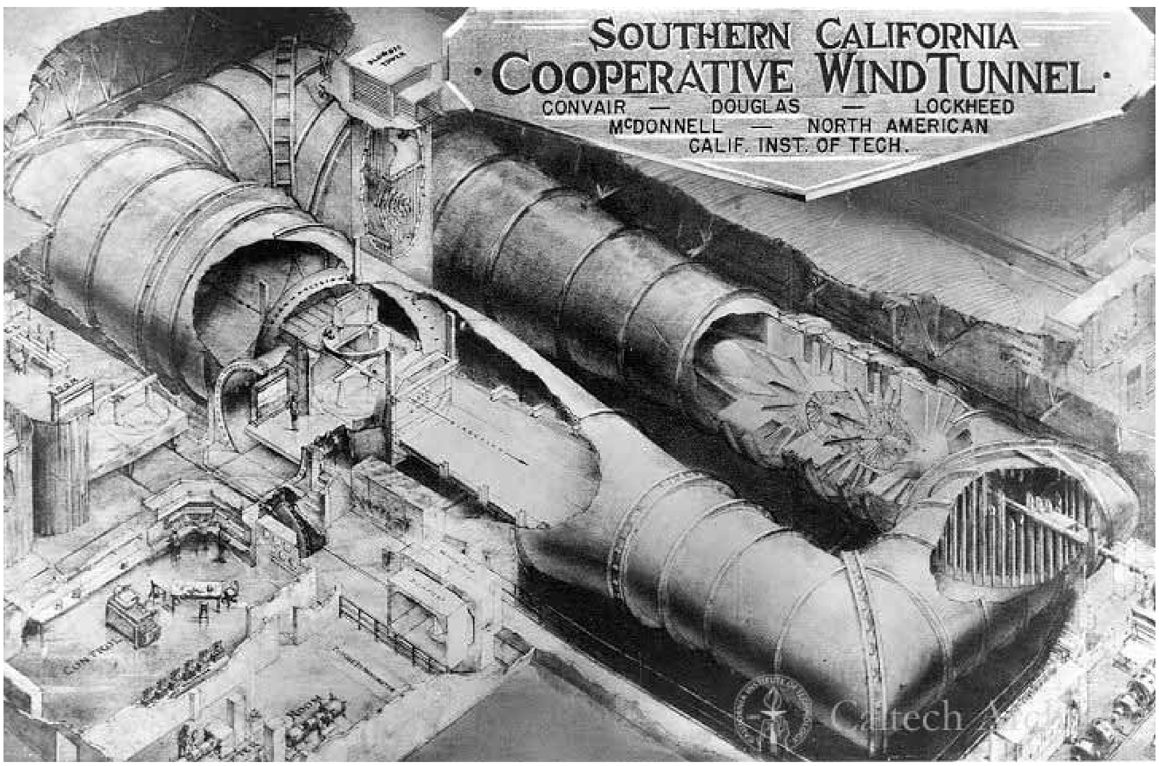

Figure 1: Russell W. Porter schematic of the Southern California Cooperative Wind Tunnel.

tunnels were constructed in the late 1800s, perhaps the most famous early example was the small tunnel that the Wright brothers constructed in order to study the effects of air flow over various shapes for their *Wright Flyer*. However, only a short time later much larger facilities were being built in many countries including France, Germany and the USA. This culminated in the 1930s and 1940s with the construction of some very large wind tunnels with working sections some $20ft$ in diameter. Notable examples were the Wright Field Wind Tunnel in Dayton, Ohio, with a working section $6.1m$ in diameter and capable of air speeds of $640kph$ and the Moffett Fields Wind Tunnel in Sunnyvale, California, capable of speeds up to $250mph$. Another example was the Southern California Cooperative Wind Tunnel constructed in 1945 by the local airplane manufacturers and managed by the California Institute of Technology (Figure 1). Like most of those very large wind tunnels, the Southern California Cooperative Wind Tunnel was eventually demolished, but Caltech continued many decades of experimental aerodynamic research using the smaller but more flexible Ten Foot Wind Tunnel shown in Figure 2.

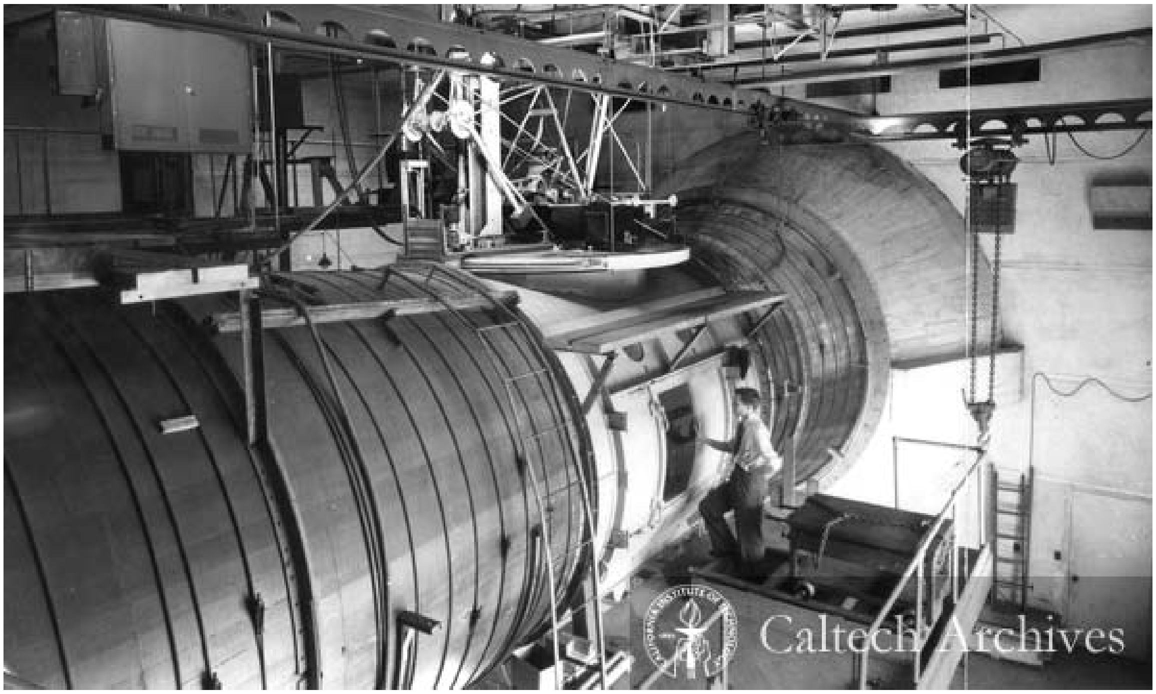

Figure 2: Ten Foot Wind Tunnel at the California Institute of Technology.

In the late 1940s and 1950s, the focus of aerodynamic research and development shifted to higher speeds and it became clear that high subsonic ($0.4 < M < 0.75$) and transonic ($0.75 < M < 1.2$) facilities would be needed. The basic design of tunnels with incoming working section Mach numbers less than unity is essentially the same as the lower speed tunnels with the minot caveat of more attention to wall effects. Thus, for example, the transonic flows around modern passenger aircraft wings and components can be studied in traditional subsonic tunnels provided attention is given to adjustments in the instrumentation. However, the supersonic aerodynamic research required for higher Mach numbers meant that an entirely

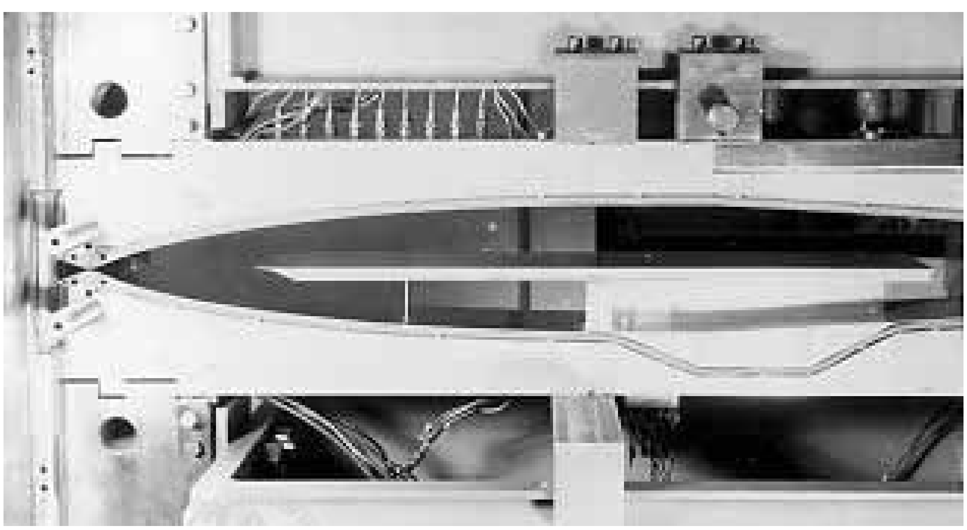

Figure 3: Hypersonic Wind Tunnel at the Jet Propulsion Laboratory.

new form of wind tunnel would be needed. To create a supersonic, incoming working section flow it is necessary for the incoming flow to proceed from a high pressure reservoir into a choked nozzle with a supersonic diffuser (see section (???)). In this way supersonic incoming working section flows as high as $M = 5$ have been achieved; even higher Mach numbers ($5 < M < 15$) are given the name *hypersonic*. The challenge with such a high-powered facility is to sustain the flow for sufficient time to make a measurement. Figure 3 shows the hypersonic wind tunnel at the Jet Propulsion Laboratory in Pasadena, California.