AERO 401: Aerospace Propulsion Systems (Fall 2021)

Supersonic Wind Tunnel

Week of: 27 Sept 2020
Assessment: Presentation
Due: Two Weeks from Lab Session

The Cal Poly Supersonic Wind Tunnel (SSWT) is a blow-down tunnel with a variable area, 2D converging-diverging nozzle leading to a 4.8 x 4.8 inch test section. Through nozzle geometry variation and pressure regulation, the tunnel can achieve test section Mach numbers ranging from 1 to 4.

The objective of the lab is to compare theory (ideal) with experimental (real) implementation of inducing supersonic flow using a converging-diverging nozzle, and experience the use of high-energy fluid for producing thrust. Pressure measurements used to calculate the test section Mach number will be compared to the theoretical Mach number predicted with the nozzle geometry.

We recall from AERO 303 class the four basic types of supersonic wind tunnels. They are blow-down, continuous flow, atmospheric inlet and shock tube.

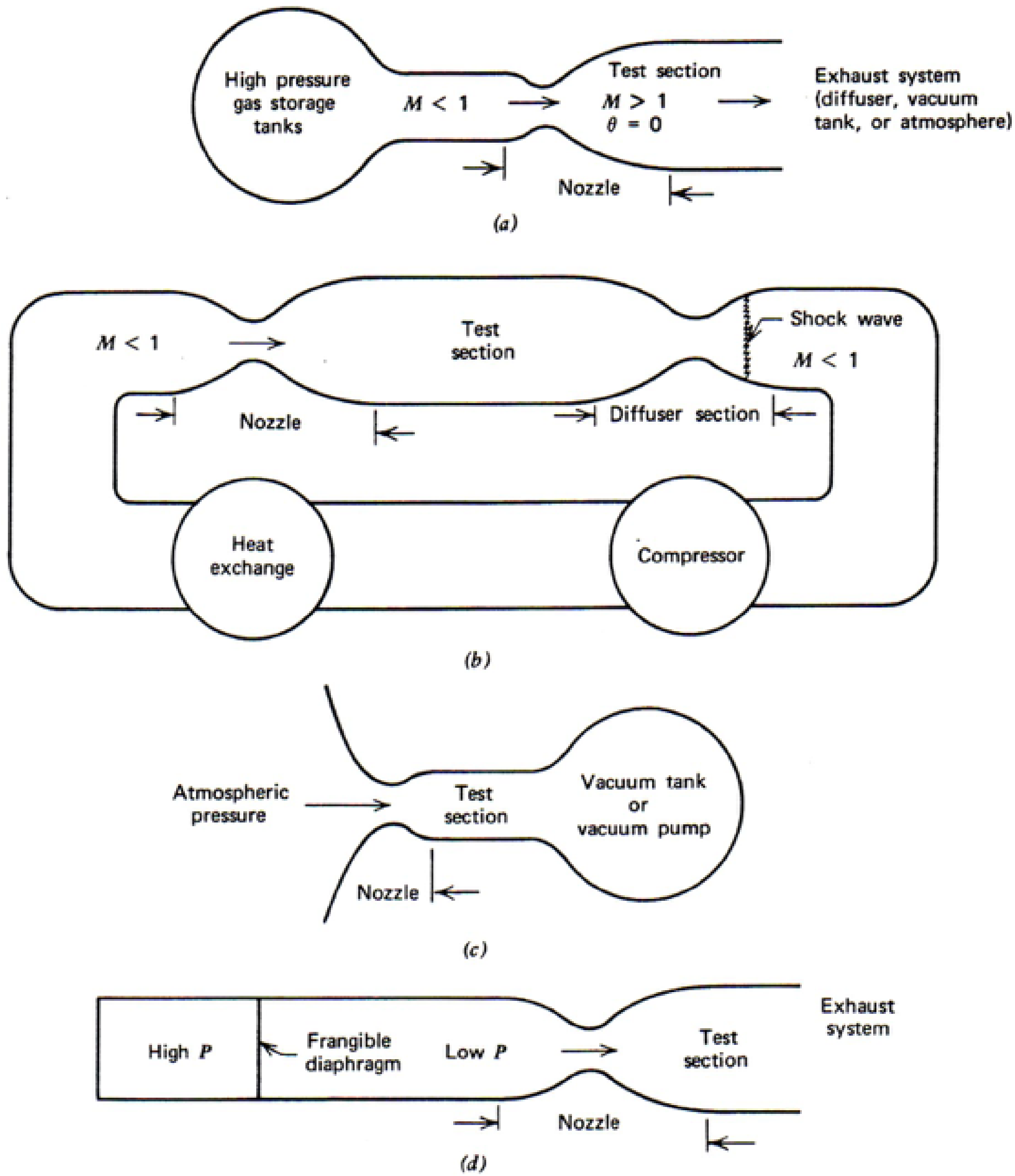
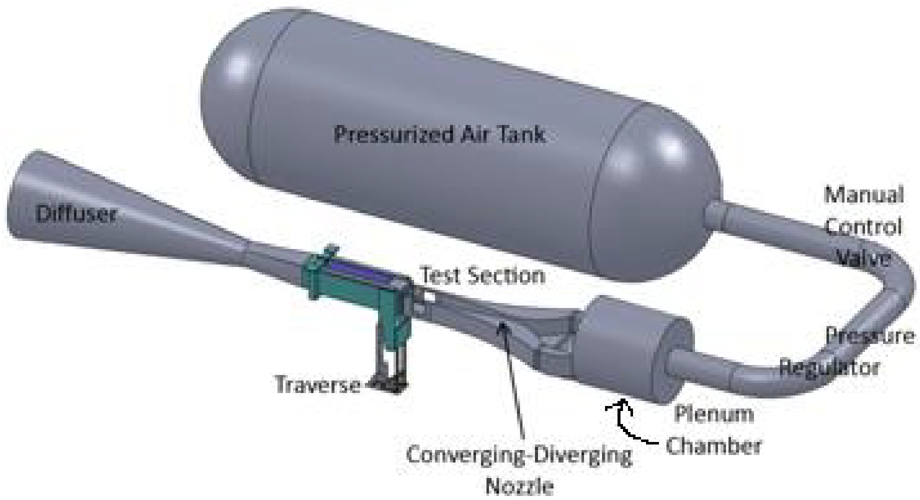


Figure 7.40 Several types of wind tunnels. (*a*) Blow-down wind tunnel. (*b*) Continuous flow wind tunnel. (*c*) Atmospheric inlet wind tunnel. (*d*) Shock tube driven wind tunnel.

APPARATUS:

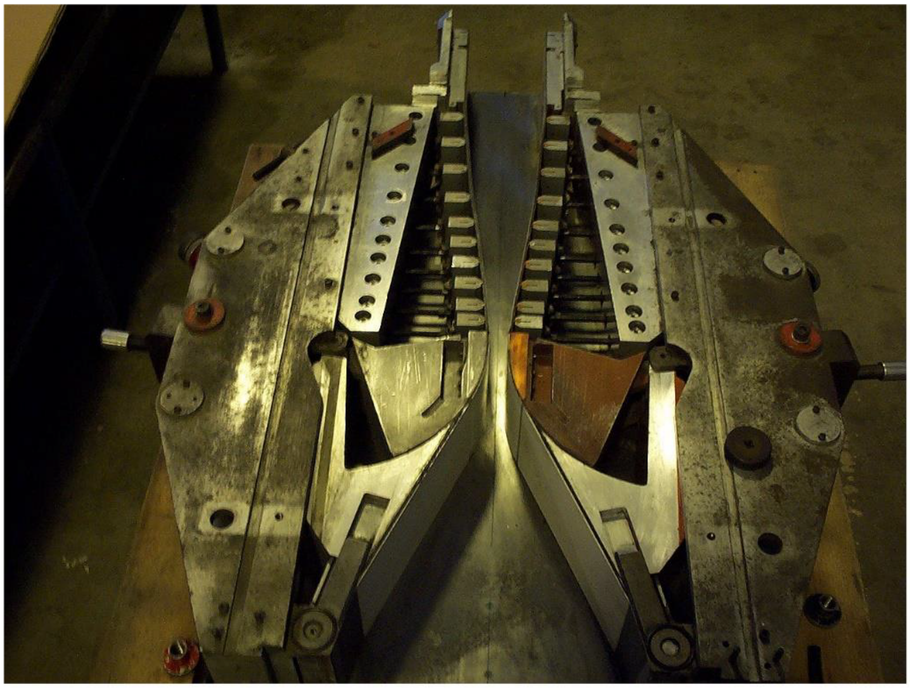
Cal Poly Supersonic Wind Tunnel (SSWT)



A storage tank provides the high-pressure air required to operate the tunnel. It is raised to pressure by an external compressor. A manual control valve is used as a “lock out” to ensure (via manual hardware) that the tank does not vent to the tunnel until desired. An electro-pneumatic valve is controlled from within the control room to start and stop pressurized airflow from the tank to the tunnel.

A manual pressure regulator is used to set and hold the pressure downstream of the electro-pneumatic valve. The pressure-regulated air enters a plenum chamber where internal screens straighten the flow. The air then passes through the converging- diverging nozzle and into the test section.

The nozzle shown below is made of adjustable walls that allow the geometry to be modified for the desired test section Mach number. First, the throat area must be small enough to choke the flow for the given mass flow rate. The accuracy of the divergent section wall contour is critical to achieve isentropic flow expansion and the desired Mach number. The method of characteristics is used to determine the necessary wall contour.



Cal Poly-Model Supersonic Wind Tunnel Specifications:

- The air storage tank is 25 ft long, 8 ft in diameter.
- The pressure limit in the air tank is 190 psi.
- The plenum chamber velocity is approximately zero.
- The test section dimensions are 4.8 x 4.8 inches.

DATA ACQUISITION:

Pressure transducers are used to measure pressure in the storage tank, plenum chamber, and a pitot-static probe measures pressure in the test section. The voltages from the Omega PX613 -100G5V (accuracy of 1%) pressure transducers are routed to a National Instruments USB-6008 data acquisition unit, which converts the analog voltages to digital data, which is routed to the National Instruments LabVIEW software running on the SSWT facility PC.

SSWT LAB ASSIGNMENT:

Calculations and Results:

1) Plot the four measured pressures (psia) vs time, all on one plot.

2) Determine the test section Mach number based on the geometry of the throat and test section, using a throat width of 1.02 inches. How accurate is this calculation?

3) Determine the test section Mach number from the pitot pressure measurement, calculated using P_{02}/P_{01}. How accurate is this calculation?

4) Determine the test section Mach number from the pitot static pressure measurement, calculated using P_{02}/P_{2}. How accurate is this calculation, since the static pressure is measured at an angle and not parallel to the flow?

Plot the three freestream Mach numbers vs time. Take an average of the Mach number over the run time, how do the answers compare to each other?

5) Using the Mach number calculated in question 2, calculate the freestream static temperature in the test section, being sure to do the calculation in absolute units. How does this relate to the condensation at the tunnel exit when the tunnel is running? Use a temperature of 84 Deg F for the testing day.

Discuss the following points in your presentation:

6) Discuss the relative tank and plenum air pressure during the run.

7) Describe the purpose of all the tunnel's major components.

8) Describe the process of changing the test section Mach number.

9) If the flow field in the test section is determined to be non-isentropic at some location, what can be done to correct it?

10) Describe the transient operation of tunnel start-up and shutdown. Show a sketch of the flow.

11) Discuss why accuracy of the data diminishes at both of the Mach number limits for this wind tunnel.

12) Calculate the most probable error in the measured Mach number (from P_{02}/P_{01}) and explain the possible reasons that the calculation may be inaccurate.

13) How and why does mass flow rate change throughout the test?

14) What did you see in the plenum that indicates the flow into the converging portion of the nozzle isn't ideal?

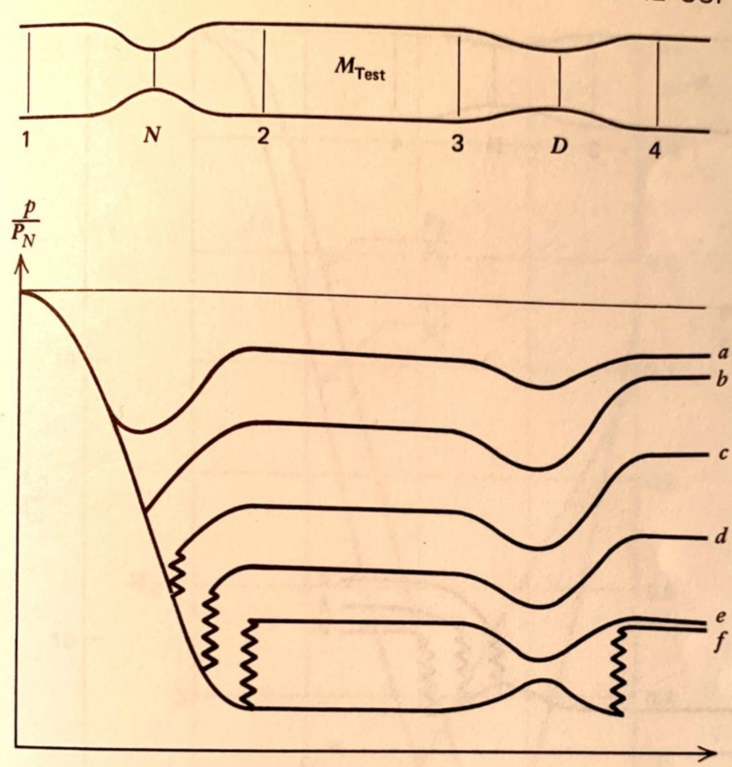


Figure 7.42 Pressure distributions for several stages during the start-up of a supersonic wind tunnel.