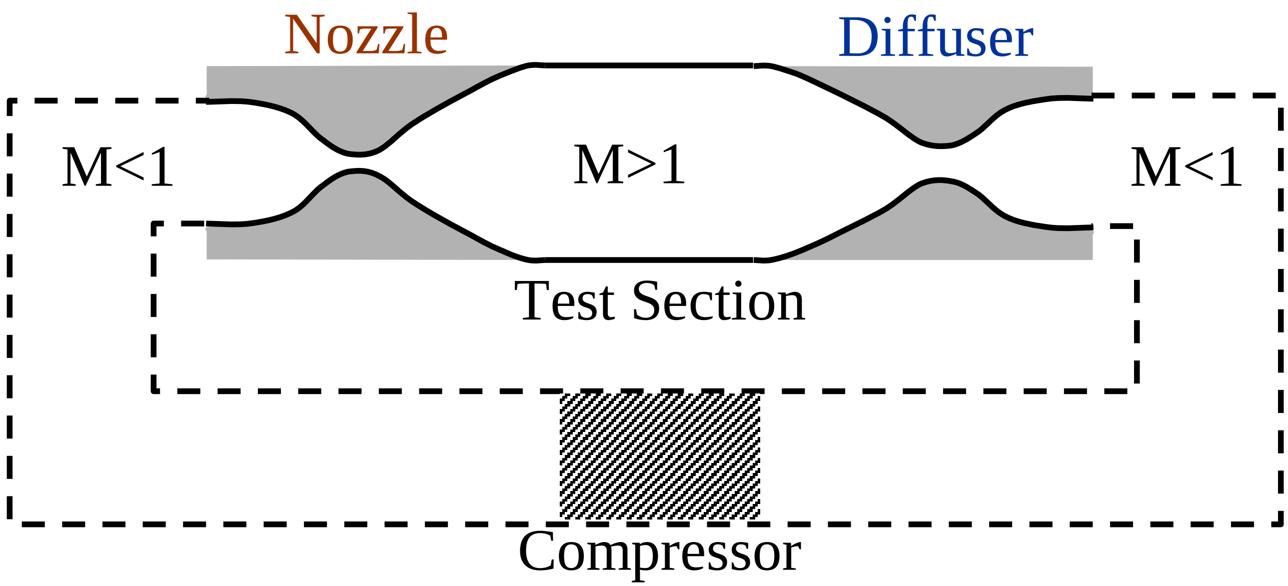
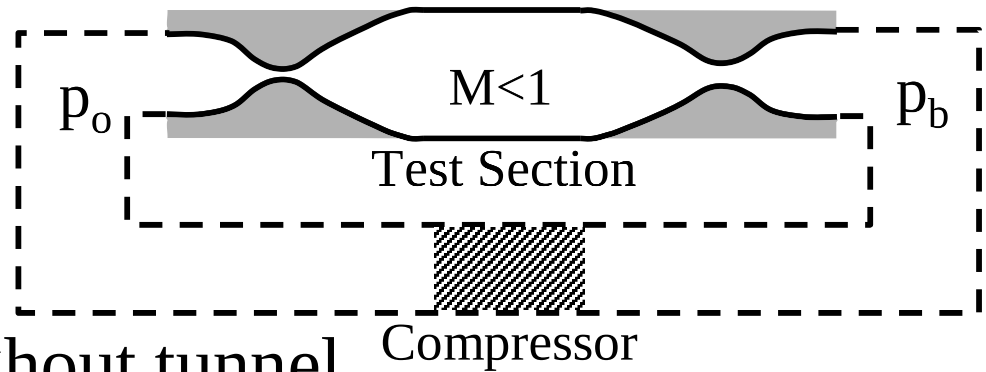
Supersonic Windtunnels

- For supersonic wind tunnels, closed circuit tunnel requires less power to operate then open tunnels
  - do not have to accelerate flow as much

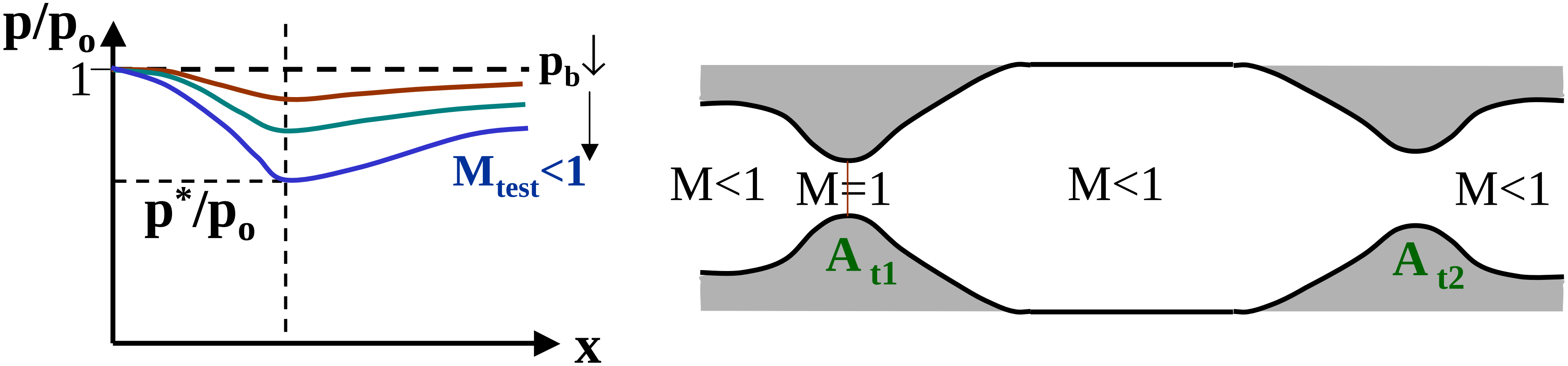


- Use two CD nozzles (really nozzle and diffuser)
  - need subsonic flow (compressors)
  - less p_o loss than using shock to get subsonic flow

Starting Problem

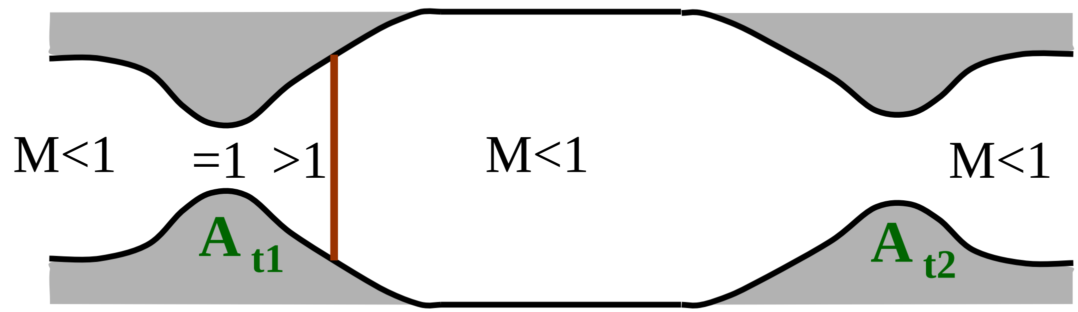


- What happens during tunnel startup
  - no initial velocity
  - pressure uniform throughout tunnel
  - start tunnel by changing $\mathbf{p_o/p_b}$ using compressor
- As raise p_o/p_b, start with subsonic flow everywhere
  - eventually reach M=1 at 1st throat (if $A_{t1} \leq A_{t2}$)

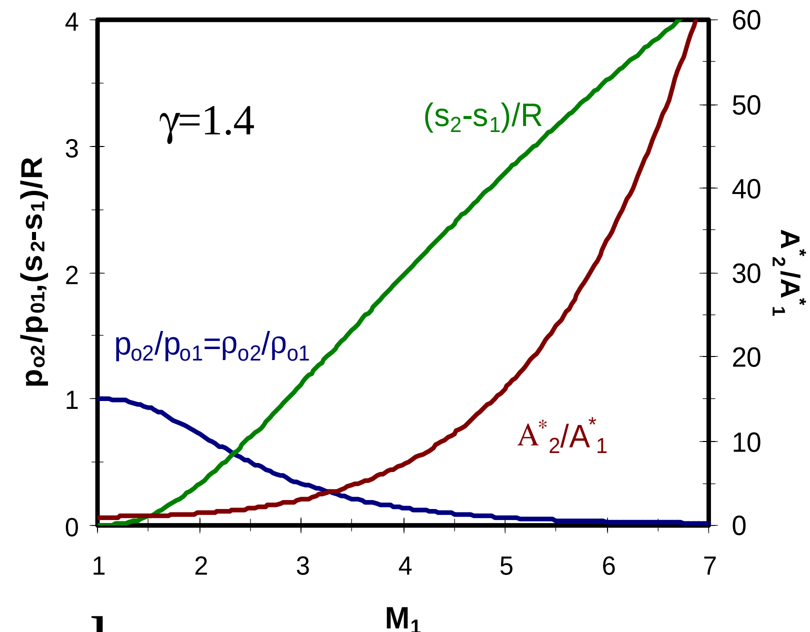


Starting Shock

- Further increase in p_o/p_b
  - normal **shock** in diverging section of "nozzle"

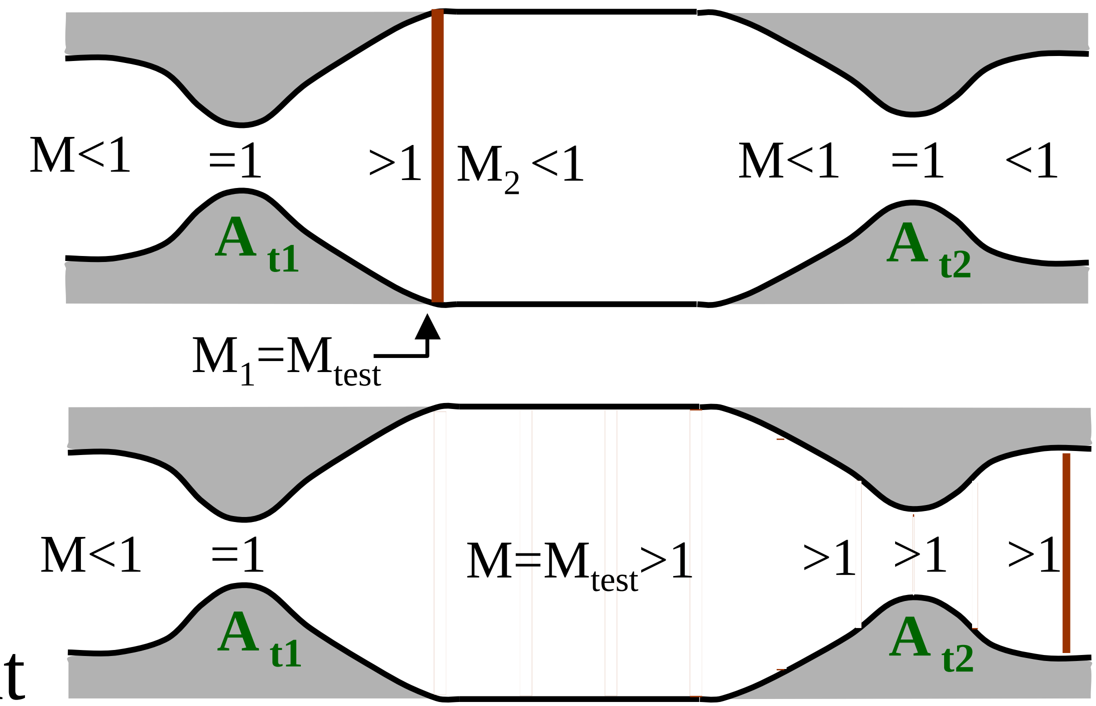


- Can $A_{t2}=A_{t1}$?
  - A* increase across shock ($A_2^*/A_1^* \sim p_{o1}/p_{o2}$)
  - to get same mass flowrate through 2nd throat, **$A_{t2}>A_{t1}$**



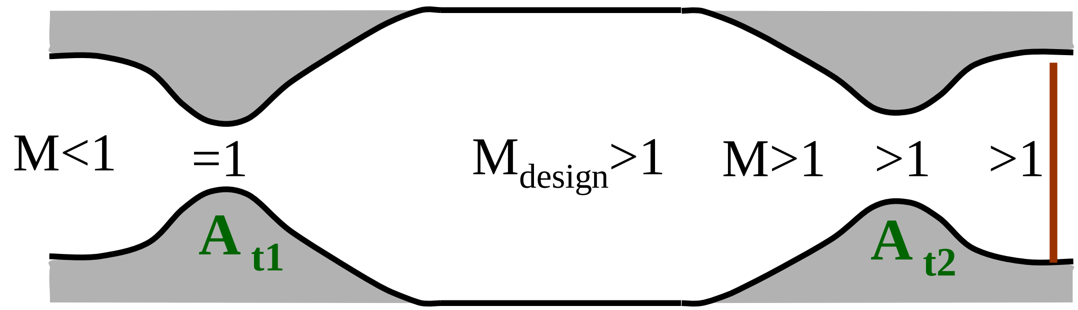
- How big does A_{t2} have to be?
  - biggest p_o loss for strongest shock
    ⇒ shock in test section

Swallowing Shock

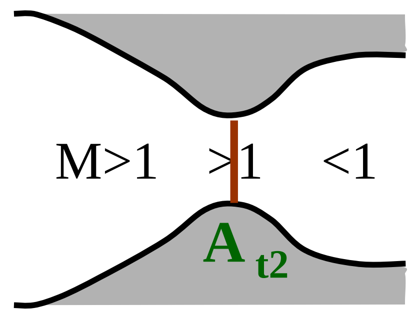


- So raise p_o/p_b until shock enters test section
  - M in test section = M_2 after shock
- To have shock “disappear,” must pass through 2nd throat
  - $A_{t2}=A_2^*@M_2$ after shock at M_{test}
  - increase p_o/p_b slightly above previous case
  - shock leaves test section, enters “diffuser”
  - A_2^* drops (M↓); shock keeps going; **shock swallowed**

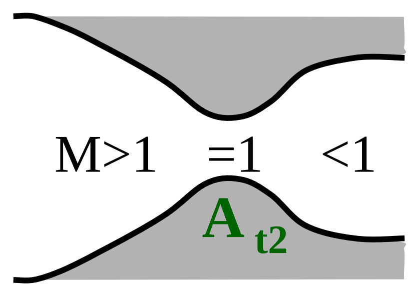
Operating Conditions



- Want to run tunnel with **lowest power** requirements
  - lowest p_o loss
  - operate with weakest shock possible



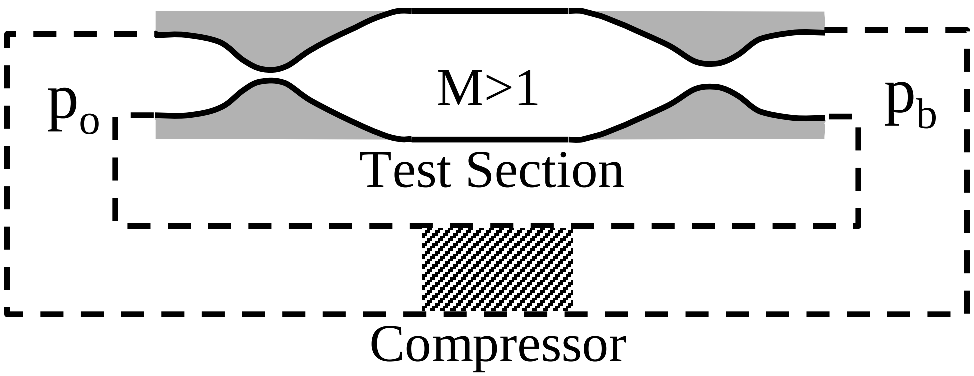
- **Fixed diffuser throat area**
  - weakest shock (M lowest) when it is at diffuser throat
  - more stable operation (for p_o/p_b variations) if shock just downstream of throat



- **Variable diffuser throat area**
  - lowest p_o loss for no shock (M=1)
  - reduce **A_{t2} to A_{t1}** (stability, $A_{t2}=A_{t1}+\Delta$)

Example: Windtunnel Design

- **Given:** Supersonic windtunnel designed to run on N_2 (nitrogen) and operate at M_{test}=3, 1 m^2 test section



- **Find:**
  1. Minimum diffuser throat area to start tunnel i.e., get supersonic flow in test section
  2. Maximum p_o loss during startup
  3. Minimum p_o loss during operation for fixed area diffuser

- **Assume:** TPG/CPG with γ=1.4