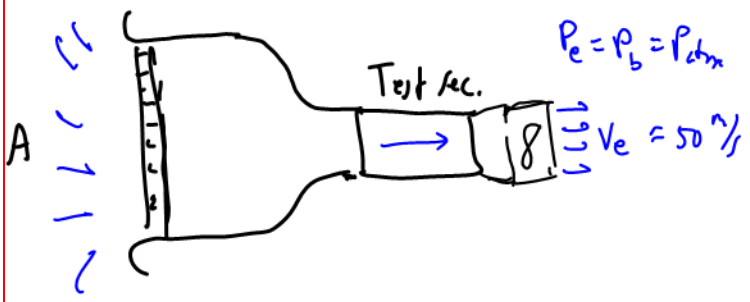
Today, we will:

- Discuss subsonic versus supersonic wind tunnels and the effects of second throats and supersonic diffusers
- Do Candy Questions for Candy Friday

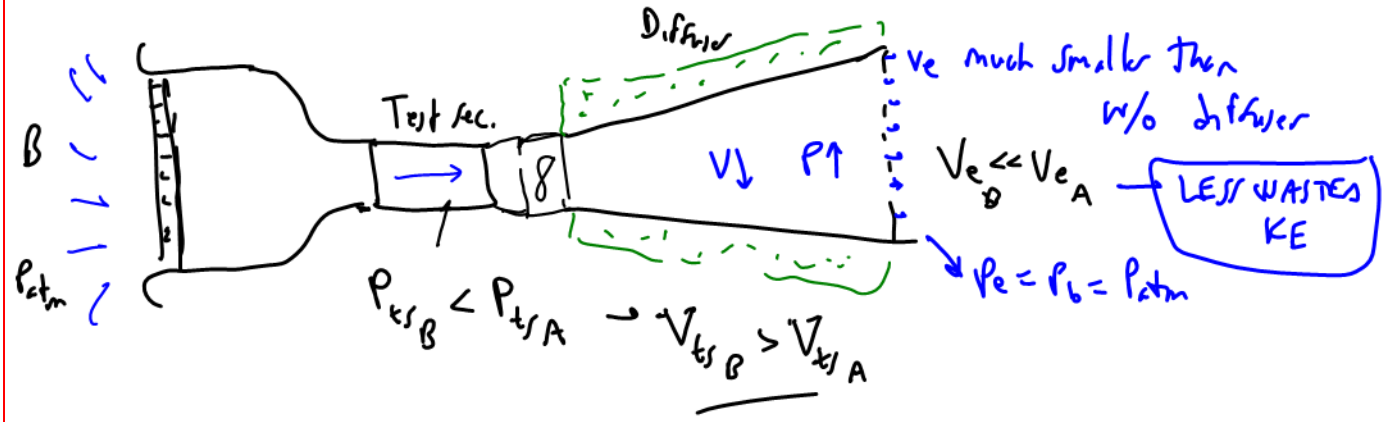
✡ SUPERSONIC WIND TUNNELS

SUBSONIC WIND TUNNEL



$KE \propto V_e^2$

ALL WASTED



V_e much smaller than w/o diffuser

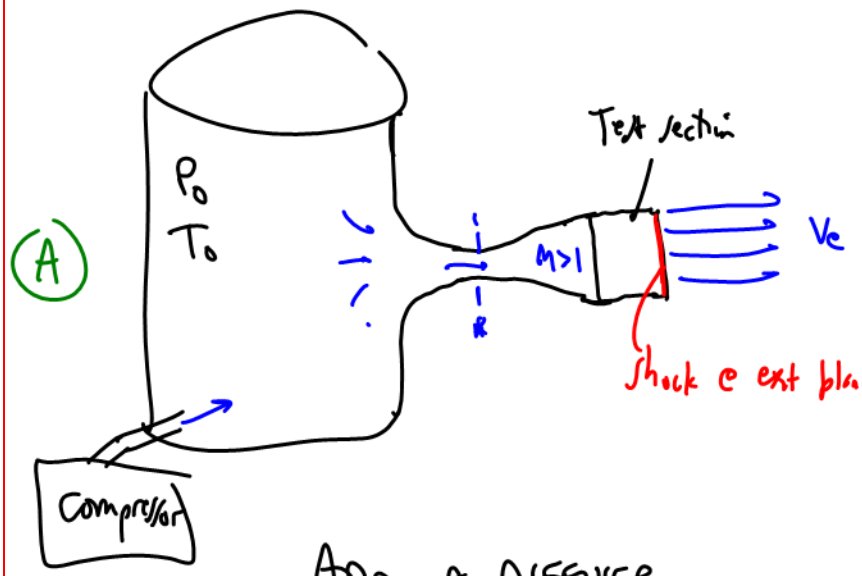
LESS WASTED KE

for "Free" 1) Faster flow in test section

or 2) Lower power requirement for the same flow speed

CAN WE DO SIMILAR FOR SUPERSONIC?

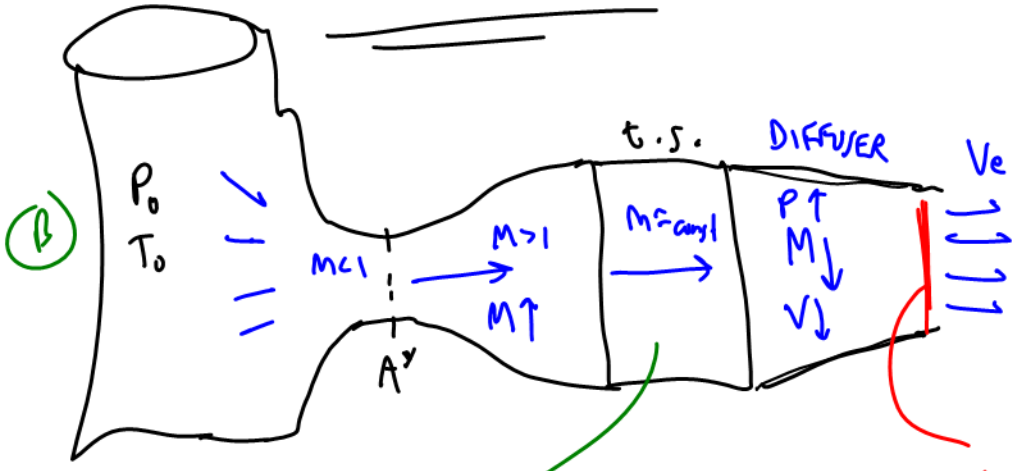
SUPERSONIC WIND TUNNEL – "Blow Down" type



$K.E.$ of jet $\propto V_e^2$
is all wasted

Shock @ exit plane or supersonic jet comes out

ADD A DIFFUSER



OR, can have a shock – Then $M_e < 1$

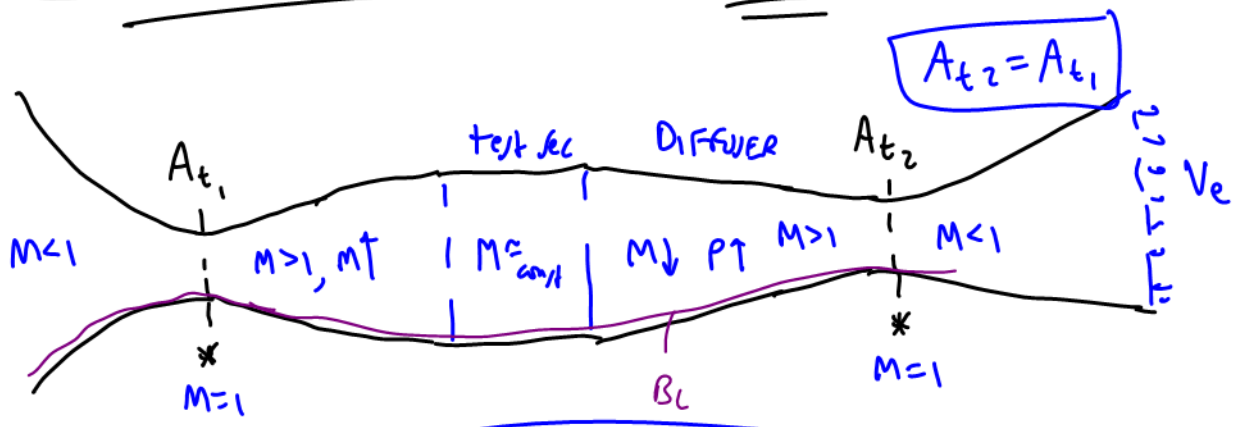
This $P_{ts_B} < P_{ts_A}$ → ∴ $P_{0_B} < P_{0_A}$ to achieve same $M_{t.s.}$

Smaller P_0 → less $

CAN IMPROVE EVEN MORE

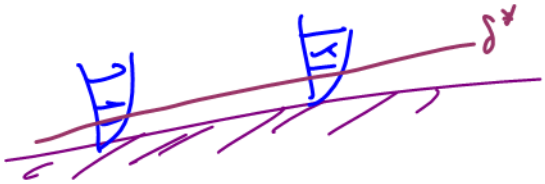
ADD A second throat

IDEAL CASE



REAL LIFE → A_{t_2} must be > A_{t_1} to achieve this

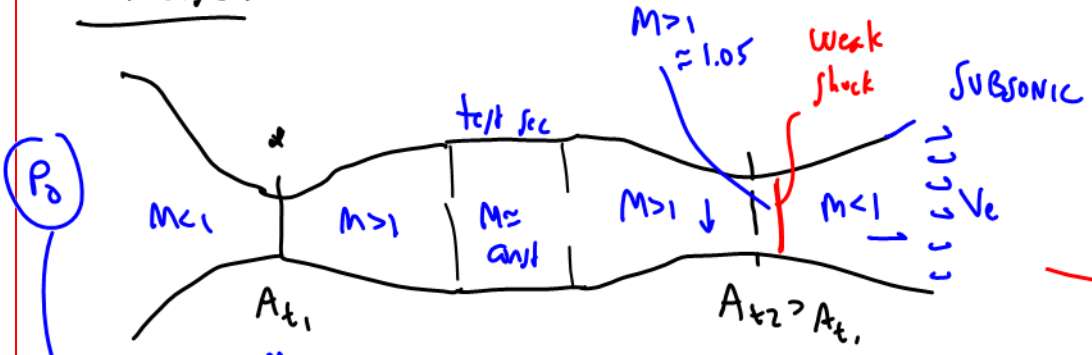
We have BL, always walls → DISPLACEMENT THICKNESS



Effect is a "thicker" wall

For same effective throat area, A_{t_2} must be > A_{t_1} to account for displacement thickness

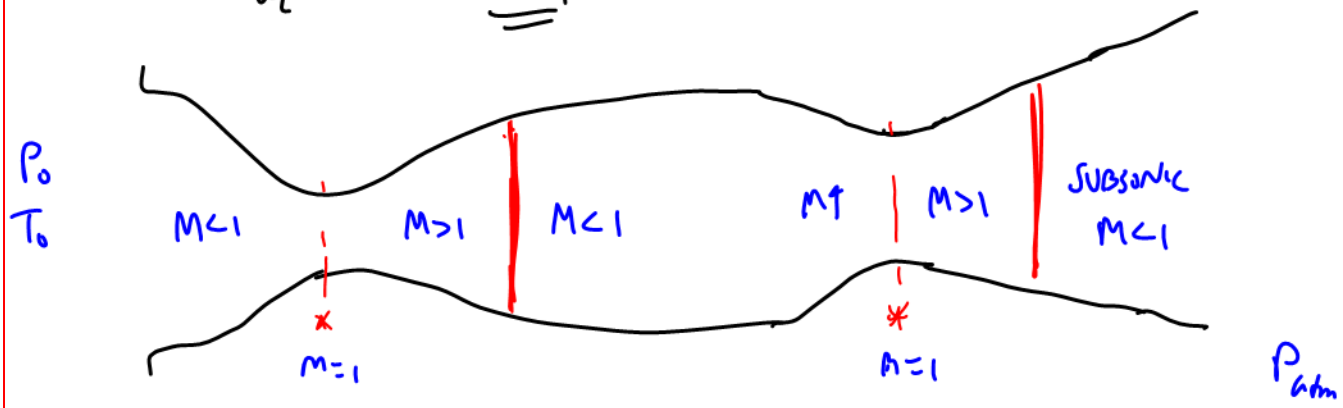
Real case:



least possible energy waste

Can achieve same M_{ts} with a smaller P_0 → ∴ less $

IF A_{t_2} is too small



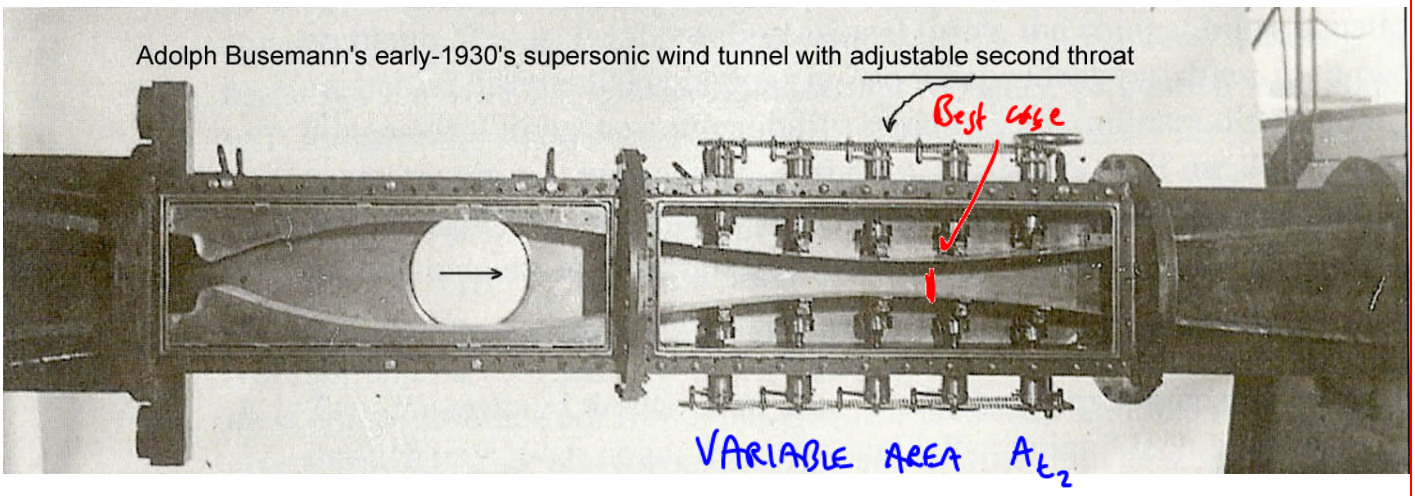
THIS IS CALLED BLOCKED

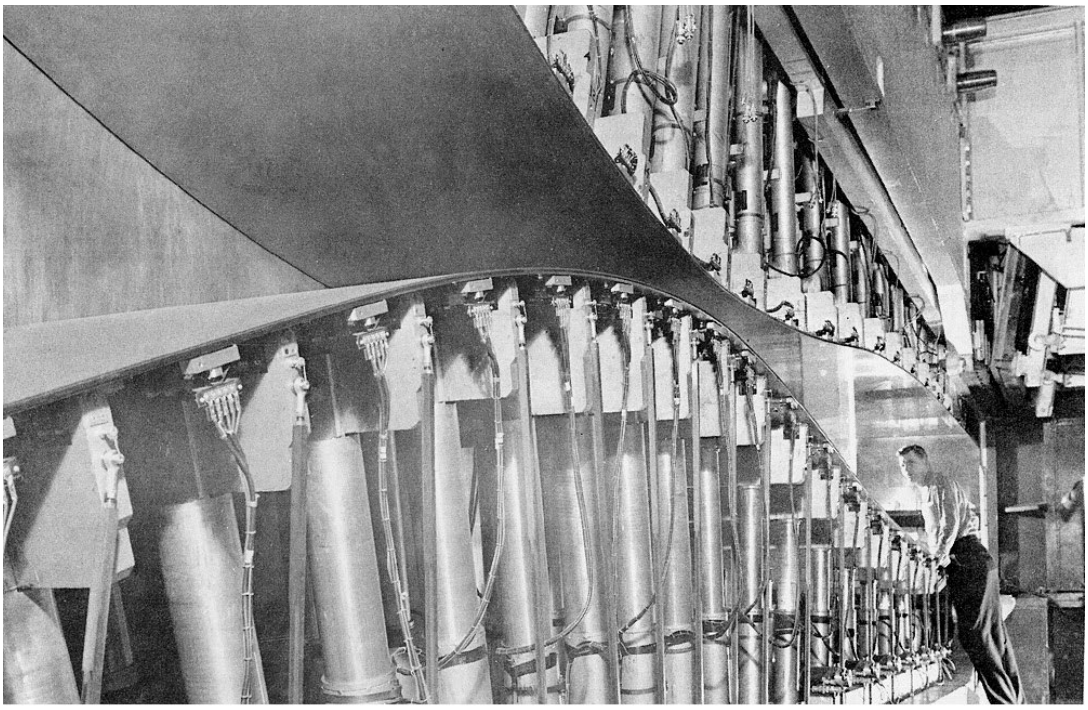
BAD

TO AVOID THIS, MUST MAKE A_{t_2} slightly bigger

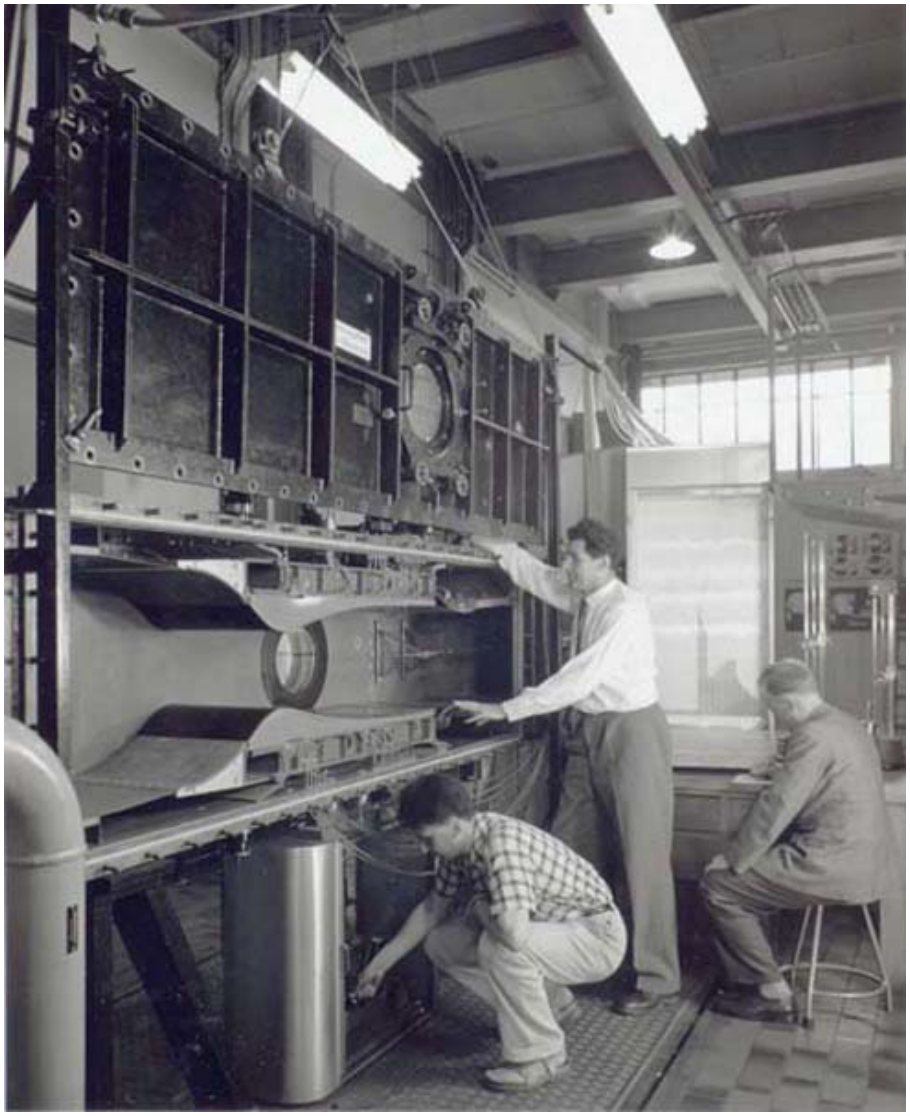
upstream shock will suddenly move out → have M>1 in test section

Some pictures and diagrams of supersonic wind tunnels:

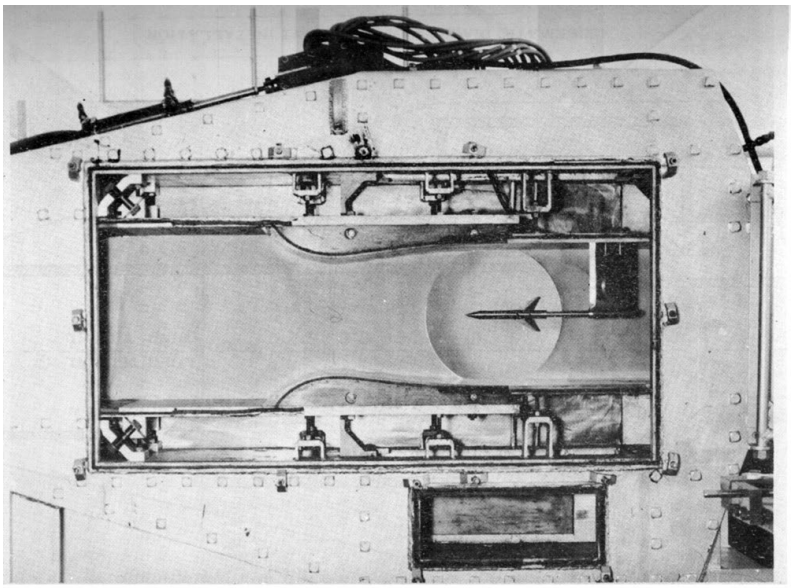




Variable-area-ratio nozzle via flexible hydraulic-actuated ceiling and floor plates (USAF AEDC Tunnel A)



Jakob Ackeret's supersonic wind tunnel in Germany.

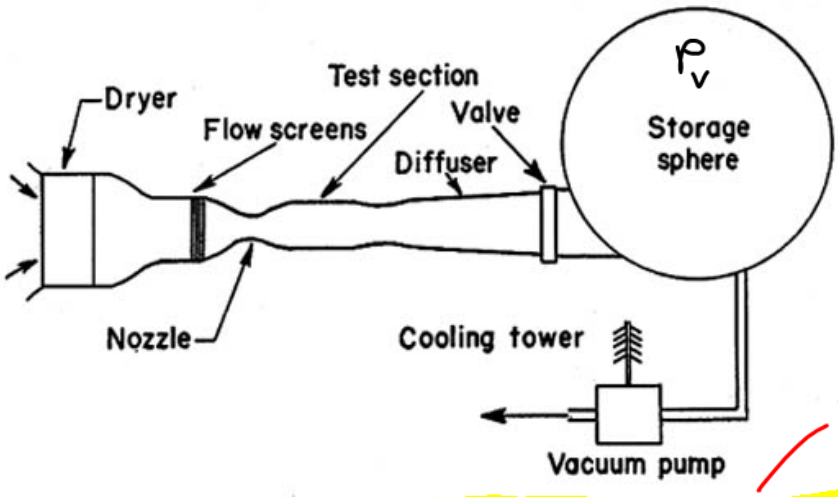


Fixed nozzle blocks for M = 1.5 (UTIAS Rpt. 15, 1953)

Three main types of supersonic wind tunnel:

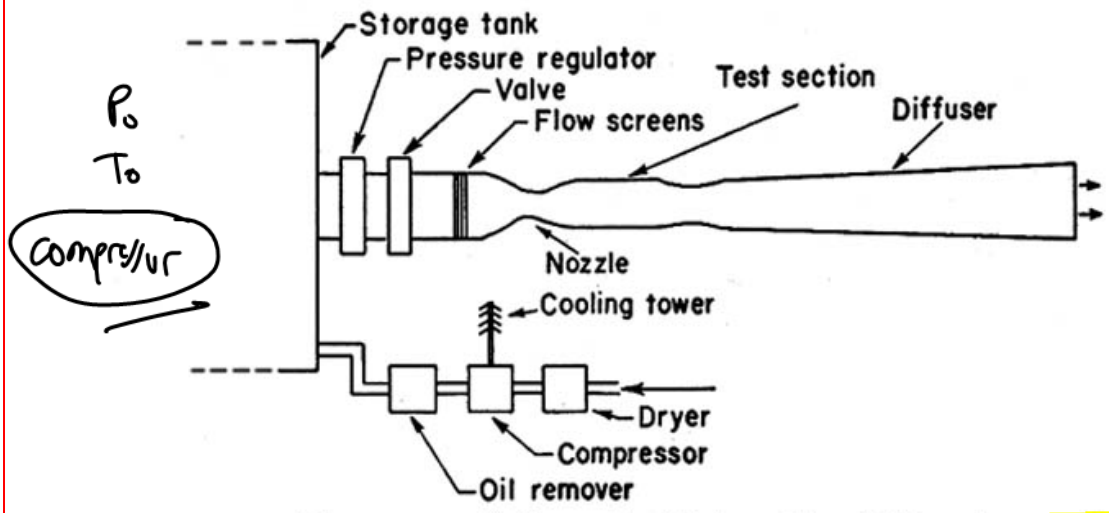
$P_o = P_{atm}$

P_v = Vacuum Pressure



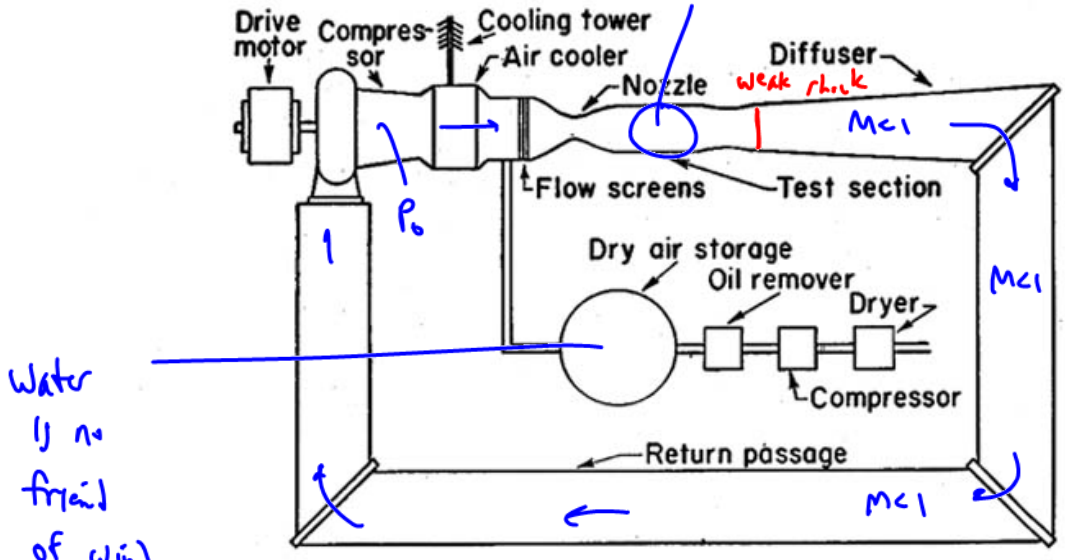
Diagrammatic layout of intermittent indraft wind tunnel.

If Vacuum pump large enough, can be steady state



Diagrammatic layout of intermittent blow-down wind tunnel.

TEST SECTION $M \simeq$ const, $M_{ts} > 1$

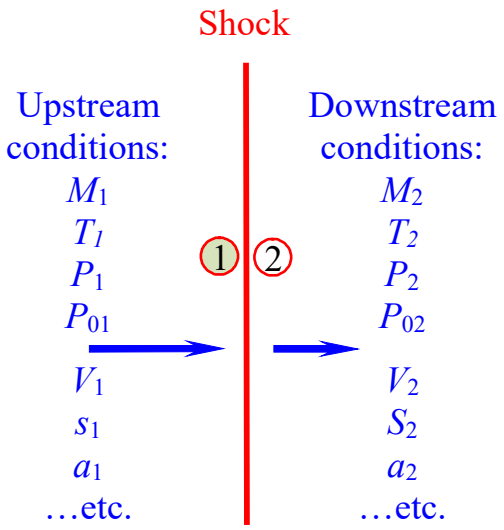


Water is no friend of wind tunnels

Diagrammatic layout of closed-circuit supersonic wind tunnel.

Next up: *Quantitative* analysis of normal shocks (Derive equations for ideal gases).

For now, though, know ***qualitatively*** how properties change across a stationary normal shock.



Properties that ***increase*** across the shock:

- $P_2 > P_1$
- $T_2 > T_1$, thus:
  - $a_2 > a_1$
  - $h_2 > h_1$
- $\rho_2 > \rho_1$
- $s_2 > s_1$
- $A_2^* > A_1^*$

Properties that ***decrease*** across the shock:

- $M_2 < M_1$
- $P_{02} < P_{01}$
- $\rho_{02} < \rho_{01}$
- $V_2 < V_1$

Properties that ***stay the same*** across the shock:

- $T_{02} = T_{01}$
- $h_{02} = h_{01}$
- $a_2^* = a_1^*$

END OF EXAM 1 MATERIAL
