MAE 352 – Experimental Aerodynamics II
Lab 5 – Converging-Diverging Nozzle Analysis

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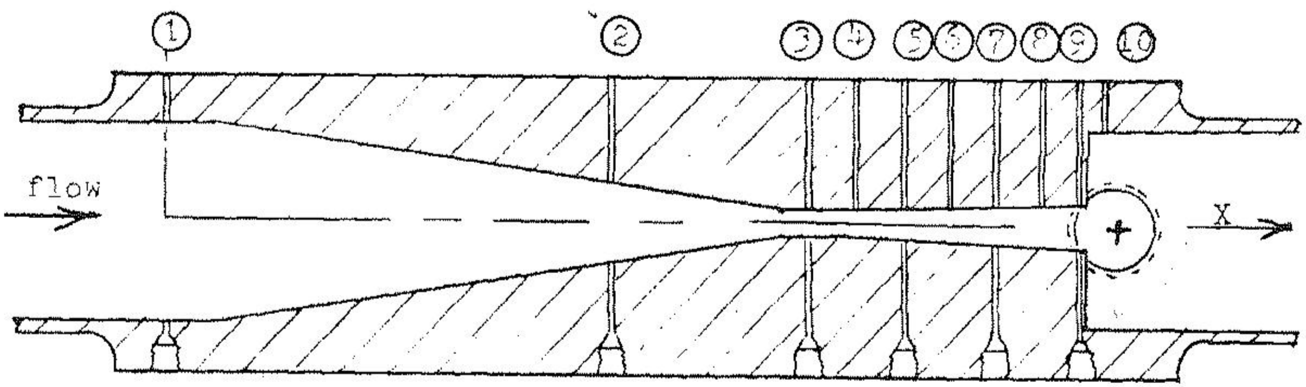
Outline

- Lab 5 - Objective
- Lab 5 – Theory
- Lab 5 - Expectations

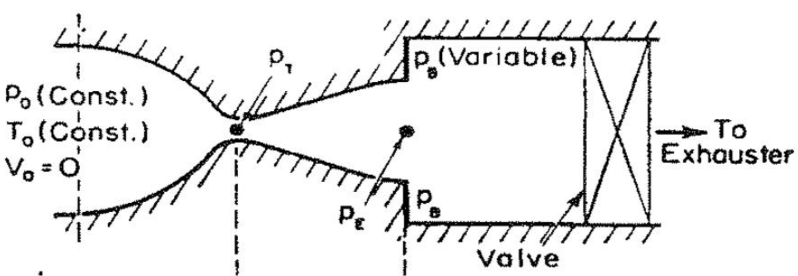
Lab 5 - Objective

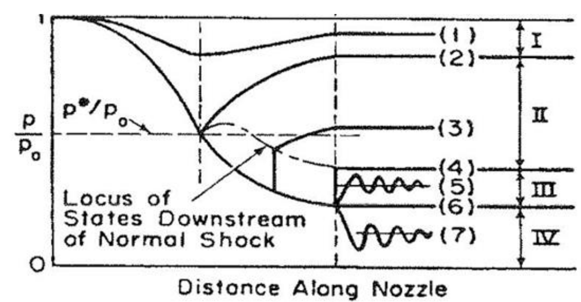
- Understand the nozzle test rig in NCSU's supersonic wind tunnel facility.
- Observe the different regimes of flow in a converging-diverging nozzle.
- Plot and study the pressure and temperature variations across the converging-diverging nozzle from no-flow to supersonic-isentropic flow condition.



Lab 5 - Theory

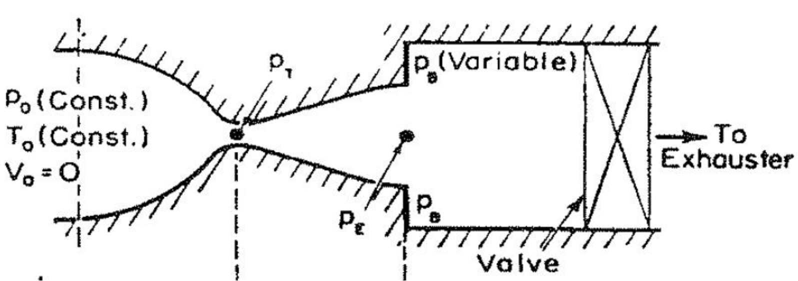
- CD-nozzles are used to accelerate the fluid to M > 1.
- The back pressure (p_B)/ temperature (T_B) is the driving factor that determines the flow condition in the nozzle.
- When $p_O = p_B$, there is no flow through the nozzle.
- As p_B is reduced, the Mach number at the throat (p_T) keeps rising until the flow is chocked ($M_T = 1$).
- Beyond that point, a decrease in back pressure ratio can result in the following flow conditions:
  - subsonic isentropic flow (the flow decelerates after the choked condition)
  - supersonic non-isentropic flow (where the flow accelerates supersonically, forms a normal shock, and decelerates subsonically after the shock)
  - supersonic isentropic flow (where the flow accelerates supersonically after the choked condition).

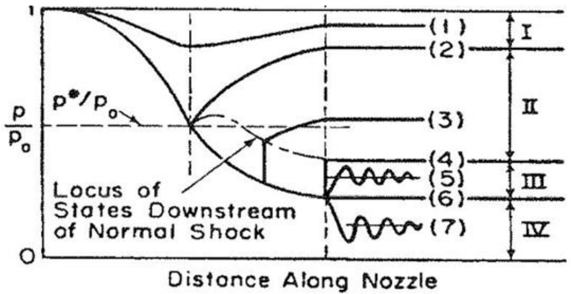




Lab 5 - Theory

- The following are the flow conditions that can be observed in a converging-diverging nozzle,
  - Subsonic flow (never reaches choked condition).
  - Subsonic flow reaching choked condition, never reaching supersonic velocities (considered isentropic).
  - Subsonic flow reaching choked condition, the resulting supersonic flow results in a normal shock, then subsonic deceleration.
  - Subsonic flow reaching choked condition, the resulting supersonic flow results in a normal shock, after the nozzle (considered isentropic in the nozzle).
  - Over-expanded flow.
  - The flow after the choked condition is supersonic through the nozzle, and no shock is formed.
  - Under-expanded flow.





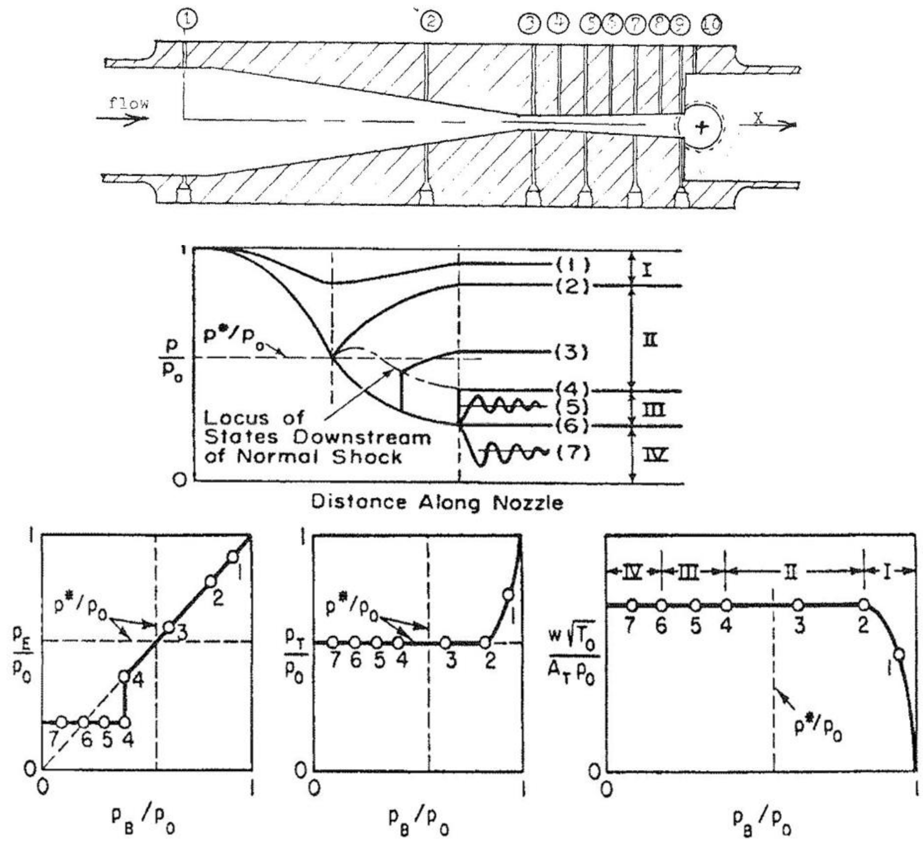
Lab 5 – Expectations

- Using the nozzle test rig in NCSU's supersonic wind tunnel facility, characterize the converging-diverging nozzle.
- Data acquired:

Tap Number	Tap Axial Positon (inches)	Nozzle Area Ratio (A/A_i)	P_{static} (psi)	P_O (psi)	Mass Flow Rate (slugs/second)	P_{atm} (psi)

- Plot the following data (calculated at the tap locations) with respect to the normalized nozzle distance for all runs:
  - p/p_O
  - Mach Number
- Identify the flow regimes and flow conditions in the above.
- Plot the mass flow parameter (*MFP*) with respect to the back pressure ratio (p_B/p_O).
- Plot the pressure ratios at the throat and exit with respect to the back pressure ratio and identify the flow regimes and conditions
  - p_E/p_O vs. p_B/p_O
  - p_T/p_O vs. p_B/p_O

Lab 5 – Expectations



- Pressure readings from tap 10 can be considered as the back pressure (p_B) conditions.
- Pressure readings from tap 9 can be assumed to be the exit pressure (p_E) conditions.
- Pressure readings from tap 3 can be assumed to be the throat pressure (p_T) conditions.