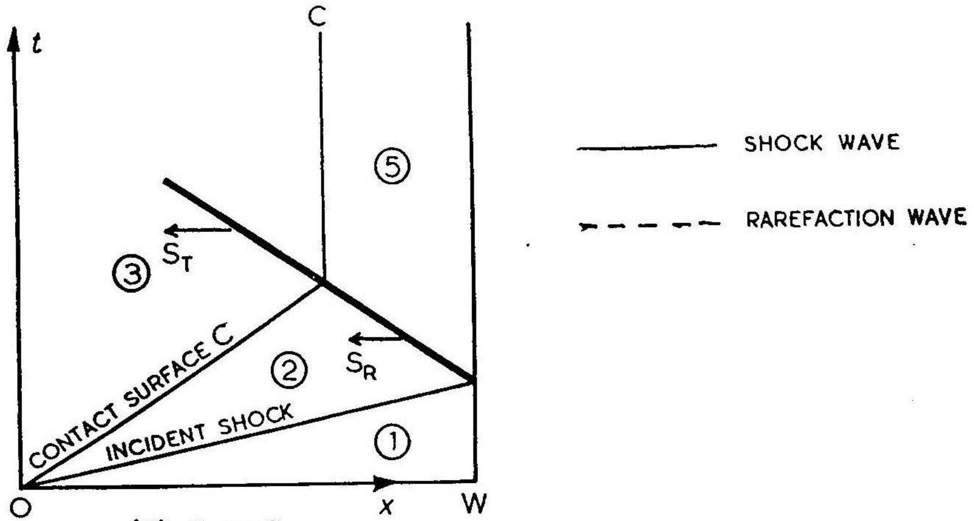
Acoustic impedance (z) –its relevance to shock propagation

- $z = \rho \times a$ of a medium, where ρ - density and a-speed of sound.
- If z of two media is the same, shock wave would propagate through these media without any reflection.
- Tailored mode of operation is an example of the match of acoustic impedance between regions 2 and 3 of a shock tube.
- As the $\rho << a$ in gases, magnitude of a is considered for the determination of the status of wave propagation at the interface.



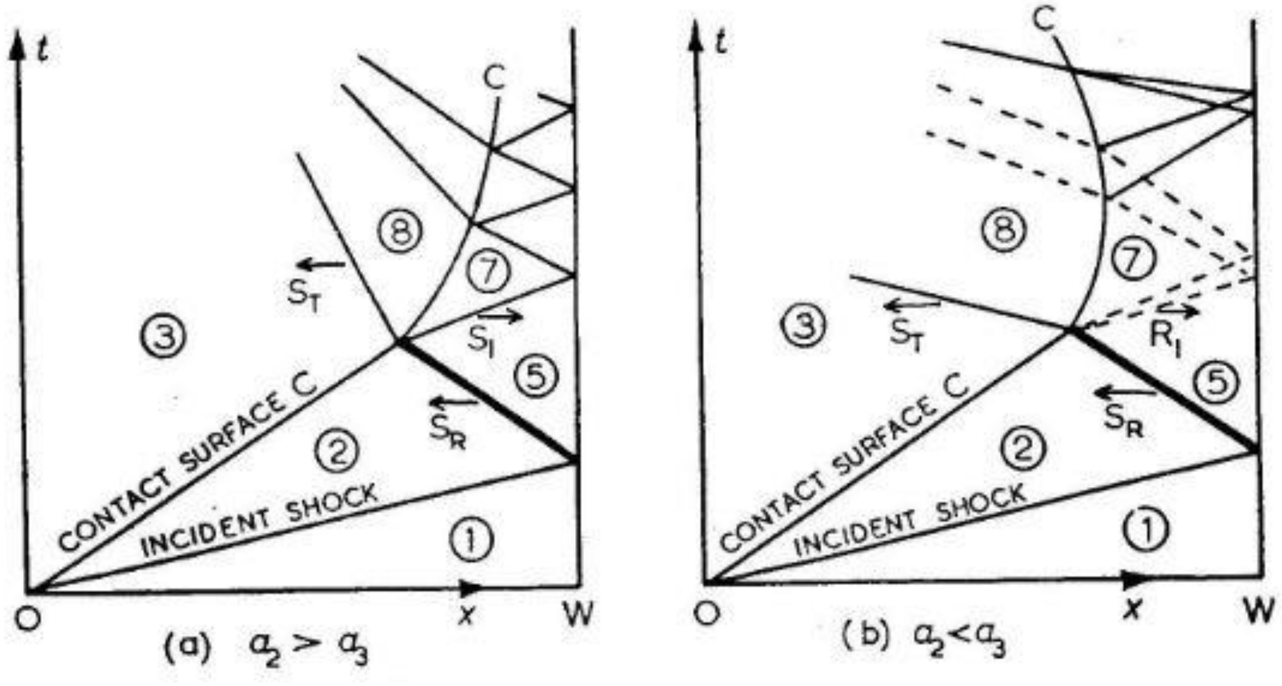
(c) $a_2 = a_3$

- ✓ The fraction of wave reflection due to mismatch of acoustic impedance between two media is given by the expression for *R*, where *R* is the coefficient of reflection at the interface.
- ✓ Coefficient of transmission, T= 1-R.

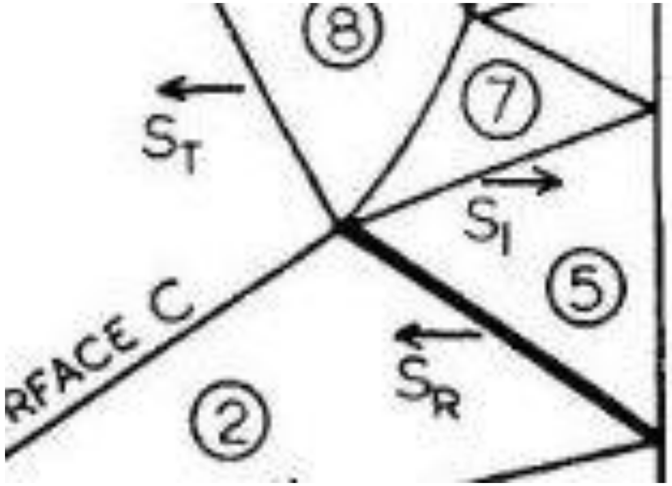
$$R = \left(\frac{z_2 - z_1}{z_2 + z_1}\right)^2$$

- ✓ Shock wave reflects as the wave of the same nature if the medium ahead of the interface is denser; and as the wave of the opposite nature if the medium ahead is of lower density.

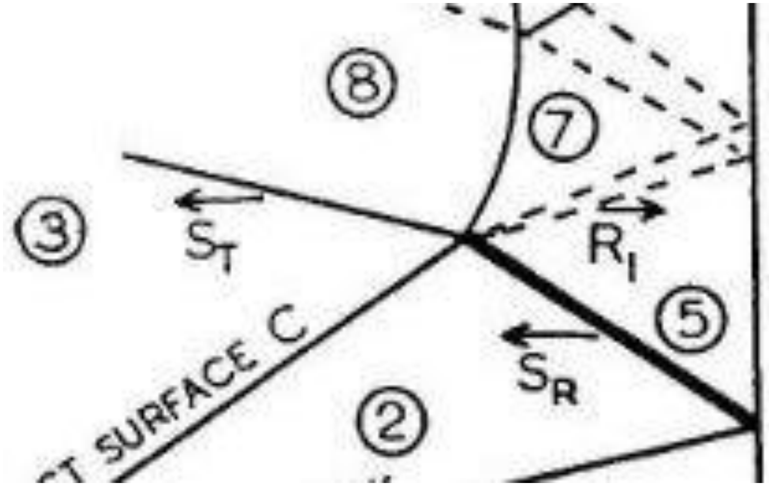
- Non-tailored modes



Non-tailored modes-physics



- When $a_2 > a_3$: for a given shock speed, M_s could have increased in region 8, which could have resulted in a higher pressure in 8. To preserve pressure equality b/w 7 &8, a shock wave reflects back into region 5. The shock in region 8 is slowed down.



- When $a_2 < a_3$: M_s could have decreased in zone 8 for the same shock velocity. To preserve pressure equality b/w 7 &8, an expansion wave reflects back into region 5. The shock in region 8 is accelerated.

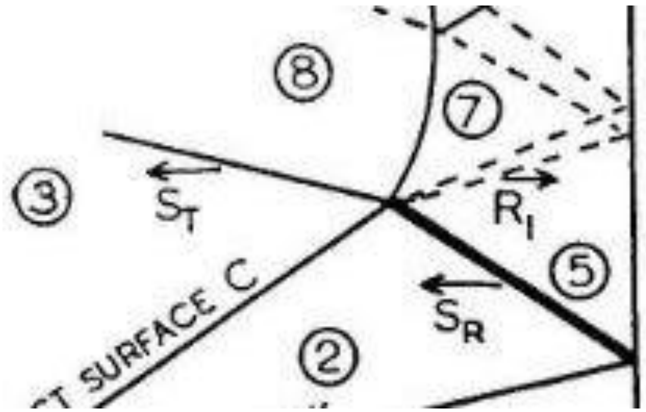
Problems to identify the possible wave systems generated due to collision of shock wave & contact surface.

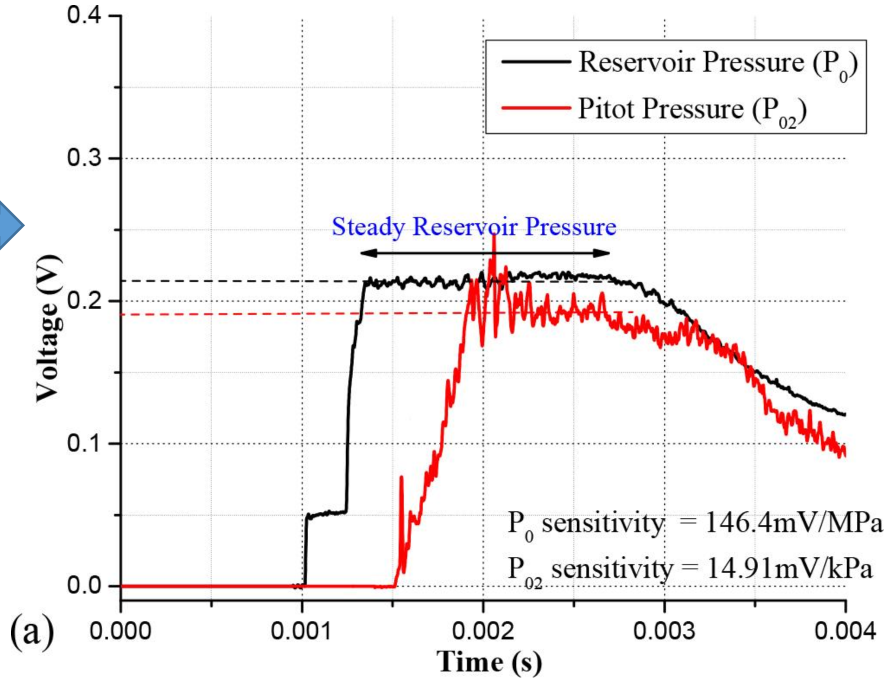
Q1. A quick valve of a shock tube, filled with *He* on the driver side and *air* on the driven side opens suddenly, generating an incident shock wave of Mach 3. The driver gas was initially at a temperature and pressure of 300 K and 930 kPa, respectively. The driven gas initial conditions were 21 kPa pressure & 300 K temperature. Determine the wave system generated at the end of the tube when the waves interact with the contact surface.

<u>Procedure</u>: 1. For given M_s, find ${}^{T_2}/_{T_1}$ from the gas tables. Once T_2 is obtained, find a_2.

2. Next objective is to find a_3.
   Find ${}^{p_2}/_{p_1}$ for given M_s; obtain p_2. Across contact surface $p_2 = p_3$.
3. Analyze the driver side: Driver gas encounters an expansion fan. Any expansion (hypersonic/supersonic) is isentropic, as far as no chemical reactions.
   Find T_3 from isentropic relation: $\frac{p_4}{p_3} = \left(\frac{T_4}{T_3}\right)^{\frac{\gamma}{\gamma-1}}$; $\gamma = 1.667$ for He.
   Find a_3.

If $a_2 < a_3$





If $a_2 > a_3$