SCRAMJET TESTING IN SHOCK TUNNELS

Indian Institute of Science

Bangalore

Shock Tunnel Terminology

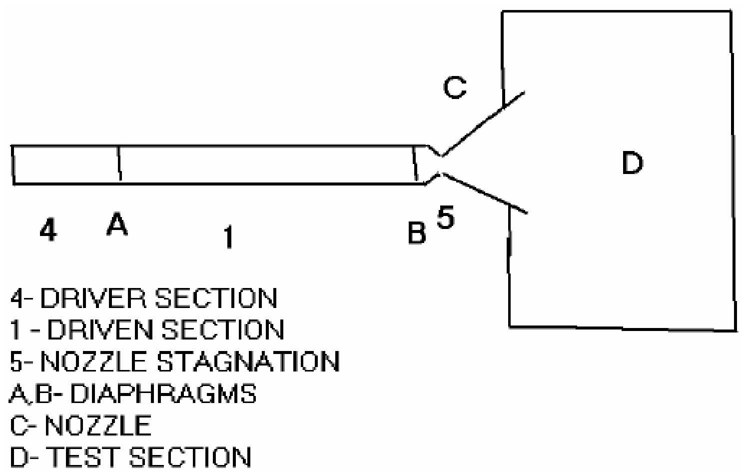
- No 4 –Driver Section (high pressure light gas-hydrogen,helium etc)
- No 1-Driven Section (low pressure gas such as air)
- A –diaphragm
- B –diaphragm
- C-nozzle
- D-test section at very low pressure
- No 5 –nozzle stagnation condition (settling chamber)
- When A bursts shock wave travels at Mach No Ms from A towards B;
- An expansion wave travels from A towards driver section end;

How Shock Tunnel Works

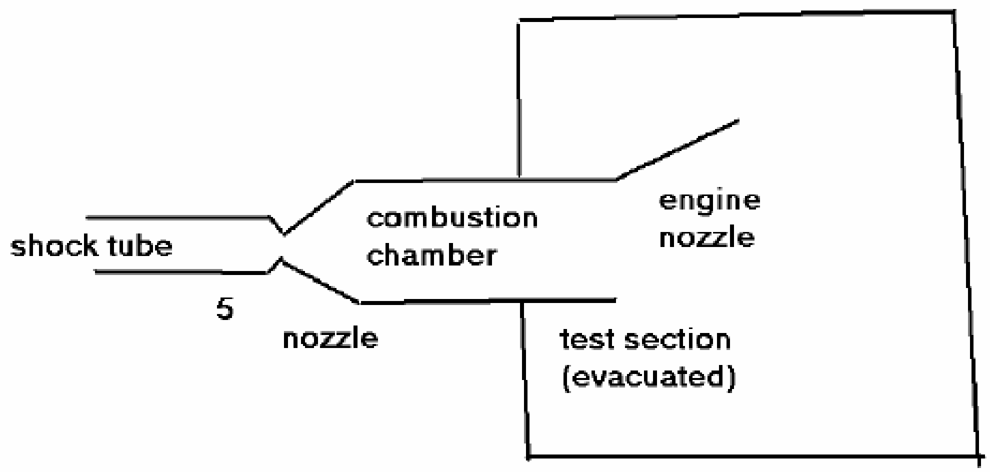
Shock wave reaches diaphragm B and gets reflected and moves towards A; high ressure and temperature P5 and T5 created between shock wave and diaphragm B; diaphragm bursts and P5,T5 expands through nozzle to test section to desired Mach number;

* Expansion wave gets reflected from driver section end and travels towards B;

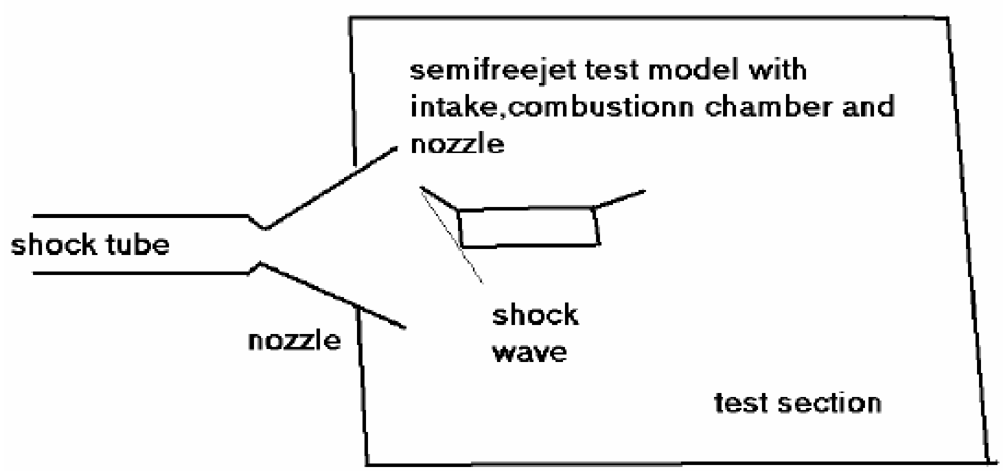
* Tunnel run time begins at instant of bursting of B and ends at instant expansion wave reaches B; this is usually about 1ms;



SHOCK TUNNEL TERMINOLOGY



CONNECTED PIPE TEST MODE



SEMIFREE JET MODE OF SCRAMJET TEST

Typical HRV Flight Conditions And Shock Tunnel Operating Parameters

CASE	1	2	3
Alt (km)	25	30	35
Mach No	6	6.5	7
P inf(mb)	27	12.5	6
T inf(degK)	220	231	243
P5 (atm)	50	41	34
T5 (degK)	1624	1931	2258
M (shock)	3.5	3.9	4.3
P1 (mb)	600	350	250
P4(atm)	18	21	25

(For Hydrogen as driver gas)

Note: It is seen that the tunnel operating conditions are benign and feasible

Literature Survey

- Australia –complete scramjet model with intakes,burners,thrust surfaces , tested in T4 (Paulletal1995); thrust greater than drag recorded; stress wave balance used (from website of Univ. of Queensland)
- Japan –NAL proposed to test 2m long full configuration model at Minf=8 in HIEST free piston shock tunnel. A system of accelerometers to be used to measure forces. Model is freely suspended using fine wires (Takahashi etal–22ndInternational Symposium on shock waves)
- Russia-joint USA-Russia hypersonic combustion experiments in TsniimashPGU 11 . Minf=10,P5=1000 bar,T5=4000 deg K.Hydrogen fuel (Orthand Kislykh–AIAA 96 –4584-CP)
- Italy –connected pipe supersonic combustion tests with hydrogen fuel ; M=3 flow; rectangular cross section tunnel; multicascade compression

principle of PGU11 ; runtime ~ 10ms (Reggiorietal-8thIWSTT-Sept 2002-IISc)

Major Impulse Tunnels Worldwide

- Aachen, Germany-shock tunnel-1500 bar,8000 degK, M =6 to 20,nozzle .5m,1.0m,2.0m , .5 to 10ms test time;
- HEG,Germany-FPST -1500 bar,10000 degK, M= 8 to 10, .8m dianozzle, 1ms test time;
- T4, Australia –FPST –2000 bar, 8600 degK, M=6, .25m dianozzle, .4 ms runtime;
- CALSPAN, USA –shock tunnel, 1300 bar, 8000 degK, M =6.5 to 20, 1.2m dianozzle , .7 to 20 ms runtime;
- HIEST Japan –FPST –1500 bar, 9000 degK, 25MJ/kg , 1.2m dianozzle ,1ms runtime;
- PGU 11 Russia –impulse facility-2500 bar, 10000 degK, 30MJ/kg, 1.0m nozzle dia, 500ms runtime ;

Proposed Plan of Action

- Conduct preliminary combustion tests at IISc shock tunnels on a small scale during 2003;
- Set up large shock tunnel at DRDL by end of year 2003 ;
- Conduct tests at DRDL shock tunnel during 2004;
- Design large impulse tunnel by end 2003;
- Establish large impulse tunnel as a national facility by end 2006; conduct tests from end 2006;