

Blow down W/T

By

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High Speed wind tunnels?

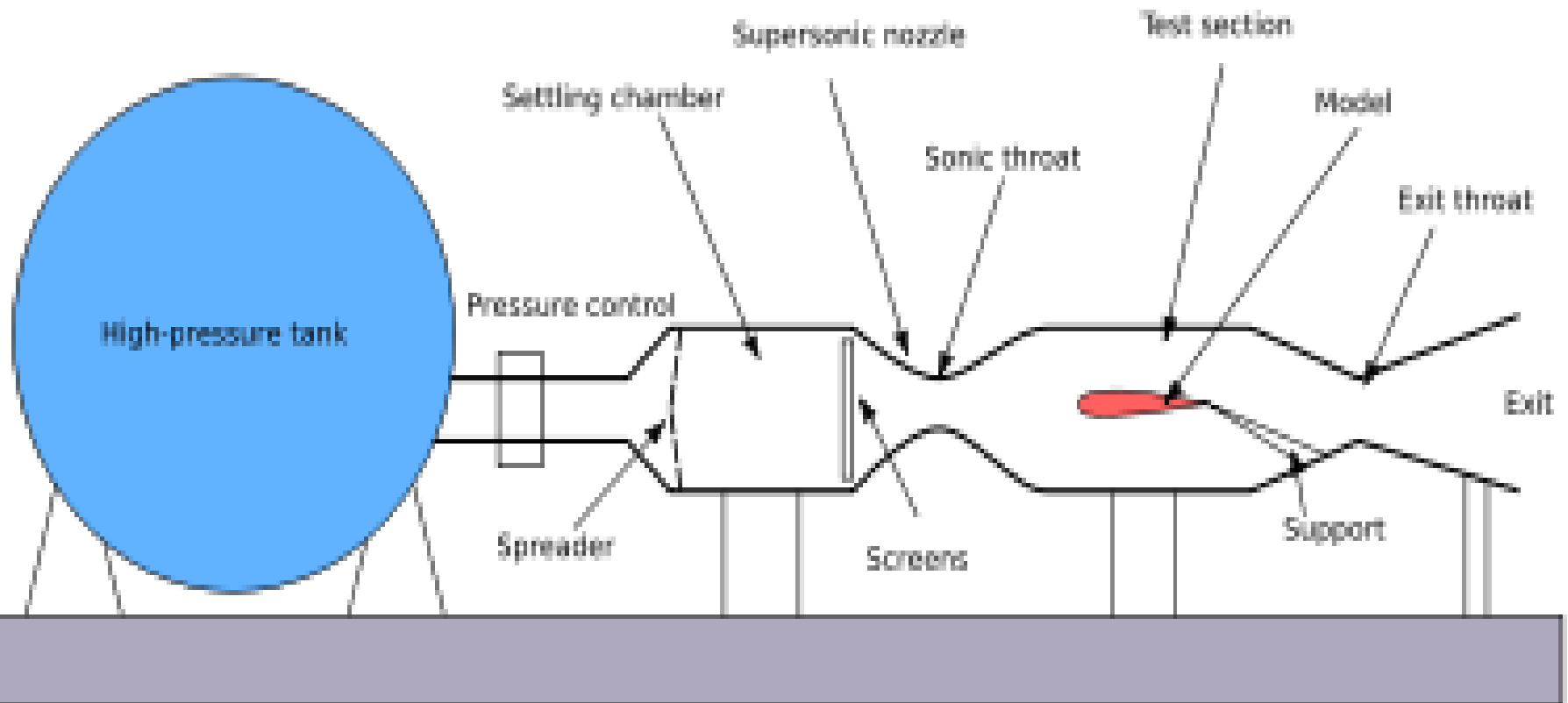
A High Speed wind tunnel is a tunnel where the operating speed requires compressible flow inside the wind tunnel. The speed of the test section is usually talked about in terms of the Mach No.

- Power required for low speed W/T varies as the cube of the test section velocity.
- Above rule does not apply for high speed W/T
- Power requirement for high speed w/t is 'intermittent'
- Energy is stored in form of pressure or vacuum or both and is allowed to drive the tunnel only a few seconds out of each pumping hour.

Following are the different types of high speed W/T

- Closed circuit, continuous flow supersonic wind tunnel
- Intermittent blow down tunnel
- Intermittent indraft wind tunnel
- Hypersonic pressure Intermittent vacuum tunnel

Intermittent blow down tunnel

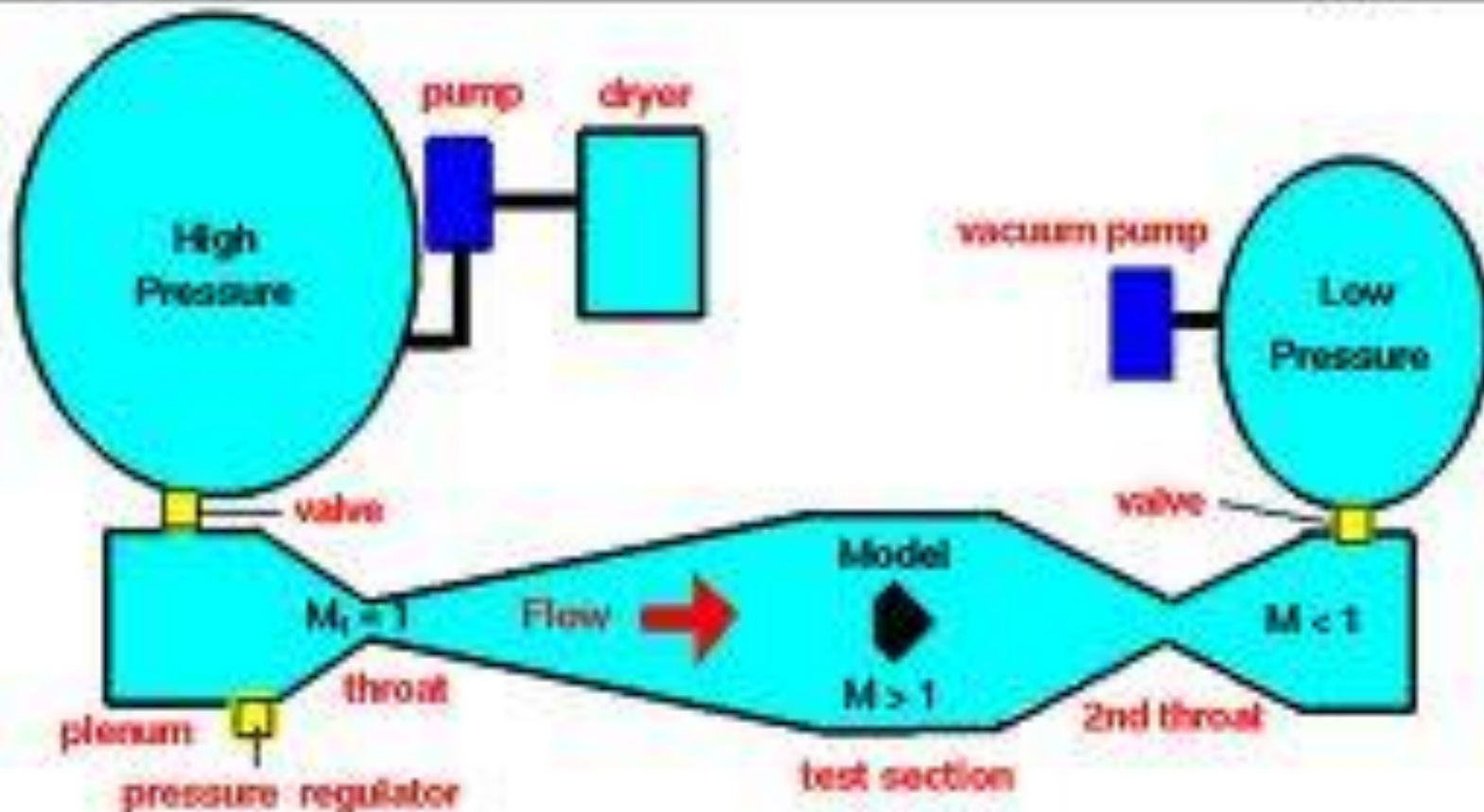


Hypersonic pressure Intermittent vacuum tunnel



Blowdown Wind Tunnel

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Closed Configuration

Designing of Blow down tunnel

(Input Mach No at test section)

- Following points need to ensure correct flow condition at the test section
 - Achieving desired velocity in test section
 - Enough mass to meet the tunnel size and run time requirement
 - Dry to avoid the condensation
 - Hot to avoid liquefaction
- Blow down tunnel consists of following
 - Compressor
 - Air storage Tank
 - Pressure control
 - Test section
 - Exhaust

Determine the allowable operating pressure

- After knowing the test section mach no, isotropic relation/table/graph can be used to find out the pressure ratio
- As blow down the exhaust is to atmosphere so exist pressure is known and the operating pressure can be easily find out from above relation

Determining the size of tunnel

- The complete W/T size depend on the size of the test section
- With reasonable cost , largest test section possible to make
- Larger model can be kept in side large test section
- It is easier to work on large model than small model
- Reynolds no is directly proportional to model size
- For a given air supply and given run time the largest Reynolds is possible using smallest test section.

Specifying Run Times

- Tunnel run time is normally determined from the type and amount of data required during test
- More time is required to measure the pressure
- The effect on stabilization time increase rapidly with pressure below 1 psi
- For this type of measurement minimum 15 to 20sec is required
- In force test the model is attached with the strain gage balance to measuring the load
- Time required on this type of system depend on the drive mechanism and the alpha range
- This type of test minimum 15 sec is required
- Also time is depend on the recorded device
- Blow down W/T is usually designed for 20 to 40 sec run time

Calculating the Air Flow rate

- The rate of mas flow is one of the primary consideration is sizing the tunnel

Calculating run time

- There are two way in which blow down W/T is operated
 - With Constant q
 - With constant mass flow rate
- For Constant q operation the pressure regulator is only necessary control
- For Constant mass flow the temperature also need to be controlled by the heater
- The run time can be calculated by assuming following
 - Polytrophic expansion in storage tank
 - Heater that keep constant temperature
 - Pressure regulator that keep pressure constant
 - No heat loss in duct
 - Isentropic expansion in settling chamber

Compressors

- There various type of compressor available to pump the storage tank
- Most frequently used type is piston compressor
- This is economy and commercial available in many size
- Heat is added to air in compression process by compressor
- Cooling mechanism should be implemented to cool the air

After Coolers

- After cooler removes the heat from the compression air after compressor
- This is a very simple device where the hot air air flow at low velocity through water tube or pipe

Oil Filter

- Oil filter is used to remove the oil from air for following causes
 - To avoid the danger of air-oil mixture explosion
 - The effectiveness of air dryer will reduce when oil is mixed with air
 - The oil also collected at windows and nozzle for which other system may impacted due to oil

Air Driers

- This is used to remove the water moisture from the air particle
- The desiccant used in blow down W/T driers is silica gel, activated alumina or zirconia.
- Air driers always operate at high pressure
- From the air drier the air will go to storage tank

Air Storage Tank

- The size of tank depend on the mass flow rate (velocity) and the duration of run
- Spherical tank prove less expensive for the large size
- The tank should painted black in order to attain the maximum temperature produce by solar heating
- Tank should be provided with safety valve. Which should fail before the tank fail

Piping and Valves

- The cost of piping and valve increase with the diameter size
- The mach number inside pipe should be subsonic (less than 0.4)
- The tight shutoff is required to prevent the leakage of high pressure air from the storage tanks through the tunnel.
- There should be at least one valve to regulate the pressure
- There can be other valve to regulate for different system

Diffuser

- Flow inside the test section can be improved by providing the large area, low velocity section immediately upstream of the nozzle.
- The large area and low velocity section is called the ‘Settling Chamber’
- The diffuser a device which will connected between the small diameter pipe (High velocity) and the settling chamber (low velocity)
- Wide angle diffuser is used for Blow down tunnel
- The divergence angle between opposite wall are 45 to 90 deg
- The average velocity inside the diffuser should be below 0.5 mach for all the condition
- The diffuser is usually conical in shape

The settling Chamber

- The settling chamber is usually a cylindrical shape and one diameter or more long
- This get the air from the wide angle diffuser and deliver uniform low turbulence air to test section
- The static pressure in the settling chamber is higher than at any down stream point in tunnel but should be less than the tank and regulator outlet
- A safety disc should be provided in the settling chamber to make safe the settling chamber due to more pressure
- Screens are used inside the settling chamber for uniform flow and to reduce the turbulence
- The velocity inside the settling chamber should not be more than 80 to 100 feet per sec and should not be less than 10 feet per sec
- Settling chamber should be designed for easy removal or easy access to inside of settling chamber
- It should have facility to measure the pressure

The Nozzle

- This is a part of tunnel where flow is accelerated from low speed to high speed
- This is placed between the settling chamber and test section
- Nozzle will be designed depending on the speed of test section
- The generation of supersonic flow in nozzle requires a convergence to a minimum area cross section and then a divergence to large area (first throat)
- Divergence area distribution required for each mach number
- Some time down stream of the nozzle is vented by means of slots or holes to minimize the shock wave effect on the air flow over the model
- Flexible wall nozzle can be designed to operate the tunnel at various mach no
- The construction cost of flexible nozzle is more, difficult to set the angle for different Mach no and maintenance cost is more
- From isentropic area relation (A/A^*) the nozzle area can be found out for different mach no

Test section

- Cross section of model inside the test section should not exceed 1 percent of the test section for transonic tunnel
- The model diameter should not exceed one-ninth of the test section height
- In supersonic tunnel the model length is limited due to the reflection of shock wave from wall
- It is necessary to control the pressure inside the test section due to sock wave and area blockage due to model
- Plenum chamber can be used to control the pressure at the test section
- The plenum chamber can be connected to auxiliary pumping system or direct to atmosphere

Windows

- Model viewing is necessary for optical analysis of the flow as well as simple observation of the flow
- Glass is the best suitable for transparent of light
- Quartz window is used for high temperature wind tunnel

- Enclosed free jet noise level is less
- Need less power
- High velocity air mixed with stagnation air of enclosed chamber at nozzle exit

Model Support System

- Support system should be rigid enough to take the dynamic pressure
- Should have facility to record the data from wind tunnel
- Should have good mechanism to change the different angle
- Shock wave created from support system should not disturb the flow over the model

Diffuser

- Diffuser is connected just after the test section
- Transonic wind tunnel the section immediately downstream of test section is somewhat larger in cross section than the test section. This section use to expand the air leaving the test section at low speed
- In case of supersonic tunnel the diffuser should will have a throat (second throat)

- The cross section of throat should be less than the test section
- This throat area depend on the operating mach no
- Some tunnel the second throat also adjustable
- This adjustable throat is used for variable mach no

Silencer

- This is used to reduce the noise level of super sonic blow down tunnel
- This is last part of blow down tunnel
- It should have some sort of door to keep the birds and insect out of tunnel

Injector and Ejectors

- The blow down tunnel required specific stagnation pressure (pressure ratio) to start the tunnel
- Injector and ejector are devices that work towards overcoming the above difficulties
- Injectors are jets of relatively high energy air at the downstream and of the test section which is used to reduce the the compression ratio for a particular mach no
- Ejector s are the nozzle located well down stream of the diffuser which is used to droop the exist pressure cause to reduce the compression ratio

Intermittent indraft tunnel

- It store energy less than the atmosphere pressure (vacuum)
- During operation air flow from atmosphere to vacuum tank
- In this prosses the tank pressure is increase
- The run end when the ratio of atmospheric pressure to tank pressure decrease below the required to drive the tunnel
- Following are main componenets of the intermittent indraft tunnel
 - Door for inlet (some time)
 - Drier
 - Settling chamber
 - Nozzle
 - Test section
 - Diffuser
 - Valve between test section and vacuum tank
 - Vacuum storage tank
 - Vacuum pump

Calculating run time

- The run time of an in draft tunnel is limited by the rising pressure in the vacuum tank
- To calculate run time, the product of weight flow of air through the tunnel and run time is equated to the change in weight of air in the vacuum tank during the run
 - See the formula

Upstream Door

- Some method to close the inlet when the tunnel is not used
- This will prevent dust or foreign particle entering the tunnel, when tunnel is not used

Air Inlet

- This should be sized for very low speed a value of 20 mph
- A screen (filter) advise to fix at the inlet
- Drier, Settling chamber, Nozzle, Test section, Diffuser are similar function as discussed for blow down tunnel

Downstream valve

- A tight sealing valve is required between test section and vacuum tank
- This valve is used to start or stop the tunnel

Vacuum Tank and Vacuum pump

- The size of vacuum tank is spherical in size
- The size of the tank depend on the test section size, test section Mach no and run time
- Time required to vacuum the tank is :
- The exhaust from vacuum pump need to be cooled if the air is going to re-use. Need not cool if the air is exhausted to atmosphere

Safety

- Although the probability of injury is far less with an indraft tunnel than with blow down tunnel, since high pressure is possibility of outward explosion.