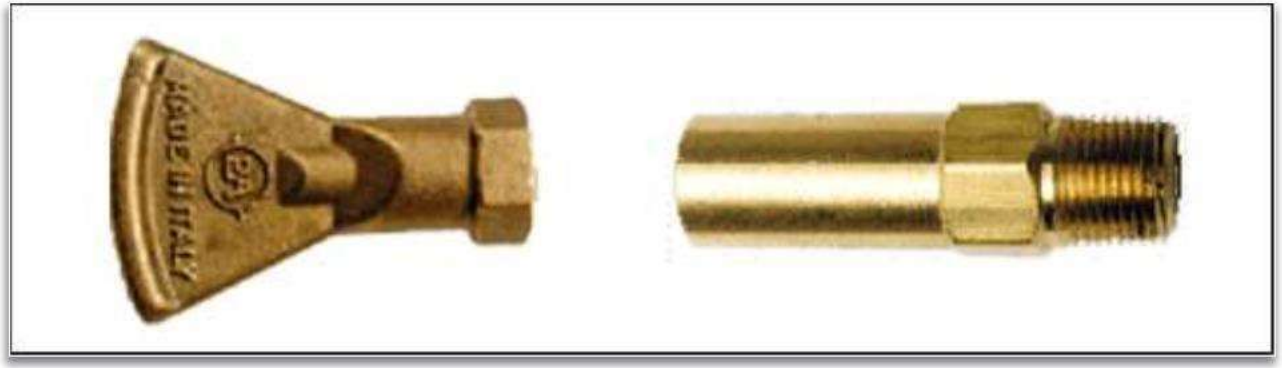
UNIT-6

Steam Nozzle

INTRODUCTION

What is a steam nozzle????

A nozzle is a device designed to control the direction or characteristics of a fluid flow (especially to increase velocity) as it exits (or enters) an enclosed chamber or pipe.
A nozzle is often a pipe or tube of varying cross sectional area, and it can be used to direct or modify the flow of a fluid (liquid or gas). Nozzles are frequently used to control the rate of flow, speed, direction, mass, shape, and/or the pressure of the stream that emerges from them.Finally the goal of a nozzle is to increase the kinetic energy of the flowing medium at the expense of its pressure and internal energy.



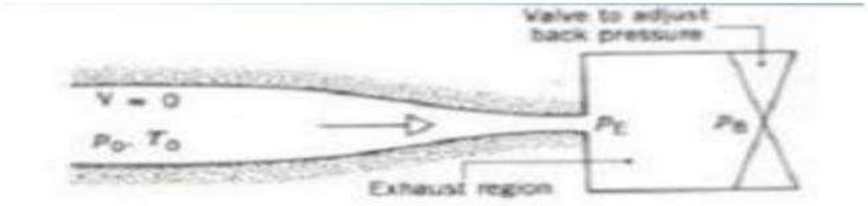
Types of nozzles

<u>Three types of nozzles:-</u>

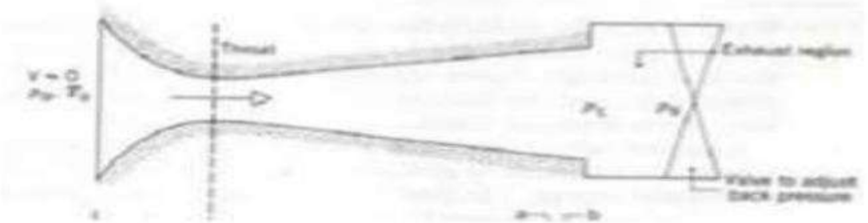
- **Convergent**:- The cross section of nozzle tapers to a smaller section allow for changes which occur due changes in velocity, specific volume dryness fraction – as the flow expands, it has lower expansion ratio and hence lower outlet velocities.

- **Convergent-----Divergent**:- The nozzle which converges to throat and diverges afterwards. It has higher expansion ratio – as addition of divergent portion produces steam of higher velocities.Eg– De–Laval Nozzle

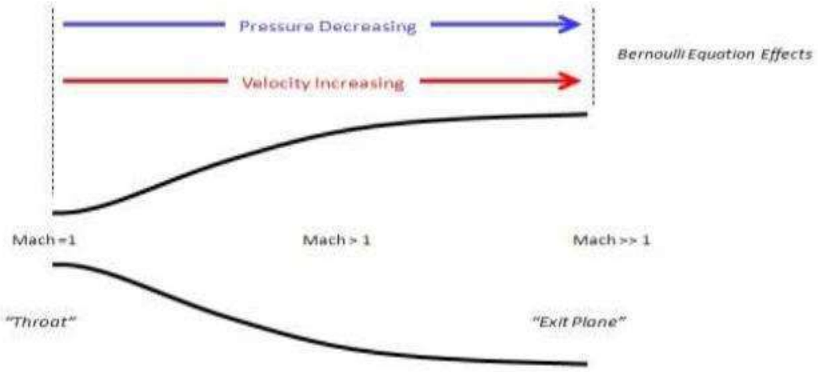
- **Divergent**:- A nozzle whose cross section becomes larger in the direction of flow is known as divergent nozzle.



CONVERGENT NOZZLE



CONVERGENT-DIVERGENT NOZZLE



DIVERGENT NOZZLE

CRITICAL PRESSURE RATIO

For a perfect gas undergoing an adiabatic process the index - *n* - is the ratio of specific heats - $k = c_p / c_v$. There is no unique value for - *n*. Values for some common gases are

- Steam where most of the process occurs in the wet region : $n = 1.135$
- Steam superheated : $n = 1.30$
- Air : $n = 1.4$
- Methane : $n = 1.31$
- Helium : $n = 1.667$

Example - Air Nozzles and Critical Pressure Ratios

The critical pressure ratio for an air nozzle can be calculated as

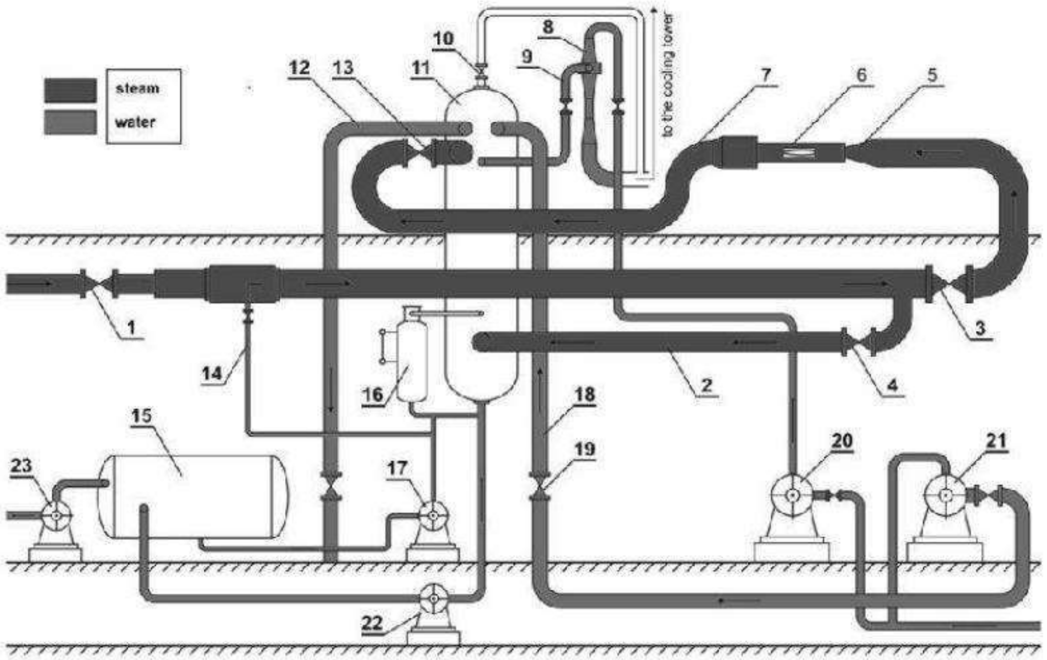
$$p_c / p_1 = (2 / (1.4 + 1))^{1.4 / (1.4 - 1)}$$

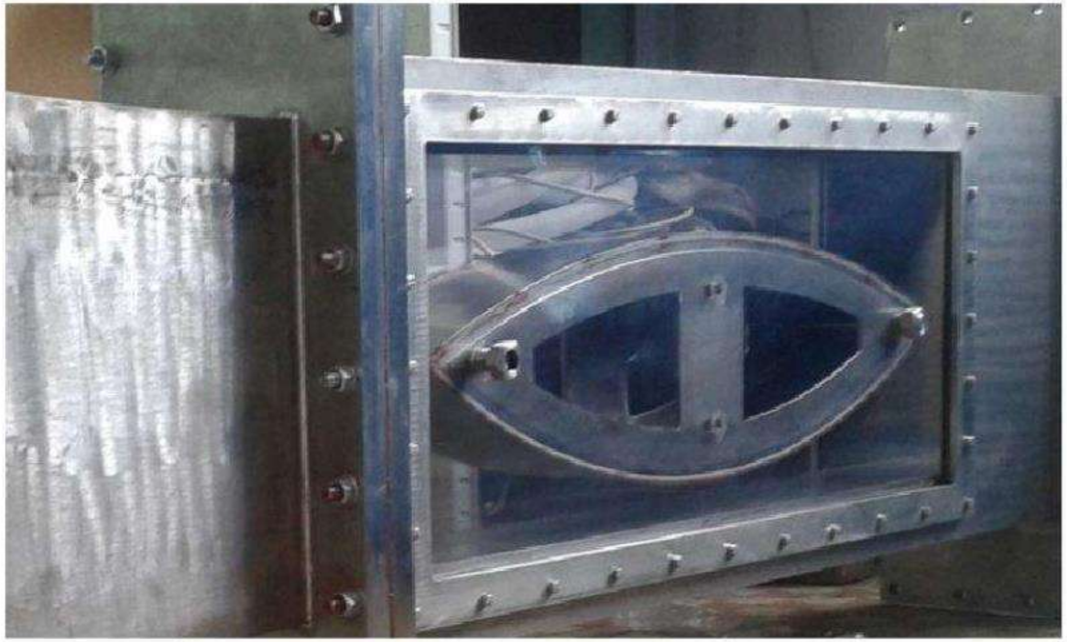
$$= \underline{0.528} \qquad \textbf{(1)}$$

Critical pressures for other values of - *n:*

n	1.135	1.300	1.400	1.667
p_c / p_1	0.577	0.546	0.528	0.487

steam transonic flows in Laval nozzles





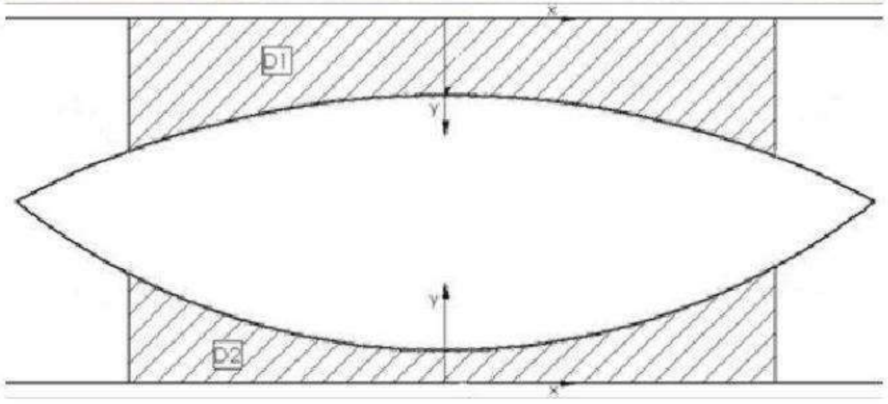
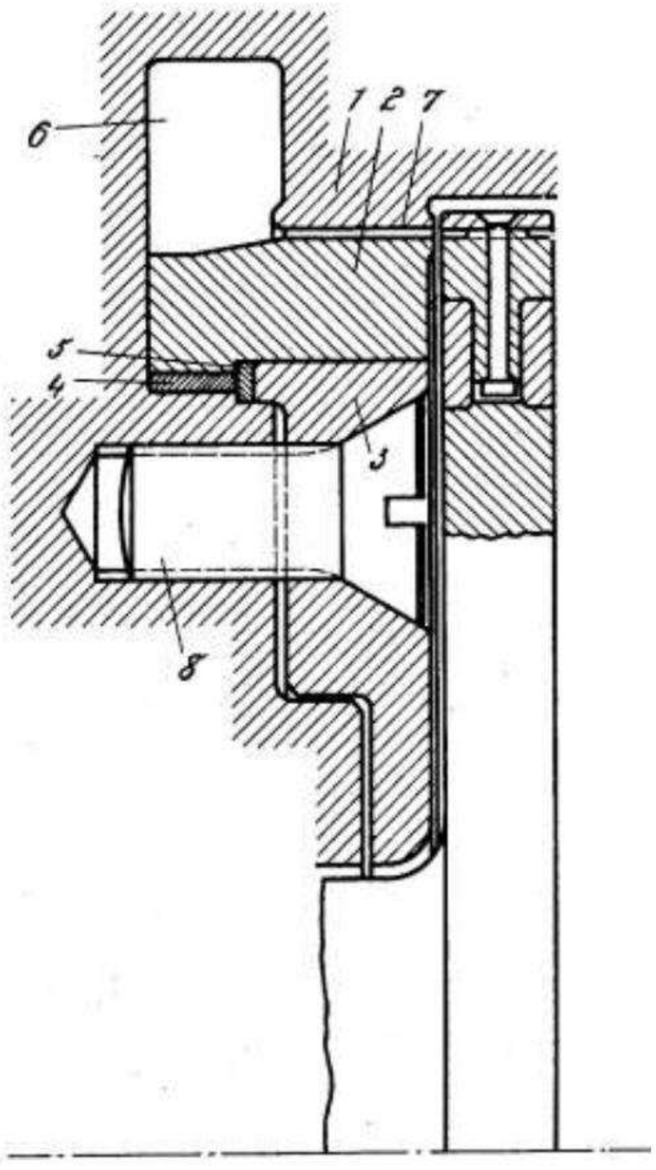


Figure 1: Steam tunnel with auxiliary devices: 1) Control valve, 2) By-pass, 3) Stop gate valve, 4) Stop gate valve at by-pass, 5)

9) Pipe, 10) Safety valve, 11) Condenser, 12) Suction line, 13) Throttle valve, 14) Desuperheater, 15) Condensate tank, 16) Control system of condensate level, 17) Condensate pump, 18) Discharge line, 19) Stop valve, 20) Water injector pump, 21) Cooling water pump, 22) Condensate pump, 23) Pump

Construction of steam nozzle



If great pressure differences exist in front and at the back of inlet nozzles of steam turbines a secure attachment of the nozzles is sometimes rather difficult.

undivided solid ring.

turbine casing, and having its outer periphery shrunk against the inner

casing without making use of a special guide wheel body. The attachment of the ring 2 in the

further development the nozzle ring is secured in position by a further locking ring. This ring is

the casing 1 and the ring 2 by caulking. It is particularly applicable to super-pressure turbines.

Effects of friction on nozzle efficiency

For stream flowing through a nozzle, its final velocity for a given pressure drop is reduces to:
- Friction between nozzle surface and stream
- Internal friction of stream itself.
- Shock losses.

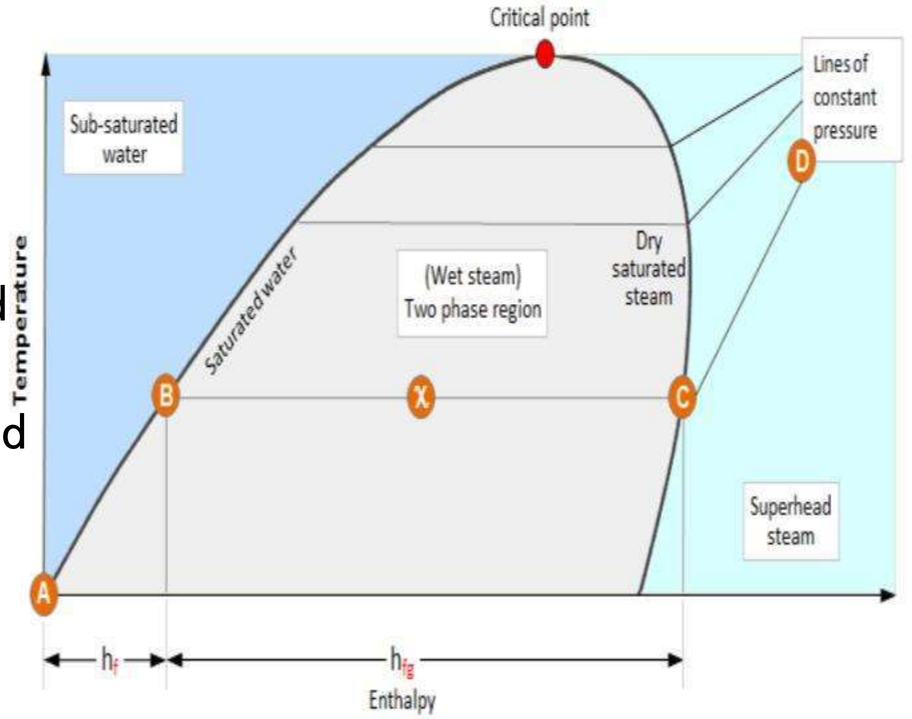
Most of the frictional losses occur between the throat and exit in nozzle, producing following effect.
  - Expansion is no more isentropic.
  - Enthalpy drop is reduced.
  - Final dryness fraction of steam increases.(kinetic energy– heat, due to friction and gets absorbed.)
  - Specific volume of steam increases.(steam becomes more dry due to friction reheating)

Parameters of steam nozzle

- Foundation
- Rotor or shaft
- Cylinder or Casing
- Blades
- Diaphragm
- Steam Chest
- Coupling
- Bearings
- Labyrinth seal
- Front pedestal
- TSI
- D-EHC(governor)
- MSV(main steam stop value)
- CV(control value)
- IV(intercept value)
- CRV(combined reheat value)
- Turbine Turning Gear
- Turbine Bypass and Drains
- Lube oil system
- EHC oil system
- Gland steam systems
- Condenser
- Steam jet Ejector
- Vacuum Breaker

SUPER SATURATED FLOW

When dry and saturated steam is caused to expand in a nozzle, the actual measured steam flow is found to be greater than the theoretical calculated flow. This is due to the time lag in the condensation of steam and the steam remains in dry state instead of wet. Such a steam is called supersaturated steam. This time lag is caused due to the fact that, the converging part of the nozzle is too short and the steam velocity is too high that the molecules of steam have insufficient time to form droplets.

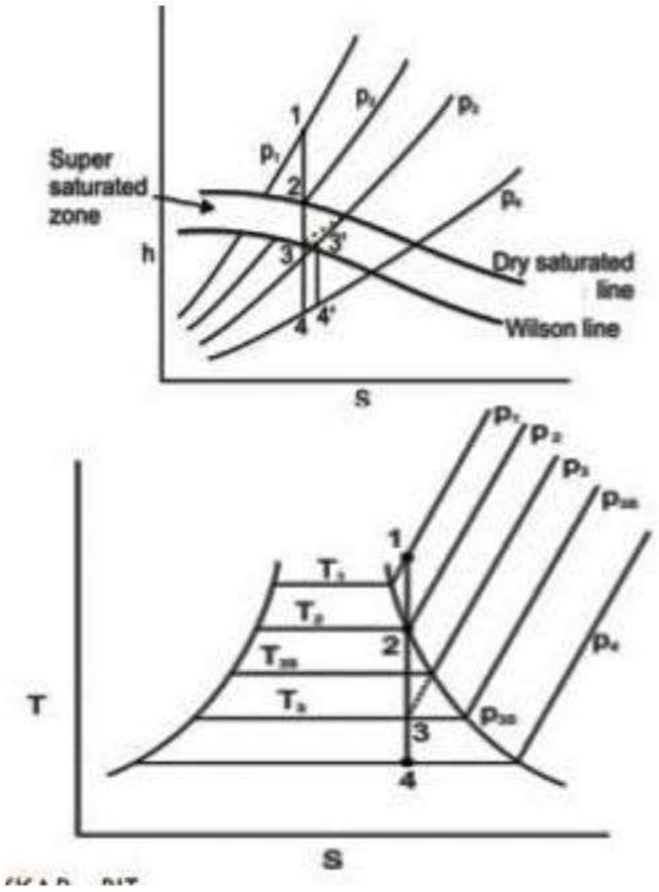


EFFECTS OF SUPERSATURATED

✓ Final dryness fraction increases.

✓ Density of supersaturated steam is more than that for equilibrium conditions(As no condensation during supersaturated expansion => supersaturation temperature < saturation temperature corresponding to the pressure).

✓ Thus , measured discharge (=>mass) is greater than that theoretically calculated.



MACH NUMBER

Mach number is the ratio of flow velocity passed the boundary to the local speed of sound.
It is a dimensionless quantity:- $M=u/c$
Where,

M= Mach Number.

u= Local flow velocity with respect to the boundaries.

c= Speed of the sound in the medium.

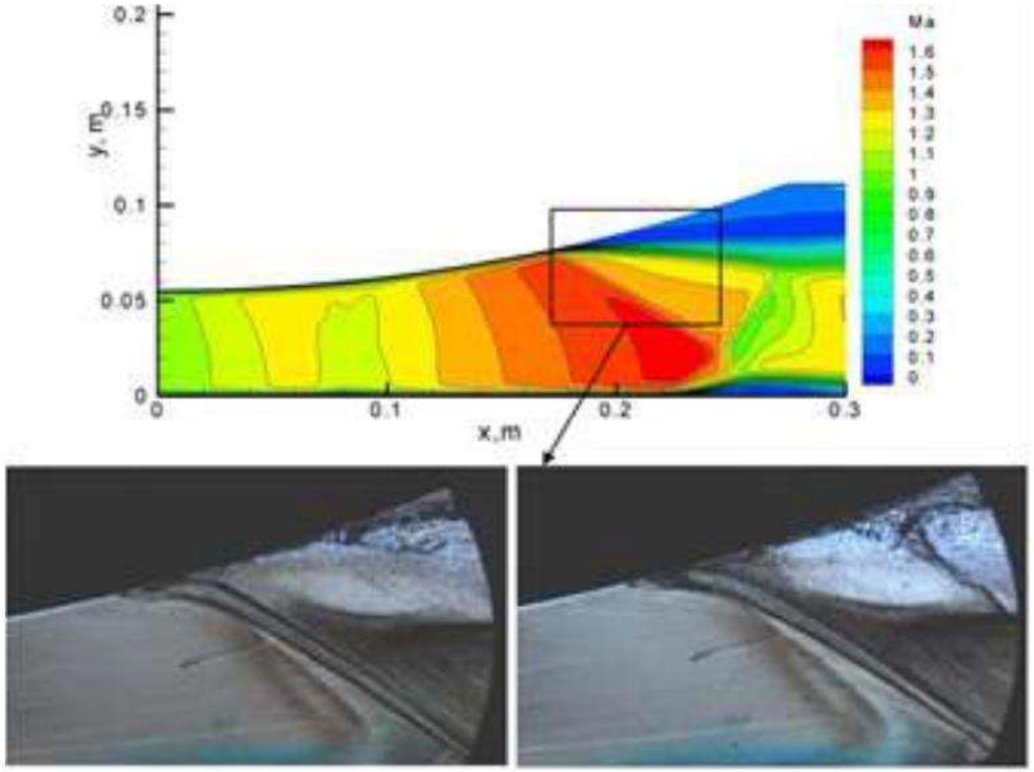


Figure 4: Calculated Mach number distribution (top) and Schlieren pictures from experiment for D1 nozzle

If ,

$M>1$, the flow is supersonic
$M<1$, the flow is subsonic
$M=1$, the flow is sonic

APPLICATIONS OF STEAM NOZZLE

- To rotate steam turbine.
- Thermal power plant.
- Steam nozzle are also used for cleaning purpose.
- To produce a very fine jet spray.