1. Boiler Mounting – These are different fitting and devices which are necessary for the operation and safety of a boiler. Usually these devices are mounted over boiler shell.

In accordance with the Indian boiler Regulation the following mounting should be fitted to the boilers.

- Two safety valve
- Two water level indicator
- A pressure gauge.
- A steam stop valve.
- A feed check valve
- A blow-off cock.
- A man hole.

Boiler Accessories – These are required for steam boilers for their proper operation and for increase of their efficiency.

Following are boiler accessories –

- Economiser
- Air pre-heater
- Superheater
- Feed pump
- Steam seperator etc.

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Difference between fire-tube and water tube boiler are –

Particulars	Fire tube boiler	Water tube boilers
1. Position of water and hot gases.	Hot gases inside the tube and water outside the tube	Water inside the tubes and hot gases outside the tubes
2. Mode of firing.	Generally internally fired.	Externally fired.
3. operating pressure.	Limited to 16 bar	Can be 100 bar.
4. Rate of steam production	Lower	Higher.
5. Suitability	Not suitable for larger plants	Suitable for larger plants.
6. Risk of bursting	Lesser risk	More risk.
7. Floor area	Occupies more floor area for given power.	Occupies less floor area for given power
8 - Construction	Difficult	Simple
9. Treatment of water	Not so necessary	More necessary
10. Requirement of skill	Require less skill for efficient and economic working	Require more skill & careful attention.

2. A condenser where the exhaust steam from the turbine is condensed operates at a pressure lower than atmosphere. The need of a condenser is as follows -

i) To reduce the turbine exhaust pressure so as to increase the specific output of the turbine.

ii) To recover high quality feedwater in the form of condensate and feed it back to the steam generator without any further treatment.
As a result only makeup water to replenish the water losses in the cyclic plant needs be treated.

There are two broad classes of condensers :-

a) Direct contact type condensers – where the condensate and cooling water directly mix and come out as a single stream.

b) Surface condenser – which are shell-and-tube heat exchangers where the two fluids do not come in direct contact and the heat released by the condensation of steam is tranferred through the walls of the tubes into the cooling water continuously circulating inside them.

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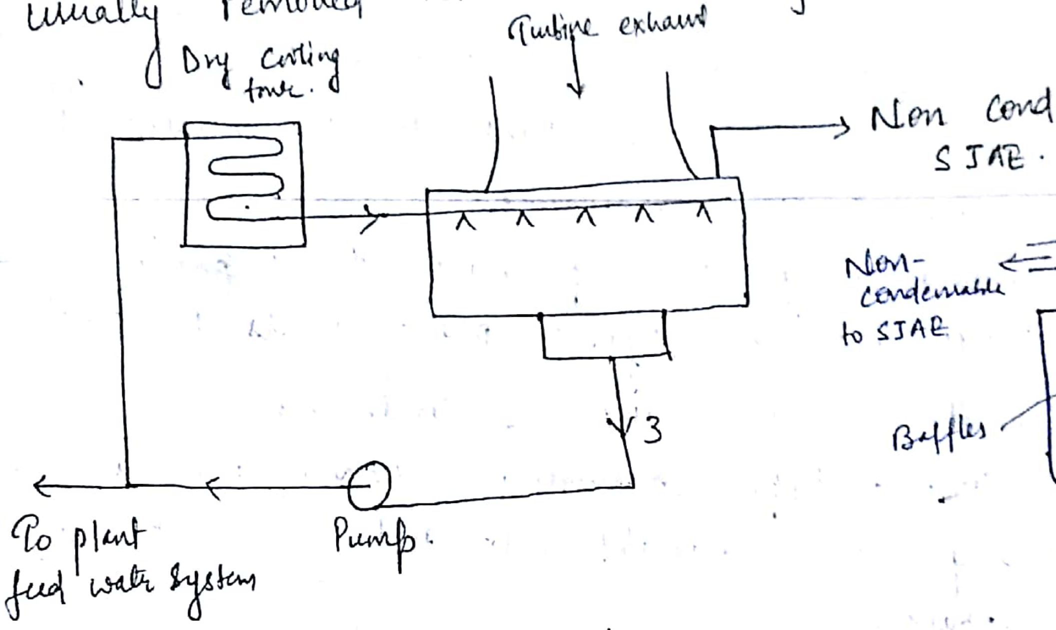
There are three direct contact condensers –

i) Spray condenser – The cooling water is sprayed in to the steam. Steam by mixing directly with cold water gets condensed.

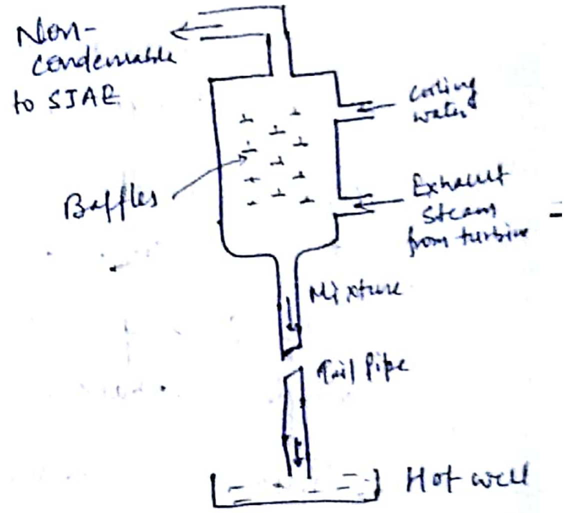
ii) Barometric condenser – The cooling water is made to fall in a series of baffles to expose large surface area for the steam feed from below to come in direct contact. The steam condenses and the mixture falls in a tail pipe to the hot well below.

iii) Jet Condenser – In the jet condenser, the height of the tail pipe is reduced by replacing it with a diffuser. The diffuser helps raising the pressure in a short distance than a tail pipe.

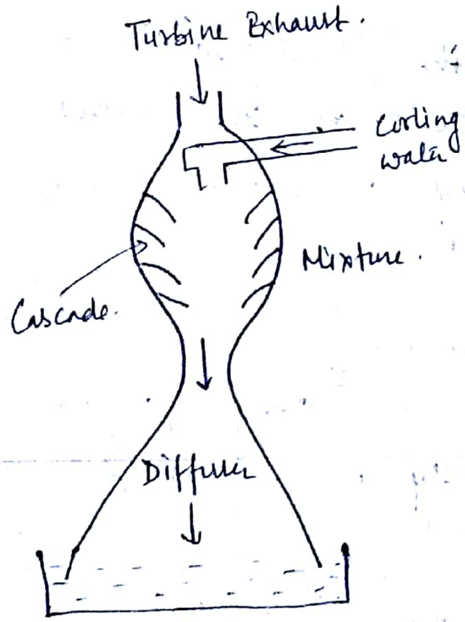
In spray type condensers, the non-condensable gases are usually removed with a steam jet air ejector (SJAE).



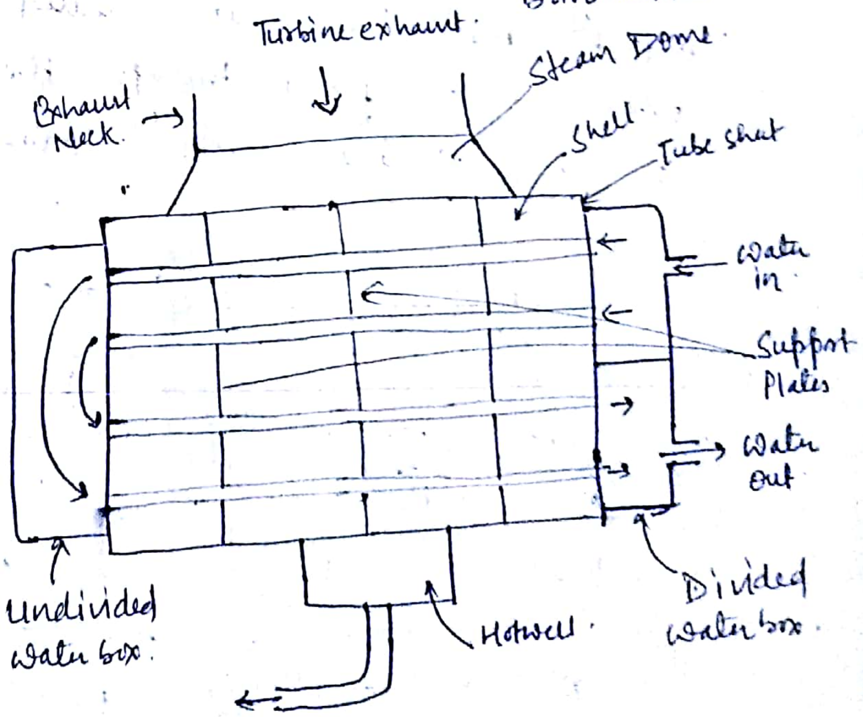
Direct-contact spray condenser.



Barometric condenser.



(Diffuser or jet condenser)



(Two pass Surface Condenser)

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3. For isentropic flow through nozzle,

$$h_0 = h + \frac{V^2}{2}$$

Since, stagnation enthalpy does not change,

$$dh = -V dV$$

from the property relation,

$$Tds = dh - vdp$$

For isentropic flow,

$$dh = \frac{dp}{\rho}$$

$$\therefore -VdV = \frac{dp}{\rho}$$

$$\frac{dP}{dV} = -V\rho$$

$$\therefore \frac{dP}{dV} < 0$$

For flow through nozzle, as pressure decreases, velocity increases.

The continuity equation gives,

$$\dot{m} = \rho A V$$

By logarithmic differentiation,

$$\frac{d\rho}{\rho} + \frac{dA}{A} + \frac{dV}{V} = 0$$

$$\frac{dA}{A} = -\frac{dV}{V} - \frac{d\rho}{\rho}$$

$$\because dp = -\rho V dV \qquad \frac{dV}{V} = \frac{dP}{-\rho V^2}$$

$$\therefore \quad = \frac{dp}{\rho V^2} - \frac{d\rho}{\rho}$$

$$= \frac{dp}{\rho V^2}\left[1 - \frac{d\rho}{\rho} \cdot \frac{\rho V^2}{dP}\right]$$

$$= \frac{dp}{\rho V^2}\left[1 - \frac{V^2}{(dP/d\rho)}\right]$$

$$= \frac{dp}{\rho V^2}\left[1 - \frac{V^2}{C^2}\right] = -\frac{dV}{V}(1 - M^2)$$

$$\therefore \boxed{\frac{dA}{A} = \frac{dV}{V}(M^2 - 1)}$$

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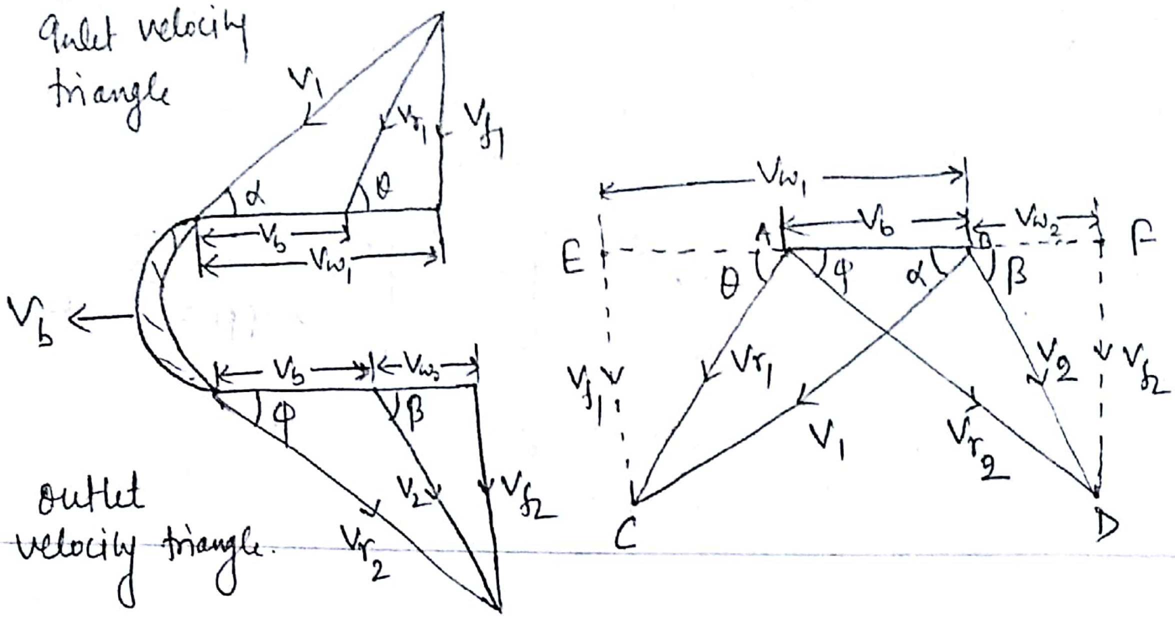
4.



V_1 = Absolute velocity of steam coming out from the nozzle.
V_{r_1} = Relative velocity of steam with which it strikes the blade
V_b = Mean peripheral velocity of blade.
V_{r_2} = Relative velocity of steam leaves the blade.
V_2 = Absolute velocity of steam leaves the blade.
α = Nozzle angle
θ and φ are inlet and exit blade angle.

<u>Work done on the blade,</u> →

Tangential force on the wheel $= \dot{m}_s \times Accl^n$
$= \dot{m}_s \times$ change in velocity
$= \dot{m}_s \times (V_{w_1} - V_{w_2})$

The value of V_{w_2} is actually −ve as the steam is discharged in the opposite dir^n to the blade motion.

∴ Tangential force on the wheel $= \dot{m}_s \times (V_{w_1} + V_{w_2})$

∴ Work done on blade/s = Tangential force × distance travelled.
$= \dot{m}_s (V_{w_1} + V_{w_2}) \times V_{bt}$

$$= \frac{\dot{m}_s (V_{w_1} + V_{w_2}) \times V_b}{1000} \text{ KW}$$

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$\therefore$ Diagram work/s $= \dfrac{\dot{m}_s (V_{w_1} + V_{w_2}) V_b}{1000}$ kW

$= \dfrac{\dot{m}_s V_w V_b}{1000}$ kW

$\therefore$ Blade or diagram efficiency $= \dfrac{\text{Work done on the blade}}{\text{Energy supplied to the blade}}$.

$$\eta_{blade} = \frac{\dot{m}_s V_w V_b}{\frac{\dot{m}_s V_1^2}{2}} = \frac{2 V_b V_w}{V_1^2}$$

$$\boxed{\eta_{blade} = \eta_{diagram} = \frac{2 V_b \cdot V_w}{V_1^2}}$$

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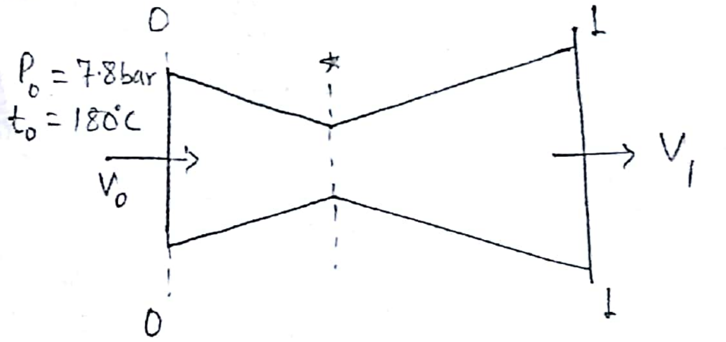
5.



The critical pressure ratio for air is,

$$\frac{p^*}{P_0} = \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}} = \left(\frac{2}{2.4}\right)^{\frac{1.4}{0.4}} = 0.528$$

$$\therefore p^* = 0.528 \times 7.8 = 4.12 \text{ bar}$$

$$\frac{T^*}{T_0} = \frac{2}{\gamma+1} = \frac{2}{2.4} = \frac{1}{1.2}$$

$$T^* = \frac{180+273}{1.2} = 377.5 \text{ K}$$

$$v^* = \frac{RT^*}{p^*} = \frac{287 \times 377.5}{4.12 \times 10^5} = 0.263 \text{ m}^3/\text{kg}$$

$$V^* = \sqrt{\gamma RT^*} = \sqrt{1.4 \times 287 \times 377.5} = 389.46 \text{ m/s}$$

[Also, $V^* = 44.72\sqrt{h_0 - h^*} = 44.72 \times \sqrt{c_p(T_0 - T^*)}$

$= 44.72 \times \sqrt{1.005 \times (75.5)} = 390.5$ m/s]

$$A^* = \frac{m v^*}{V^*} = \frac{3.6 \times 0.263}{389.46} = 0.002431 \text{ m}^2$$

$\therefore$ Area of throat $= 2431$ mm^2 Ans

Now,

$$\frac{T_0}{T_1} = \left(\frac{P_0}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{7.8}{1.03}\right)^{\frac{0.4}{1.4}} = 1.784$$

$$T_1 = \frac{453}{1.784} = 253.9 \text{ K}$$

$$\therefore v_1 = \frac{RT_1}{P_1} = \frac{287 \times 253.19}{1.03 \times 10^5} = 0.7075 \text{ m}^3/\text{kg}$$

$$V_1 = 44.72 \times \sqrt{1.005(453 - 253.9)} = 634.17 \text{ m/s}$$

$$A_1 = \frac{m v_1}{V_1} = \frac{3.6 \times 0.7075}{634.17} = 0.004016 \text{ m}^2$$

Exit Area $= 4016$ mm^2 Ans

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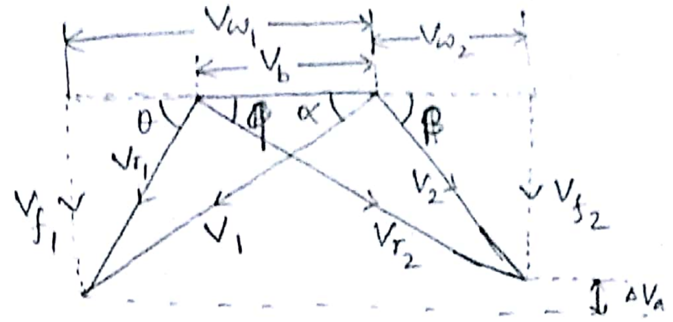
6. Given,



$D_m = 800$ mm
$N = 3000$ rpm
$V_1 = 300$ m/s
$\alpha = 20^\circ$, $K = 0.86$
$F_a = 140$ N

$\therefore V_b = \frac{\pi D_m N}{60} = \frac{\pi \times 0.80 \times 3000}{60} = 125.6$ m/s

$V_1 = 300$ m/s

$\tan\theta = \frac{V_1 \sin\alpha}{V_1 \cos\alpha - V_b} = \frac{300 \sin 20^\circ}{300 \cos 20^\circ - 125.6} = \frac{102.61}{281.91 - 125.6}$

$\tan\theta = 0.6565$

$\therefore \theta_1 = 33.3^\circ \Rightarrow \theta = 33.3^\circ$

Since, blades are equiangular,

$\therefore \theta = \phi = 33.3^\circ$.

$\because V_1 \sin\alpha = V_{r_1} \sin\theta$

$\therefore 102.61 = V_{r_1} \sin 33.3^\circ$

$\therefore V_{r_1} = 187$ m/s

$\therefore V_{r_2} = K V_{r_1} = 0.86 \times 187 = 161$ m/s

$V_{r_2} = 161$ m/s

$\therefore$ Axial thrust, $F_a = \dot{m}_s (V_{r_1} \sin\theta - V_{r_2} \sin\phi)$

$= \dot{m}_s V_{r_1} \sin 33.3 (1 - K)$

$140 = \dot{m}_s \times 187 \sin 33.3 \times 0.14$

$\therefore \dot{m}_s = 9.7456$ kg/s

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$\therefore \Delta V_w = V_{r_1} \cos\theta + V_{r_2} \cos\phi$

$= V_{r_1} \cos\theta + K V_{r_1} \cos\phi$

$= 187 \cos 33.3 (1 + 0.86) = 290.71$ m/s

$\therefore$ Power developed $= \dot{m}_s \cdot V_b \cdot \Delta V_w = 9.7456 \times 125.6 \times 290.7 = 355.84 \times 10^3$ W

$= 355.84$ kW Ans