→ The liquid - vapor saturation curve

* Objective

To show the pressure & temperature are independent Properties in the saturation region.

* Apparatus

Marcet boiler ; and it consists of a small cylendrical boiler fitted with a thermometer and a pressure gauge.

* $\frac{dT}{(dP)_{sat.}} = \frac{T v_{fg}}{h_{fg}}$; This equation is Known as the clausius - claperon equation.

* After comparing the experimental values of the [slope from the graph] with [theoretical values] ; we found differences between two values because of :-

1) Personal errors in reading the Temp. & Pressure.

2) small number of collected readings.

3) systematic errors relative to the vapor loss from the apparatus itself during the experiment

* Sample of calculations

1. $P_{abs.} = P_{gauge} + P_{atm.}$, **1 bar = 100 kPa**

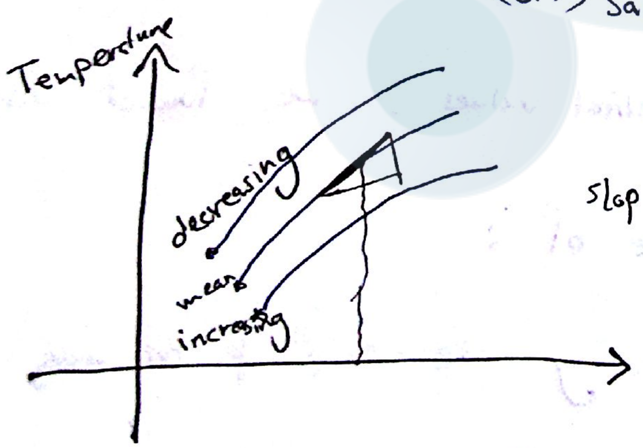
2. $$\text{mean Temperature} = \frac{\text{increasing temp.} + \text{decreasing temp.}}{2}$$

3. Theoretical $\Rightarrow$ $$\frac{dT}{(dP)_{sat.}} = \frac{T\, v_{fg}}{h_{fg}}$$

   v_f & h_f $\rightarrow$ measured of saturated liquid

   v_g & h_g $\rightarrow$ measured of saturated vapor

4. Experimental $\Rightarrow$ $\frac{dT}{(dP)_{sat.}}$ = slope of the Pressure – Temperature curve for saturated steam.



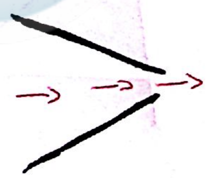
$$slop = \left(\frac{dT}{(dP)_{sat}}\right)_{exp.}$$

→ Flow through a nozzle

* Objective

To study pressure distribution for different exit Pressures and different flow rates

* A **nozzle** is a steady state - flow device
  - → The purposes:-
    To create a high velocity fluid stream @ the expense of it's pressure
  - → The utilizations:-
    in get engine, rocket, space craft, garden hoses.
  - → changes The properties (pressure & velocity) due to change in diameter



  - → Nozzle profiles (types)
    ① convergent, ② convergent - divergent,
    ③ convergent - Parallel → (بنلاحظها باللاب)
    ↳ The pressure decrease by small amount due to friction.

→ Sample of calculations

[1] [redacted] throat area

$$A_t = \frac{\pi}{4}\left(d_{Nozzle}^2 - d_{Prope}^2\right)$$

[2] mass flow rate

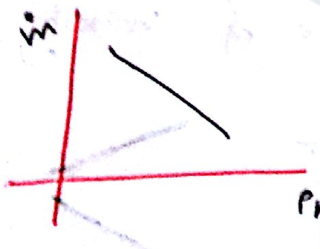
$$\dot{m} = A_t \, P_0 \left(\frac{P_t}{P_0}\right)^{\frac{1}{\gamma}} \sqrt{\frac{2\gamma}{(\gamma-1) R T_0}\left[1 - \left(\frac{P_t}{P_0}\right)^{\frac{\gamma-1}{\gamma}}\right]}$$

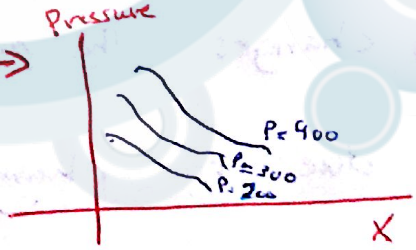
$\gamma = 1.4$, $R = 0.287$, P_0 = chest pressure

$P_t = P_{throat}$ (من الجدول الي حطناه) , T_0 = ambiant Temperature (K)

[3] Pressure ratio

$$= \frac{\text{back pressure}}{\text{chest Pressure}} = \frac{P_{atm}}{P_{chest}}$$ ← [illegible] :P

→ 

→ 

→ $\left(\frac{X}{L}\right)$ increase ↑ , Pressure decrease ↓ , velocity increase ↑

→ ($\dot{m}$) Pressure ratio increase ↑ , $\dot{m}$ decrease

Scanned by CamScanner

* Losses in pipes

→ Objective

① variation of friction factor & Reynold number

② loss coefficient for each fitting (K)

③ relationship between Ry. and f

→ Apparatus

consist of two separate hydraullic circuits

1. Dark blue circuite
2. Light blue circuite

+ **hydraullic bench** to supply curcuites by water.

→ losses in internal flow

- → major losses → Because friction
- → minor losses → Because fitting (values, bends..)

→ major h_f → $h_f = f \frac{L}{D} \frac{V^2}{2g}$

f → darcy friction factor

V → mean velocity

→ minor h_m → $h_m = \Delta h + \Delta ke - h_f$ القانون العام

→ in expansion and contraction [h_f = zero]

→ in Bends [Δke = zero]

→ in Globe value [h_f = zero , Δk_E = zero]

→ in all cases of [expansion , contraction, & Bends] ; The pressure change across each of the components is measured by a Pair of Pressurized piezometer tubes.

→ in the case of Valves ; pressure measurement is made by U- Tube manometer containing mercury. (Hg)

→ friction losses due to shear stress on the wall of dark ; $\Delta h = h_f$

→ Pipes are made from copper.

→ if Re. > 2300 ; the flow is Turbulent

→ if Re. < 2300 ; the flow is laminar

→ Sample of calculations.

* mass flow rate ($\dot{m}$) = $\frac{mass}{\Delta t}$

* mean velocity (v) = $\frac{\dot{m}}{\rho * A}$

* Reynolds number (Re.) = $\frac{\rho V D_{small}}{\mu}$ → $1.8 * 10^{-6}$ (viscosity)

* friction factor → can be calculated using $\frac{1}{\sqrt{F}} = -2 \log \left[\frac{\epsilon/D}{3.7} + \frac{2.51}{Re\sqrt{F}} \right]$
  → or by using moody chart.

* For **Light** blue circuite:

* Expansion $\Delta h = h_7 - h_8$

$h_f = 0$

$h_m = \Delta K_E + \Delta h$, $\boxed{\Delta K_E = \frac{\Delta V^2}{2g}}$

* contraction $\Delta h = h_9 - h_{10}$

$h_f = 0$

$h_m = \Delta K_E + \Delta h$

* Bends $\boxed{\Delta h_J = h_{11} - h_{12}}$, $\boxed{\Delta h_H = h_{13} - h_{14}}$, $\boxed{\Delta h_G = h_{15} - h_{16}}$

$\Delta K_E = 0$

$h_f = f \frac{L}{D} \frac{V^2}{2g}$

$\boxed{h_m = \Delta h - h_f}$

* Hydrostatic pressure force on a plane surface

- center of pressure -

→ Objective

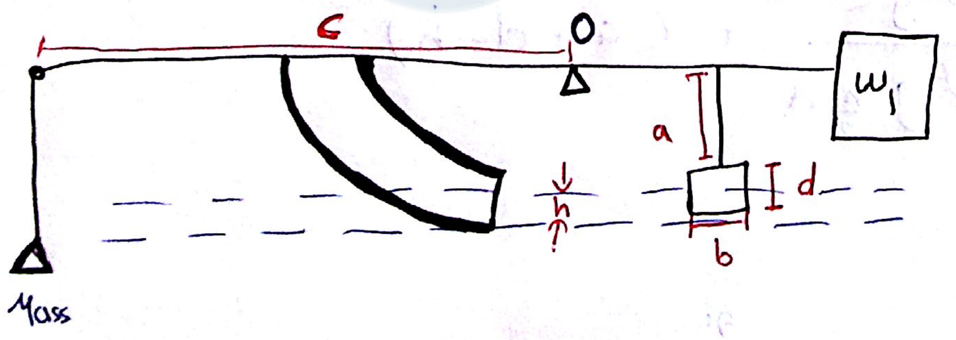
1. to determine the position of the center of pressure on the rectangular face of the toroid.

2. to compare measured value and theoretical value of y_{cp}.

→ To determine the position of the center of pressure; we take moments about O.

→ Apparatus

The toroid which is Immersed in a tank containing water and the depth of immersion is measured by a hook gauge.



a = 0.1 m b = 0.075 m c = 0.3 m d = 0.1 m

* Sample of calculations

→ Partial immersion ($h < d$)

1. Immersed area.

$$A = h * b$$

2. Theoretical y_{cp}.

$$y_{cp} = y_c + \frac{I_{xx}}{y_c * A} \quad , \quad y_c = \frac{h}{2} \quad , \quad I = \frac{1}{12} b h^3$$

$$\therefore y_{cp} \Rightarrow \frac{2}{3} h$$

3. experimental y_{cp}.

$mg\,c = F L$ → to calculate L

$$a + d = h + L - y_{cp}$$

$$\therefore y_{cp} = \frac{mgc}{\rho g \frac{h}{2} A} + (a + d - h)$$

→ Total immersion $(h > d)$

1. y_{cp} experimental

$$y_{cp} = \frac{mc}{(h-(d/2))\, b\, d\, \rho} + h - (a+b)$$

$\rho = \frac{1}{1000}$

2. y_{cp} Theoretical.

$$y_{cp} = y_c + \frac{I_{xx}}{y_c * A}$$

$$y_c = h - \frac{d}{2}, \quad I_{xx} = \frac{bd^3}{12}, \quad A = b * d$$

→ Impact of a water jet

* Objective

To determine the force produced by a water jet when it strikes a flat vane & a hemispherical cup.

* Apparatus

Hydrallic bench , waterjet apparatus , stopwatch.

* Applications

- → Pelton wheel
- → impulse turbine in first or second stage of steam turbine.
- → extinguish fires in high rise building
- → cutting method & deburring.

→ In the flat plane ; the forces are smaller than it in the hemispherical cup; due to change in angle.

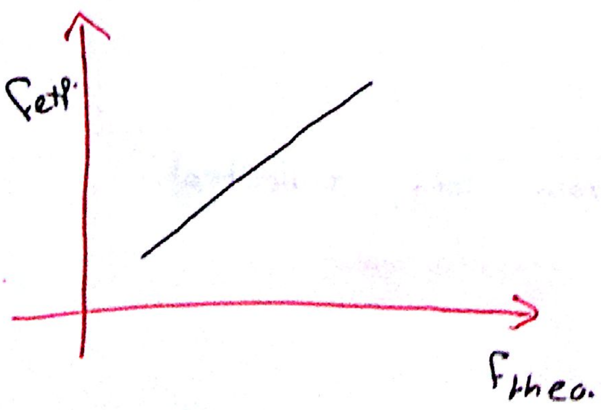
* in the hemispherical cup $\boxed{\theta = 180^\circ}$

$$F_{theo.} = \dot{m} u_0 * (1 - \cos 180^\circ)$$
$$= \dot{m} u_0 (1 - (-1)) = 2 \dot{m} u_0$$

* in the flat plane $\boxed{\theta = 90^\circ}$

$$F_{theo.} = \dot{m} u_0 (1 - \cos 90^\circ) = \dot{m} u_0$$

(zero)



→ Sample of calculations

1. mass flow rate

$$\dot{m} = \frac{m}{\Delta t}$$

2. $$u = \frac{\dot{m}}{\rho * A}$$

3. u_o from bernoulli equation

$$u_o = \sqrt{u^2 - (2*g*S)}$$

$S = 0.04m$ (Height of vane above nozzle outlet)

4. a) $F_{theo.}$ for flat plane

$$F_{theo.} = \dot{m} * u_o$$

4. b) $F_{theo.}$ for hemispherical cup

$$F_{theo.} = 2 * \dot{m} * u_o$$

5. $F_{exp.} = 4 * g * \Delta X$ → From data collected.

* Thermal conductivity

→ Objectives

[1] to determine (k) for a copper & stainless steel.

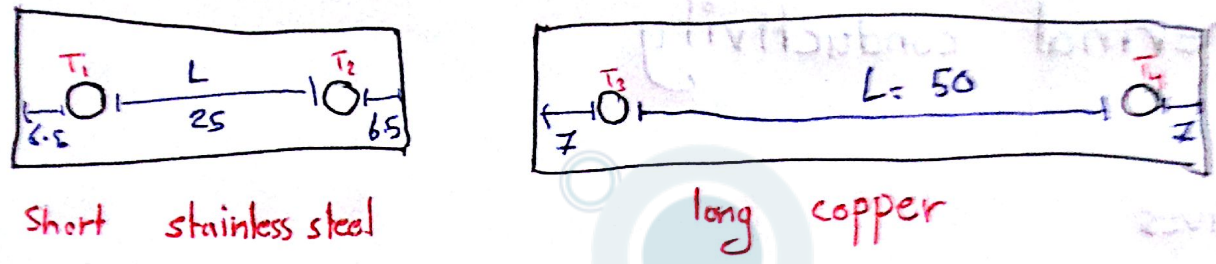
[2] to determine rate of heat transfer ($\dot{Q}$)

→ When energy transfer from high Temperature region to low temperature region, Than energy is transfered by conduction and ($\dot{Q}$) per unit area is proportional to the temperature gradiant $\left(\frac{dT}{dx}\right)$. $\dot{Q} = -k A \frac{dT}{dx}$

→ Apparatus

- Thermal conductivity apparatus. -
- The apparatus is assembled with one short specimen (~~Stailers~~ Stainless steel, low conductivity material) in lower position and one long specimen (copper, high conductivity material) in upper position.
- Four NiCr/NiAl thermocouples are fitted and connections are provided for a suitable potentiometer instrument to give accurate metal temperature reading.

*

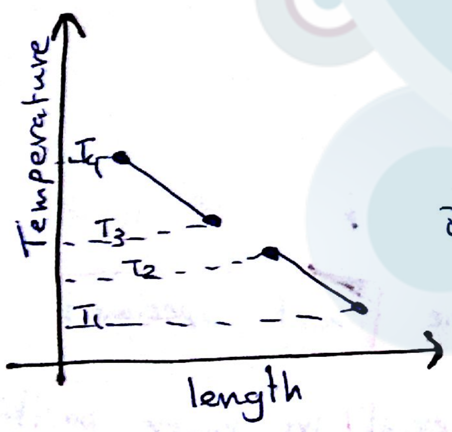


→ Two holes are provided in each specimen for insertion of the thermocouples.

→ Adding silicon @ the ends of the specimens before assembly; to ensure good thermal contact

→ Thermocouple:- measure a temperature.

→



* بزيادة الطول تقل" الحرارة
بسبب الابتعاد عن مصدر الحرارة

→ Sample of calculations.

[1] $\dot{Q}$: the rate of heat transferred to the cooling water ^_^ ; and is given by

$$\dot{Q} = \dot{m} * c * (T_{out} - T_{in})$$

$c = 4.18$ (kJ / Kg °C) specific heat for water.

For ST.steel → $\dot{Q} = \dot{m}\, c\, (T_2 - T_1)$

For copper → $\dot{Q} = \dot{m}\, c\, (T_4 - T_3)$

[2] $\dot{m}$: mass flow rate

$$\dot{m} = \rho * \dot{V} \quad ; \quad \dot{V} = \frac{Volume}{\Delta t}$$

[3] A : cross-sectional area

$$A = \frac{\pi}{4} d^2$$

[4] $\frac{dT}{dx}$: Temperature gradiant

for ST. steel → $\frac{dT}{dx} = \frac{T_1 - T_2}{L}$

for copper → $\frac{dT}{dx} = \frac{T_3 - T_4}{L}$

5 k : Thermal conductivity

$$k_{exp.} = \frac{-\dot{Q}}{\left(\frac{dT}{dx}\right) A}$$

6 % error = $\left| \frac{k_{exp.} - k_{actual}}{k_{actual}} \right| * 100\%$

* Heat pump and air cooler

→ Objective

To determine the COP for heat pump & air cooler

→ Apparatus

The apparatus consists of two separate units: ① air conditioner
② control console

and these are connected by electrical [redacted] cabels, thermocouple wires and nylon water pipes.

→ Sample of calculations

[1] $\dot{m}_{air} = 0.00105 * \sqrt{\frac{H_1 * P_o}{T_2}}$, P_o = ambiant pressure (Pa)

1bar = 100 KPa

H_1 : قراءة المانوميتر (velocity head)

T_2 : T for air out (@ discharge)

[2] $\dot{Q}_{L\,air\,cooler} = \dot{m}_a (h_2 - h_1) + \dot{m}_a (w_2 h_{v2} - w_1 h_{v1}) - \dot{m}_c h_c$

from air

$\dot{m}_c h_c$ = zero. There is no condensate.

h_2 & h_1 : enthalpy of dry air @ exit and inlet conditions

w_1 & w_2 : Humidity ratios of air

h_{v1} & h_{v2} : enthalpy of water vapor

3 $\dot{Q}_H = \dot{m}_{air}(h_2 - h_1) + \dot{m}_{air}\,\omega\,(h_{v1} - h_{v2})$

Heat pump — ω ↓ humidity

4 $\dot{Q}_H = \dot{m}_w * (h_{f4} - h_{f3})$

air cooler — from tables.

5 $\dot{Q}_L = \dot{m}_w (h_{f4} - h_{f3})$

Heat pump

6 For air cooler

$$COP = \frac{\dot{Q}_L}{\dot{W}_{net}} = \frac{\dot{Q}_L}{\dot{Q}_H - \dot{Q}_L}$$

$$COP_{max} = \frac{T_{10}}{T_8 - T_{10}} = \frac{T_L}{T_H - T_L}$$ → reversible, carnot, ideal cycle

→ The air flow is measured by means of a Pitot tube mounted in the center of the discharge duct. and The pressure of air @ this point equal to the atmosphere P_0

→ Psychrometric chart @ 1atm total pressure

To determin humidity (ω)

→ The air cooler and heat pump, have the same cycle; but the difference between them is in the ~~dir~~ flow rate direction ONLY.

→ Comparsion of pump characteristics.

* Objectives

To establish a set of pump characterstics @ constant & variable speeds for Positive displacement reciprocating pumps, and cintrifugal pump.

* Apparatus

Universal pump test

* The system is instrumented for the measurement of speed (1), Torque (2), flow rate (3), Pressure (4).

* Primary functions of pumps :

1) transportation of fluids

2) add energy to the transported fluids

* Driving motor D.C :- machine coupled to a spring dynamometer (max current)

comparsion

	centrifugal Pump	Positive displacement reciprocating Pump
Pressure	low	high
Head pump	low	high
Price	low	high
$\dot{Q}$	High	low
speed	High	low
motion	horizontal	vertical
uses	home	industrial uses
Type of flow	continuose	descrete.

→ Sample of calculations

1. Volumetric flow rate (m^3/s)

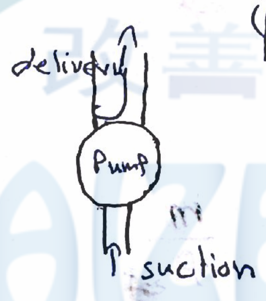
$$\dot{Q} = \frac{m}{\rho_{\Delta T}}$$

2. Brake load (N)

Brake load = spring load (kg) * 9.81 m/s^2

3. Head pump (m)

$$H_p = \frac{\Delta P}{\rho * g * 10^{-5}}$$; ΔP = delivery pressure (P_d) − suction pressure (P_s)



4. water power

water power = $\rho * g * h_p * \dot{Q}$

5. Brake power

Brake power = $2\pi \, W F R * 10^{-3}$

W: motor speed (rev./s)

F: Brake load.

R: torque arm radius.

6 overall efficiency

$$\eta_o = \frac{\text{water power}}{\text{Brake power}} < 1$$

7 volumetric efficiency

$$\eta_v = \frac{\dot{Q}_{measured} \text{ measured volumetric flow rate}}{\text{Calculated volumetric flow rate } \dot{Q}_{calculated}}$$

→ $\dot{Q}_{measured} = \frac{\dot{m}}{\rho}$ → 1000 Kg/m³

→ $\dot{Q}$ calculated

→ for a double pump (reciprocating) (المتقطعة بالأب)

$$\dot{Q}_c = 2 \times A_p \times L \times \omega_{r.pump}$$

$\omega_{reciprocating\ pump} = \frac{\text{motor speed}}{5}$, A_p: area of crosssection

→ for centrifugal pump

$$\dot{Q}_c = \frac{0.75}{12.5} \times 10^{-3} \times \omega_{centrifugal}$$

$\omega_{centrifugal} = 2 \times$ motor speed

* Flow visualization

→ Objective

To make the student familiar with the flow patterns and to see the stream lines when different shapes of objects are inserted in the flow path.

- To see the stream lines in the different model -

→ Apparatus

[1] Flow visualization equibment which is powered by a syn_chronous A.C.

[2] Integrated smoke generator ; in this equibment, an oil mist is formed by the atomization of a heated mineral oil in an air stream.

→ Stream lines ; family of curves that are instantaneously tangent to the velocity vector of the flow. These show the direction of a fluid element will travel @ any Point in time.

→ The shape of stream line depend on the slope of the model;

→ The stream lines exert pressure on the object Then, the force is being introduced causing energy difference @ each particular place in the model.

→ Models used

1. cylinder model 
2. single widge model 
3. double widge model 
4. fired cylinder model 

وَإذا كانتِ النُّفوسُ كِبارًا..
تَعِبتْ في مُرادِها الأجسامُ..