Experiment ① (vapor - Liquid equilibrium)

objective:-

for any distillation process.

① obtained equilibrium data (binary system @ constant P)

② obtaine activity coefficient. (two suffix, Margules, Vanlar, NRTL, UNIQUAC wilson equation).

③ compared experimental data with predict activity coefficient using UNIFAC and with ~~value~~ reported literature values.

Equipment:-

~~① champer heater~~

① boiling champer ⇒ heat mixture to produced vapor - liquid mixture (by emartion heater).

② spiral glass ~~tube~~ (mixture enter spiral glass at high velocity)

③ thermometer's pocket (which contains thermo couple to measure the boiling temp.).

④ central tube (vapor rises gently through it and liquid drop full back to champer)

⑤ heating tep (proued extra heating to prevent condensat of vapor).

⑥ condenser (total condense of vapor by ~~cooling~~ cooled liquid from refrg.)

⑦ Refractometer.

⑧ temp. reading device.

~~* whom add the mixture~~

* added the mixture slowely to prevent formation of air bubble (which reduce heat transfer).

* take small volume from liquid and vapor for sample to don't affect on volume of operation. (few drop).

* first part of ~~exp~~ experiment we add 120 mL of pure hexane to calculate the builing temp and composition then add ~~80~~ 20mL of toluene every time to reach 80 mL ~~from~~ toluene.

. In sconed part we add 120mL of pure toluene. then add 20 mL of hexane every time

- When heated a liquid mixture of two volatile comp. the temp. rises and rate of evaporization increase, vapor pressure of liquid mix. increase.

- P_T increase until it is equal to the pressure applied, so liquid mix. start to bubble and the temp. at this point is boiling temp.

P_T depend on composition and temp.

$$P_T = \sum_{i=1}^{2} P_i = \sum x_i P_i^{sat}.$$

$y_i P$

depend only on temp. (Antoine equation).

* Raoult's Law: → • for ideal mixture
• represent the max. seperation (purification) could be achieved.

* Modified Raoult's Law → • Low pressure.
• ideal gas mixture
• non ideality is accounted by γ in liquid phase.

γ depend on T, P, composition.

$$\gamma_i = \frac{y_i P_T}{x_i P_i^{sat}}$$

way to determine the composition of vapor-liquid mix
① refractometer (refractive index).
② gas chromotography (GC)
③ HPLC

* hexane more volatil

Temp. → C°
ρ → kg/m^3
P → mmHg.

* positive deviation from Raoult's Law ⇒ bubble curve above Raoult's Line
This mean the vapor pressure for the mix. is higher than the vapor pressure for each comp. which lead both comp. ~~lead~~ escape from solution easily.

* ~~the ratio~~ γ greater than "1" give pressure that larger than the sum of the pure vapor pressure (positive deviation)

* increase the composition of hexane lead to increase ~~activation~~ activity coeff.

Van Laar, Margules. (modified Raoult's law).

in crease in liquid composition of hexane $\Rightarrow$ increase γ

Calculation :-

RI (liquid) = $\square$ $\Rightarrow$ from chart %Vol (hexan) = *

% Vol (toluene) = 1 − *

$$X(\text{hexane}) = \frac{\rho_H * \%\,Vol_H}{\rho_H * \%\,Vol_H + \rho_T * \%\,Vol_T}$$

$$X(\text{Toluene}) = 1 - X(\text{hexane}).$$

RI (vapor) = $\square$ $\Rightarrow$ from chart % Vol (hexan) = *

% Vol (toluene) = 1 − *

$$Y(\text{hexane}) = \frac{\rho_H * \%\,Vol_H}{\rho_H * \%\,Vol_H + \rho_T * \%\,Vol_T}$$

$$Y(\text{Toluene}) = 1 - Y(\text{hexane}).$$

- Activity coefficient.

$$\gamma(\text{Toluene}) = \frac{P_T * y(\text{toluene})}{P^{sat} * X(\text{toluene})}$$

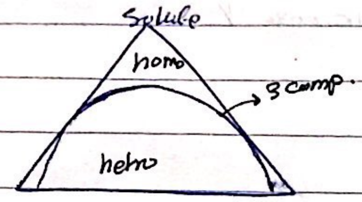
$$\gamma(\text{hexane}) = \frac{P_T * y(\text{hexane})}{P^{sat} * X(\text{hexane})}.$$

Experiment (2) Liquid-Liquid equilibrium.

objectives:-

① obtaine equilibrium (Solubility curve)

② Tie Line (Line between two point on equilibrium curve).

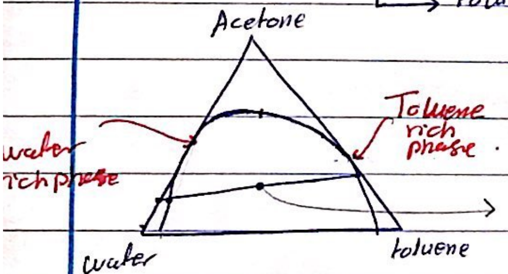


Equipment:-

mixer sittler → 3-cell, capacity for each cell 100mL

- Side arm near the top to charging the Liquid.
- glass jacket to maintain the cell content at constant temp.
- Valve for emptying contents.

* Solubility curve → water rich phase (water + Acetone, titreation by toluene).
→ toluene rich phase (toluene + Acetone, titreation by water).



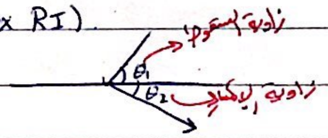
* end point ⇒ turbidity, cloudiness (3-comp. at equil).

* In mixer sittler, mix 20 min. and sittling 20 min.

* They separat by density (toluene Low density).

* Refractometer. (refractive index RI)

~~RI = Sin θ1 / Sin θ2~~

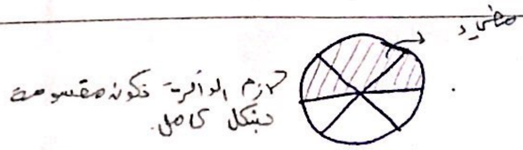


$RI = \sin(\theta_1/\theta_2)$

* Sample on prime and source of Light.

* يوجد عدستين عدسة لرؤية علية سقوط الضوء

عدسة لـ scal reading.



* Liquid-Liquid extraction → any operation in which material dissolved in one Liquid phase and transfer to a Second Liquid phase.

Solvent must be insoluble, or soluble to Limited extent (if solvent and solution completely miscible, will not be transfering the ~~feed~~ solute from original phase to ~~anothe~~ Second phase).

So the Solubility of solvent in solution, and solution with it comp. in solvent very important to choose the solvent and the operation of extraction.

* LLE ~~have~~ consist of 2-steps:-

① mixing of solvent with solution ⇒ transfer the solute to solvent.

② separation of Liquid Solution phase; and Liquid Solvent phase.

complete extraction ⇒ seperation + recovery of solvent.

- we do recovery when the solvent is costly and special.
  - ① distillation
  - ② heating, cooling (dimish the solubility of solute or of solvent).

Use LLE when:-

① The comp. are non-volatile. * distillation required heat.

② The comp. have same volatilities

③ The comp. sensitive to the temp.

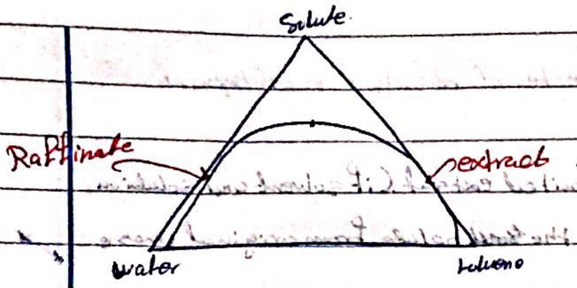
④ The disired comp. is less volatile and ~~are~~ present in solution in small amount.

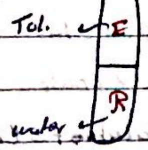
* different distribution of the comp. of the feed mixture between the two layer at equilibrium is depended upon to effect the desired separation.

  - layer contaning the greater concentration of the solvent and smaller conc. of the feed Liquid (extract).
  - Layer containing greater conc. of feed Liquid and smaller conc. of solvent (raffinate)

* represent extract and raffinate at ① right-diagram ② equilateral diagram

* for each state of equilibrium there is only one tie Line.





down → R

up → E

* Tie line represent the amount of raffinate and extract, and represent the point in which the solution extract to 2- phase.

Calculation :-

$m = \rho * V$

$\Rightarrow X = \frac{m}{m_T}$, estimate X on ternary diagram.

* Tie line

$m = \rho * V \Rightarrow m_T \Rightarrow$ mass fraction

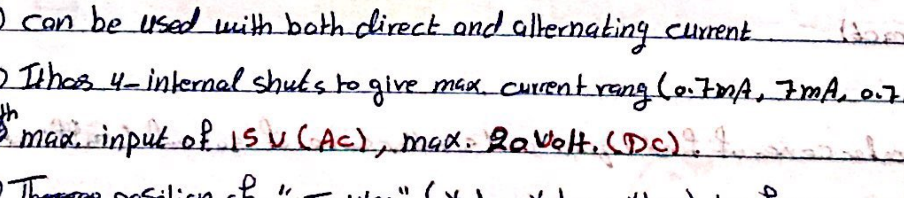
RI $\Rightarrow$ curve $\Rightarrow$ X_A , $(1 - X_A)$ water

X_A, $(1 - X_A)$ toluene

Experiment ③ Digital joule meter.

Equipment:

① digital Joule meter measures electrical energy directly in joule and power in watt. Clear digital display which most valuble for many demonestration.



emarction heater (Ac power supply)

② can be used with both direct and alternating current

③ It has 4- internal shuts to give max. current rang (0.7mA, 7mA, 0.7A, 7A)
with max. input of 15 V (Ac), max. 20 Volt. (Dc).

④ Three position of "Joules" (*1, *10, *100) to four range

objective:-

There is 3-objective

① To determine the specific heat capacity.

② To determine the specific latent heat of vaporization of liquid.

③ To investigate the efficiency of small electrical motor and study it's variation with load and applied voltage.

For objective "1" :-

from Joule meter $Q = m c_p \Delta T$ ($\Delta T \to T_1 - T_2$) $m \to kg$, $T \to {}^\circ c$, $Q \to J$

* We need power supply 12V (ac), immersion heater (12V, 50A), Aluminum block, thermometer.
* We put the aluminum block inside isolate to prevent loss heat.
  * أولاً نشغل ال Suppy ونستنى ترفع درجة الحرارة درجتين لأنه أول حرارة تروح لتسخين ال heater
  وبعدها نصفر لحتى الحرارة تروح لتسخين الألمنيوم.
* when temp. of the block has risen about 20°c read thermometer and read jolue meter.

Source of error → forget rest the Juel meter after rising temp. 2°c

For objective "2"

Joule meter من ال $Q = m \lambda$
لكمية الماء اللي بتبخر

* Switch on the ~~heater~~ heater and wait until the liquid boils and record it's boiling temp.
* follow record T_b, put the beaker on isclulation and vaporize 5g of liquid.

For objective "3"

$$\eta = \frac{out}{in} = \frac{mgh}{electrical\ (from\ joule\ meter)}$$

($m \to kg$, $h \to m$, electrical $\to J$)

* need to determine the η of motor (→ DC) pull the weight on certain h

Two part → ① mass vary, Volt. constant.

② mass constant, Volt. vary.

* نثبت الوزنة على ارتفاع 20 ونرفعه لـ 70 يعني $\Delta h = 50$
* نضيف على وزن الوزنة وزن ال holder

* ~~Heat~~ C_p → heat energy that is needed to raise the temp. of 1kg of sub. by 1°c.

λ → heat energy must be add to transform a given quantity of the sub. into gas.

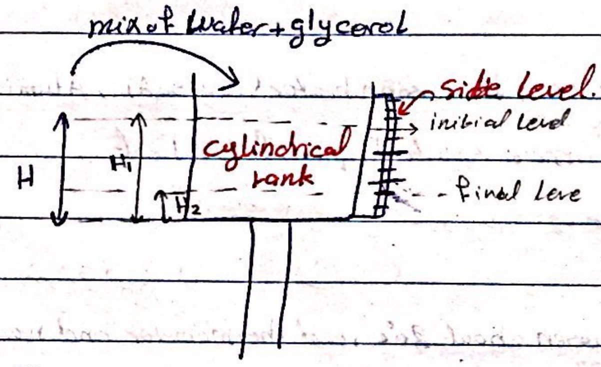
* The efficiency of the motor is inversily proportional to the mass added and directly proportional to the voltage of the power supply.

* At constant m, vary V ⇒ Q_{out} constant, V↑ ⇒ Q_{in}↓ ⇒ η↑ / At con. V and vary m ⇒ m↑ ⇒ Q_{out}↑ ⇒ Q_{in}↑ ⇒ η↓
increase more than Q_{out}

Experiment (4) efflux time for a tank with exit pipe.

Objective:-

To show the effect of exit pipe length and diameter on the efflux time.



There is factors effect on efflux time

① dia. tank and shape.
② head (In this exp. every time we began discharge at same level) → h↑ ⇒ تفريغ أسرع
③ ρ, μ of solution
④ exit pipe (diameter, length)

① ② ③ are constant in this experiment

* The longest pipe take more time, pipe has least dia. take more time that this because friction (friction reduce velocity).

* on each pipe we repeat exp. 2-time to take avarge time (to reduce error).

* Assuming a quasi steady state momentum balance and ignore the head loss due to the entrance and the exit of the pipe.

calculation:-

- mass of mix. = mass of tank with mix. − mass of empty tank.
- $\rho = \frac{mass}{Vr}$
- $A = \frac{\pi}{4} d^2$
- $Q = \frac{V_{Drained}}{t_e}$ → in exp. = 1 L
- $u = Q/A$
- $Re = \frac{\rho u d}{\mu}$ → pipe dia. ; μ: $\frac{N.S}{m^2}$

* first find volume of bottle

m_{water} = mass water bottle − mass bottle

ρ_{water} (known)

$V = \frac{m_{water}}{\rho_{water}}$

→ Laminer ($Re < 2100$) $t_c = \frac{32 \mu L D_T^2}{\rho g . d^4} . \ln\left(\frac{L + H_1}{L + H_2}\right)$

$\bar{V} = \frac{(L+H) \rho g d^2}{32 . \mu L}$, ($f = 16/Re$).

→ Turbulnet. $t_c = \frac{7}{3} \frac{D_T^2}{d^2} \frac{1}{c} \left((L + H_1)^{3/7} - (L + H_2)^{3/7}\right)$

$\bar{V}$ ⇒ Time-averge velocity ($m.s^{-1}$) $\bar{V} = (L + H)^{4/7} . C$, $f = 0.079 Re^{-0.25}$

$\therefore C = \left(\frac{g d^{5/4} \rho^{1/4}}{(0.079 * 2) . 2 . \mu^{1/4}}\right)^{4/7}$

→ constant for incompressible fluid and isothermal.

* At constant diamtere, $L \downarrow \Rightarrow t_{eff} \downarrow \Rightarrow Q \uparrow \Rightarrow u \uparrow \Rightarrow Re \uparrow$
* more long pipe → more friction → less velocity → less Renylod #. (more Laminer). *
* At constant length, $d \uparrow \Rightarrow A \uparrow \Rightarrow Re \uparrow \Rightarrow$ friction $\downarrow$, $\Rightarrow t_{eff} \downarrow$

Velocity in small d is slower and need more time to drain (higher viscous force between fluid and pipe)

$D_T/d \uparrow \Rightarrow t_e/t_c \uparrow$ then $\downarrow$ (at constant length, not linear).

* when Dia. is much low the t_e and t_c are increased and values become closer to each other that make the ratio low. This explain why the curve is coming down when decreasing the dia. of pipe with respect to the dia. of tank.

* measure μ by viscometer, density ⇒ mixture using 50mL density bottle by calculating the mass of mix. first then devide it by V.L. to get density.

Experiment "5" compressible fluid flow.

objectives:-

a. Simple pipe friction duct :-

① investigate the relation between friction loss and velocity for incompressible flow

② find approximate value for f

③ investigate the relation between f and Re.

b. Sudden enlargment duct:-

① investigate the relation between the pressure recovery across sudden enlargment and upstream flow velocity (assuming incompressible flow).

② investigate the validity of the formula for the pressure rise across a sudden enlargment for compressible flow.

Equipment:-

① Fixed motor driven compressor.

② Two inclined tube manometer.

③ Two vertical manometer fill with mercury.

④ 13 mm Simple pipe.

⑤ A sudden enlargment duct.

* Inclined manometer:-

- fill with kerosen
- has three position (top, mid, bottom), we change the inclination to read scale at higher range.
- the manometer must be horizontal well (مفرغ)

- use inclined manometer at Low ΔP, and mercury manometer at high ΔP.

* Locking nuts → to secure them firly to the track for an experimental hook

* Ensure the inlet nozzles on each test free from any neighboring obstacle that might interface with smooth passage of air into the test duct

→ increase velocity at the begining of the proces (used for measure the flowrate).

* density of gas vary

* when chang in pressure small ⟹ The density change are also small and it flow can be treated as incompressible.

* Assumption:-

① flow variable are uniform (over cross section ⊥ to the flow direction)

the duct can be considred to be a single Stream with one dimension.

② flow steady.

③ pontential energy changes are negligible

* خلال التجربه لما نوصل لسرعة 6.5 الـ inclined man. ببطل ~~...~~ يقدر يقرأ لانه بجيب ΔP عالي

* flow rate is determine from $(P_0 - P_1)$

P_0 → atm. , P_1 → throte

appro. assumption ⟹ no losses, work, heat transfer, density change.

⟹ uniform velocity distribution

→ from this arise error, so to get more accurate value of V and $\dot{m}$ we multiplying $(P_0 - P_1)$ by K (kN/m²)

K → depend on Re at throte, and $\frac{P_0 - P_1}{P_0}$

* ρ_0 ⟹ calculated from the ideal gas low using Patm.

Calculation:-

Simple pipe:-

k((P0-P1) & kPa)

~~ΔP from inclined kPa~~

ΔP from mercury mmHg.

- $f = \frac{(P_2 - P_3)\, d}{4 \rho L\, k (P_0 - P_1)}$

- $Re = \frac{d \sqrt{2\rho}}{\mu} \sqrt{k (P_0 - P_1)}$, $\rho_0 = \frac{P_0\, M_{wt(air)}}{R\, T}$

, $\mu = 1.71 \times 10^{-5} \left(\frac{393}{\theta + 393}\right) \left(\frac{\theta + 273}{273}\right)^{3/2}$

μ → (N·s/m²) , θ → T at c°

$V = \sqrt{\frac{2k (P_0 - P_1)}{\rho_0}}$

$\dot{m} = a_1 \sqrt{2 \rho_0 k (P_0 - P_1)}$

a_1 → $\frac{\pi}{4} d^2$, d → 13mm

Sudden enlargment:-

$\rho_o = \frac{P_o \, Mw}{R T}$

$P_1 = P_2$, $P_o - P_1$ is given and $P_o = 680 \, mmHg = 90.659 \, kpa$.

$\Rightarrow P_2 = P_1 = P_o - (P_o - P_1) \quad (kpa)$.

$\Rightarrow P_3 = P_2 + (P_3 - P_2) \quad (kpa)$.

$\rho_2 = \frac{P_2 \, Mw}{R T}$, $\rho_3 = \frac{P_3 \, Mw}{R T}$ (kg/m^3)

$a_1 = a_2 = \frac{\pi}{4} d_2^2 \quad (d = 0.013 \, m)$

$a_3 = \frac{\pi}{4} d_3^2 \quad (d = 0.019 \, m)$.

with increase the velocity.

* $(P_o - P_1)\uparrow \Rightarrow Re\uparrow \Rightarrow f\downarrow$ (~~relation~~ between ~~these 3 parameter~~ is direct).

* Blasius equation is applicable (measured slope equal theoritical one). $f = 0.079 \, Re^{-0.25}$
* kikuradse - Von karmane $\frac{1}{\sqrt{f}} = 4 \log(Re \sqrt{f}) - 0.396$ ~~Not~~ applicable
  (~~measured slope wasn't equal to the theortical one~~).

simple pipe

* friction is constant as long as no change in ~~pass~~ Ac
  $\Delta P\uparrow \Rightarrow f\uparrow$ / friction loss $\uparrow \Rightarrow V\downarrow \Rightarrow \Delta P\downarrow$ / $\log f\uparrow \Rightarrow \log Re\downarrow$ but $f\downarrow \Rightarrow Re\uparrow$ ⑥ ..

Experiment (6) Determination of Losses in small Bore piping system.

* objective :-
  - To determine total head lose of fluid
  - Variation of f with Re (moody chart)

Total head lose
- major lose $\Rightarrow$ due to flow Liquid through pipe (shear stress between Liquid and wall of pipe)
- minor lose $\Rightarrow$ due to flow Liquid through fitting
  - fitting $\Rightarrow$ ① Valves
    ② elbows
    ③ bends
    ④ sudden expansion and contraction

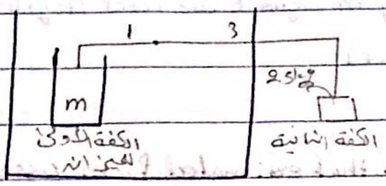
* Equipment :-

- system consist of two circuit seperated on eachother.

dark blue (major losses) — Light blue (minor loses)

- hydrulic bench ⇒ it's source of water, and water turn from circuit to it.

we measure $\dot{m}$ from it also.



* نعبي ماء ع الخزان لحتى لما تساوى الكفتين (بكون عندنا كمية الماء اللازمة)

$2.5 * 3 = m * 1$

$= 7.5\ kg$ في كل Trail

* mass constant on each trail (لاي بتغير فتحة ال Valve)
* There is two valve → for ~~dark~~ dark blue gate valve / → for Light blue globe valve } they diff. by head losses
* first trail fully open valve
* manometer connected with valve is U-tube manometer valve (fill with mercury (mmHg))
* manometer on board is inversed U-tube manometer (piezometer) (fill with water (mmH2o))

objective (from manual).

a. Head loss in straight pipe (major)

① Head loss as a function of volume flow rate.

② friction factor as a function of Re.

b. Head loss in sudden expansion:-

To compar the measured head raise with rise calculated on assumption

① no losses.

② h_L (head loss) $= \frac{(V_1 - V_2)^2}{2g}$

c. Head Loss in sudden contraction.

To compare the measured fall in head with fall calculated on assumption

① No head loss

② $h_L = \frac{K V_2^2}{2g}$ (K, dimensionless depend on A_2/A_1)

d. Head loss In Bends

To measure loss coeff. k for (90° miter, 90° elbow, 50mm bend, 100mm bend, 150mm bend).

e. Head loss in Valves:-

To determine the relationship between loss coeff. and Volume flowrate for a globe type and gate type.

* Two categories for head loss

① due to viscous resistance extending throughout the total Length of circuit (major)

② due to localized effect (minor).

• Total head loss may differ from that estimated from losses due to individual because of mutual interface between neighboring comp. in complex circuit

* calculation:-

For Dark blue circuit

① gate valve.

$(h_1 - h_2)$: Δh (mmHg) $\Rightarrow$ (mH2O).

$$Q = \frac{m}{\rho * t} \Rightarrow u = Q/A$$

$\frac{\pi}{4} d^2$ (stright pipe)

$$Q\% = \frac{Q}{Q \text{ at fully open}} * 100\%$$

$$k = \frac{\Delta H}{u^2/2g}$$ due to fitting only.

② Stright pipe ($h_3 - h_4$ (mH2O)).

Δh ✓.

$$Q = \frac{m}{\rho t} \Rightarrow u = Q/A \Rightarrow Re = \frac{\rho * d u}{\mu}$$

$$f = \frac{\Delta h f d g}{2 L u^2}$$

* Dark blue circuit

① gate valve

② standard elbow bend.

③ 90° miter bend.

④ stright pipe.

* 10.333 mH2O = 760 mmHg

③ Standard elbow 90

Δh ✓

$Q = m/\rho t \Rightarrow U = Q/A$.

$\Delta H = \Delta h_1 - \Delta h_f$

due to fitting only — total — ↳ straight pipe.

$k = \dfrac{\Delta H}{U^2/2g}$, r/d ↳ diam. of pipe.

radius of elbow

④ 90 miter bend

Δh ✓, $Q = m/\rho t \Rightarrow U = Q/A$.

$\Delta H = \Delta h - \Delta h_f$

$k = \dfrac{\Delta H}{U^2/2g}$, r/d.

- For light blue.

* light blue

① globe valve

2. sudden expansion

3. sudden contraction

4. 152.4 mm 90° radius bend

5. 50.8 mm 90° radius bend.

① Globe Valve

$\Delta h\,(mmHg) \rightarrow \Delta h\,(mH_2O)$

$Q = m/\rho t$

$Q\% = (Q / Q \text{ at fully open}) * 100\%$.

$k = \dfrac{\Delta h}{U^2/2g}$.

② sudden expansion.

- d_1 , d_2 $(d_1 < d_2)$, $Q = m/\rho t$.

- Δh (experiment)

- $U_1 = Q/A_1$, $U_2 = Q/A_2$. $U_1 > U_2$

$\Delta h(\text{noloss, cal}) = (U_1^2 - U_2^2)/2g$.

$\Delta h\,(\text{Loss, cal}) = (U_1 - U_2)^2/2g$.

$\Delta h\,(\text{loss}) = \Delta h(\text{noloss}) - \Delta h(\text{Loss, cal})$.

③ sudden contraction

d_1, d_2, Δh_{exp}.

$Q \rightarrow U_1, U_2$

$\Delta h(\text{noLoss}) = (U_1^2 - U_2^2)^2/2g$. , $\Delta h(\text{Loss, cal}) = \dfrac{(U_1 - U_2)^2}{2g}$, $h(\text{Loss}) = \Delta h(\text{noloss}) - \Delta h(\text{Loss})$.

$h_f = \dfrac{k * U_2^2}{2g}$, $\Delta H = \Delta h + h_f$.

* Smooth bend.

- 50mm radius bend

Δh ✓

$Q = \frac{m}{\rho * v}$, $A = \frac{\pi}{4} d^2_{\text{stright pipe}}$ $\Rightarrow U = Q/A$.

$Re = \frac{\rho d u}{\mu}$, $Re > 2100$.

$f = 0.079\, Re^{-0.25}$

$\Delta hf = \frac{4 f L u^2}{2 d g}$ (L → stright pipe, d → stright pipe)

$\Delta H = \Delta h - \Delta hf$.

Same procedure is applied for Radius bend 100, 150, 50.

* Head loss $\Rightarrow$ measure of the reduction in total head (sum of elevation head, Velocity head and pressure head) of the fluid.

* Frictional loss $\Rightarrow$ part of headloss that accurs as the fluid flows through Stright pipe.

* head loss directly proportional to L and u^2, f.
  " " inversly proportional to d.

$f \Rightarrow$ depend on Re and the degree of raughness of the pipe's inner surface.

* flow $\uparrow \Rightarrow \Delta P \uparrow \Rightarrow \Delta hf \uparrow$
  $u \uparrow \Rightarrow Re \uparrow \Rightarrow f \downarrow$

* globe valve have higher values of k when changing flow rate, which make gate valve a choice for less loss piping system (drak blue), also have very little fluid flow resistance in fully open and have small ΔP

* globe valve $\Rightarrow$ high ΔP, big resistance (due to compact geometry).

* [illegible] $k \uparrow \Rightarrow Q\% \downarrow$ for gate valve and globe valve.

$k \uparrow \Rightarrow \Delta H \uparrow \Rightarrow u \downarrow$ (friction is less when velocity is higher).

$d \downarrow \Rightarrow k \downarrow$

- friction loss in 90 miter higher than 90 elbow
- head loss of sudden expansion higher than sudden contraction

Experiment (7) pitot tube experiment.

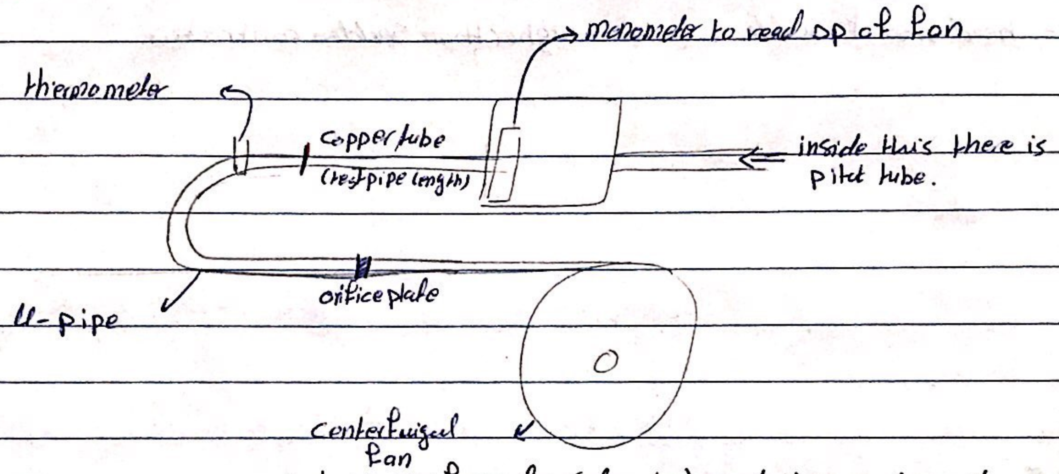
objectives:

① To measure the radial velocity profile for flow of air in pipe. — velocity profile

② To determine mean velocity, volumetric flow rate, ṁ using — Tucheak arrangment between them. / orifice discharge

③ To identify if the flow laminar or turbulent from — velocity profile / Re.

Equipment:-



(draws air from atm. (at center), and the air leave it tangentional)

- orifice plate ⟹ measure ΔP through orifice to measure flow rate of air.

- pitot tube ⟹ hollow tube (L-shape), orifice of pipe on the flow rate of air
(measure stagnent pressure)

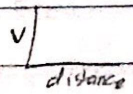
- It is traversed across the dia. of the pipe.
- It's position at any point is read directly from a combined linear scale and varnier.
- pitot pipe measure only stagnention pressure, static pressure sensed at tapping point in the wall of the pipe.

$P_{stagnent} - P_{static}$ (cm H_2O)

* The difference between two pressure measure by differential water manometer.

* في أول التجربة بكون موقع الـ pitot tube (pipe) على طرف الـ tube وبكل مرة نحركه 2mm داخل الـ pipe

لحد ما يوصل الـ side الثاني للـ pipe ونأخذ قراءة الـ pressure عند كل نقطة لنرسم الـ velocity profile



* pitot tube ⟹ device to measure velocity of flow.

manometers :-

① pitot tube diff.

② orifice pressure drop

③ test length pressure drop

④ pressure fan

} take it at the end of the experiment

* when moving fluid is caused to stop because it encounter the stationary object (pitot tube tipe) a pressure is created (stagnention pressure), is greater than the p of the fluid stream (static pressure)

* Calculation:

- ρ at orifice $= \frac{P_{orific} * M_{wt}}{RT}$, $P_{orifice}$ = Barometric p + fan p. (pa) (atm)

$R = 287.05 \ N.m/kg.k = 8.314 \ \frac{m^3 . pa}{mol . K}$ (pa)

- ρ at pitot tupe $= \frac{P_{static} * M_{wt}}{RT}$ P_{static} = Barometric p + $\frac{276}{1524}$ test Length pressur drop (pa) (atm).

- mass flowrate (w) = $\rho_{orific} * A_{orific} * Cd * \sqrt{\frac{2\Delta P}{\rho}}$ → at orfice.

orifice discharge coff. (0.613)

- Averge velocity $\bar{V} = \frac{w}{\rho \pi R^2}$ → pipe radious.

→ ρ in the pipe (pitot)

- local velocity (at a point the pitot plane) $= \sqrt{\frac{2(P_s - P)}{\rho}}$ → pa

→ at pitot

* When draw $V*r$ vs r we can find w by.

$W = 2\pi\rho \int_0^R V r \, dr$ → 0.5 * pipe diam. − pitot tube position

R → radious of tube

↳ test pipe

integrate this by simpson's $\frac{3}{8}$ rule

$\frac{3h}{8} \left(f(x_0) + 3f(x_1) + 3f(x_2) + f(x_3) \right)$

then find $\bar{V} = \frac{W}{\rho \pi R^2}$ ⟹ $Re = \frac{\rho \bar{V} D}{\mu}$

* Velocity profile increase when get become closer to the center and decrease when become closer to the side because of friction (max. velocity at the center).

* We measure W in two way.

① radial velocity (plot V*r with r and then $W = 2\pi\rho \int_0^R V r\,dr$ (↳ find this by numerical method).

② orifice discharge ($W = \rho * A * cd * \sqrt{2\Delta p/\rho}$)

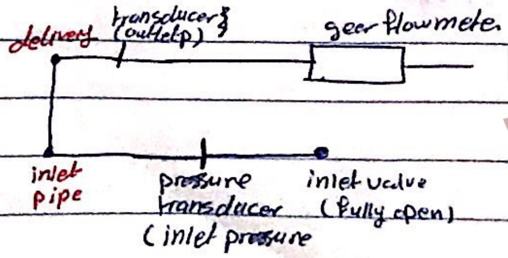
There is difference between two value, because of :-
radial velocity (pitot tube) → measure velocity at only one point of stream
whereas orifice measure velocity for full flow stream

• when flow become turbulent the velocity profil tend to be flat so it become independed on the position of pitot ~~tube~~ pipe.
* Some time T. of fan ↑, so turn off the fan once in while make sure temp. is constant.

Experiment (8), positive displacement pumps charactristics

* objective :-
- To demonestrate how pumps work (piston, van)
- show the performance of pumps at constant and variable velocity.
- compare the efficiency ~~to~~ for two pumps under identical speed condition

Apparatuse.
• motor, main switch, control on motor speed, sensor read speed input and other read torque input
• Working fluid is oil
• The pump draw the oil from reservior and then go through the circuit at then end back to reservior.
• There is two pipe connect with pump (inlet (suction), outlet (delivery)).



① oil com from resirvear through Inlet velve and through pump.

② passes through relief valve and delivery valve ⇒ (control of delivery pressure).

③ passes through gear flowmeter and back to reservier.

* thermo cuple to measure temp. of oil

7.15 $\frac{cc}{rev}$ (how much the distance in on revelution).

* الـ pressure : اللي بتغير بالتجربة هو الـ pressure delivery (P_2)

pressure (1 bar — 10 bar) step = 1 bar.

Speed (200 — 1000 rev/min) step = 100

* most important qualities for pump
  ① increase in pressure
  ② increase in flow rate
  ③ efficiency and power need.

- The pressure difference → the difference between the pressures befor and after the pump.
- flow rate → amount of flued pass through the pump.

power:
- mechanical power (into pump) ⇒ the shaft power at the pump. (W_D).
- Hydraulic power (from the pump) ⇒ due to the flow through the pump and increase in pressure.

$$W_P = (P_2 - P_1) * Q_V$$

P_2: delivery; P_1: inlet (suction).

over all efficiency :-

$$\eta_p = (W_P / W_D) * 100.$$

Volumetric efficiency.

$$\eta_v = \frac{Q_V \text{ (Actual)}}{V_s * N_p \text{ (theo.)}} * 100\%.$$

V_s = Swept volum (cm³/rev)
(how much distance in on revelution).
→ depending on the type of the pump.

N_p = Speed of pump (rev/min).

* before ~~we~~ start we should do:-
① fully open valve (inlet, delivery)
② Zero all pressure.
③ Zero the torque reading.

objective of constant speed to show how pump perform for range of delivery.

- objective of constant 'p' " " " " " " " of speed.

* Values of speed for van pump (6.6) lower than piston pump (7.15), also flowrate for piston ~~pump~~ pump higher than van pump (at constant speed).

* when the pressure difference increase the shaft power for van and piston pumps increase, but the increase power for piston much higher than power of van pump.

* Volumetric efficiency increase with flowrate at constant speed.
Low speed value have greater η_v, w_d)
So η_v for van higher than ~~pump~~ piston.

~~overall~~
- η_p depend on w_p, w_d.
- w_p effect positively with Δp, flow rate
- $w_d \downarrow \Rightarrow \eta_p \uparrow$ (η_p for van higher than piston).
- Low speed help pump to ~~give~~ get high η.

* At constant pressure.
• Speed $\uparrow \Rightarrow$ flow rate $\uparrow$ (same for van and piston)
• speed $\uparrow \Rightarrow w_d \uparrow \Rightarrow w_p \uparrow$
$w_p = \underset{\text{const}}{\Delta p} * Q_v$ ↳ increases with ~~value~~ speed
So w_p increase with speed.

* At constant speed.
$p \uparrow \Rightarrow w_d \uparrow \Rightarrow w_p \uparrow \Rightarrow Q \downarrow \Rightarrow \eta_v \downarrow \Rightarrow \eta_p \uparrow$

At constant p.
$s \uparrow \Rightarrow w_d \uparrow \Rightarrow w_p \uparrow \Rightarrow Q \uparrow \Rightarrow \eta_v \uparrow$

Experiment (10) The performance of a Radial fan

objective:-

To determine the performance of a radial flow rotor in air (net-η) over wide range of operating condition for impeller with radial blades.

equipment:-

① single stage radial flow fan equipped with interchangable impellers with forwarde, backward and radial blades.

② variable speed.

③ counter for speed measurment.

④ three mano meter (at nozzel, befor inlet the fan, After the fan).

⑤ nozzel.

⑥ Throttling valve.

Speeds ⇒ (3 → 1050 rpm, 4 → 1520 rpm, 5 → 2150 rpm)

* The fan draws air from atm. Through nozzel (flow straightener and diffuser). while fan discharge into atm. is regulated by throttle valve.

* Froce from spring diometer (load on motor).

* Any pumping job can be done with roto-dynamic mach. having rotating element called impeller.

* Roto dynamic < radial, mixed (centrifugal). / axial flow.

centrifugal ⇒ for high pressure diff.

* Vary high pressure diff. can be produced by multi stage radial flow.
↳ eg. air compressor for a jet engine.

fan total pressure ⇒ pressure diff. of fan outlet and fan inlet.
(total pressure imposed on air by fan).

* The cross sectional area at inlet and exit of the fan are equal, so the velocity head at inlet and ~~outlet~~ outlet are equal.

$\Rightarrow$ The fan total pressure = outlet static pressure − Inlet static pressure.

calculation:-

$$\Delta P_s = 98.1 (\underbrace{h_{out}}_{delivery} - \underbrace{h_{in}}_{suction}) \quad (pa).$$

$(h_{out} - h_{in})$ (cmH_2O), so $1 cm H_2O = 98.1 \ N/m^2 (pa)$.

$$u = 273.3 \left(\frac{hT}{P_a}\right)^{1/2} \qquad R = 287 \ J/kg \ air . K$$

nozzel

$$Q = A * u$$

$$= \frac{\pi}{4} d^2 * 273.3 \left(\frac{hT}{P_a}\right)^{1/2} * k$$

$\hookrightarrow$ dicharge coeff. of nozzel (0.96)

$d = 75mm$

$$\Rightarrow Q = 1.16 \left(\frac{hT}{P_a}\right)^{1/2}$$

* Airpower $\rightarrow$ useful work done, is equal to the product of fan total pressure ΔP_s and volumetric flow rate.

$$\text{Aire power} = 98.1 (h_{out} - h_{in}) * Q.$$

* power input $\Rightarrow$ from dynamometer.

Shaft work $= T * N/k \rightarrow$ Brake constant $= 1$

torque = Loader

force

redious of dyna.

$\hookrightarrow$ Angular velocity.

$$\eta = \frac{\text{Air power}}{\text{Shaft work}}$$

* when decrease cross sectional Area by gate, the pressure diff. increase

$\Rightarrow$ flow rate will decrease.

* flow rate $\downarrow$ $\Rightarrow$ Air power $\downarrow$ $\Rightarrow$ $\eta \downarrow$
* speed $\uparrow$ $\Rightarrow$ flow $\uparrow$ $\Rightarrow$ Air powe $\uparrow$ $\Rightarrow$ $\eta \uparrow$

So at speed 1050 rpm the η Lower than the η at 1520 rpm.