دفتر مادة..

أنظمة التبريد

لجنة الميكانيك

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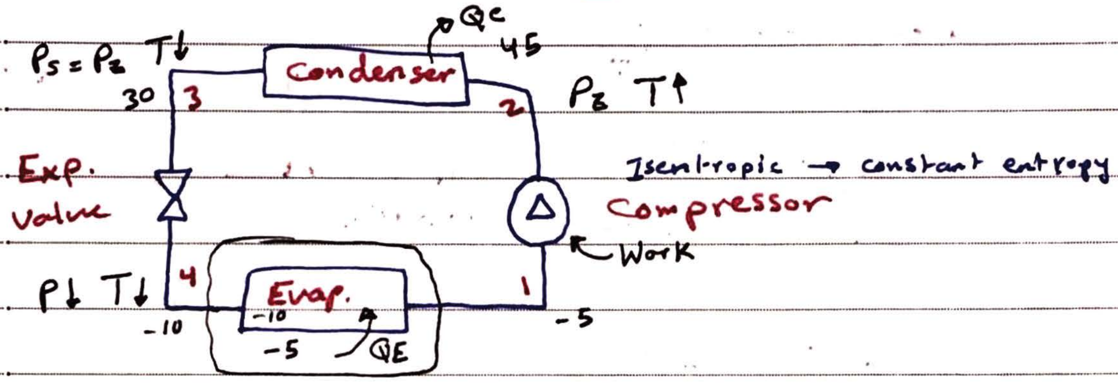
FB.com/Groups/Mid.Group

5/6/2017
١٠- رمضان
الإثنين

Refrigeration

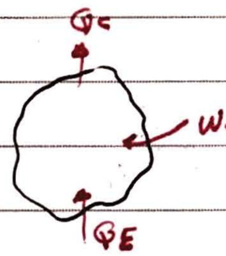
Vapor compression cycle



$Q = UA\Delta T$ → for heat exchanger

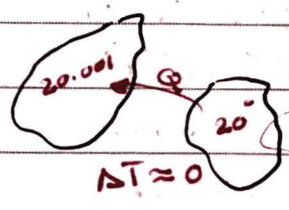
$$COP_R = \frac{\text{Desired output}}{\text{Required input}} = \frac{Q_E}{W_c}$$

$$COP_H = \frac{Q_c}{W_c} = COP_R + 1$$



$$= \frac{Q_E + W_c}{W_c} = COP_R + 1$$

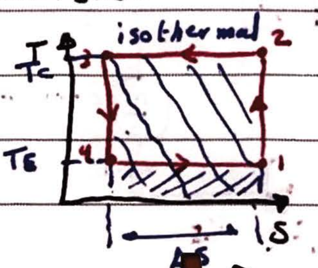
$$Q_E + W_c = Q_c$$



Carnot cycle

* every process is reversible.

$$COP_R\Big|_{carnot} = \frac{Q_E}{W_c}$$



$S_1 = S_2$
isentropic compression

$2 \to 3$ حرارة خارجة

$$\Delta S = \frac{-Q}{T}$$

$4 \to 1$

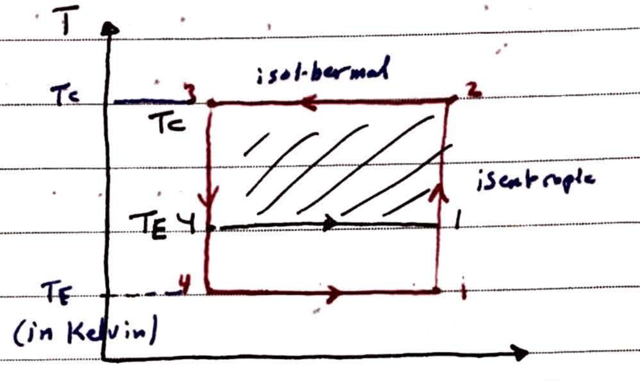
$$\Delta S = \frac{+Q}{T}$$

$$Q = T \Delta S$$

$$Q = \int T ds$$

$$Q_E = \int T_E ds$$

carnot cycle



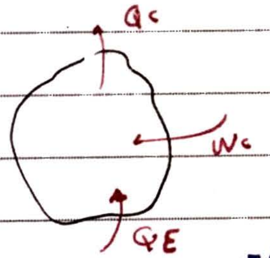
$(T_c - T_E) \downarrow$ $COP \uparrow$

$$COP_R = \frac{T_E \Delta S}{(T_c - T_E)\Delta S}$$

$$COP_c = \frac{T_E}{T_c - T_E} = \frac{1}{\frac{T_c}{T_E} - 1}$$

← عندما يقل الفرق في درجات الحرارة

تزداد الـ COP



$$W_c = Q_c - Q_E$$

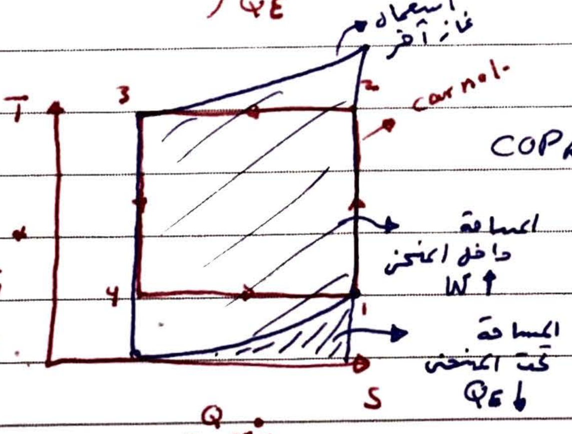
$$Q_c = Q_E + W_c$$

2017 / 6 / 6

11 - رمضان

الثلاثاء

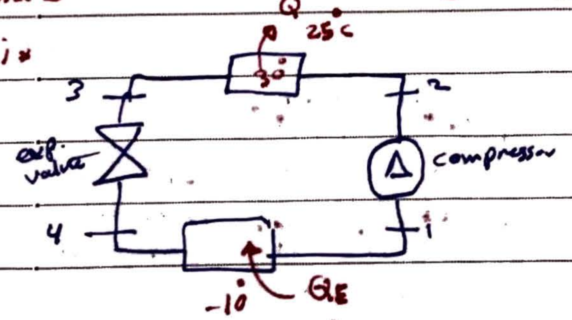
* أفضل شيء هو أن تكون قريبين من الشكل المستطيل carnot لـ



$$COP_R = \frac{T_E}{T_c - T_E}$$

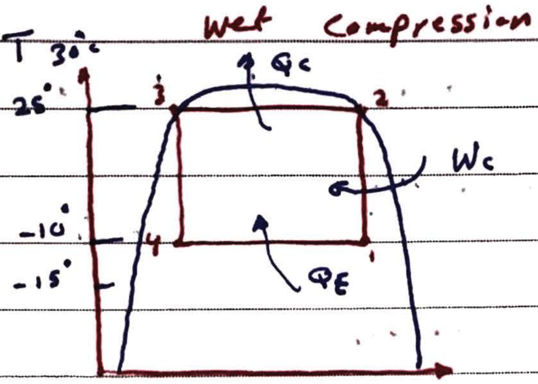
$$COP_R \downarrow = \frac{Q_E \downarrow}{W \uparrow}$$

* أفضل من استعمال أي غاز من الهواء مثلا.



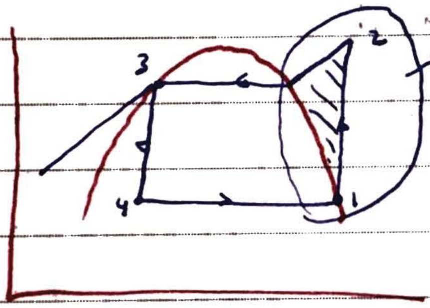
$$\uparrow Q = \dot{m} c_p \Delta T \uparrow$$

Use of a Refrigerant



Dry compression

→ compr. * لا يدخل أي نوع من السوائل إلى

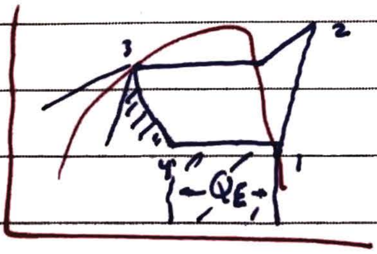


$$COP_R = \frac{Q_E \uparrow}{W_c \uparrow}$$

isentropic ($\Delta S = 0$) : reversible Adiabatic

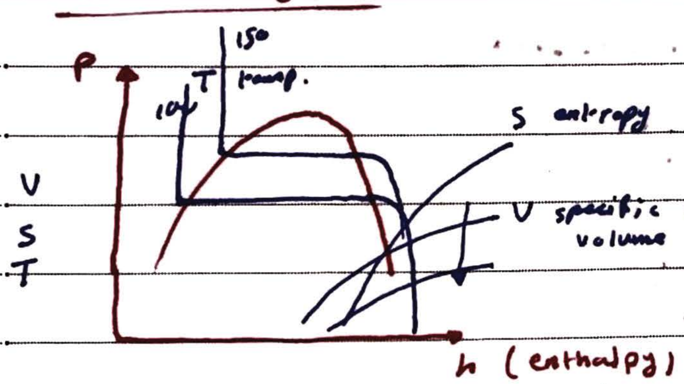
* في حالة 3→4 يوجد احتكاك عالي عند استخدام الـ exp. valve
لذلك فهي irreversible ، يمكن استبدال الـ exp. valve
بـ turbine لكن الـ turbine غير مجدي بشكل فعال
ويحتاج إلى طريقة معقدة لنقل الطاقة الصادرة عنه إلى الـ compressor
لذلك عادة لا يستخدم .

expansion



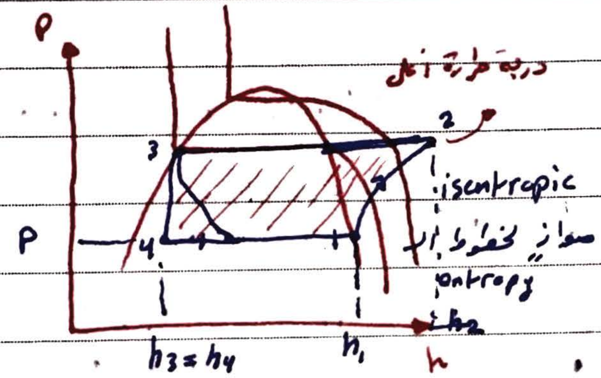
$$COP_R \downarrow = \frac{Q_E \downarrow}{W_c \downarrow}$$

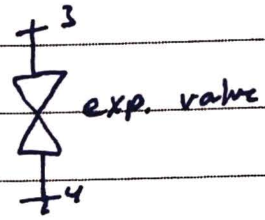
P-h diagram



$T\uparrow \quad P\uparrow \quad V\downarrow$

$$\frac{\dot{V}}{v} = \dot{m}$$





$h_3 = h_4$

$Q - W = \dot{m}\Delta h$

$\Delta h = 0$

$h_3 = h_4$

$Q_E = \dot{m}(h_1 - h_4)$ +ve

$Q_C = \dot{m}(h_3 - h_2)$ −ve

$-W_C = \dot{m}(h_2 - h_1)$ −ve

$Q - W = \dot{m}\Delta h$
$(h_2 - h_1)$

$$COP_R = \frac{Q_E}{W_C} = \frac{h_1 - h_4}{h_2 - h_1}$$

* احفظ ال Chart ال R-22

7/6/2017

١٥ - رمضان

الأربعاء

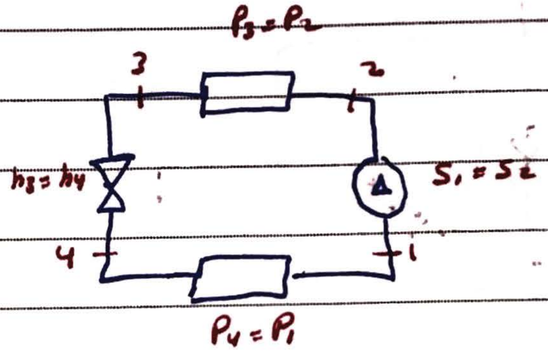
Ex: 10-1

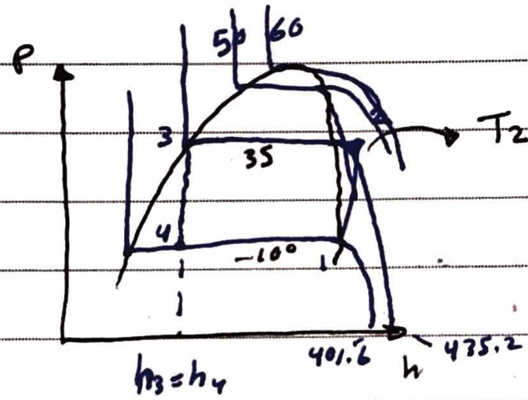
R-22

$Q_E = 50\ kW$

$T_c = 35^\circ c$

$T_E = -10^\circ c$





$h_3 = h_4$

$= 243.1\ kJ/kg$

$$q_e = \frac{Q_E}{\dot{m}} = h_1 - h_4$$

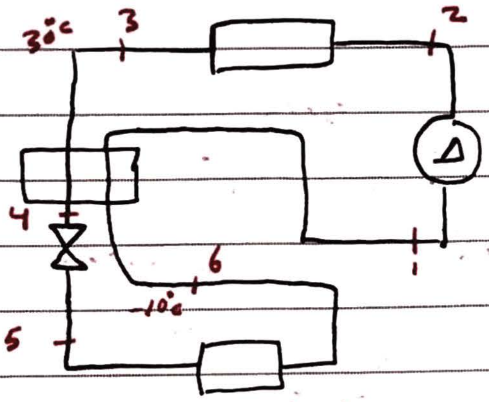
$$\boxed{\Delta h = 158.5\ kJ/kg}$$

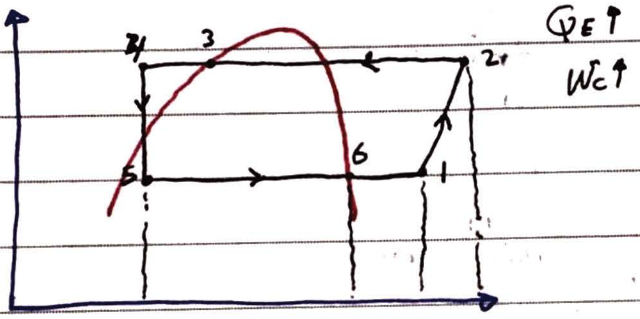
$$\dot{m} = \frac{Q_E}{q_e} = \frac{50}{158.5} = 0.315\ kg/s$$

$$COP_R = \frac{Q_E}{W_c} = \frac{50}{10.6} = 4.72$$

$$W_c = \dot{m}\Delta h = 0.315(435.2 - 401.6) = 10.6\ kW$$

$$\frac{\dot{V}_1}{v_1} = \dot{m} \qquad \frac{\dot{W}_c}{Q_E} = \frac{1}{COP_R}$$





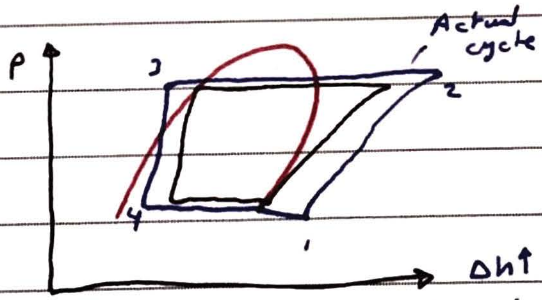
$Q_E \uparrow$

$W_c \uparrow$

$$COP = \frac{Q_E}{W_c} \qquad Q_E \downarrow = \dot{m} \downarrow \Delta h \uparrow$$

$$\dot{m} \downarrow = \frac{\dot{V}}{v \uparrow} = \rho \downarrow \dot{V}$$

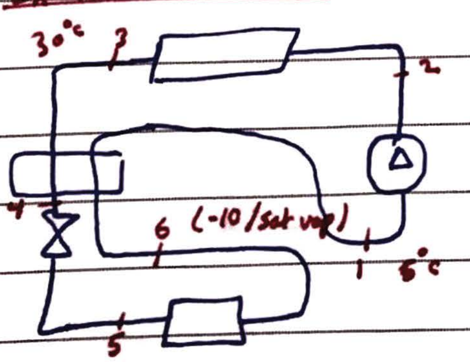
Actual cycle :-



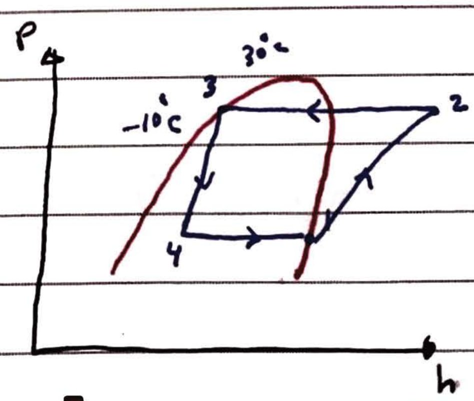
$\Delta h \uparrow$

$h \quad W_c \uparrow$

* Ex 10-7 P 204 :-

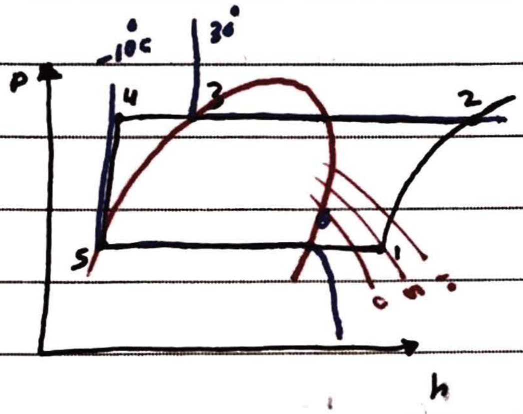


a)



$$COP = \frac{Q_E}{W_c} = \frac{h_1 - h_4}{h_2 - h_1} = 5.46$$

b) With the heat exchanger



$$Q_1 = Q_2$$

$$\cancel{\dot m}(h_4 - h_3) = \cancel{\dot m}(h_3 - h_8)$$

$$\boxed{h_4 - h_3 = h_1 - h_6}$$

$$COP = \frac{Q_E}{W_c} = 5.37$$

$$\dot W_c = \dot m (h_2 - h_1)$$

$$Q_E = \dot m (h_6 - h_5)$$

$$\dot m = \frac{\dot V}{v}$$

$$\dot V = 12\,L/s \longrightarrow Q_E = \dot m \Delta h$$

11/6/2017
١٦- رمضان
الأحد

CH.11 Compressors :-

Compressors :

1- Reciprocating. non rotating.
2- screw
3- vane
4- centrifugal

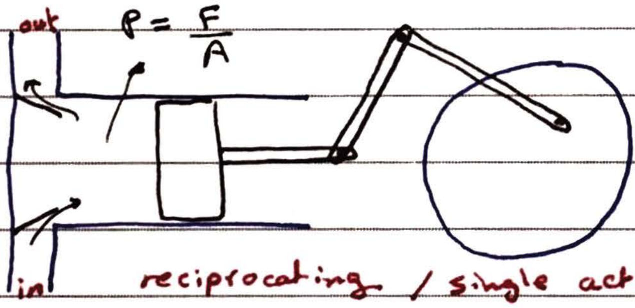
(screw, vane and centrifugal: All Rotating.)

Positive displacement

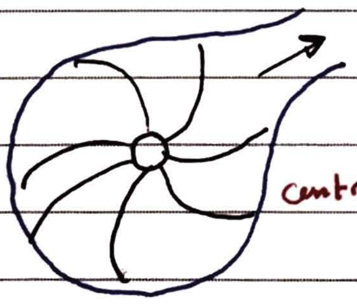
Reciprocating / screw / vane

Rotodynamic (centrifugal)

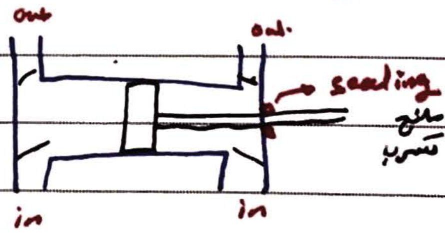
centrifugal.



reciprocating / single acting / double acting



centrifugal.



fraction of KW ⟶ 100's of KW's

Resiprocating compressor

- Open type: كل جزء موجود لوحده
- Hermetically Sealed: Motor + compressor in one casing
- Semi Hermetic: الأجزاء موجودة مع بعضها مع احتمالية تبديل القطع

Condensing unit :- Compressor + condenser

* Refrigeration capacity (QE) + Power consumption. } عوامل لتقييم الـ comp.

Volumetric Eff.

- Clearance Vol. eff.
- Actual vol. eff.

$$\text{Actual } \eta_{va} = \frac{\text{volume flow rate entering comp}}{\text{Displacement rate of comp}}$$

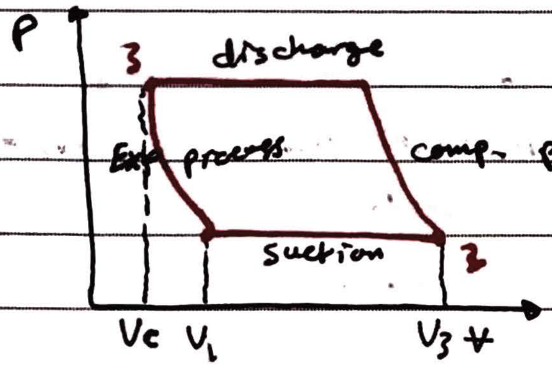
$$= \frac{\text{Actual}}{\text{theoritical}}$$

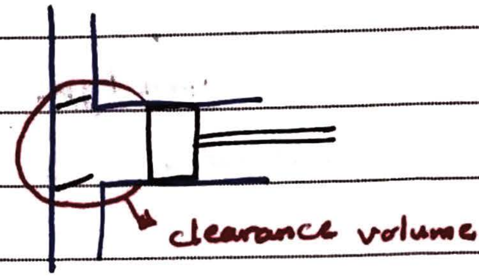
$$Vol = \frac{\pi D^2}{4} \cdot S \cdot Z$$

(S: stroke, Z: عدد الcylinders)

$$\dot{V} = \frac{\pi D^2}{4} \cdot S \cdot Z \cdot N\left(\frac{rev}{s}\right)$$

$$\dot{V} = \frac{\frac{\pi D^2}{4} \cdot S \cdot Z \cdot rev}{time\,(sec)}$$





Clearance Vol. efficiency :-

$$\eta_{v,c} = \frac{V_3 - V_1}{V_3 - V_c} * 100\%$$

$$\text{Clearance volume percent} = \frac{V_c}{V_3 - V_c} * 100\% = m$$

$$\eta_{v,c} = \frac{V_3 - V_1}{V_3 - V_c} + \frac{V_c - V_c}{V_3 - V_c}$$

$$= \frac{V_3 - V_c + V_c - V_1}{V_3 - V_c} = \frac{V_3 - V_c}{V_3 - V_c} + \frac{-V_1 + V_c}{V_3 - V_c}$$

$$= 1 + \frac{-V_1 + V_c}{V_3 - V_c}$$

$$\eta_{v,c} = 100 - m\left(\frac{V_{suc}}{V_{del}} - 1\right)$$

12/6/2017

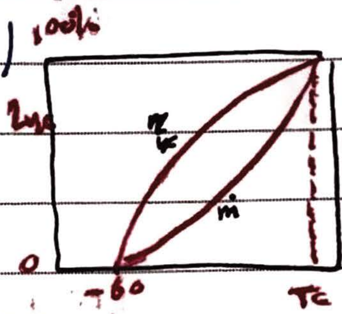
١٧- رمضان

الاثنين

Performance of Ideal compressor

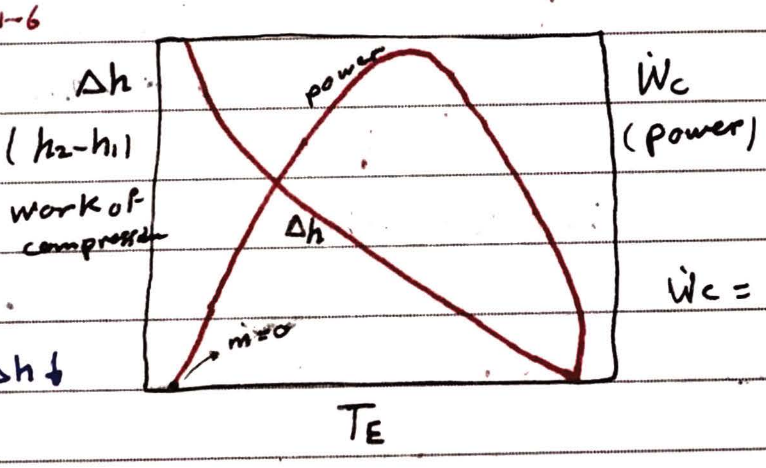
$T_E \uparrow \downarrow$ $\quad \eta_{v,c} = 100 - m\left(\frac{V_{suc}}{V_{dis}} - 1\right)$

$\eta_{v,c} \uparrow \quad \dot{V} \uparrow \quad \dot{m} \uparrow = \frac{\dot{V}}{v}$



$$\dot{m} = \frac{\text{displacement rate} \times \eta_{vc}/100}{V_{suction}}$$

Figure 11-6

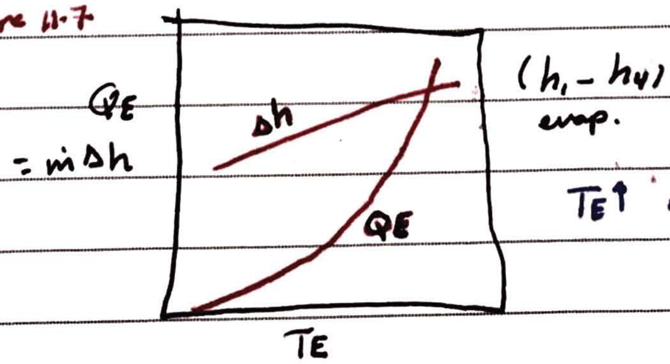


$\dot{W}_c = \dot{m}\Delta h$

$T_E \uparrow \quad \Delta h \downarrow$

* كلما زادت درجة الحرارة تقل Δh_{comp} ، وتزداد $\dot{m}$

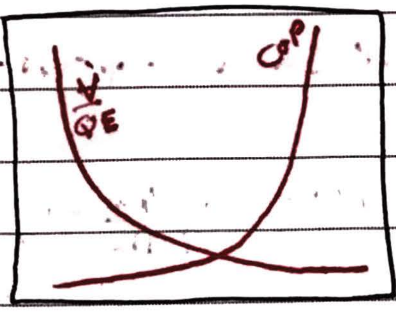
Figure 11-7



$T_E \uparrow \quad \Delta h_{evap} \uparrow$

COP

$COP\uparrow = \frac{\uparrow Q_E}{W_c \downarrow}$

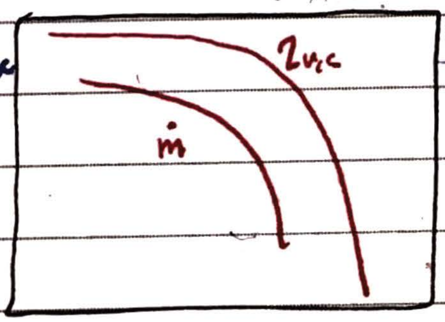


T_E

Volume flow rate per unit capacity

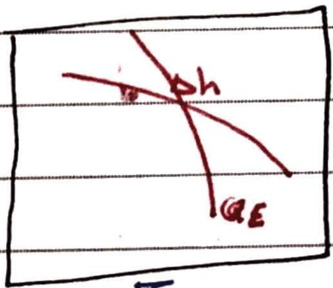
$\dot{V}/Q_E \uparrow$ ↓

Effect of condensing temp:-

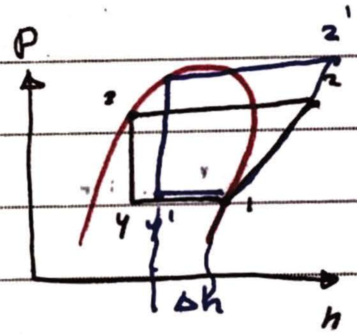


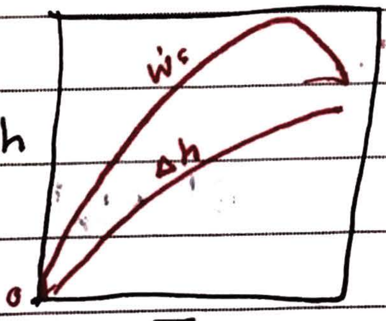
* كلما زاد الضغط تزيد درجة الحرارة
بالتالي الى انخفاض كفاءة الـ compressor

T_c / T_E = -20%



T_c





$\dot{W}_c = \dot{m}\Delta h$

T_c

Problem 11-11

Ammonia / m = 5 %

displacement rate = 80 L/s

$T_c = 40°c$ / $T_E = -10°c$

$$\dot{m} = \frac{\text{displacement rate } \eta_{vc}/100}{V_{suc}}$$

$$= \frac{0.080 \times \eta_{vc}/100}{V_{suc}}$$

p. 433 tables — ايجاد القيم من *

Figure A-1

$$\eta_{vc} = 100 - 0.05\left(\frac{V_{suc}^{0.4}}{V_{dil}^{0.12}} - 1\right) = 88\ \%$$

$$\dot{m} = \frac{0.08 \times 0.88}{0.4} = 0.177 \ kg/s$$

الثلاثاء
١٨- رمضان
13/6/2017

* Performance of actual reciprocating compressor :-

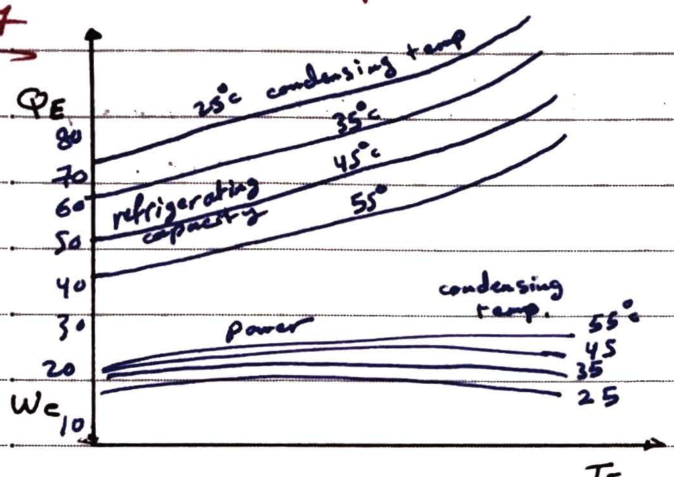
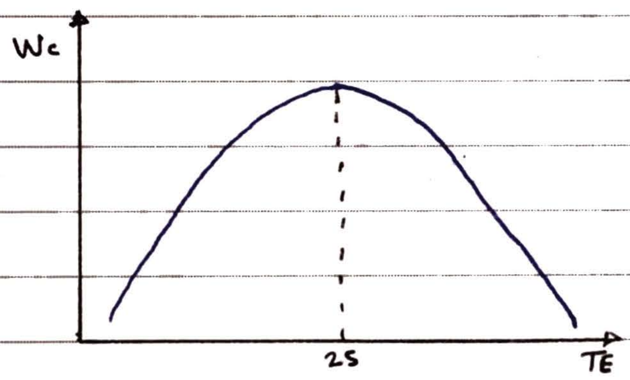


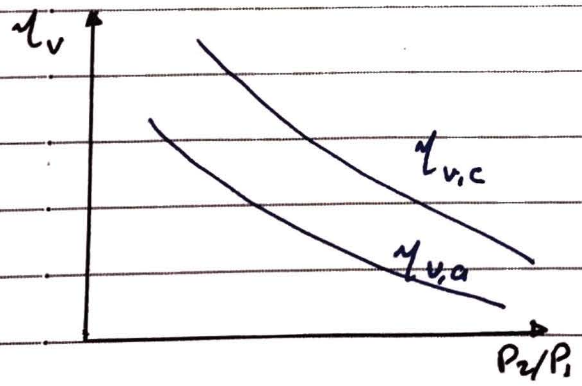
Figure 14.1 P 282

∴ C.O.P
دائماً أكبر من 1



$$\eta_{v,a} = \frac{V_{actual}}{displacement} \Rightarrow displacement\ (A\ S\ N\ Z)$$

$$\eta_{vc} = 100 - m\left(\frac{V_{suc}}{V_{dis}} - 1\right)$$



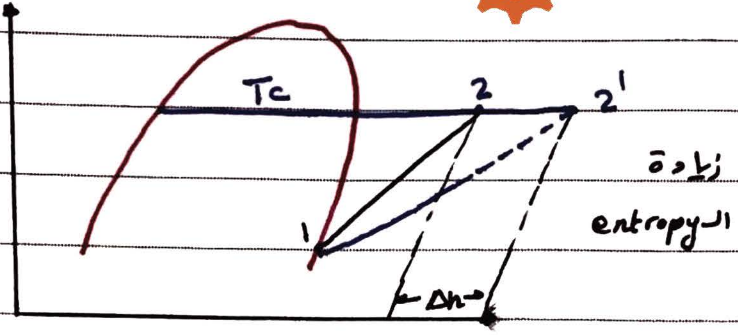
من أسباب انخفاض الـ $\eta_{v,a}$:-

١- Clearance ٢- التسرب

٣- عدم انتظام اغلاقه الـ valves

٤- التحول إلى غاز عند تشغيل الـ compressor
وزيادة درجة الحرارة وبالتالي تقل الكفاءة
وتزداد v وبالتالي $\frac{V_{suc}}{V_{dis}} \uparrow$

٥- diff. pressure drop



* عند وجود الـ friction يزداد Δh ويزداد الـ Power

$$\eta_c = \frac{\text{Isentropic work}}{\text{Actual work}} = \frac{\dot{m}(h_2 - h_1)}{\dot{m}(h_2' - h_1)}$$

Example 11-1 P. 218

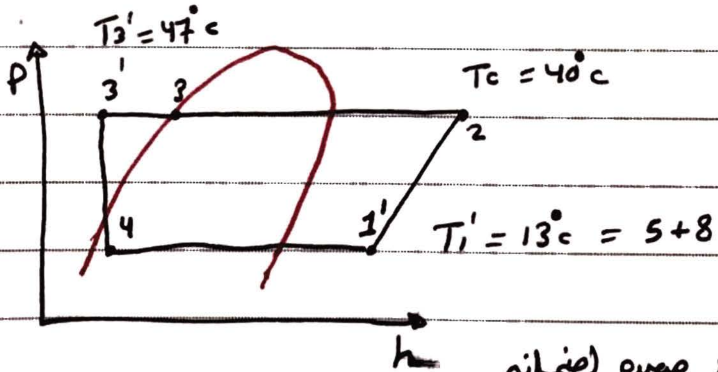
R22 , $Z = 6$, $N = 29\,\text{ps}$, $Q_E = 96.4$ kW

$W_{comp} = 28.9$ kW , $T_E = 5°c$, $T_c = 50°c$,

subcooling = 3°c , supheating = 8°c , D = 67 mm ,

$S = 57$ mm , $m = 4.8\%$

Sol:-



* يتم التسخين بعد الـ evap لضمانه دخول الماء غاز فقط .

$$\eta_{v,c} = 100 - m\left(\frac{V_{suc}}{V_{dis}} - 1\right)$$

$V_{suc} = 43.2$

$$= 100 - 4.8\left(\frac{43.2}{14.13} - 1\right)$$

$V_{dis} = 14.13$ /kg

$$\eta_{v,c} = 90.125\%$$

$$\eta_{v,a} = \frac{V_{act}}{V_{th}}$$

$$\Rightarrow V_{th} = ASNZ$$

$$= \frac{\pi}{4}(0.057)^2 \times 29 \times 0.057 \times 6$$

$$= 0.03497\ m^3/s$$

$$Q_E = \dot{m}(h_1 - h_4)$$

$$96.4 = \dot{m}(413.1 - 259.1)$$

$$\Rightarrow \dot{m} = 0.626\ kg/s$$

$$\dot{m}_a = \frac{\forall_a}{v} \qquad 0.626 \times 43.2 = \forall_a$$

$$\forall_a = 0.0274$$

$$\eta_{v,c} = \frac{0.0244}{0.03497} \times 100\% = 77.3\%$$

$$\eta_c = \frac{h_2 - h_1'}{(h_2' - h_1')}$$

Actual work = 29.9

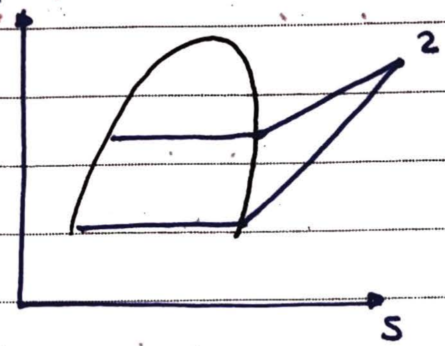
$$\eta_c = 68\%.$$

18/6/2017
رمضان ٢٣ -
الأحد

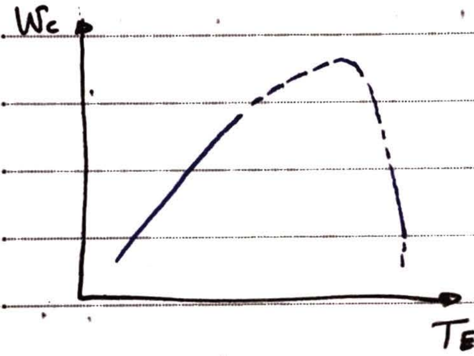
sec (11.14) compressor discharge temp.

$PV = RT$ (gas)

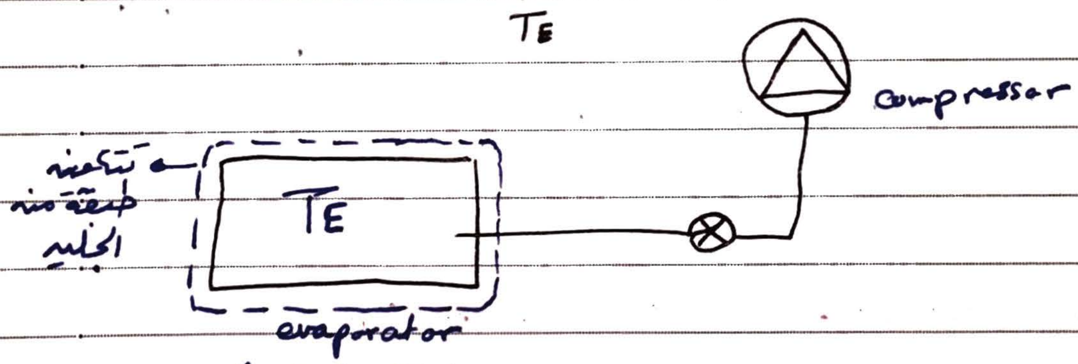
$T\uparrow \rightarrow \mu\downarrow$



capacity control :-



$T_E\downarrow \rightarrow Q_E\downarrow \rightarrow W_C\downarrow$



if $Q_E\downarrow$ $T_E\downarrow$

* المساوئ :-

[١] حدوث تجمد على الـ evap. والتجمد يعمل كعازل مما يقلل من درجة الحرارة $T_E\downarrow \rightarrow Q_E\downarrow$

[٢] إذا أزيلت بعض البضائع تستقل درجة الحرارة كثيراً مما يؤثر سلباً على البضائع

* عند انغلاق الصمام (valve) بشكل جزئي يقل الضغط وتقل درجة الحرارة.

Several methods are commonly used to reduce the compressor capacity :- طريقة التحكم في درجة الحرارة آلي لا تنخفض بشكل كبير جداً .

1- Cycling :

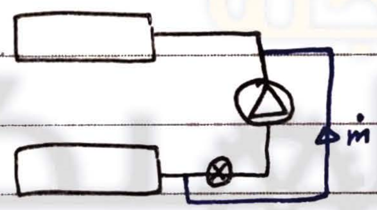
تعمل على فصل الـ compressor عند درجة حرارة معينة .

2- Back-pressure regulation .

تعمل على اغلاق الصمام للـ comp. وبالتالي زيادة الضغط وزيادة درجة الحرارة والمحافظة عليها .

3- Bypassing the discharge

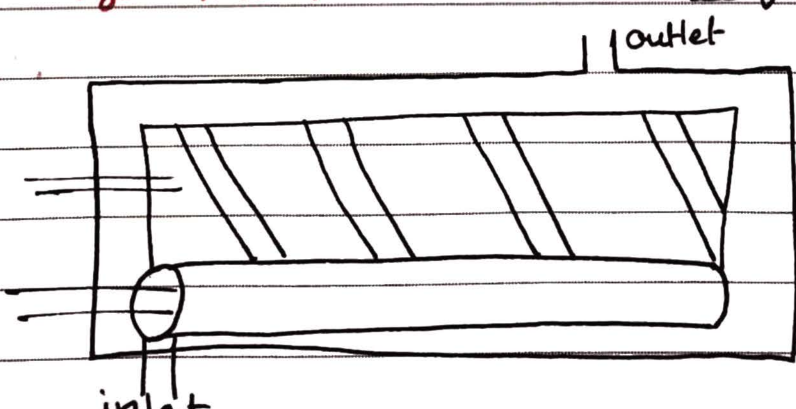
$$Q_E \downarrow = \dot{m} \downarrow \Delta h$$



4- Cylinder unloading.

* Rotary screw compressor :-

figure 11-15 P. 221 :- * مطلوب مبدأ العمل فقط .



* flow is moving with screw to reach to outlet .

* Vane Compressors P. 222 - 223

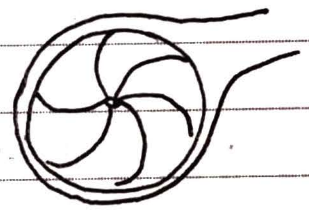
1. Single Vane type (roller).
2. Multivane type.

* multy cylinder rotate a round a disk center.

* الـ disk يبقى ملامساً للسطح الداخلي بسبب وجود الزمبرك.

* see figures 11-18 and 11-20 * الرسمات مطلوبة

Centrifugal compressors :-



$$P = \frac{F}{A}$$

$$\dot{m}_1 = \dot{m}_2$$

$$\rho V_1 A_1 = \rho V_2 A_2$$

$V \downarrow \longrightarrow P \uparrow$

السرعة → الضغط

Bernouli's equation.

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} = \frac{P_2}{\gamma} + \frac{V_2^2}{2g}$$

Q_E : 200 to 10000 KW

very high load.

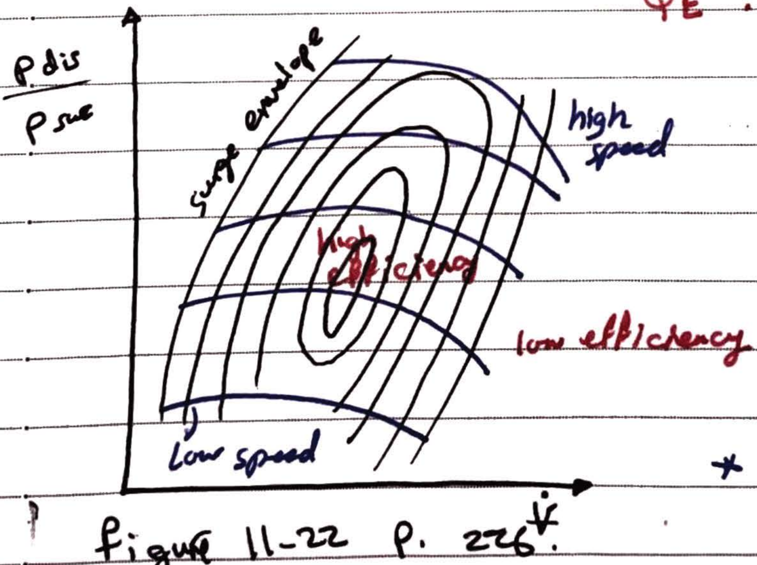


figure 11-22 p. 226.

* Best efficiency in high efficiency area.

Page 226:-

$$Power = W_c = T \cdot \omega$$

$$T = m\,(V_{2t} r_2 - V_{1t} r_1)$$ (zero)

$$T = m V_{2t} r_2$$

$$W_c = \dot{m} V_{2t} (r_2 \cdot \omega)$$ ($r_2 \cdot \omega \rightarrow V_{2t}$)

$$W_c \uparrow = m (V_{2t})^2 \uparrow$$

$$W_c = \dot{m} \Delta h \times 1000$$ → to convert from KJ to J

$$\Rightarrow \dot{m} V_{2t}^2 = \dot{m} \Delta h \times 1000$$

Ex:- 11-2 P. 227

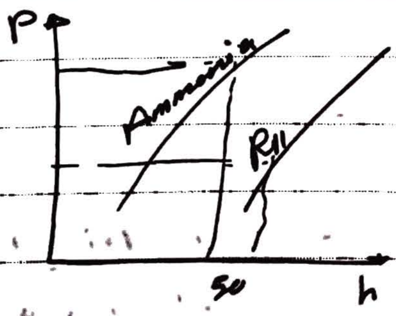
a) R_{11} :- $\Delta h = 12.8$ KJ / kg

$V_{2t} = 113.1$ m/s

$V_{2t}^2 = 1000\, \Delta h$

b) Ammonia :-

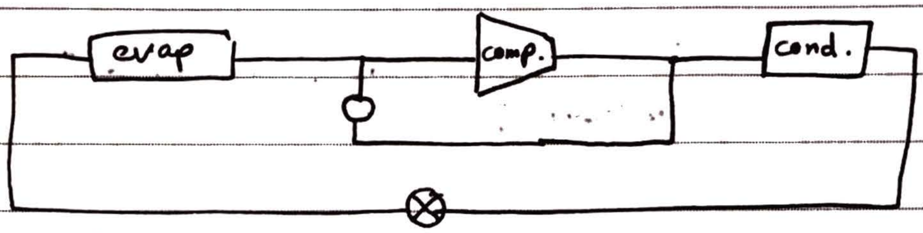
$V_{2t} = 297$ m/s



* عند نفس ال temp :
الضغط يزيد والسرعة تقل .

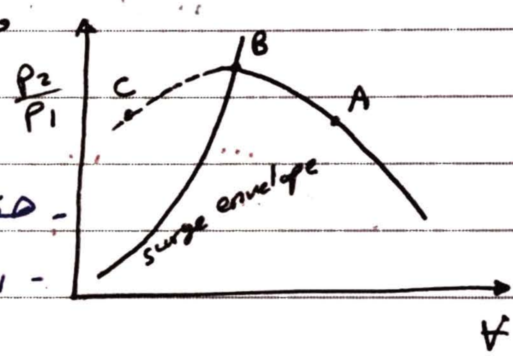
الإثنين ٢٤-رمضان — Choice of impeller and refrigerant — غير مطلوب
P 227 – 228
19/6/2017

Surging :- اهتزاز يؤدي الى تلفه الـ comp. بعد مدة



* عندما يغلق الـ valve ← تحدث reverse flow

وبالتالي :- ← يقل الضغط في الـ condens.
← يسخن مرة أخرى .

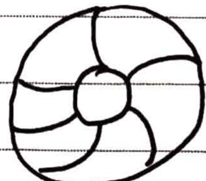


- هذه العملية تحدث في غضون ثواني
- التصميم يكون في المنطقة B — A

* للتغلب على هذه الظاهرة نضيف pipe
* ظاهرة الـ surging تؤدي الى حدوث vibration
* الأسباب لحدوث هذه الظاهرة مطلوبة بالفقرة الأخيرة من الموضوع .

Capacity Control :-

$Q_E = \dot{m}\,\Delta h$



١- تغيير زاوية الشفرات .
٢- التحكم بالسرعة ω من خلال الـ motor .

Sec: 11-28 P. 230

كل المطلوب منه هذا الموضوع ⇩

Refrigeration point Q_E.

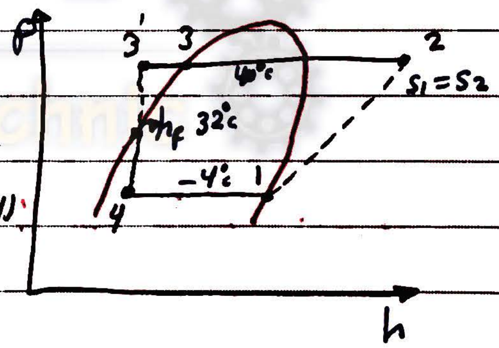
Vane } 0.2 – 300 KW
reciprocating }

screw } 300 – 500 KW

centrifugal } > 500 KW

Pb 11.3 P. 231 — R_{22} / $Z = 4$ / $N = 29$ r/s / $T_C = 40°C$ / $T_E = -4°C$
$Q_E = 115$ kW / $\eta_m = 0.9$ / $W_m = 34.5$ kW
$D = 87$ mm / $S = 70$ mm / $T_3' = 32°C$.

$\eta_{va} = \dfrac{\dot{V}_{ac}}{\text{dis. rate}}$



dis. rate $= ASNZ$

$= \frac{\pi}{4} * (0.087)^2 * (0.07)(29)(4)$

$= 0.0483 \ m^3/s$

$\dot{V}_{ac} = \dot{m} v_1$

$Q_E = \dot{m}(h_4 - h_1)$ — 115, 164.77

$\dot{m} = 0.698$ kg/s

$h_1 = 404$ kJ/kg

$h_4 = h_3 = h_{f|32°}$

$h_4 = 239.23$ kJ/kg

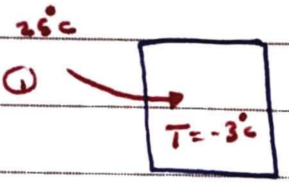
$h_2 = 437$ kJ/kg.

⟹ $\eta_c = \dfrac{\text{Ideal work}}{\text{actual work}} = \dfrac{\dot{m}(h_2 - h_1)}{31.05}$ (23.034)

$= 74.2\%$

$\eta_m = \dfrac{W_{actual}}{W_m}$ (0.9, 34.5) $\dot{W}_{ac} = 31.05$ kW

Refrigeration Load Estimation (Q_{RL})



- Heat transfer.
- Product Heat.
- Lights + Machines
- Infiltration.
- Respiration.
- Occupants.
-

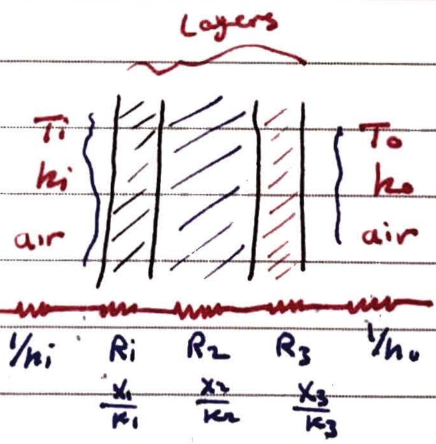
Refrigeration types :-

- Short term. (few days, one week)
- Long term. (few months, one year.)

Heat Transfer :-

$$Q = UA\Delta T$$

$$U = \frac{1}{\Sigma R}$$



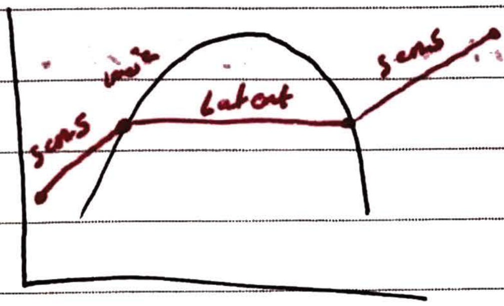
Q product

Q product = Q sensible (حرارة محسوسة) + Q latent (حرارة كامنة) + Q sensible

- Q sensible: before freezing
- Q latent: during freezing
- Q sensible: After freezing.

$$Q_{product} = \underset{sens.}{\dot{m} c_p \Delta T} + \underset{latent}{\dot{m}\Delta h} + \underset{sens.}{\dot{m} c_p \Delta T}$$

- first ΔT: (25 − Freezing point)
- Δh: Latent heat of fusion
- last ΔT: (Freezing point − T_f)



$$Q_{product} = \frac{\dot{m} C_p \Delta T + \dot{m} \Delta h + \dot{m} C_p \Delta T}{Time * F_{chilling}}$$

Chilling Factor

يعوض الإختلاف في قيمة ال Cp بسبب اختلاف درجات الحرارة .

20/6/2017
٢٥- رمضان
الثلاثاء

Ex: 1 5000 kg of beef fresh meat enters a cold room at 35°c , and it's to be stored at -25°c , Find the cooling load of products Assuming a chilling factor of 0.67 and 18 hour period of cooling ?

$$Q_{prod.} = Q_{sen/before\ freezing} + Q_{lat} + Q_{sen/after\ freezing}$$

$$= \frac{M C_{p_{before}} (T_i - T_{freezing})}{Time \times F_{chilling}} + \frac{M \Delta h_{lat}}{Time * F_{chilling}}$$

$$+ \frac{M C_{p_{after}} (T_{freezing} - T_f)}{Time * F_{chilling}}$$

$$= \frac{5000 \times Cp_{1\,before}^{(3.2)} \times (35-(-2))}{18 \times 3600 \times 0.67} + \frac{5000 \times 230}{18 \times 3600 \times 0.67} + \frac{5000 \times 1.7 \times (-2+25)}{18 \times 3600 \times 0.67}$$

* إذا ذكر في السؤال التبريد لغاية 10°c في هذه الحالة نستخدم الجزء الأول من المعادلة فقط ولا دخل للأجزاء الباقية

* 10°c أو أي درجة قبل درجة التجمد freezing .

$$= 13.64 + 26.49 + 4.5 = 44.63 \text{ KW}$$

Respiration refrigeration load (vegetables + Fruits)

الحرارة التي تنشأ عند تحلل السكريات والنشويات داخل بعض أنواع الفواكه والخضروات .

$Q_{resp.} = M \times \text{resp. rate}$.

Product	Temp	Heat of resp. [W/ton]
Apples	2	12
Bananas	13	48
Potatoes	1.5	9

Ex:2 3000 kg Boxes of Apples enters at 30°c and are stored at 2°c, The apples enter at a rate of 200 box/day for 15 days, The mass of apples/box is (27 kg) Box mass is 2 kg each, where $Cp_{box} = 2.5$ kJ/kg.K, The lightening Load is 500 W for 3 hours/day. Two persons and one forklift (Battery operated) of 4.17 kW operating for (3 hours). Find ref. load $F_{chilling} = 0.67$

$Q_{ref} = Q_{prod.} + Q_{resp} + Q_{light} + Q_{boxes} + Q_{occ} + F~~ork~~ lift.$

$Q_{prod} = \frac{M C_p \Delta T}{Time \times F_{chill.}} = \frac{200 \times 27 \times (3.65) \times (30-2)}{24 \times 3600 \times 0.67}$

$= 9.4$ KW.

$Q_{resp} = M \times resp.\ rate$

$= 200 \times 27 \times \left(\frac{12}{1000}\right)$

$= 0.64$ KW

$Q_{light} = \frac{Power}{time}$

$= \frac{500 \times 3 \times 3600}{24 \times 3600} = 0.062$ KW

$Q_{boxes} = \frac{M C_p \Delta T}{time \times F_{chill.}} = \frac{200 \times 2 \times 2.5 \times (30-2)}{24 \times 3600 \times 0.67}$

$= 0.483$ KW

$Q_{occ + forklift} = \frac{4.17 \times 3 \times 3600}{24 \times 3600} = 0.52$ KW

$Q_{ref.load} = 9.4 + 0.064 + 0.062 + 0.483 + 0.52$

$= 10.53$ KW

نضيف S.F من 1.1 إلى 1.15 .

21/6/2017
26-رمضان
الأربعاء

Short Method of Load Calculations for General purpose *

Q product = Interior volume of room (m^3) * usage factor ($W/m^3.c^\circ$) * TD (c°)

TD = To − Ti
↳ Temp diff.

* كلما زاد حجم الغرفة احتجنا لحرارة أعلى.

Ex:3 A general purpose cold store of interior volume 6 * 4 * 3.4 m, Heat gain of the structure of space is 900 W, To = 30°c, mixed vegetables / usage factor (0.58), Ti = 5°c find Qref ??

Q prod = (6 * 4 * 3.4) * 0.58 * (30 − 5) = 1183.2 W

Q ref = 1183 + 900 = 2083 W

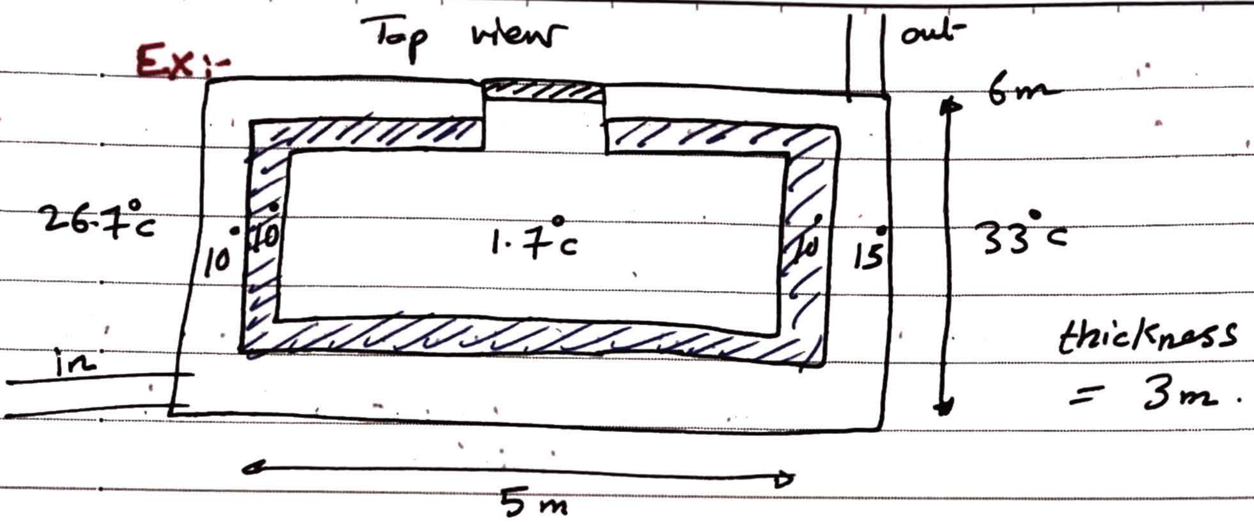
for 24 hours of cooling ⟶ 2083 W

for 16 hours to reach the same temp

$$Q_{ref} = \frac{2083 * (24 * 3600)}{(16 * 3600)}$$

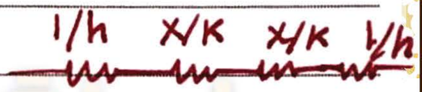
⟹ Q_{ref} in 16 hours = 3124.5 W.

Ex:-



Heat Transfer

$$Q = UA\Delta T \quad , \quad U = \frac{1}{\Sigma R}$$



الداخل $U_{w_1} = 0.385 \ W/m^2 \cdot K$

الخارج $U_{w_2} = 0.22 \ W/m^2 \cdot K$

$U_{ceiling} = 0.385 \ W/m^2 \cdot K$

$U_{floor} = 0.322 \ W/m^2 \cdot K$.

$$Q_{w_1} = U_{w_1} A_{w_1} \Delta T = 0.385 * [6*3 + 5*3](25)$$

$$Q_{w_2} = 0.22\,(6*3 + 5*3)(31.3)$$

$$Q_c = 0.385 * (6*5)(33 - 1.7)$$

$$Q_f = UA\Delta T = 0.323\,(30)(25)$$

أسباب الـ infelteration هو فتح وإغلاقه الأبواب والنوافذ ← دخول الهواء الساخنه لغرفة التبريد.

$$Q_{infelteration} = \dot{m}_f (h_{out} - h_{inside})$$

enthalpy.

to find $\dot{m}_f$ from ACH (Air change per hour)

مثلاً ACH = 10

← بالتالي التغير سيكون عشر أضعافه ← $\forall_f = \frac{ACH * V}{3600}$

$$\boxed{V_f = \frac{ACH * \forall}{3600}}$$

$$\boxed{\dot{m}_f = \rho \forall_f}$$

ACH : اما انه يكون معطى او منه خلال الجدول

interior volume	ACH

Ex: in the last example let ACH = 10

$$\forall_f = \frac{10 * 8106}{3600} = 0.2266 \ m^3/s$$

$$\dot{m}_f = 0.2712 \ kg/s$$

$$Q_{inf} = \underset{0.2712}{\dot{m}_f} (\overset{50}{h_{out}} - \overset{10}{h_{ins.}}) = 10.8 \ kW$$

4/7/2017 الثلاثاء

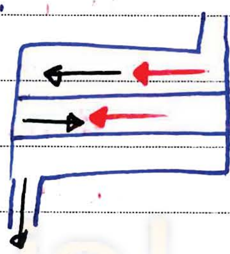
Ch 12

Condensers and evaporators.

Types of heat exchangers :-

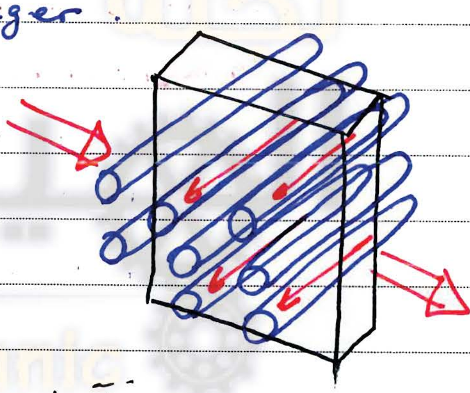
1- Concentric heat exchanger.

- Baralllel flow →
- Counter flow →



2- Cross flow heat exchanger.

- finned with both unmixed.
- unfinned, one mixed other not mixed.



* تتجنب استخدام الـ finned مع أنه أفضل في الـ evap. لتجنب الانسداد في حال حدوث تجمد.

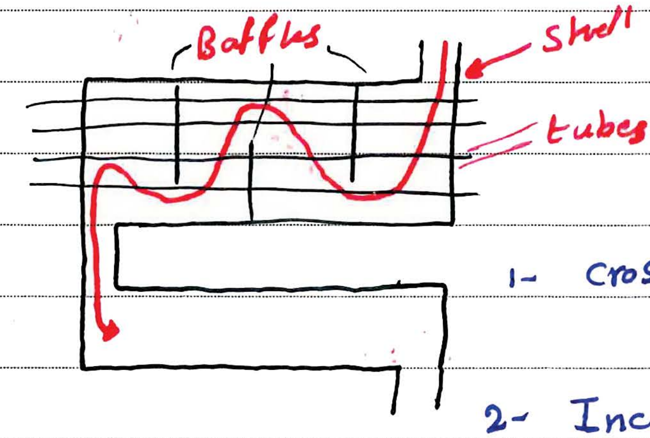
3- Shell and Tube.

Baffles : 1) cross flow (h↑)
2) Increased turbulance so increase H.T

4) Compact H.E.

Condensers and Evaporaters

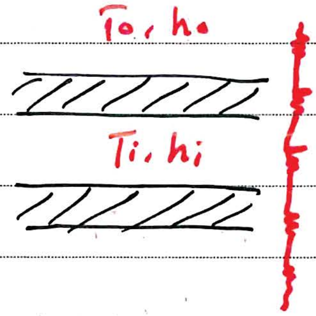
Shell and tubes



1- Cross Flow ($h\uparrow$)

2- Increased turbulence

Heat transfer through Heat Exchangers :-



$$Q = UA\Delta T = \frac{\Delta T}{R}$$

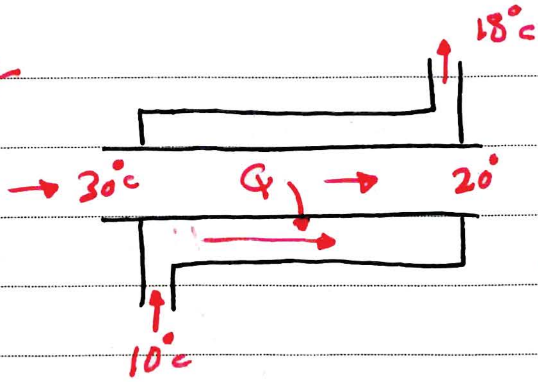
$$R_{tot} = \frac{1}{h_o A_o} + \frac{\ln r_o/r_i}{2\pi k L} + \frac{1}{h_i A_i} + R_{fouling}$$

$$U_o A_o = \frac{1}{R_{tot}} \qquad R_{fouling} = \frac{1}{h_{ff} A_i}$$

$$A = \pi D L = 2\pi r L \qquad h_{ff} = \text{fouling Factor}$$

المساحة الجانبية للإسطوانة .

Ex:-



ΔT :-

Arithmetic Mean diff.

$$\Delta T = \frac{\Delta T_1 + \Delta T_2}{2} = \frac{20 + 2}{2} = 11°c$$

LMTD (log mean temp. diff.)

$$LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln \frac{\Delta T_1}{\Delta T_2}} = 7.8°c$$

$$Q = UA\,LMTD$$

$$Q = \dot{m} C_p \Delta T$$ (sensible) → No phase change

* تستخدم هذه المعادلة فقط إذا لم يكن هناك تغير في طور المادة .

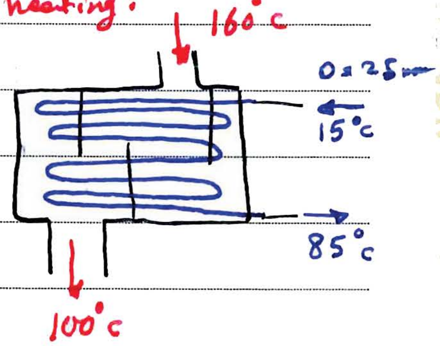
9/7/2017
الأحد

Ex:- A counter flow heat exchanger must be designed to heat 2.5 kg/s of water from 15 to 85°c, the heating is to be accomplished by passing hot engine oil, which is available at 160°c, through the shell side of the exchanger, the oil is known to provide an average convection coefficient of $h_o = 400\ W/m^2 \cdot K$ on the outside of the tube, ten tube pass the water through the shell, Each tube is thin walled, of diameter of 25 mm, and makes 8 passes through the shell, if the oil leaves at 100°c, what is it's flow rate? How long must the tubes be to accomplish the desired heating?

$Cp_{oil} = 2.35\ KJ/kg.K$

$h_w = 3061\ W/m^2.K$

$Cp_{wat.} = 4.186\ KJ/kg.K$



$-Q_{oil} = Q_{water}$

$-\dot{m}_o Cp_o \Delta T = \dot{m}_w Cp_w \Delta T$ * نستخدم هذا القانون لعدم وجود تغير في حالة السائل.

$-\dot{m}_o (2.35)(100-160) = 2.5(4.186)(85-15)$

$\Rightarrow \dot{m}_{oil} = 5.195\ kg/s$

$Q = U_o A_o LMTD$

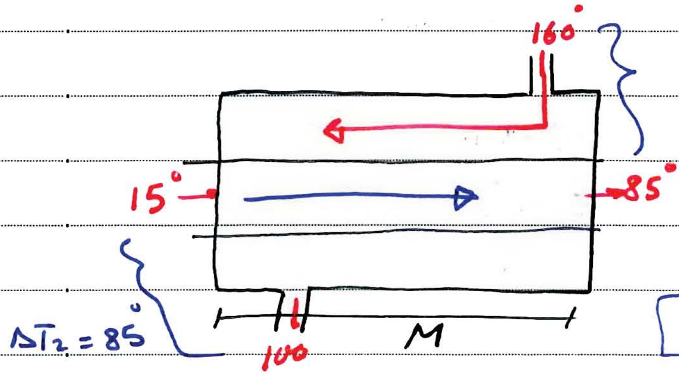
$Q = Q_{oil} = Q_{water} = U_o A_o LMTD$

وحدة Q عند استعمال Cp تكون بال KW وعند استخدامها بالقانون الثاني نحولها الى W.

$732495 = U_o(\pi D L \underline{N})(79.9)$

No. of tubes

$$LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln \frac{\Delta T_1}{\Delta T_2}}$$



$\Delta T_1 = 75°$

$$M = \frac{L}{\text{no of passes}}$$

shell طول

$$\boxed{LMTD = 79.9°c}$$

$$U_o = \frac{1}{\frac{A_o}{h_i A_i} + \frac{x A_o}{K A_i} + \frac{A_o}{h_o A_o}}$$

$x \approx 0 \rightarrow$ thin walled

$$U_o = \frac{1}{\frac{1}{h_i} + \frac{1}{h_o}} = \frac{1}{\frac{1}{3061} + \frac{1}{400}}$$

$$\boxed{U_o = 353.7 \ W/m^2.c}$$

$$732495 = 353.7 * (\pi * 0.025 * L * 10)(79.9)$$

$$\boxed{L = 33 \ m}$$

$\Rightarrow$ with fouling factor resistance :-

fouling factor $= 0.000176 \ m^2.K/W$

$$U_o = \frac{1}{\frac{A_o}{h_i A_i} + \frac{x A_o}{K A_i} + \frac{A_o}{h_o A_o} + \left(\frac{A_o}{h_{ff} A_i}\right)}$$

$\rightarrow$ نضيفها إضافة .

$$U_o = \frac{1}{\frac{1}{3061} + \frac{1}{400} + \frac{1}{0.000176}}$$

$$U_o = 333 \ W/m^2.K$$

$$\Rightarrow \boxed{L = 35 \ m}$$

Types of condensers :-

1) Air Condenser → Table R12

2) Water Condenser → Table R13

$$Q_c = Q_e + W_c$$

$$Q_c \approx \underset{T_c/T_E}{\underline{1.2}} \ Q_e$$

$$Q_c = \underset{\text{Heat rejection factor}}{\underline{HRF}} \cdot Q_e$$

Tables :-

Hermetic

T_E \ T_c	32	100	110
-40			
-34.3			
-23.9			

Air Condenser → Table R12

Unit size	no. of circuits	R12	R22	R502
3		13.2		
5		22.0		
8		35.8		

At sea level

$T_D = T_c - T_{amb} = 16$

$Q_c = HRF * Q_e * T_D$ correction factor

Altitude . Factor

معامل الارتفاع يوجد فقط في حسابات الـ Air ولا يوجد في حسابات الـ water.

Alt. (m)	correction factor
0	1.000
160	0.989
330	0.977

TD	correction factor
6	
8	
10	
16	1.00

$Q = \dot{m} C_p (T_{cond.} - T_{air})$

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

10/7/2017
الإثنين

Air Condenser Table R12

Ex:- An open type compressor uses R22, with a cooling load of (21 KW) / $T_E = 5°c$ / $T_c = 49°$ / $T_{amb} = 35°c$ / Altitude = 1500 m
Select the condeser from table R12.

$$Q_c = \frac{\overset{1.19}{HRF}\ \overset{21}{Q_e}\ \overset{1.14}{T_D\ correction}}{\underset{0.903}{\text{Altitude Factor}}}$$ ⇒ from table 1500 → 0.903

$T_D = \overset{49}{T_c} - \overset{35}{T_{amb}} = 14$ ⇒ T_D correction = 1.14
Table R-12B

HRF → table 2 - open compressors

$$Q_c = \frac{1.19 \times 21 \times 1.14}{0.903} = 31.8\ KW$$

From table R12 A

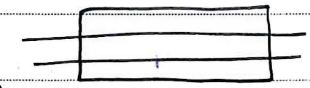
Unit size	No. of circuits	Capacity R22 Total unit KW	Capacity R22 KW per circuit
		—	
		—	
8	2	← 36.9	

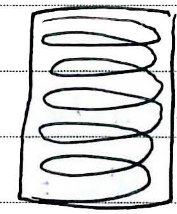
$Q_c = \dot{m}\, c_p\, \Delta T$ * في ال Air-condenser
$\dot{m}$ = فان نحتاج الى مروحة للتبريد.

Water cooled Condenser → Inside the pipe

Types :-

- Double pipe condenser (concentric)
- Shell and oil
- Shell and tube

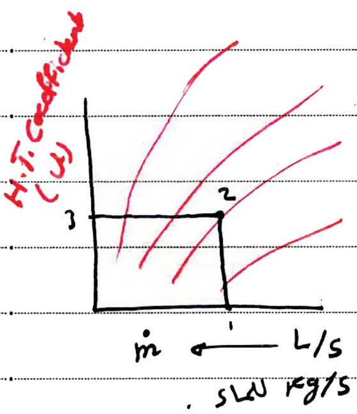


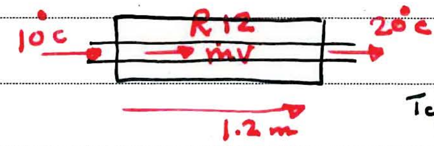


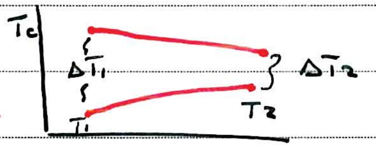
* في ال water-condenser نستخدم ال correction To

لأنه درجة حرارة الماء تختلف عنه المحيط

$$Q = U A_s \, LMTD \qquad LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln \frac{\Delta T_1}{\Delta T_2}}$$







Selection Procedures For R13 table

1 Find Q_c corrected.

$$Q_c = HRF \; Q_e$$

2 Find $\dot{m}_{water}$

$$Q_c = \dot{m}_w \, C_p \, \Delta T$$

3 . Find LMTD $\Delta T_1 = T_c - T_{wi}$ $\Delta T_2 = T_c - T_{wo}$

$$LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln \frac{\Delta T_1}{\Delta T_2}}$$

4 Find $U_{overall}$ from Fig (1).

5 Calculate As from

$$Q_c = U_{ov} A_s \, LMTD$$

Ex3: 4 pass shell and tube HE, that uses R12, $Q_e = 105$ KW

compressor in open type $T_E = -1°C$ / $T_c = 38°C$

$\dot{m}_w = 0.036$ L/s / per 1 KW condensation

$F.F = 0.001 \; m^2 . °C / W$.

Max. length = 3 m , $T_{wi} = 25°C$.

press. drop حتى لا يزيد ال

– $Q_c = HRF \; Q_e$

↳ Table A2 – open –

$Q_c = 1.17 * 105 = 122.9$ KW

$Q_c = \dot{m}_w \, c_{pw} \, \Delta T_w$

$$T_{wo} - T_{wi} = \frac{Q_c}{\dot{m}_w C_{pw}}$$

$$\dot{m}_w = Q_c * \frac{\dot{m}_w}{KW}$$

$= 122.9 * 0.036$

$\boxed{\dot{m}_w = 4.42 \; L/s}$

$$T_{wo} - T_{wi} = \frac{122.9}{4.186 * 4.42} = 6.64°C$$

$\Rightarrow T_{wo} = 31.64°C$

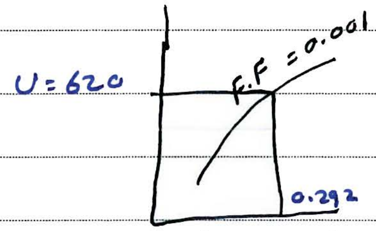
- LMTD :-

$$\Delta T_1 = T_c - T_{wi} = 38 - 25 = 13^\circ c$$

$$\Delta T_2 = T_c - T_{wo} = 38 - 31.64 = 6.36^\circ c$$

$$LMTD = \frac{13 - 6.36}{\ln \frac{13}{6.36}} = 9.29^\circ c$$

$$Q_c = U_{ov} \, A_s \, LMTD$$



$$\frac{\dot{m}_w \times pass}{tubes} = \frac{4.42 \times 4}{60} = 0.292$$

$$A_s = \frac{Q_c}{U_{ov} \, LMTD} = \frac{122.9}{620 \times 9.29}$$

$$A_s = 21.3 \ m^2$$

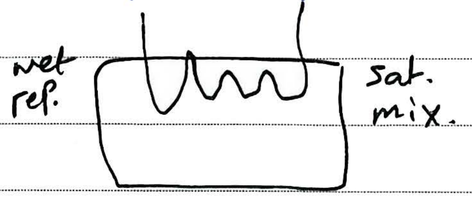
11/7/2017
الثلاثاء

Simple classification for evaporator :-

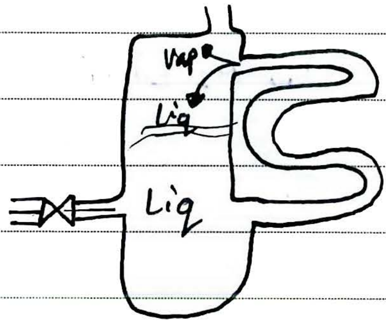
- Air cooled
  - Forced
  - Natural
- Liquid → (Chillers)
  - water
  - others
  - (Chillers)
    - vap. comp.
    - Absorb. cycle.

Methods of Refrigeration :-

1) DX (direct - expansion)



2) flooted

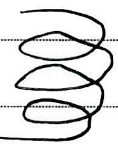


Types of construction :-

- bare tube
- Finned tube

Types of flow - control :

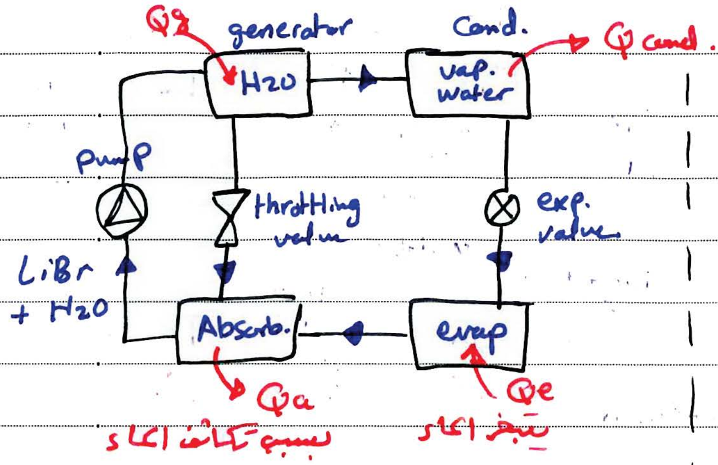
- expansion valve
- capillary tube

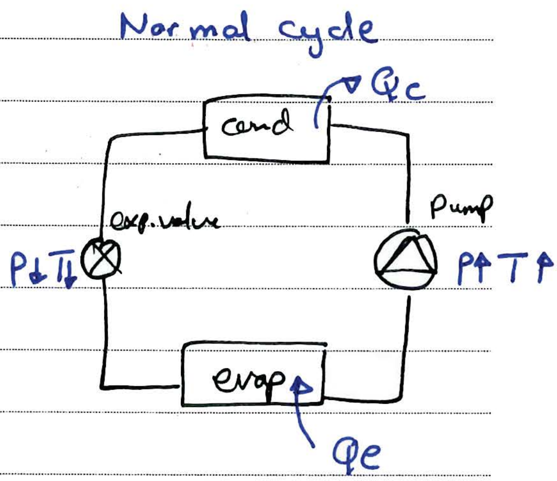


يقل الضغط كلما زاد طوله .

Ch 17 Absorption cycle :

by using : Absorbant Refrigerant
(LiBr _ water)
or (water - ammonia)



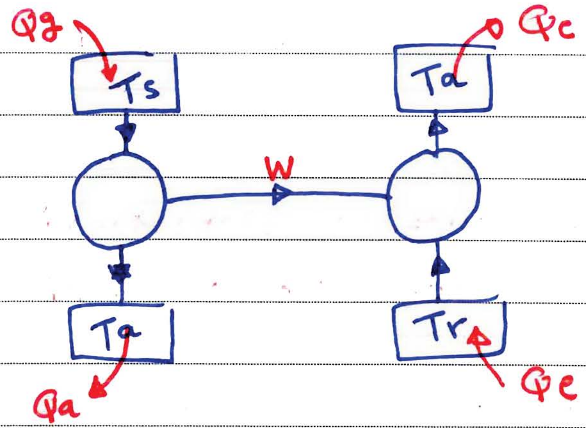


$(COP \approx 0.7 - 1)$

$$COP = \frac{Qe}{Qg}$$

$(COP \approx 2 - 4)$

$$COP = \frac{Q_E}{W}$$



(Refrigerating)

COP لحساب
carnot :-

$$w = \eta \, Qg$$

$$\eta_{carnot} = \frac{w}{Qg} = \frac{Tg}{Tg - Ta}$$

$$\frac{Qg}{w} = \frac{Tg - Ta}{Tg}$$

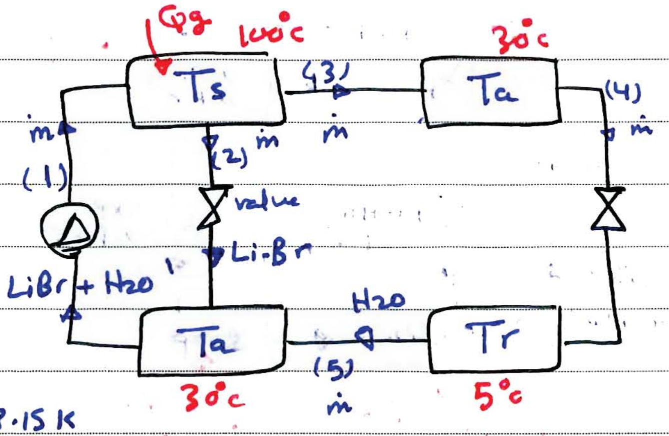
$$\frac{Q_E}{W} = \frac{T_E}{Tc - T_E}$$

$$COP = \frac{qe}{qg} = \frac{T_E(Tg - Ta)}{Tg(Tc - T_E)}$$

$(COP \ 0.7 - 1)$

Ex: 17-1

amb Temp = 30°c



$$COP = \frac{T_r (T_s - T_a)}{T_s (T_a - T_r)} = \frac{Q_E}{Q_g}$$

T_r = 278.15 K, T_s = 373.15 K

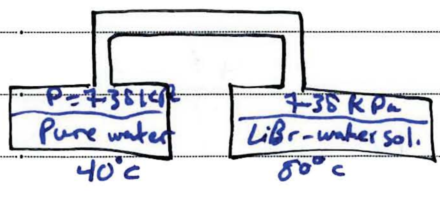
$$= \frac{278.15 (100-30)}{373.15 (30-5)} = 2.09$$

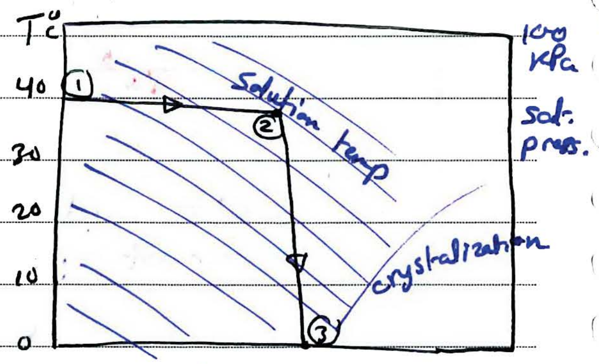
12/7/2017
الأربعاء

Temp - Pressure concentration properties of Li-Br - water solution :-

$$Q = \dot{m} \Delta h$$

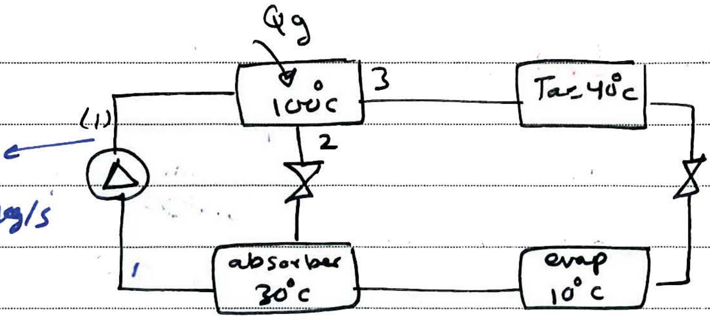
$$\dot{m} = \frac{Q}{\Delta h}$$





$$X = \frac{m_{LiBr}}{m_{solution}}$$

Ex. 17.2



given
$\dot{m}_1 = 0.6$ kg/s

$\dot{m}_3 = \dot{m}_5$?? (mass flow rate | refrigerant

$$\dot{m}_1 = \dot{m}_2 + \dot{m}_3 \quad --- (1)$$

$$0.6 = \dot{m}_2 + \dot{m}_3$$

كمية ال LiBr التي دخلت ال pump

$$\dot{m}_1 (X_1) = \dot{m}_2 X_2 \rightarrow \text{at point 2}$$

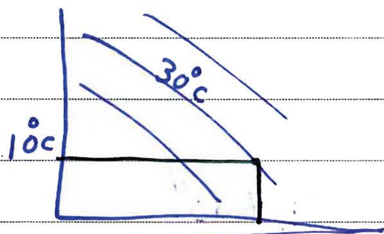
نجد X_1
X_2
ثم نجد $\dot{m}_2$

$$X_1 (0.6) = X_2 \dot{m}_2$$

باستخدام ال Fig 17.5 :

$$0.5 (0.6) = (0.664) \dot{m}_2$$

$$\boxed{\dot{m}_2 = 0.452 \text{ kg/s}}$$



$X_1 = 0.5$

$$\dot{m}_1 = \dot{m}_2 + \dot{m}_3$$

$$0.6 = 0.452 + \dot{m}_3$$

$$\boxed{\dot{m}_3 = 0.148 \text{ kg/s}}$$

$X_2 \rightarrow$ 40° حرارة الماء النقي
100°c حرارة المخلوط
⇒ From Fig 17.5
$X_2 = 0.664$

Enthalpy - of LiBr solution

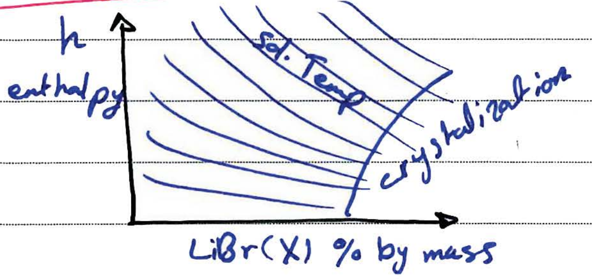


Fig. 17-8
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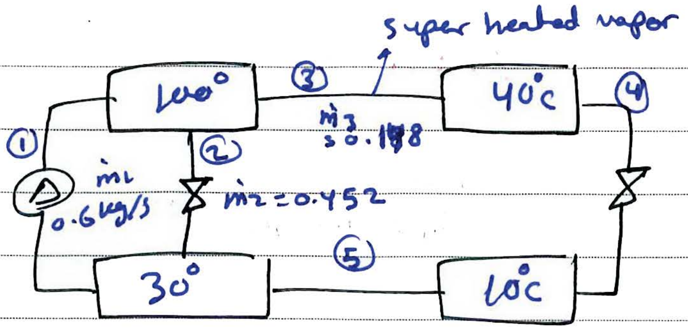
16/7/2017
الأحد

Ex: 17-3

compute

q_b, q_e, q_a, q_c



$$q_e = \dot{m}_4 (h_5 - h_4)$$

لا يمكن استعمال الـ chart لإيجاد
قيم h لأنه ماء نقي .

h_5 (sat. vap)

$h_5 = 2520$

$h_4 = 167.5$ kJ/kg

T	v	h_f	h_{fg}	h_g

$$q_e = 0.148(2520 - 167.5) = 348.2 \text{ KW}$$

$$-Q_a + \dot{m}_1 h_1 = \dot{m}_2 h_2 + \dot{m}_5 h_5$$

($-$: لأنها خارجة; $\dot{m}_1 = 0.6$; $\dot{m}_2 = 0.452$; $\dot{m}_5 = 0.148$; $h_5 = 2520$)

h_1 from chart: -168 kJ/kg

h_2 from chart: -52 kJ/kg

$$-Q_a = -\dot{m}_1 h_1 + \dot{m}_2 h_2 + \dot{m}_5 h_5$$

$$= -0.6 \times -168 + 0.452 \times -52 + 0.148 \times 2520$$

$$Q_a = \ominus 450.3 \text{ kw}$$

لأنها خارجة منه النظام
والإشارة السالبة تدل على الإتجاه فقط

$$Q_g + \dot{m}_1 h_1 = \dot{m}_2 h_2 + \dot{m}_3 h_3$$

$$Q_g = -\dot{m}_1 h_1 + \dot{m}_2 h_2 + \dot{m}_3 h_3$$

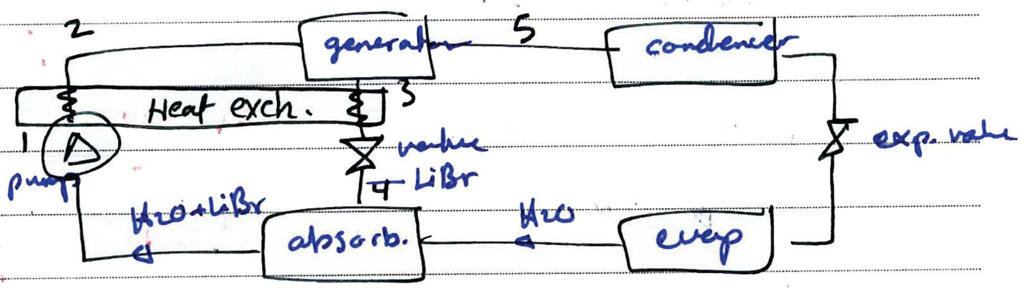
$$= -0.6(-168) + 0.452(-52) + 0.148(2670)$$

$$Q_g = 473.3 \text{ kW}$$

$$COP = \frac{Q_E}{Q_g}$$ Q_E → output, Q_g → input

$$COP = \frac{348.2}{476.6} = 0.736$$

Ex 17-4



$X_2 = 50\%$

$T_2 = 52°$

$h_2 = ??$

flow rate or energy balance :-

$$Q_g + \dot{m}_2 h_2 = \dot{m}_3 h_3 + \dot{m}_5 h_5 \quad — ①$$

$T = 100°c$

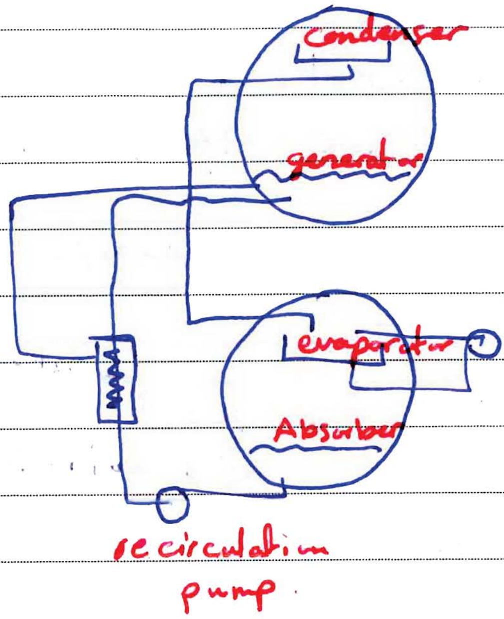
LiBr Balance :- $X = 67\%$

$$\dot{m}_2 (h_2 - h_1) = \dot{m}(h_4 - h_3) \quad — ②$$

17-7/2017

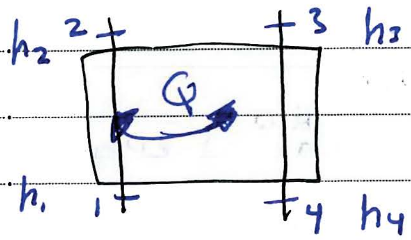
الأشنيه

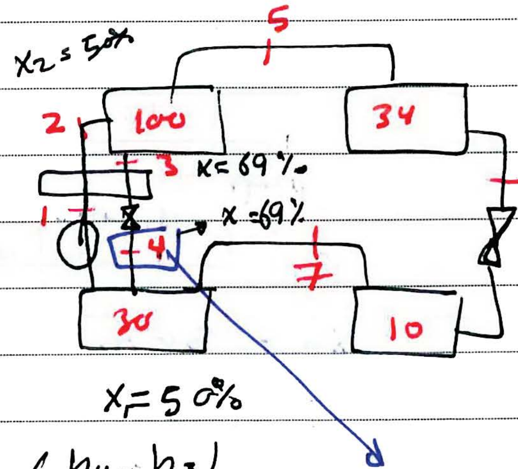
Fig 17-10 P. 339



Crystalization:-

Ex 17.5 P.340





$$\dot{m}_1 (h_1 - h_2) = \dot{m}_3 (h_4 - h_3)$$

هنا يحدث crystalization

إذا لم يحدث هنا فلن يحدث في أي مكان آخر.

$$\Sigma Q = 0$$

$$-Q_{1-2} + Q_{3-4} = 0$$

$$Q_{1-2} = Q_{3-4}$$

$\dot{m}_2 = \dot{m}_3 + \dot{m}_4$

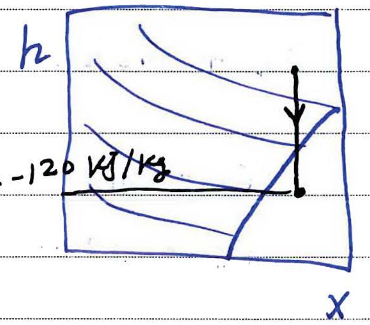
0.60

$m_2 X_2 = \dot{m}_3 X_3$

$0.6(0.5) = 0.96\, \dot{m}_3$

$\dot{m}_3 = 0.435$ kg/s

$Q_E \downarrow = \dot{m} \downarrow (h_7 - h_6)$

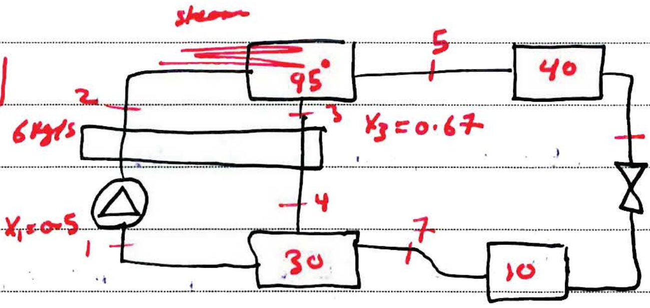


Capacity control :-

1. Reducing the flow rate delivered by the pump at I
2. Reducing the generator temperature.
3. Increasing the condensing temperature.

18/7/2017
الثلاثاء

Ex 17-6
P. 342



$h_6 = 167.5$

$h_7 = 2520$ kJ/kg

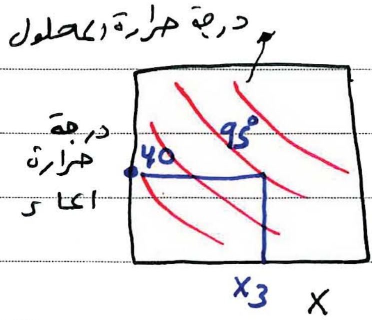
$Q_E = \dot{m}_5 (h_7 - h_6)$

$Q_g =$

$COP = \frac{Q_E}{Q_g}$

$\dot{m}_2 = \dot{m}_3 + \dot{m}_5$

$0.6 =$



$\dot{m}_2 X_2 = \dot{m}_3 X_3$

$(0.6)(0.5) = \dot{m}_3 (0.65)$

$\dot{m}_3 = 0.462$ kg/s

$Q_g + \dot{m}_2 h_2 = \dot{m}_3 h_3 + \dot{m}_5 h_5$

h_5 → sat. vap at 95°

$Q_g = 414$ KW

$Q_E = 324.6$ KW

$COP = \frac{324.6}{414} = 0.783$

17-12 Double effect system.

Ex 17-7
P. 346

Position	P	h	$\dot{m}$
1	1500	3080	1.2
2	100	2675	1.2
3	100	419	1.2

$Q_{EG} = Q_{E\,vc} + Q_{E\,abs}$

$\overset{3.6}{COP_{vc}} = \frac{Q_{E\,vc}}{W_c}$ (486) $\Rightarrow Q_{E\,vc} = 1750$ KW

$W_c = \dot{m}_1 (h_1 - h_2) = 1.2 (3080 - 2675) = 486$ KW

$$COP_{abs} = \frac{Q_E}{Q_g}$$

$$Q_g = \dot{m}_2 (h_2 - h_3) = 1.2(2675 - 419) = 2707 \text{ KW}$$

$$Q_E = 0.7 * 2707 = 1895 \text{ KW}$$

$$Q_t = 1750 + 1895 = 3645 \text{ KW}$$

$$COP = \frac{Q_{E_t}}{\dot{m}(h_1 - h_3)} = 1.14$$

17.14 Aqua-ammonia system:-

أقل حرارة تبريد لل LiBr هي $3^{\circ}c$

أما في ال Ammonia فتصل إلى ما دون الصفر.

الضغط في دورة LiBr في ال evap. يكون سالب

مما يؤدي إلى تسريب الضغط الخارجي والهواء مما يؤدي

إلى مشاكل.

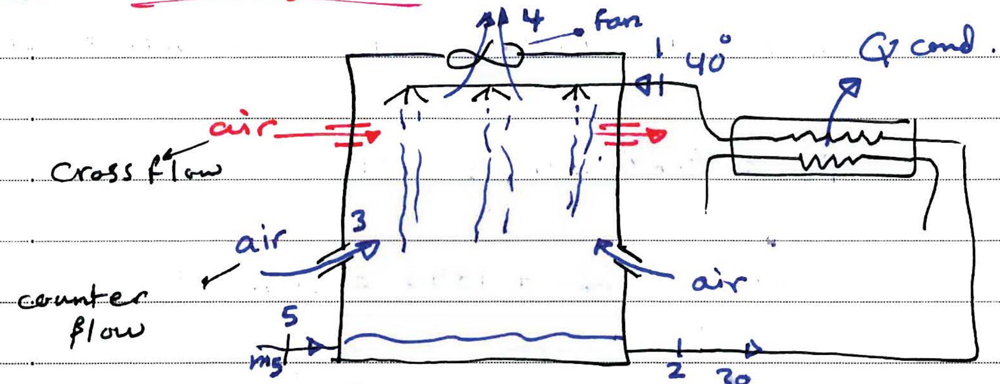
أما في دورة ال ammonia فإن الضغط داخل ال evap

يكون أعلى من الضغط الخارجي وإذا تسرب غاز الأمونيا

يمكن إعادة تعبئته.

19/7/2017
الأربعاء

Cooling Tower



- counter flow → Natural
- cross flow. → Forced

$$\sum E_{in} = \sum E_{out}$$

$$\dot{m}_3 h_3 + \dot{m}_5 h_5 + \dot{m}_1 h_1 + \dot{W}_{fan} = \dot{m}_4 h_4 + \dot{m}_2 h_2$$

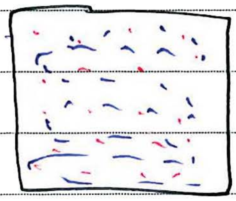
($\dot{W}_{fan}$ → 0) عادةً تكون مهملة.

h_5 → h_f at T_5 compressed liquid.

h_1 → h_f at T_1

h_2 → h_f at T_2

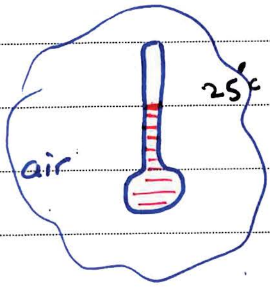
h_3 and h_4 → from the psychrometric chart

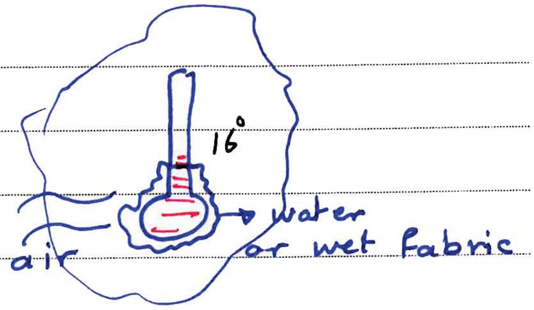


Dry Air + H_2O vap

T_{db} : Dry bulb temp
درجة حرارة الجو العادية

T_{wb} : Wet bulb temp
تستخدم لقياس درجة الرطوبة في الهواء.



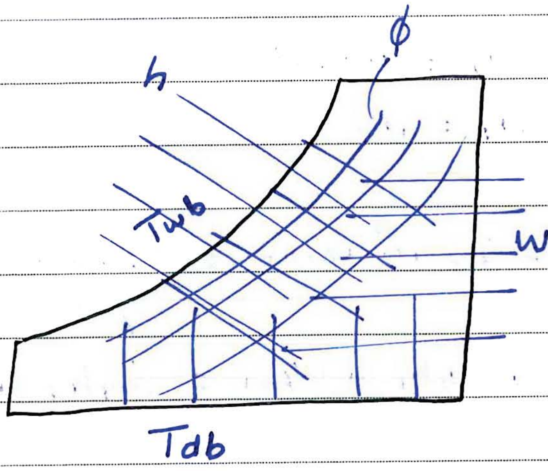


dry bulb temp

$T_{wb} \leq T_{db}$.

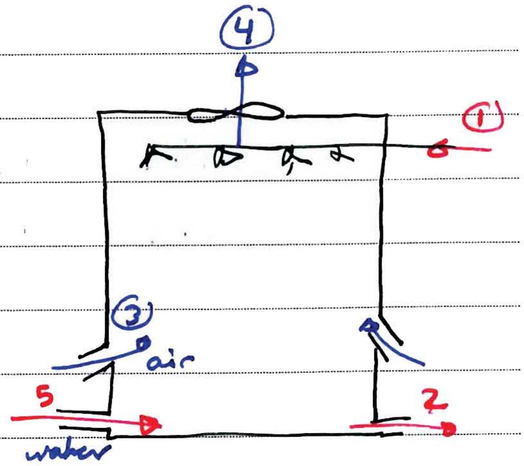
PSYCHROMETRIC CHART

Humidity ratio $= W = \frac{m_w}{m_a} = \frac{kg\ H_2O}{kg\ dry\ air}$



Tdb	Twb	w	h	ø
25	16	0.0078	45	39%
30	11.5	0.001	34	5%-7%
18.5	15	0.0092	42	70%

Ex1-
$\dot{m}_1 = 4.5 \times 10^7\ kg/hr$
$T_1 = 38°$
$T_5 = 20°c$
$T_2 = 30°$
$T_3 = 25°c$
$\phi_3 = 35\%$
$T_4 = 35°c$
$\phi_4 = 90\%$



$\dot{m}_a = \dot{m}_3 = \dot{m}_4 = ??$

$\dot{m}_5$?? Make up water (bleeding water).

$\sum \dot{m}_{w\,in} = \sum \dot{m}_{w\,out}$

$\cancel{\dot{m}_1} + \dot{m}_5 + \dot{m}_3 \omega_3 = \dot{m}_4 \omega_4 + \cancel{\dot{m}_2}$

(under $\dot{m}_3\omega_3$:) كمية الماء الموجودة في الهواء — (under $\dot{m}_4\omega_4$:) بخار في الهواء

$T_3 = 25°c$, $\phi_3 = 35\%$ } $\omega_3 = 0.0068$, $h_3 = 42.5$

$T_4 = 35°c$, $\phi_4 = 90\%$ } $\omega_4 = 0.0328$, $h_4 = 118$

$\dot{m}_1 = \dot{m}_2 = 4.5 \times 10^7$ kg/hr s 12500 kg/s

$\dot{m}_3 h_3 + \dot{m}_5 h_5 + \dot{m}_1 h_1 + W_{fan} = \dot{m}_4 h_4 + \dot{m}_2 h_2$

(h_3 = 42.5, h_4 = 118, 12500)

$\dot{m}_3 \approx \dot{m}_4$

$\dot{m}_a = \dot{m}_3 = \dot{m}_4 = 2.028 \times 10^7$ kg/hr

$\dot{m}_5 = 0.053 \times 10^7$ kg/hr.

23/7/2017
الأحد

Ex-2 If the following conditions are applied to a basic cooling tower :-

(1) Find the mass flowrate for makeup water.

(2) Find the volume flowrate of the air (3) beside

(3) the output from the condenser

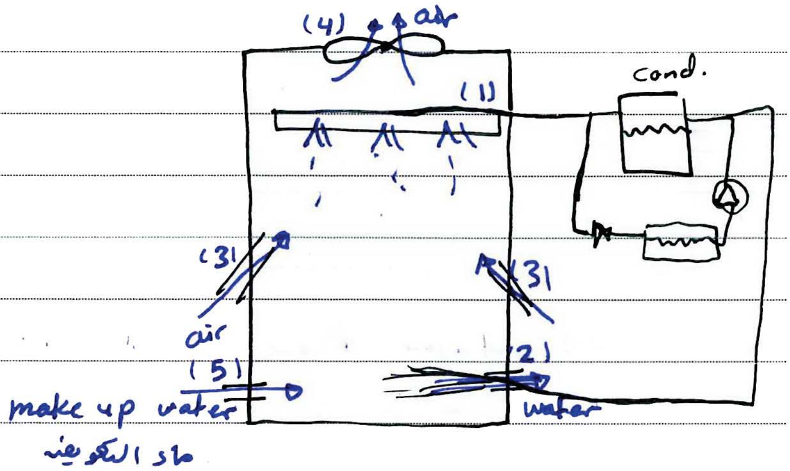
If the following conditions :-

$T_{w\,in(1)} = 35^\circ C$, $\dot m_{w\,inlet}$ (1) $= 100\ kg/s$

$T_{air\,in} = 20^\circ c$, $\phi_{3\,air\,in}$ relative humidity $= 60\%$

$T_{out(4)} = 30^\circ c$, $\phi_{air\,out(4)} = 100\%$

$W_{fan} = 0.9\ kW$, $T_5 = 20^\circ c$, $T_2 = 22^\circ$

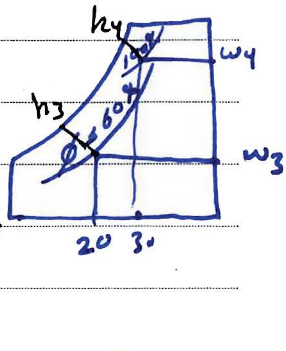


Find $\dot m_5$:-

$$\dot m_5 = \dot m_4 w_4 - \dot m_3 w_3$$

$$\dot m_5 = \dot m_a (w_4 - w_3) \quad \text{---(1)}$$

$\dot m_a = \dot m_3 = \dot m_4$; $w_4 = 0.0274$, $w_3 = 0.0086$ → From chart



in cooling tower :- (Energy inlet = Energy outlet) —(2)

$$\dot m_5 h_5 + \dot m_3 h_3 + \dot m_1 h_1 + W_{fan} = \dot m_4 h_4 + \dot m_2 h_2$$

$h_1, h_5, h_2 \rightarrow$ sat. liq.

* from tables.

$h_5 = 83.86$ kJ/kg

$h_1 = 196.56$ kJ/kg

$h_2 = 92.23$ kJ/kg.

* from chart

$h_3 = 42$ kJ/kg

$h_4 = 100$ kJ/kg.

substitute in (2)

$\dot{m}_5(83.86) + \dot{m}_a(42) + 100(146.56) + 0.9$

$= \dot{m}_a(100) + 100(92.23)$ $\qquad \dot{m}_3 = \dot{m}_4$

$\dot{m}_1 = \dot{m}_2$

solve ① and ②

$\dot{m}_5 = 1081$ kg/s

$\dot{m}_3 = \dot{m}_4 = \dot{m}_{air} = 96.9$ kg/s.

(2) volume flow rate of air :-

$\dot{m}_{air} = \frac{\dot{V}}{v_{specific\ volume}} = \rho \dot{V}$ $\qquad \rho_{air} = 1.25$ or 1.2

$96.9 = 1.25 \times \dot{V} \rightarrow \dot{V}_{air} = 81\ m^3/s$

(3) output of condenser (Q_{cond}) :-

$Q_{cond} = \dot{m} c_p \Delta T$

نفسها $= \dot{m} \Delta h \rightarrow$ أسهل لأنه اعاد لم يتغير حالته

الحرارة التي يطردها ال Cooling tower $= \dot{m}_1(146.56 - 92.23) = 544108$ KW

Factors influencing performance of cooling tower :-

1) T_{wb} air inlet — الهواء يجب انه يكون جاف حتى يحدث تبخير في الماء

$\phi \downarrow$ relative humidity أقل ما يمكن

2) Ammount of exposed water droplets

(3) Velocity of air forced through water.

لحد معين، حتى لا يتم طرد البخار منه الـ Cooling tower

(4) Direction of air relative to water

(الـ noncounter أفضل من counter)

24/7/2017
الاثنين

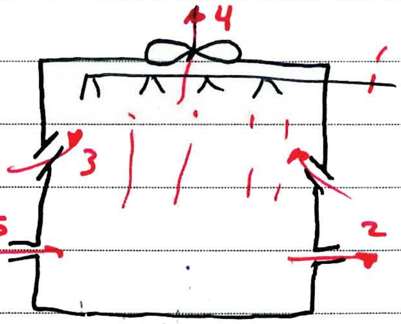
Basic Definition and Terminology.

(1) Approach = $T_{water,out|tower} - T_{w,b|air\ entering.}$

Approach = $T_2 - T_{w,b}|_3$

= 22 − 15 = 7 °c

Range of approach [5 − 15] °c

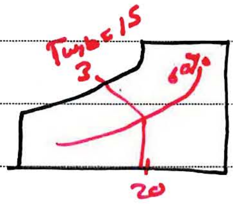


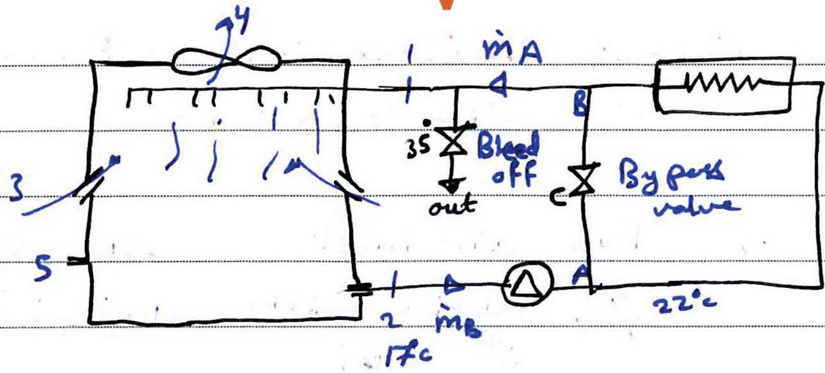
(2) Range = $T_{water,in} - T_{water,out}$

= $T_1 - T_2$

Tower load ≈ $Q_{cond.}$

$Q = \dot{m} c_p (T_1 - T_2)$





Bleed off : هدفه هو منع تشكل الترسبات (scales)
داخل الأنابيب لذلك نتخلص من الماء المترسب أو الماء
ذات نسبة الأملاح العالية منه فلاله ونعوض بماء آخر نقي.

$$\dot m_A = \dot m_B + \dot m_C$$

$$Q\uparrow\downarrow = \dot m_B \uparrow\downarrow C_p \text{ Range.}$$

$$Q_{tower} = Q_{cond}.$$

$$\dot m_B C_p (T_1 - T_2)_{tower} = \dot m_A C_p \Delta T_{condenser}$$

$$\dot m_B \Delta T_{tower} = \dot m_A \Delta T_{cond.}$$

$\dot m_w = 100$ kg

$\dot m_{bleed} = 100 * 0.0015$

Tower Range ΔT_w °C	% Bleed off
3.5	0.15
4.2	0.22
5.5	0.33
11.0	0.75

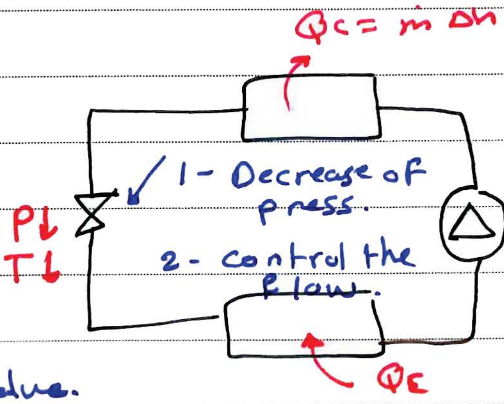
$$\dot m_{bleed\,off} = \dot m_w * \frac{\%\,\text{Bleed off}}{100}$$

$$\dot m_{bleed} = 100 \times \frac{0.75}{100}$$
$$= 0.75.$$

Expansion valves :-

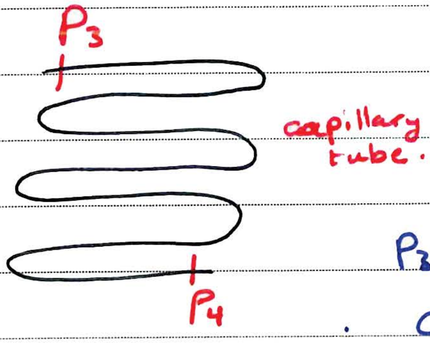
1- Capillary tube.
معرفة مبدأ العمل

2- Float value.



3- superheat expansion valve.
معرفة مبدأ العمل

4- constant pressure expansion valve.



$$\Delta P = \frac{f \frac{L}{D} v^2}{2g}$$

$P_3 - P_4 \rightarrow$ pressure drop

يزيد كلما زاد طول الـ C.tube.

Thermal expansion valve :-

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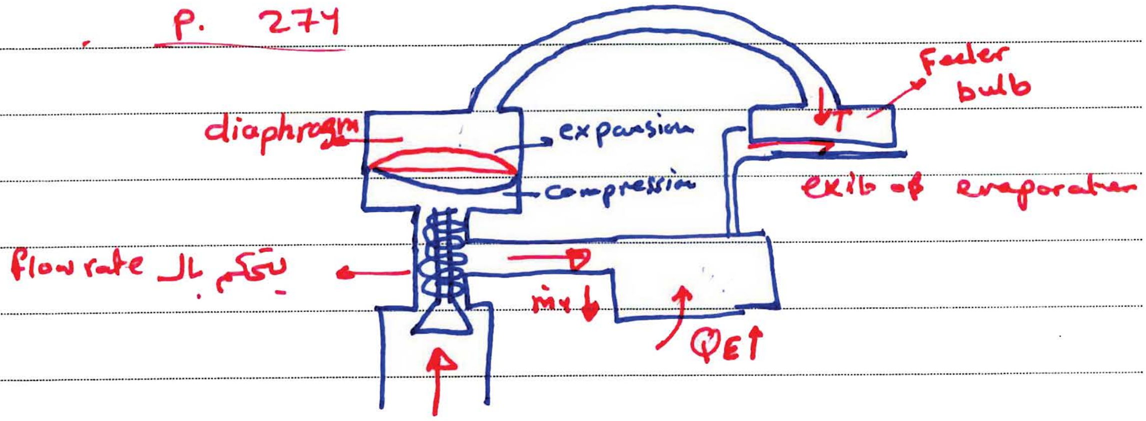

$$Q_E \downarrow = \dot{m}_f \downarrow \Delta h$$