CHAPTER 5

REFRIGERANT CYCLE CALCULATION

5.1 REFRIGERANT CYCLE CALCULATION AND SELECTION

5.1.1 Refrigerant selection

Cold agent must satisfy the requirements:

- Thermal requirements.
- Ask about physical chemistry.
- EH of Biophysics.
- Economic requirements.

There are many chilling agent, with different characteristics are therefore very difficult to find cold agent satisfy the above requirements. Here we will analyze and choose appropriate conditioning agent.

- **Amoniac NH_3 :**

It is colorless gas, odor toxic to the human body, allowable concentration in the air is 0.02mg/l. It lighter than air.

At pressure: p = 6.3bar, boil temp: $t_s = 10^0C$

p = 1bar, boil temp: $t_s = -34^0C$

- Amoniac are very dissolve in water, it allow water containing 0.2%
- No corrosion of ferrous metals, aluminum
- Easy to make, inexpensive
- Relatively large volumetric refrigerating capacity
- Less soluble oil, affecting lubrication, heat transfer, cooling is not possible.
- High compression end temperature range, otherwise good cooling compressor easy lubrication fire and damage the metal surface.

- **Freon R12 :**

It is colorless gas, special fragrance is very light feel at concentrations less than 20%, be slightly heavier than air, liquid 4.18 times heavier than water about 1.3 times

At pressure: p = 4.5bar, boil temp: $t_s = 10^0$C

p = 1.014bar, boil temp: $t_s = -30^0$C

- No ignition, is considered safe cold agent.
- Separate refrigerating capacity and volume are small volume □□ bulky structure suitable for small cold load.

- Low-temperature end of the range compression.
- Non-toxic for body.
- Non-corrosive with metal and non-conductive with electric
- Infinite soluble in oil
- Very easy to find and maintaining
- At temp >400^0C, it's burn if exposed to fire form the toxic mixture
- Mobility is poor, not water soluble so easily separated moisture
- Kinematic viscosity large, so pressure loss is large in the pipe
- Separate refrigerating capacity volume small, Therefore, the system cumbersome.
- Separate cold capacity mass little, so agents intake system more. It suitable for system with small and very small on refrigerating capacity
- Ability to leakage large, where traces of oil leaks due to good oil solubility.
- Price is very expensive.

➢ **Freon R22 :**

Is a colorless gas, very lightly scented.

In pressure: p = 6,82bar, boiling: $t_s = 10^oC$

P = 1,05 bar, boiling : $t_s = -40^oC$

- Private refrigerating capacity greater volume 1,6 with R12.
- Ability larger heat exchanger1,3 with R12.
- Not explosive.
- Endless dissolved in oil at high temperatures, while at lower temperatures, the less.
- Water solubility is about 5 times greater than R12, thereby reducing the risk of moisture switch.
- Non-corrosive metal, non-toxic.

- There are good thermodynamic properties.
- In the temperature range -20 ° C to -40 ° C since it is almost completely insoluble in oil. Therefore, avoid operating at this temperature zone.
- Capable of electrically conductive liquid, the electrical properties of R22 rapidly reduced when wet and dirty.
- Ability to account some organics room like rubber ... Therefore, the use of plastics and rubber in particular for sealing.
- Relatively expensive price.

➢ **Freon R134a**

At pressure: p = 4.15bar, boil temp: $t_s = 10^0$ Cp = 1.07 bar, boil temp: $t_s = -25^0C$

- Not explosive
- No corrosion, non-toxic
- Thermodynamic properties is good
- Dissolve in oil
- No affect in environment
- Price is very expensive
- Thermodynamic properties is not as good as R22

5.1.2 CHOICE OF REFRIGERANT

For VRV system, to move temperatures up to each room we can use intermediate get cold of agents called coolant. Coolant would be air or water.

Building design is big, there is any floor. So we choose coolant is water, by that time pipe coolant go to rooms are compact, less loss than air.

If coolant is water, distribution to air conditioning package of any room very simply. That why the ability to adjust the temperature and humidity in each room easier to implement, it ensure that the requirements of each.

In addition to the problems mentioned above, Water has the ability to meet the technical requirements and economic:

- No corrosion equipment
- Cheap, very easy to find out
- No explosure and non toxic with people

- Small viscosity.
- It good for thermal conductivity.
- Boiling large.

CHOISE THE COLD CYCLE

A. Cold temperatures agent :

Select agents cold is freon R134a.

B. Evaporation temperature:

Choose the evaporation temperature of the cold agent is t_o= 5^{o}C

C. Condensation temperature :

Here we use the air cooled condenser.

Tk according to the logarithmic mean temperature

$$\theta_m = \frac{t_{w2} - t_{w1}}{ln\frac{t_K - t_{w1}}{t_K - t_{w2}}}$$

In which: θ_m: logarithmic average temperature difference

t_{w2}, t_{w1}: -Air temperature in and out of the heat

Select : $\theta_m = 4$°C from table 6.11 sách máy lạnh air conditioner book Trần Thanh Kỳ

Ta có : T_N = 36°C, φ = 65%

Check humidity graph t-d of Carrier : $t_ư$ = 29,4°C

$$t_{w1} = t_ư + (3 \div 5) = 32°C$$

Temperature difference of condenser is $\Delta t = 5°C$

$$t_{w2} = t_{w1} + \Delta t = 37°C$$

⇨ $t_k = t_{w2} + (3 \div 5) = 42°C$

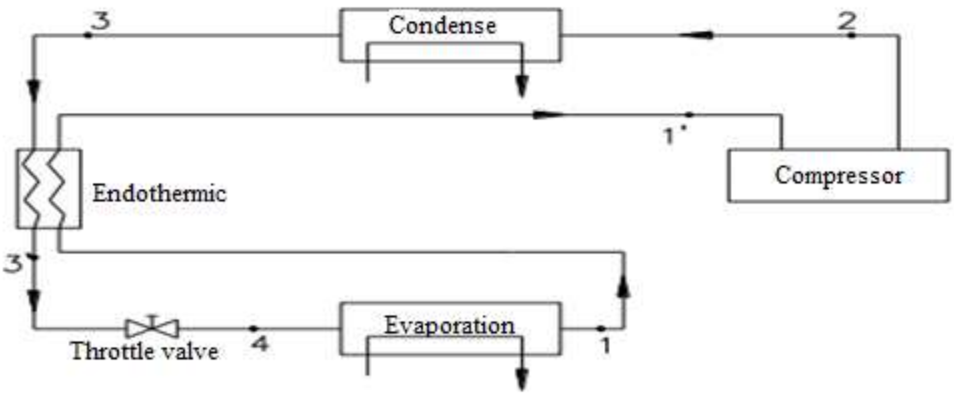
We have: p_k = 1072,1 kPa

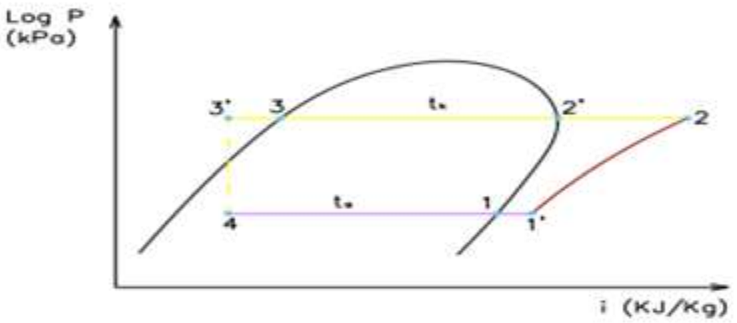
Compression ratio: $\boldsymbol{TSN} = \frac{\boldsymbol{P_K}}{\boldsymbol{P_0}} = \frac{1072,1}{349,705} = 3,066$

5.1.3 Heat chart:

Slightly R134a after the vessel vanished in State 1 will move in the space between the tubes of heat to the steam overheating in State1' , then the compressor compressor overheating to the point 2 with a pressure of P_k and then goes to the condenser. At first the cold would do little to temperatures of t_k (the process of 2-2') then condenses in P_k and t_k does not change (the 2-3) out of the condenser liquid is too cold the temple 3 ' and then go on the throttle from pressure P_k to pressure P_0 (the process of 3'-4). The temperature of the cooling agent is also reduced t_0 corresponds to P_0.

In the cycle we use the average heat to reduce losses and increase productivity q_0 at the same time increasing the compression to a value l. the average heat is usually used for the conditioning of heat ratio turns slightly and heat capacity of the liquid is relatively small (R134a and R22). The average heat more efficiently if the difference in temperature (t_k – t_0) greater.





A. Calculate the parameters of the cycle

With refrigeration cycle level 1 have chemical and chemical conditioning we have coefficient for calculation:

$t_0 = 5^0C$

$t_{qn} = t_0 + 10^0C = 15^0C$

$t_k = 42^0C$

With cycle we use Freon R134a

Point 1: Vapor saturated dry

$t_1 = t_0 = 5^0C$ look up table: Parameter saturated dry of R134a we have :

p_1 = 349,70 kPa

$i_1 = i''$ = 401,57 kJ/kg

$s_1 = s_1'' = 1{,}7247$ kJ/kg.K

$v_1 = v_1'' = 0{,}05845$ m^3/kg

Point 1': Superheat vapor

$t_{1'} = 15^oC$

$p_{1'} = p_1 = 349{,}70$ kPa

Lookup table: Parameter superheat of R134a we have:

Which p = 340 kPa p = 350 kPa

i = 411,0 kJ/kg i = 410,8 kJ/kg

s = 1,7602 kJ/kg.K s = 1,7572 kJ/kg.K

v = 0,06333 m^3/kg v = 0,06134 m^3/kg

Interpolate, we have:

$i_{1'} = 411{,}0 - \frac{349{,}70-340}{350-340}.(411{,}0 - 410{,}8) = 410{,}80$ kJ/kg

$s_{1'} = 1{,}7602 - \frac{349{,}70-340}{350-340}.(1{,}7602 - 1{,}7572) = 1{,}7573$ kJ/kg.K

$v_{1'} = 0{,}06333 - \frac{349{,}70-340}{350-340}.(0{,}06333 - 0{,}06134) = 0{,}06184$ m^3/kg

Point 2: Superheat vapor

Condenser temperature $t_k = 42^0C$ lookup table: Parameter saturated dry of R134a we have: $p_k = 1072{,}1$ kPa

Inferred: $p_2 = 1072{,}1$ kPa

And $s_2 = s_{1'} = 1{,}7573$ kJ/kg.K

Lookup table: Parameter superheat of R134a we have:

Which p = 1000 kPa

t = 50^{o}C t = 55^{o}C

v = 0,02181 m^3/kg v = 0,02246 m^3/kg

i = 431,2 kJ/kg i = 436,8 kJ/kg

s = 1,7491 kJ/kg.K s = 1,7655 kJ/kg.K

Inferred, which $s = s_2 = 1{,}7573$ kJ/kg.K (t = 50^{o}C and t = 55^{o}C look up follow s = 1,7573 kJ/kg.K) :

$t = 50 + \frac{1{,}7573-1{,}7491}{1{,}7655-1{,}7491}.(55 - 50) = 52{,}5^oC$

$v = 0{,}02181 + \frac{1{,}7573-1{,}7491}{1{,}7655-1{,}7491}.(0{,}02246 - 0{,}02181) = 0{,}02214$ m^3/kg

$i = 431{,}2 + \frac{1{,}7573-1{,}7491}{1{,}7655-1{,}7491}.(436{,}8 - 431{,}2)$ = 434 kJ/kg

Which p = 1100 kPa

t = 55^{o}C t = 60^{o}C

v = 0,01995 m^3/kg v = 0,02054 m^3/kg

i = 434,5 kJ/kg i = 440,0 kJ/kg

s = 1,7531 kJ/kg.K s = 1,7696 kJ/kg.K

Interpolate, which s = s_2 = 1,7573 kJ/kg.K we have :

$t = 55 + \frac{1{,}7573-1{,}7531}{1{,}7696-1{,}7531}.(60 - 55)$ = 56,27 ^{o}C

$v = 0{,}01995 + \frac{1{,}7573-1{,}7531}{1{,}7696-1{,}7531}.(0{,}02054 - 0{,}01995)$ = 0,0201 m^3/kg

$i = 434{,}5 + \frac{1{,}7573-1{,}7531}{1{,}7696-1{,}7531}.(440{,}0 - 434{,}5)$ = 435,9 kJ/kg

Interpolate parameter according to pressure p = 1072,1 kPa we have :

$t_2 = 52{,}5 + \frac{1072{,}1-1000}{1100-1000}.(56{,}27 - 52{,}5)$ = 55,52 ^{o}C

$v_2 = 0{,}02214 + \frac{1072{,}1-1000}{1100-1000}.(0{,}0201 - 0{,}02214)$ = 0,0207 m^3/kg

$i_2 = 434{,}0 + \frac{1072{,}1-1000}{1100-1000}.(435{,}9 - 434{,}0)$ = 435,37 kJ/kg

Point 2' : Dry saturated vapor

$t_{2'} = t_k$ = 42^{o}C lookup table: Parameter saturated dry of R134a we have :

$p_{2'}$ = 1072,1 kPa

$i_{2'}$ = i" = 420,44 kJ/kg

$s_{2'}$ = s" = 1,7108 kJ/kg.K

$v_{2'}$ = v" = 0,01890 m^3/kg

Point 3: Boiling liquid

$t_3 = t_k$ = 42^{o}C lookup table: Parameter saturated dry of R134a we have:

p_3 = 1072,1 kPa

i_3 = i' = 259,35 kJ/kg

s_3 = s' = 1,1997 kJ/kg.K

Point 3': Sub-cool condition

Heat balance equation in the average heat recovery:

$i_3 - i_{3'} = i_{1'} - i_1$

$\Rightarrow i_{3'} = i_1 - i_{1'} + i_3$ = 401,57 – 410,80 + 259,35 = 250,12 kJ/kg

With $i_{3'}$ = 250,12 kJ/kg lookup table: Parameter saturated dry of R134a we have:

$t_{3'}$ = 35°C

$p_{3'}$ = 1072,1 kPa

$s_{3'}$ = 1,1762 kJ/kg.K

Point 4: Saturated vapor status

$t_4 = t_0$ = 5°C lookup table: Parameter saturated dry of R134a we have:

p_4 = 349,70 kPa and parameter

i' = 206,72 kJ/kg

s' = 1,0242 kJ/kg.K

i" = 401,57 kJ/kg

s" = 1,7247 kJ/kg.K

The otherwise, we have: $i_4 = i_{3'}$ = 250,12 kJ/kg

Refrigerant dryness fraction: $x_4 = \frac{i_4 - i\prime}{i_1 - i\prime} = \frac{250,12 - 206,72}{401,57 - 206,72} = 0,22$

We have parameter:

s_4 = s' + x_4.(s" – s') = 1,0242 + 0,22.(1,7247 – 1,0242) = 1,1783 kJ/kg.K

Point	t(°C)	p(kPa)	i(kJ/kg)	s(kJ/kg.K)	v(m^3/kg)
1	5	349,70	401,57	1,7247	0,05845
1'	15	349,70	410,80	1,7573	0,06184
2	55,52	1072,1	435,37	1,7573	0,0207
2'	42	1072,1	420,44	1,7108	0,0189
3	42	1072,1	259,35	1,1997	
3'	35	1072,1	250,12	1,1762	
4	5	349,70	250,12	1,1783	

Table 5.1: Result calculate parameters of cycle.

5.2 COMPRESSOR CALCULATION AND SELECTION

5.2.1 Compressor calculation

The total heat loss of the building: **Q = 4460.29 kW**

Q = 1.05 × 4460.29= 4683.3 kW

We choose the system consists 4 chiller.

⇒ Refrigeration capacity of a unit: : $Q_o = \frac{4683.3}{4}$ = 1170,82 kW ≈ 332,92 RT

Each unit consists of four compressor, so refrigerating capacity of the compressor:

Q_o = 1170,82 kW

Separate refrigerating capacity (1 kg R134a):

$q_o = i_1 - i_4$ = 401,57 – 250,12 = 151,45 kJ/kg

Steam flow fact sucked into the compressor:

$G = \frac{Q_0}{q_0} = \frac{1170{,}82}{151{,}45} = 7{,}73$ kg/s

Adiabatic compression of cycle:

$l = i_2 - i_{1'}$ = 435,37 – 410,80 = 24,57 kJ/kg

Specific refrigerant capacity:

$$q_v = \frac{q_0}{v_{1\prime}} = \frac{151{,}45}{0{,}06184} = 2449{,}06 kJ/m^3$$

Cooling factor of the cycle:

$$\varepsilon = \frac{q_0}{l} = \frac{151{,}45}{24{,}57} = 6{,}164$$

Actual volume capacity of compressors (suction volume into the compressor)

$$V_{tt} = G.v_{1\prime} = 7{,}73x0.06184 = 0{,}478 m^3/s$$

Volume indicator value, select $\Delta P_h = 0{,}05$

$\lambda_i = \frac{P_0 - \Delta P_h}{P_0} = \frac{3{,}4970 - 0{,}05}{3{,}4970} = 0{,}98$

The coefficient of loss is not visible

$$\lambda_{w\prime} = \frac{T_0}{T_K} = \frac{273 + 5}{273 + 42} = 0{,}8825$$

Flow coefficient of compressor: $\lambda = \lambda_{w\prime} . \lambda_i = 0{,}8825 . 0{,}98 = 0{,}8648$

Volume suction theory

$$V_h = \frac{V_{tt}}{\lambda} = \frac{0{,}478}{0{,}8648} = 552{,}7\ m^3/h$$

Compression adiabatic work of compressors:

$N_s = G.l$ = 7,73x24,57 = 189,92 kW

Indicartor performance

$$\eta_e = \lambda_{w'} + b.t_0 = 0{,}8825 + 0{,}0025 . 5 = 0{,}895$$

$$N_e = \frac{N_s}{\eta_e} = \frac{189,92}{0,895} = 212,21\ kW$$

Capacity on the motor shaft :

$$N_i = \frac{N_e}{\eta_t} = \frac{212,21}{1} = 212,21\ kW$$

Actual refrigeration coefficient is effective : $\varepsilon_e = \frac{Q_0}{N_e} = \frac{1170,82}{212,21} = 5,52$

The amount of oil sprayed into the compressor: $V_d = \frac{Q_d}{\Delta t_d . C_d . \rho_d}$

$\rho_d = 0,83.10^3\ kg/m^3$ specific gravity of the oil

$C_d = 2,18\ kJ/kgK$ the specific heat of the oil

$\Delta t_d = 20 \div 40K$ The difference of the temperature of the oil in and out of the compressor

The preferred temperature of the oil when sprayed into the compressor is in the range $30 \div 40$°C. The temperature rise of the oil in the compressor takes approx $20 \div 40K$. Heat of oil from refrigerant Q_d, we have:

$Q_d = G.(i_{2"} - i_{2'})$ = 7,73x(438.25 – 420.44) = 137,67 kW

In which:

$$i_{2"} = i_{1'} + \frac{i_2 - i_{1'}}{\eta_i} = 410,80 + \frac{435,37 - 410,80}{0,895} = 438,25\ kJ/kg$$

So:

$$V_d = \frac{Q_d}{\Delta t_d . c_d . \rho_d} = \frac{137,67}{20.2,18.0,83.10^3} = 3,8\ l/s$$

5.2.2 Choose the chiller combination:

4 sets of product LG Model RCWW036CA2A

Specification | 60Hz

LG Life's Good

R134a (60Hz)

Model		Units	RCWW022CA2A	RCWW024CA2A	RCWW026CA2A	RCWW028CA2A	RCWW032CA2A	RCWW036CA2A	RCWW040CA2A
Standard Condition	Cooling capacity	kW	726	783	849	912	1,095	1,217	1,298
		usRT	206.4	222.5	241.5	259.3	311.4	346.1	369.1
	Input Power	kW	151.87	164.01	177.89	182.51	227.03	240.05	261.89
	COP		4.8	4.8	4.8	5	4.8	5.1	5
AHRI Conditions	Cooling capacity	kW	734.53	791.98	859.6	922.88	1,108.64	1,231.96	1,314.09
		usRT	208.9	225.2	244.4	262.4	315.2	350.3	373.6
	Input Power	kW	145.73	157.38	170.67	175.14	217.82	230.33	251.25
	COP		5	5	5	5.3	5.1	5.3	5.2
	IPLV		6.44	6.43	6.47	6.74	6.53	6.85	6.73
General Unit Data	Number of Circuits		2	2	2	2	2	2	2
	Refrigerant, R-134a	kg	95 / 95	100 / 100	110 / 110	115 / 115	145 / 145	160 / 160	175 / 175
	Oil Charge	l	18 / 18	20 / 20	23 / 23	20 / 20	28 / 28	28 / 28	28 / 28
Weight	Shipping Weight	kg	4,460	4,600	4,720	4770	5,580	5,910	5,930
	Operating Weight	kg	4,780	4,940	5,080	5,150	6,040	6,430	6480
Compressors	Compressor type		Semi-hermetic twin screw						
	Quantity	EA	2	2	2	2	2	2	2
Condenser	Evaporator type	kW	Shell and Tube						
	Water Volume	kW	59	61	61	65	80	86	86
	Max. Water Pressure	MPa	1	1	1	1	1	1	1
	Max. Refrigerant Pressure	Mpa	1	1	1	1	1	1	1
	Min. Cooling Water Flow Rate	l/s	13.6	14.6	14.6	16.9	19	21.6	21.6
	Max. Cooling Water Flow Rate	l/s	54.4	58.6	58.6	67.7	76	86.5	86.5
	Water Connections	DN	150	150	150	150	200	200	200
Evaporator	Evaporator type		Shell and Tube						
	Water Volume	l	67	83	83	87	92	112	112
	Max. Water Pressure	MPa	1	1	1	1	1	1	1
	Max.Refrigerant Pressure	Mpa	1	1	1	1	1	1	1
	Min.Chilled Water Flow Rate	l/s	12.6	13.8	13.8	15.7	18	20.2	20.2
	Max.Chilled Water Flow Rate	l/s	50.2	55.1	55.1	62.8	71.8	80.9	80.9
	Water Connections	DN	150	150	150	150	200	200	200