Әл-Фараби атындағы Қазақ Ұлттық Университеті
Механика-математика факультеті

Континенталды климат жағдайында тұрғын үйлерді жоғарыпотенциалды жылумен қамтамасыз етуге арналған **Жылу Насостарының** жұмыс режимдерін модельдеу

Орындаған: Ердеш Е.Б.

Ғылыми жетекшілер: Туралина Д.Е.
Беляев Е.К.

Кіріспе

Алматы, Қазақстан

Қысқы жылыту маусымы

Жазғы маусым

- Жылыту жүйелерінде көмірсутекті отын түрлерін қолдану
  1. тыныс алу органдары, өкпе ауруларына;
  2. аллергиялық ауруларға;
  3. генетикалық өзгерістерге себепші болады

  Алматы, Астана, Өскемен, Шымкент және т.б. қалаларда

- Жасыл энергия көзін қолдану бұл экологиялық мәселені шешеді
- Қазіргі уақытта Қазақстанда жылу насостары іс жүзінде қолданылмайды

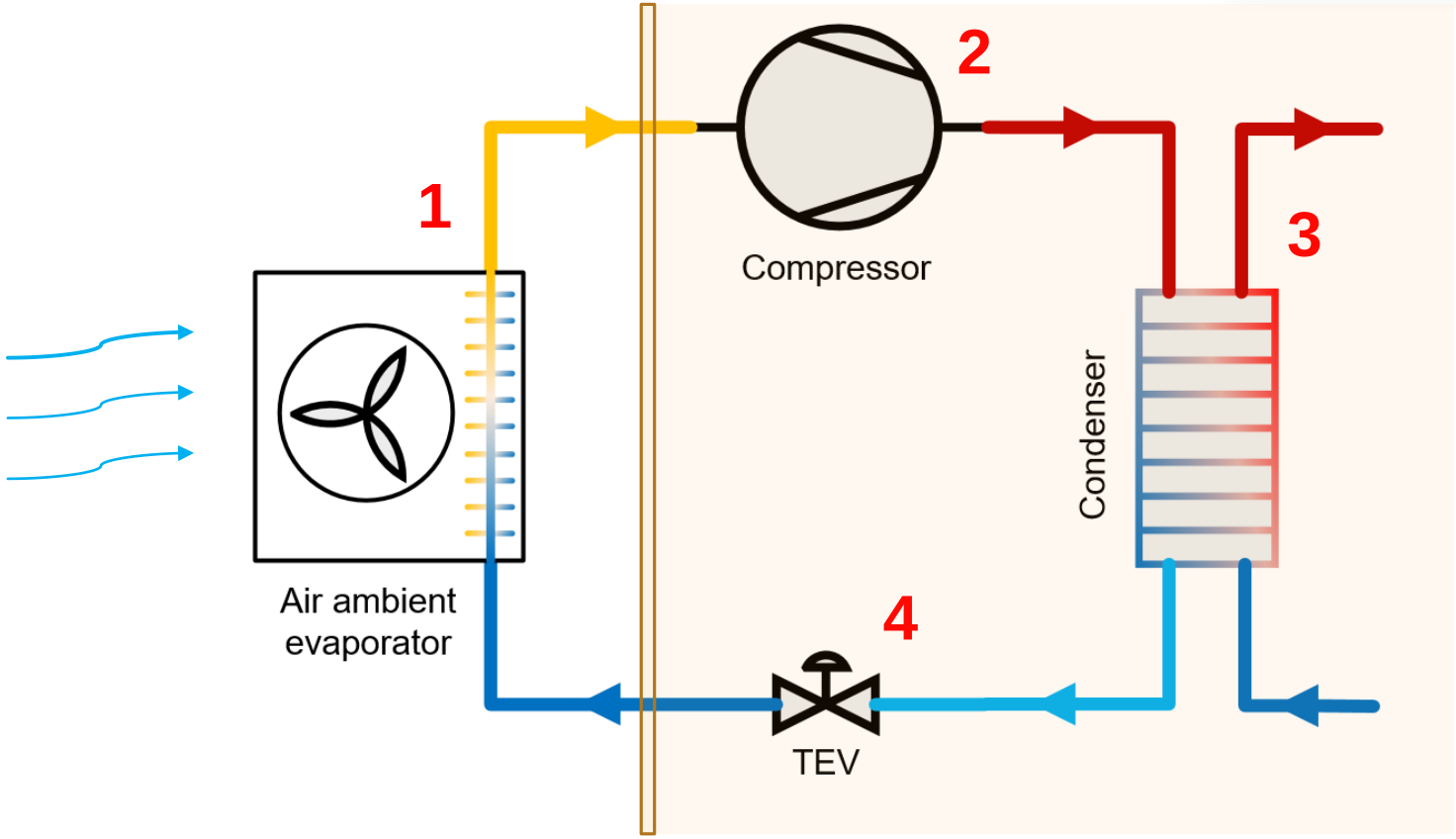
Жылу насосы

1 – Булану; **2 –** Қысымын арттыру; **3 –** Конденсация; **4 –** Қысымын төмендету

Өзектілігі

- Ғимараттарды жылыту және ыстық сумен жабдықтау жүйесінде жылу насосын пайдалану;
- Қазақстанның климаттық жағдайына арналған жылу насостарын ұсыну.

Жылу насосы компоненттері



1 – Буландырғыш;
2 – Компрессор;
3 – Конденсатор;
4 – Кеңейткіш клапан.
5 – Хладагент

Жұмыстың мақсаты

1. **Ауа жылу насосы**
    - Математикалық моделін құру (энергиялық баланс);
    - Сандық/Тәжірибелік зерттеулер;
    - Нәтижелерді талдау (ПӘК, СОР).
2. **Каскадты ауа жылу насосы**
    - Математикалық моделін құру;
    - Сандық/Тәжірибелік зерттеулер;
    - Нәтижелерді талдау.
3. **Автокаскадты күн жылу насосы**
    - Математикалық моделін құру;
    - Сандық зерттеулер;
    - Нәтижелерді талдау.

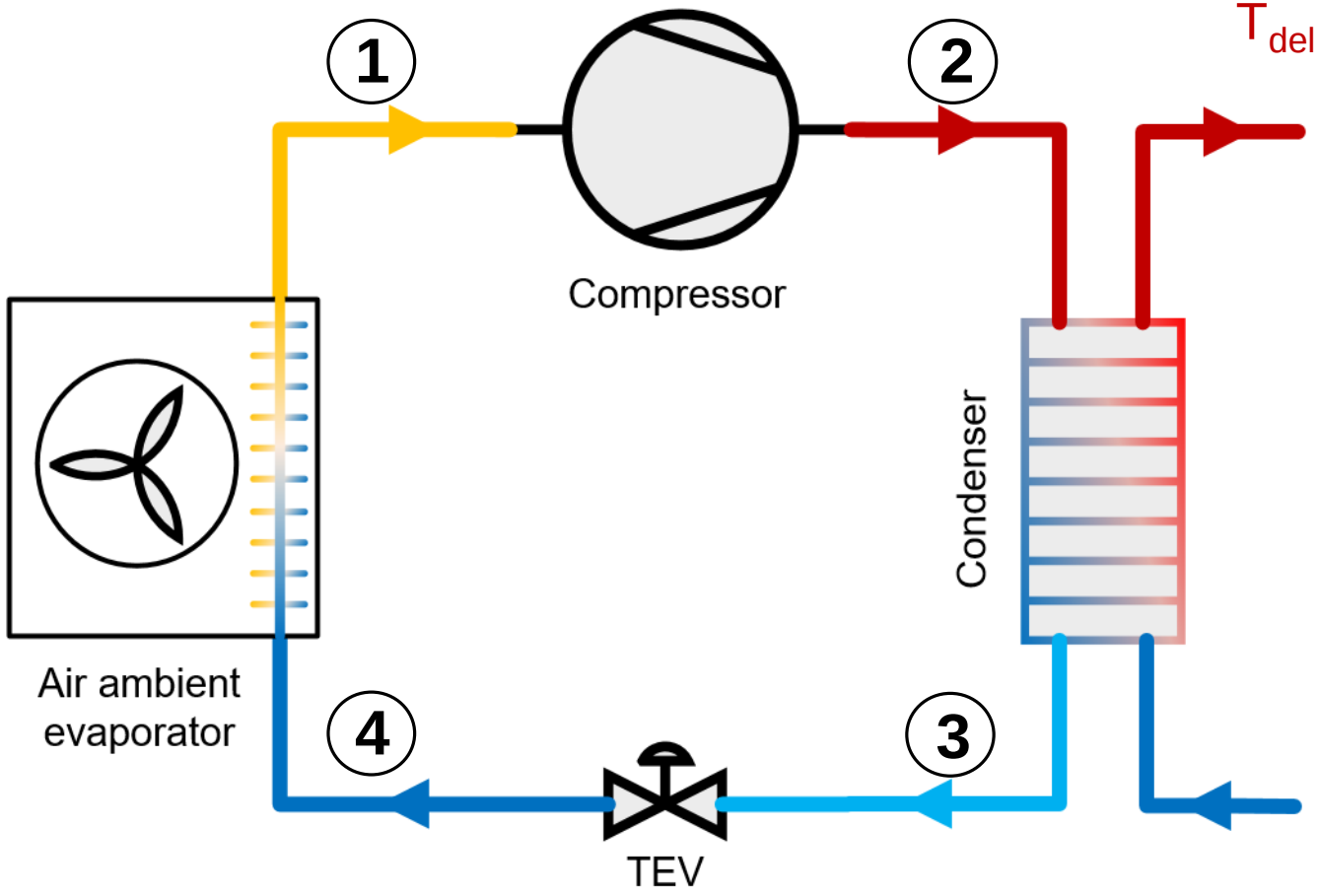
1. Ауа жылу насосы

$Q_{evap} + W_{comp} = Q_{cond} = Q_{hp}$

$Q_{hp} = 7$ кВт

$T_{del} = 50$ °C

$W_{comp} = ?$



$Q_{evap} = ?$

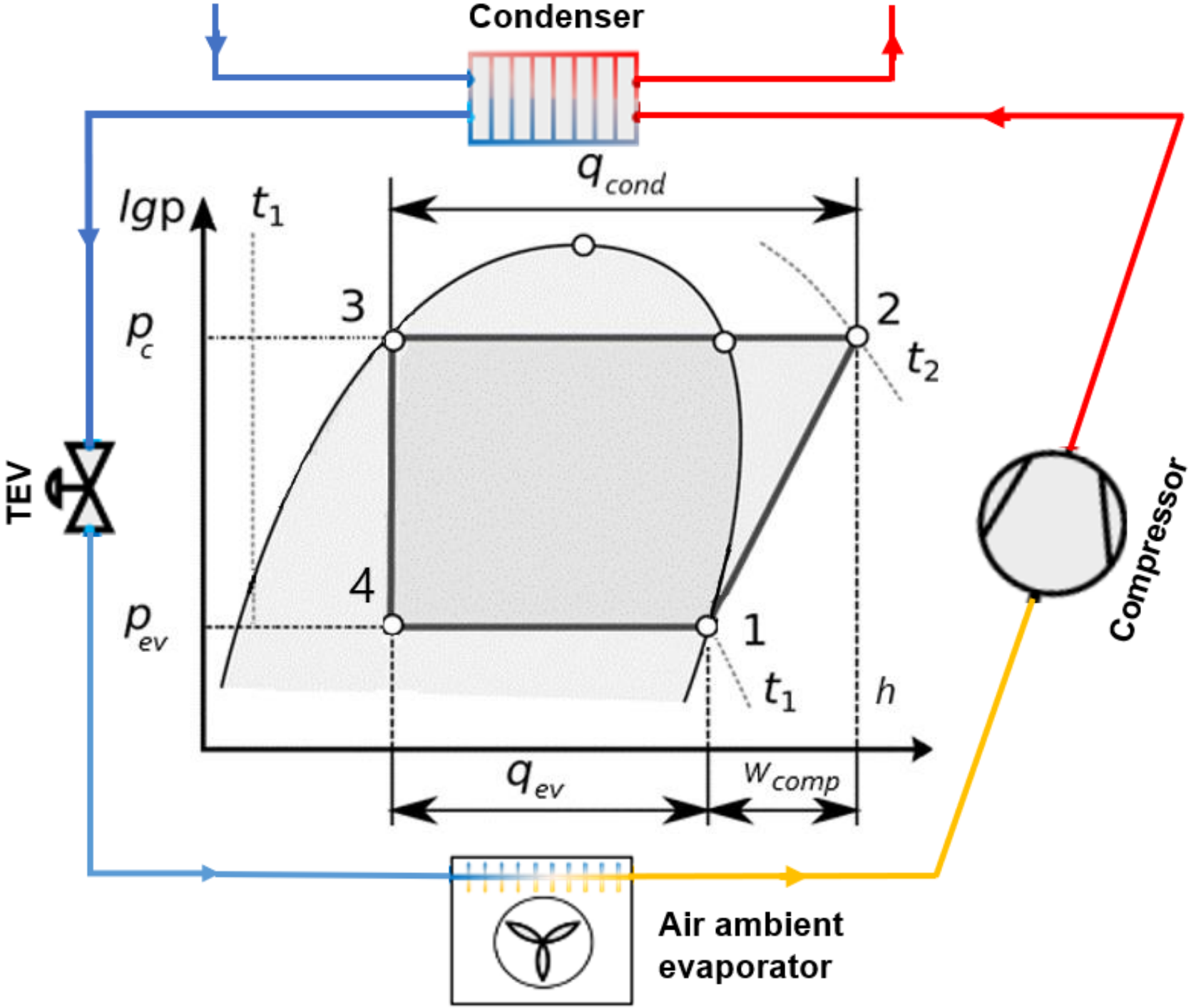
$T_{amb} = -10$ °C

Mass rate = ?

Inlet, Outlet T = ?

Max, Min T = ?

Max, Min P = ?



1-2 compression (adiabatic)
s=const

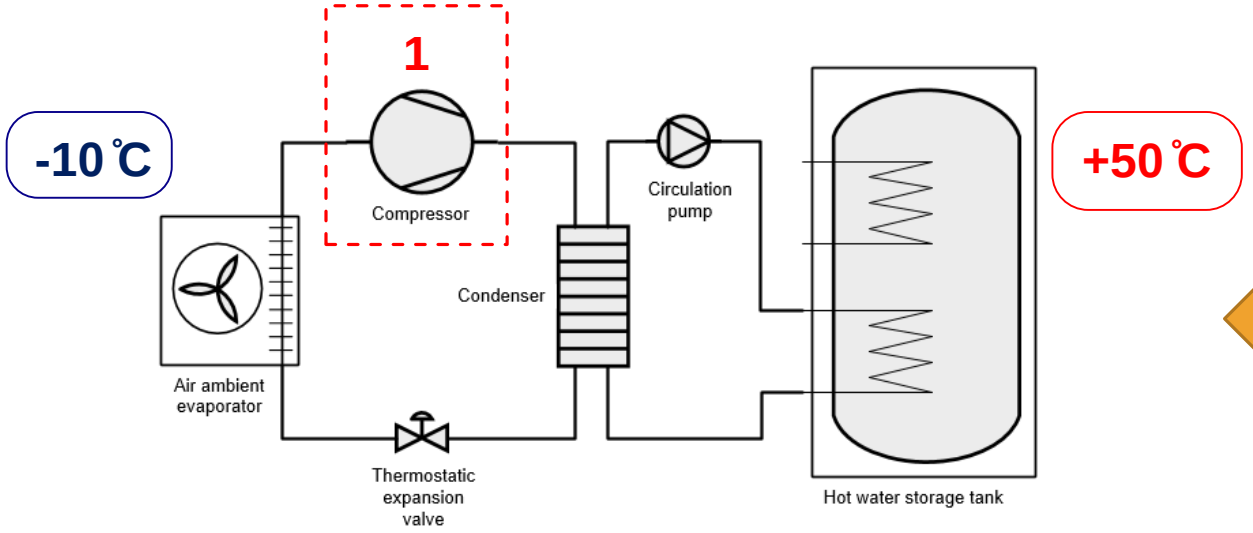
2-3 condensation (isothermal)
t= const

3-4 throttling
h = const

4-1 boiling (isothermal)
t=const

$\boldsymbol{q_{ev}}$ – specific heat of evaporation of the refrigerant;
$\boldsymbol{w_{comp}}$ – specific work of compression of the refrigerant;
$\boldsymbol{q_{cond}}$ – specific heat of condensation of the refrigerant.

Каскадты жылу насосы

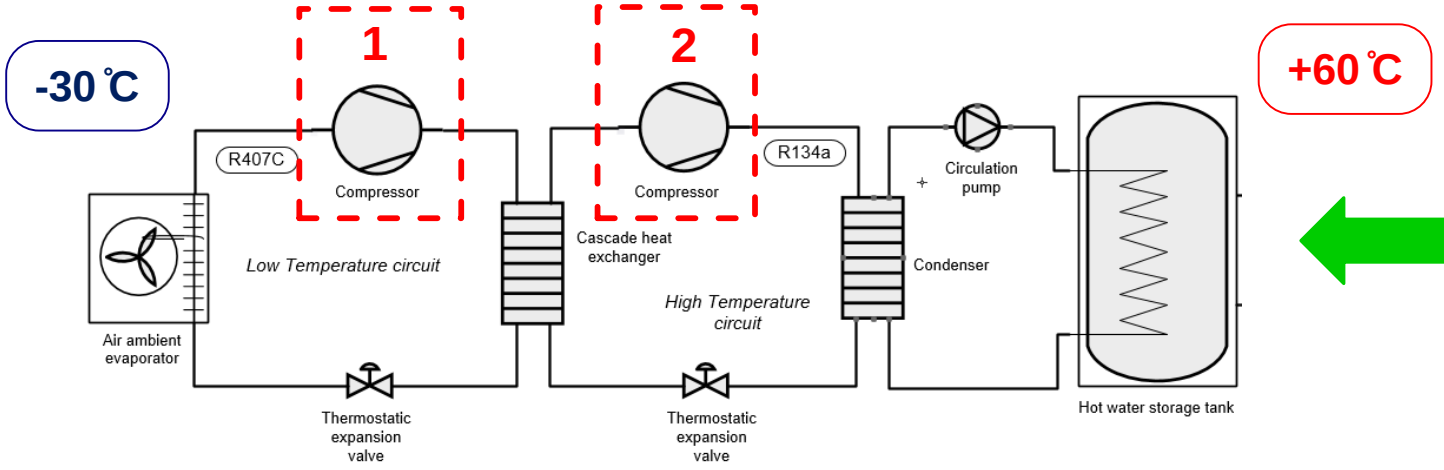


Ауа жылу насосы:

COP = 2.0-3.5

Қоршаған орта темп. **-10 ℃**

Жылыту контуры **+50 ℃**



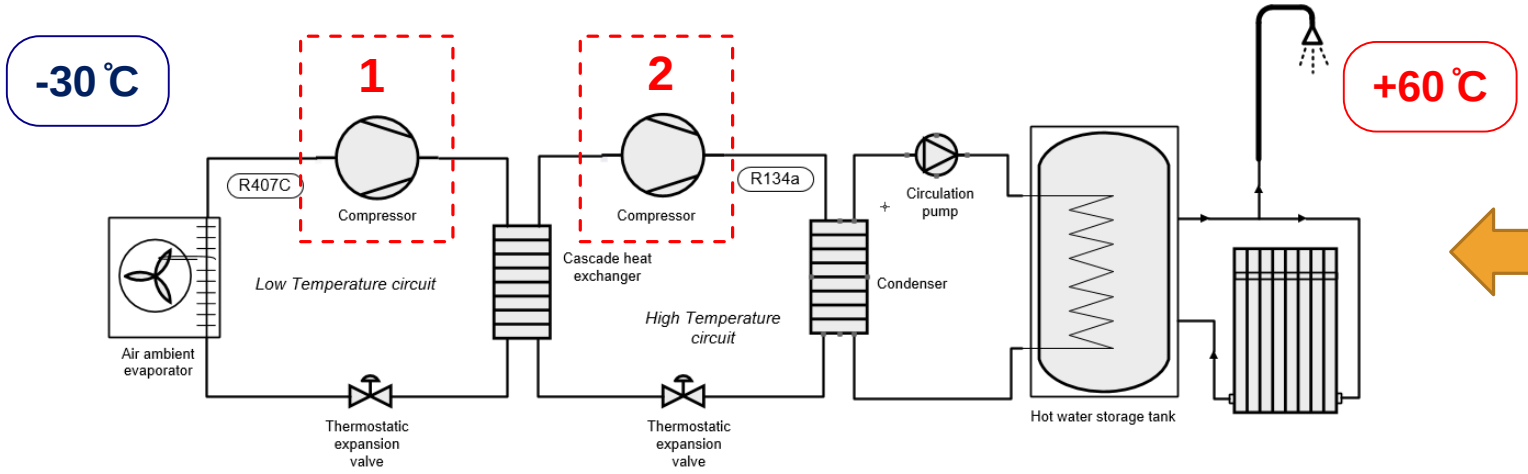
Каскадты ауа жылу насосы:

COP = 1.7-3.0

Қоршаған орта темп. **-30 ℃**

Жылыту контуры **+60 ℃**

Автокаскадты жылу насосы

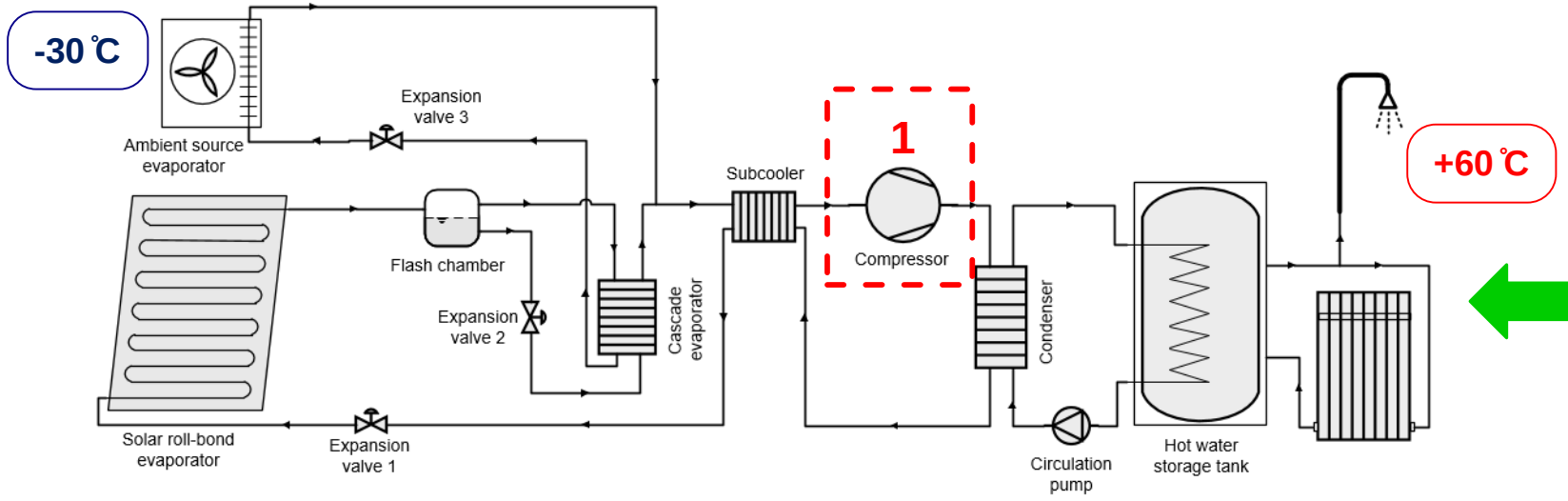


Каскадты ауа жылу насосы:

COP = 1.7-3.0

Қоршаған орта темп. **-30 ℃**

Жылыту контуры **+60 ℃**



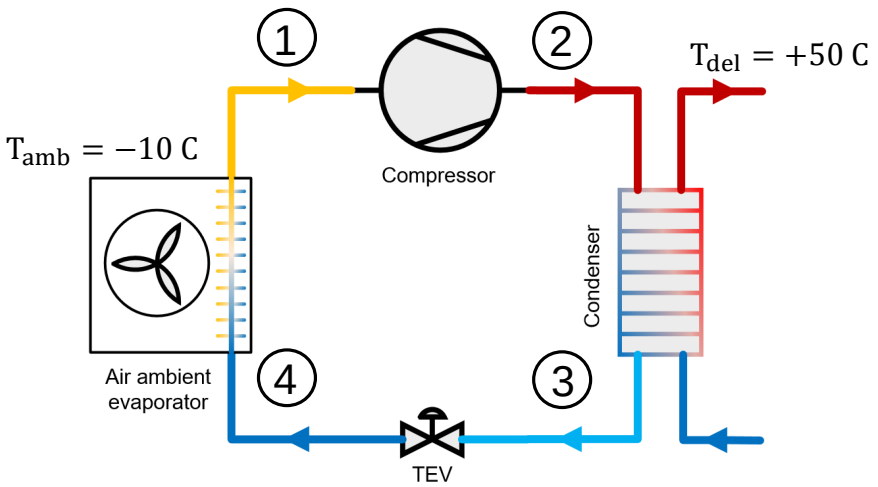
Автокаскадты жылу насосы:

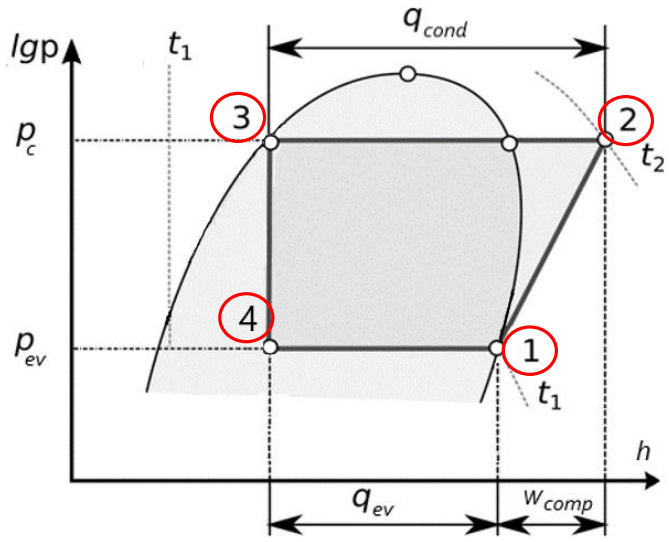
COP = 2.0-4.0

Қоршаған орта темп. **-30 ℃**

Жылыту контуры **+60 ℃**

Математикалық моделі





1

$$T_1 = T_{amb} - CAT$$
$$P_1 = P(T_1; x_1)$$

$$h_1 = h(T_1; P_1)$$
$$s_1 = s(T_1; P_1)$$

2

$$P_2 = P_3$$
$$\boxed{h_2 = ?}$$

$$T_2 = T(P_2; h_2)$$
$$s_2 = s(P_2; h_2)$$

4

$$P_4 = P_1$$
$$h_4 = h_3$$

$$T_4 = T(P_4; h_4)$$
$$s_4 = s(P_4; h_4)$$

3

$$T_3 = T_{del} + CAT$$
$$P_3 = P(T_3; x_3)$$

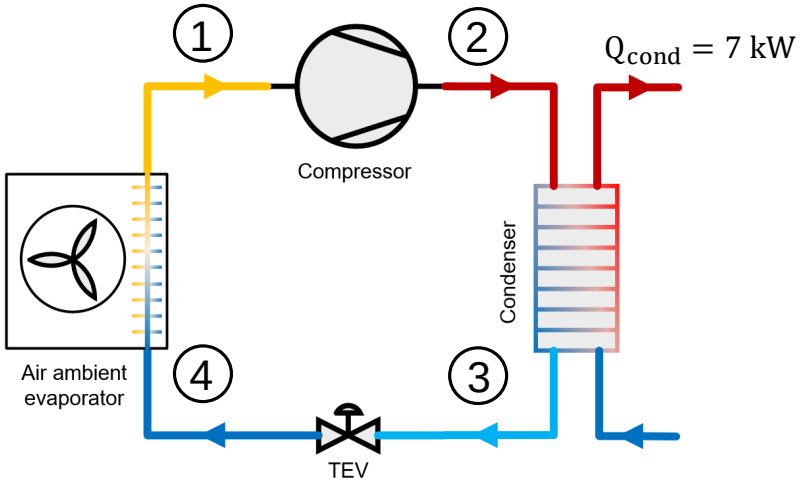
$$h_3 = h(T_3; P_3)$$
$$s_3 = s(T_3; P_3)$$

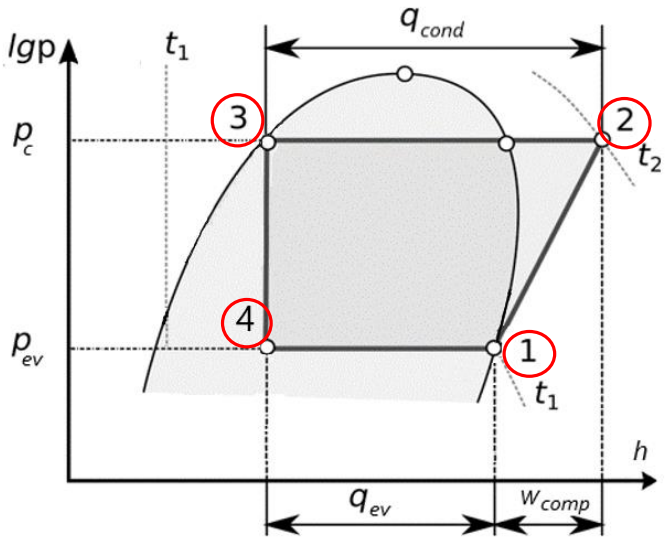
$$T_{amb} = -10\ C$$
$$x_1 = 1$$
$$CAT = 5\ C$$

$$T_{del} = +50\ C$$
$$x_3 = 0$$

CAT – *closest approach temperature*

Математикалық моделі





Evaporator:

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

Compressor:

$$W_{comp} = \dot{m}(h_2 - h_1)$$

$$W_{comp} = \dot{m}(h_{s,2} - h_1)/\eta_{comp}$$

$$h_{s,2} = h(P_2; s_1)$$

Condenser:

$$Q_{cond} = \dot{m}(h_2 - h_3)$$

$$COP = \frac{Q_{cond}}{W_{comp}}$$

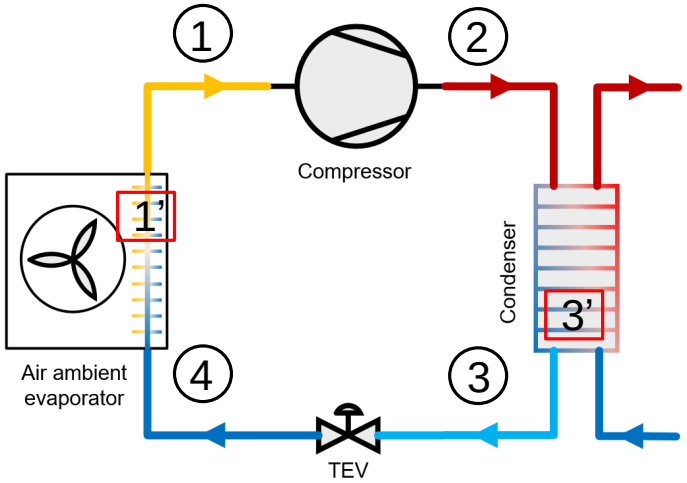
$$P_{ratio} = \frac{P_2}{P_1}$$

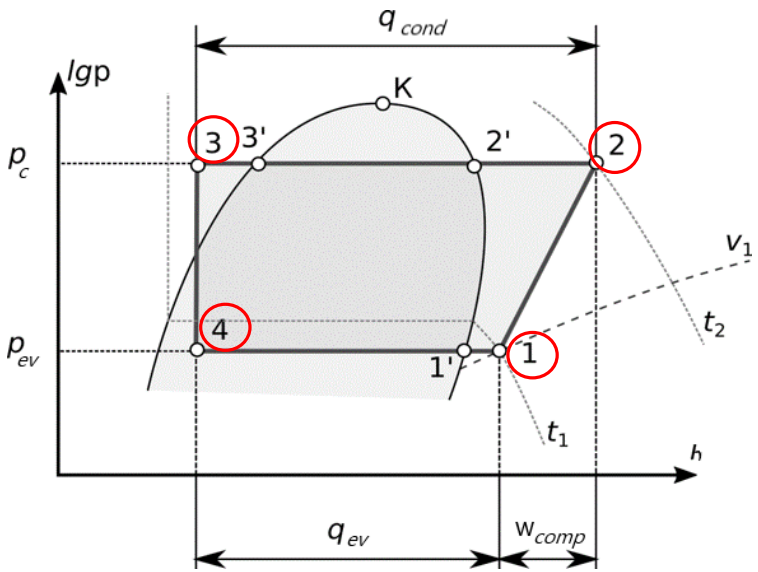
$h_2 = ?$

$\eta_{comp} = 0.8$

$Q_{cond} = 7\ kW$

Математикалық моделі





1

$$T_1 = T_{amb} - CAT$$
$$P_1 = P(T_1 - Sup_{heat}; x_1)$$

$$h_1 = h(T_1; P_1)$$
$$s_1 = s(T_1; P_1)$$

2

$$P_2 = P_3$$
$$h_2 = ?$$

$$T_2 = T(P_2; h_2)$$
$$s_2 = s(P_2; h_2)$$

4

$$P_4 = P_1$$
$$h_4 = h_3$$

$$T_4 = T(P_4; h_4)$$
$$s_4 = s(P_4; h_4)$$

3

$$T_3 = T_{del} + CAT$$
$$P_3 = P(T_3 + Sub_{cool}; x_3)$$

$$h_3 = h(T_3; P_3)$$
$$s_3 = s(T_3; P_3)$$

$$T_{amb} = -10\ C$$
$$x_1 = 1$$

$$Sup_{heat} = 5\ C$$

$$T_{del} = +50\ C$$
$$x_3 = 0$$

$$Sub_{cool} = 5\ C$$

EES (Engineering Equation Solver) бағдарламасы

Equations Window

```
"!(1) Evaporator outlet / Compressor inlet"
T[1]        = T_amb - CAT_evap
P[1]=propssi('P','T',(T[1]-Sup_evap)/1[K],'Q',1,f$)*1[Pa]
//P[1]        = p_sat(F$, T=T[1]-Sup_evap)
h[1]        = enthalpy(F$, T=T[1], P=P[1])
s[1]        = entropy(F$, T=T[1], P=P[1])


"!(2) Compressor outlet / condenser inlet"
m[2]        = m[1]

P[2]=propssi('P','T',(T[3]+Sub_cond)/1[K],'Q',0,f$)*1[Pa]
//P[2]        = p_sat(F$, T=T[3]+Sub_cond)
h_s[2]      = enthalpy(F$, P=P[2], s=s[1])
W_comp      = m[2]*(h_s[2] - h[1])/eta_comp
W_comp      = m[2]*(h[2] - h[1])
T[2]        = temperature(F$, h=h[2], P=P[2])
s[2]        = entropy(F$, h=h[2], P=P[2])


"!(3) Condenser outlet / expansion valve inlet"
m[3]        = m[2]
P[3]        = P[2]
h[3]        = enthalpy(F$, T=T[3], P=P[3])
s[3]        = entropy(F$, T=T[3], P=P[3])
Q_cond      = m[3]*(h[2] - h[3])


"!(4) Expansion valve outlet / Evaporator inlet"
m[4]        = m[3]
h[4]        = h[3]
P[4]        = P[1]
s[4]        = entropy(F$, h=h[4], P=P[4])
T[4]        = temperature(F$, h=h[4], P=P[4])
x[4]        = quality(F$, h=h[4], P=P[4])
Q_evap      = m[4]*(h[1] - h[4])

"!(5) "
h[5]=h[1]
```

US | Line: 22 | Char: 2 | Wrap: On | Insert | Caps Lock: Off | SI K Pa J mass deg | Warnings: On | Unit Chk: Auto | Complex: Off | Syntax Highlight:On

Update | Menu

Main Program

CAT_cond [K]
CAT_evap [K]
COP_heat
eta_comp
F$
h[] [J/kg]
h_s[] [J/kg]
m[] [kg/s]
P[] [Pa]
P_rat
Q_cond [W]
Q_evap [W]
Sub_cond [K]
Sup_evap [K]
s[] [J/kg-K]
T[] [K]
T_amb [K]
T_del [K]
W_comp [W]
x[]

Solution

Main

Unit Settings: SI K Pa J mass deg

CAT_{cond} = 7 [K] CAT_{evap} = 7 [K] COP_{heat} = 2.325 η_{comp} = 0.8 F$ = 'r410A' P_{ra}

Sub_{cond} = 5 [K] Sup_{evap} = 5 [K] T_{amb} = 263.2 [K] T_{del} = 323.2 [K] W_{comp} = 3011 [W]

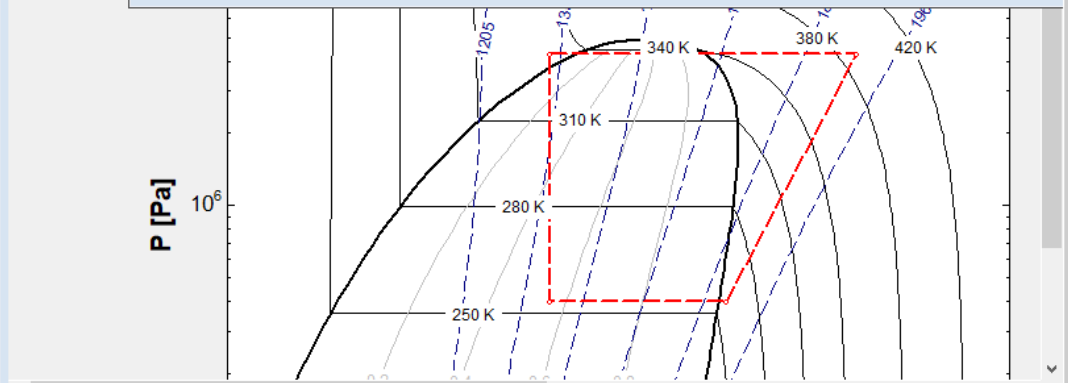
Arrays Table

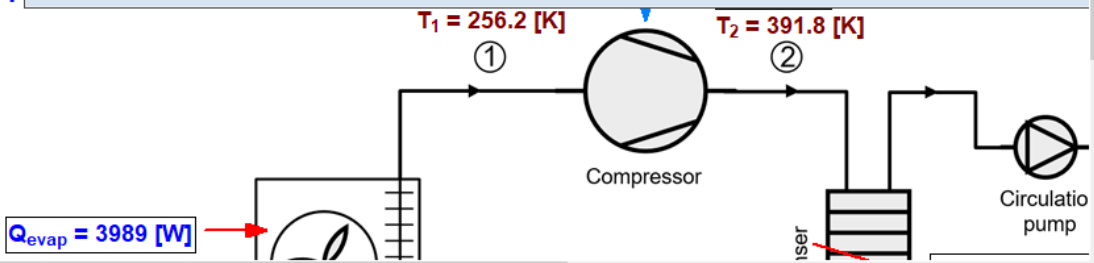
Main

Sort	h_i [J/kg]	$h_{s,i}$ [J/kg]	m_i [kg/s]	P_i [Pa]	s_i [J/kg-K]	T_i [K]
[1]	418058		0.0336	370105	1875	256.2
[2]	507664	489742	0.0336	4.014E+06	1921	391.8
[3]	299340		0.0336	4.014E+06	1318	330.2
[4]	299340		0.0336	370105	1402	251.1
[5]	418058			370105	1875	256.2

P-h: R410A

P-h: R134a

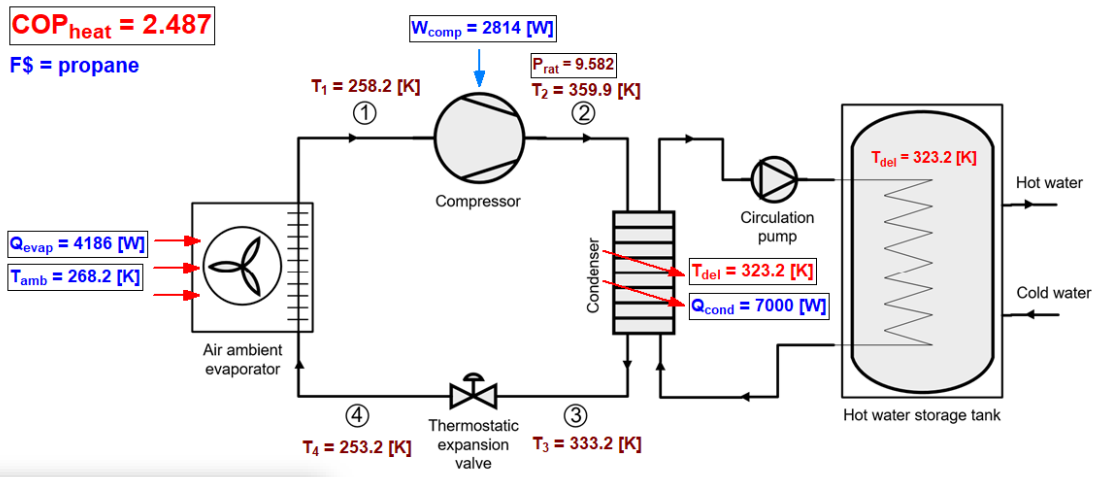


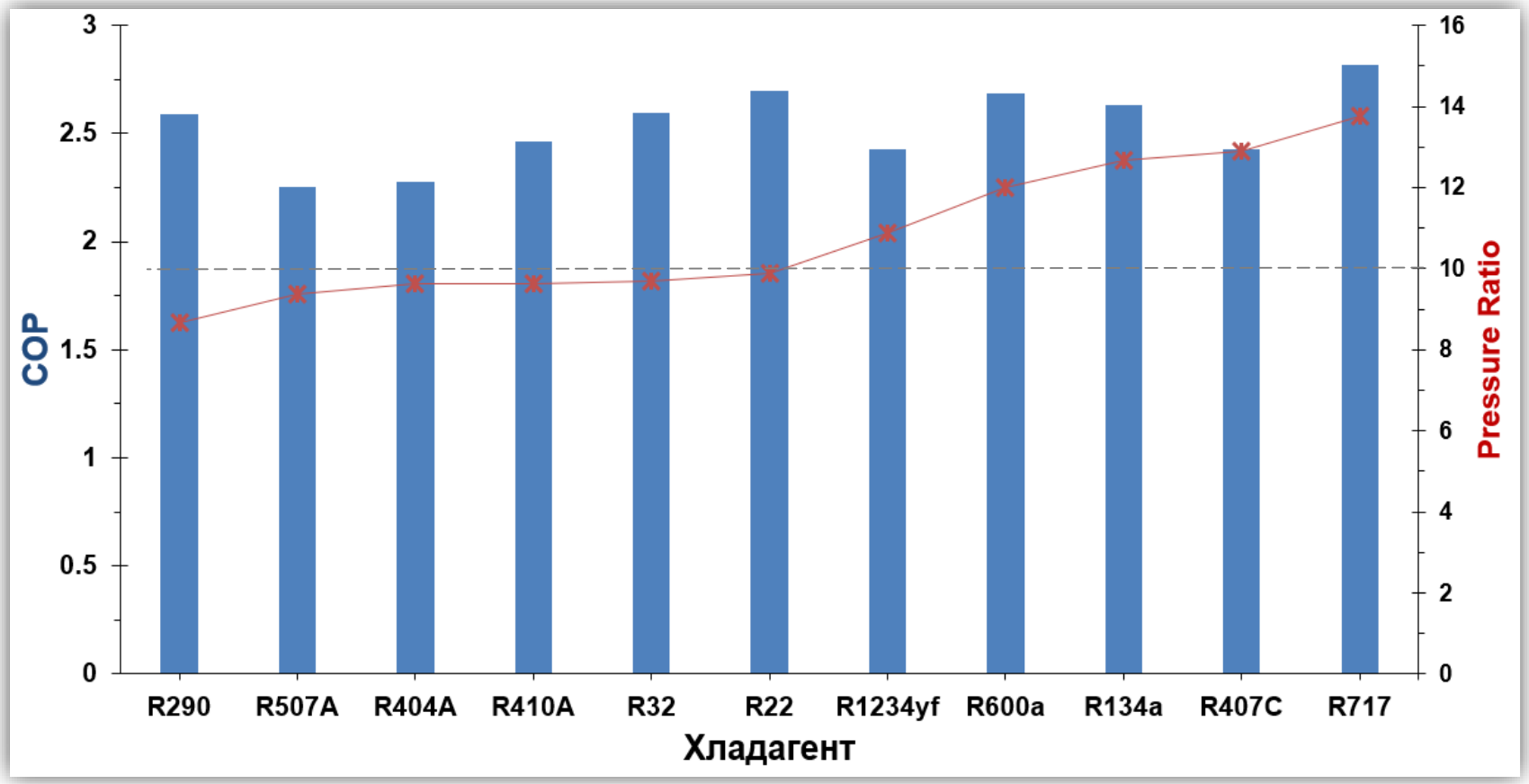


Хладагенттер

Хладагент	Химиялық формуласы	Критикалық қасиеттері		Қайнау температурасы, қ.ж. (ºC)	ASHRAE Code	ODP R11 = 1	GWP
		Температура (ºC)	Қысым (МПа)				
R22	$CHCLF_2$	96,2	4,99	-41,4	A1	0,034	1700
R32	CH_2F_2	78,2	5,8	-51,7	A1	0	550
R134a	$CH_2F\text{-}CF_3$	101,1	4,06	-26,1	A1	0	1410
R290	C_3H_8	96,7	4,25	-42,2	A3	0	20
R404A	(R134a+R125+R143a)	72,0	3,78	-46,3	A1	0	3750
R407C	(R32+R125+R134a)	87,3	4,63	-43,8	A1	0	1700
R410A	(R32 + R125)	72,0	4,93	-51,5	A1	0	1890
R507A	(R125 + R143a)	71	3,72	-47	A1	0	3900
R600a	C_4H_{10}	134,7	3,64	-11,7	A3	0	20
R717	NH_3	132,3	11,39	-33,6	B2	0	0
R1234yf	$C_3H_2F_4$	94,0	3,38	-30,0	A2L	0	4

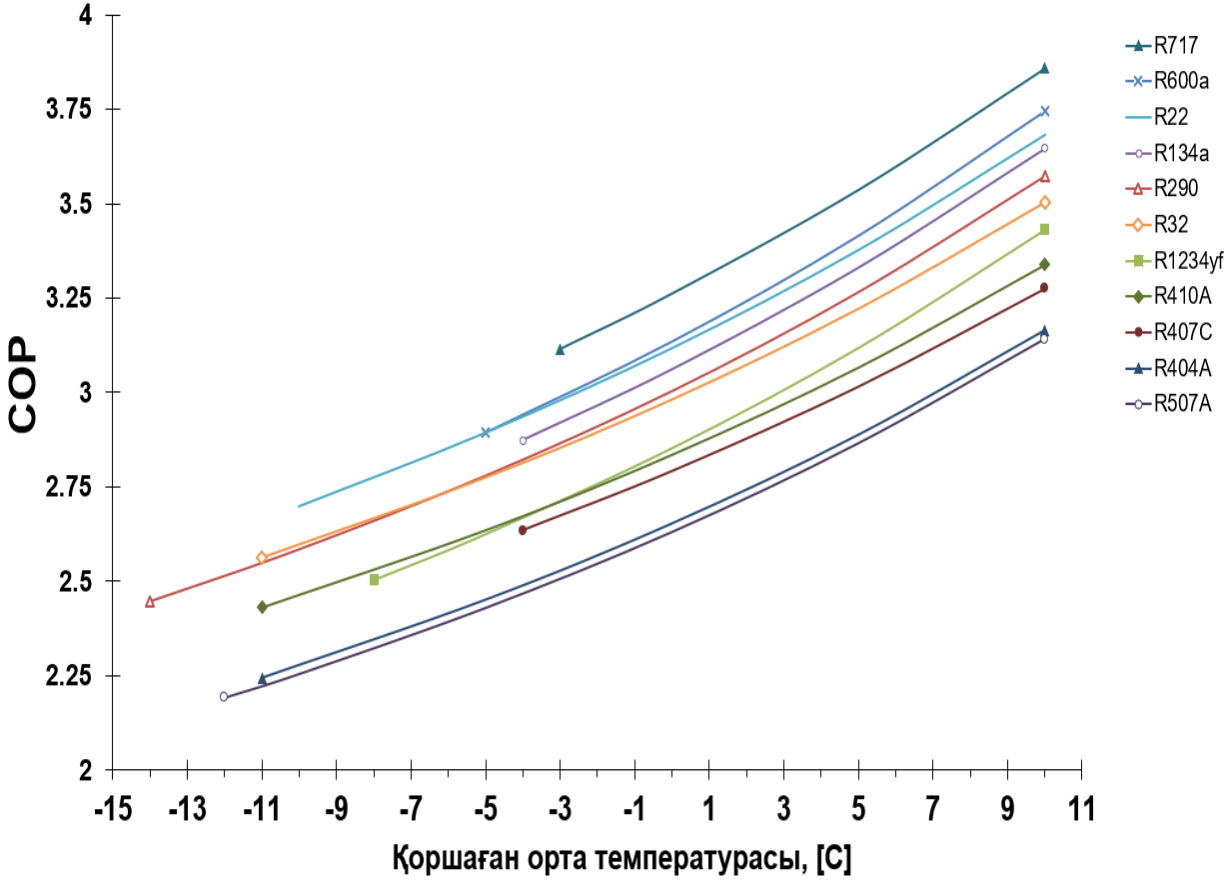
Нәтижелерді талдау



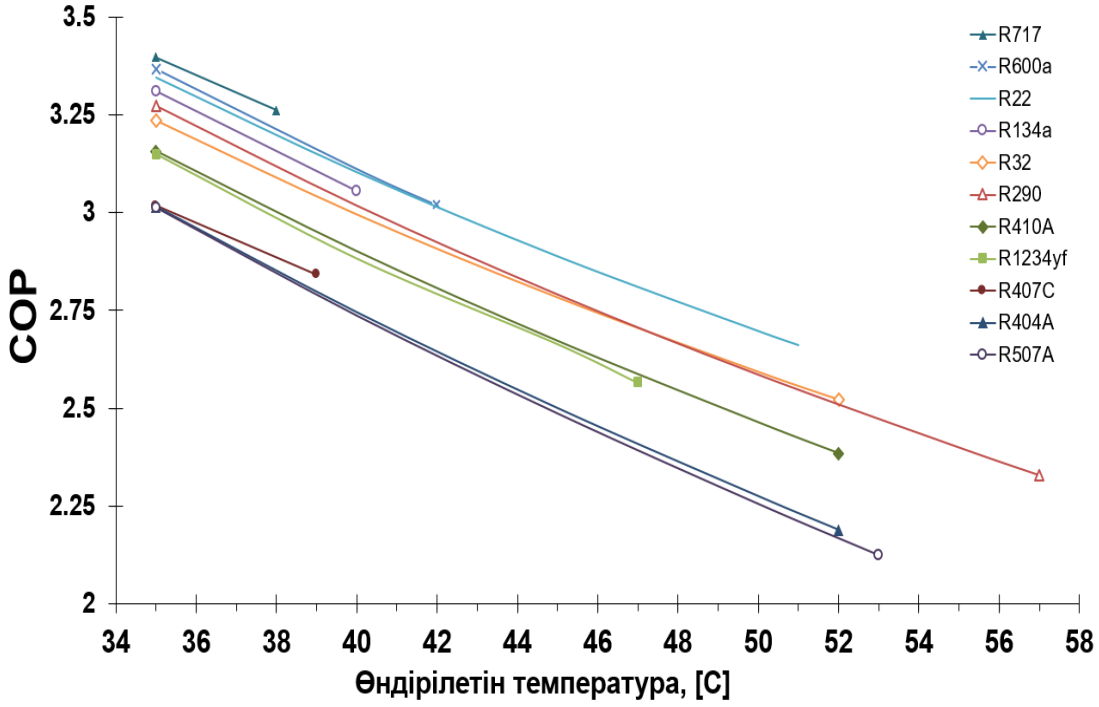


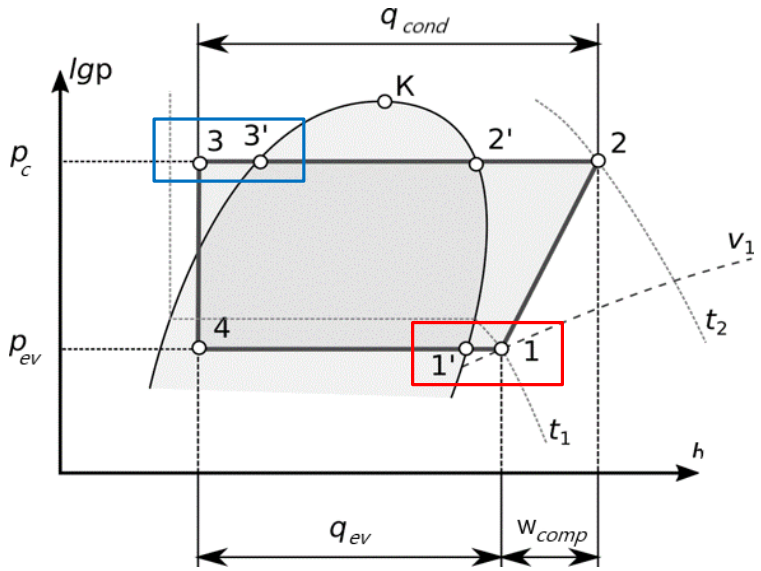
Нәтижелерді талдау

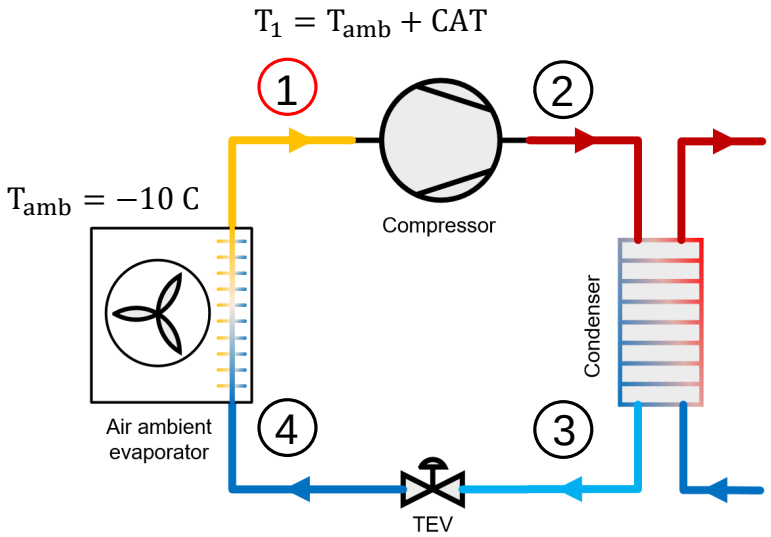
$T_{del} = +50\ C$

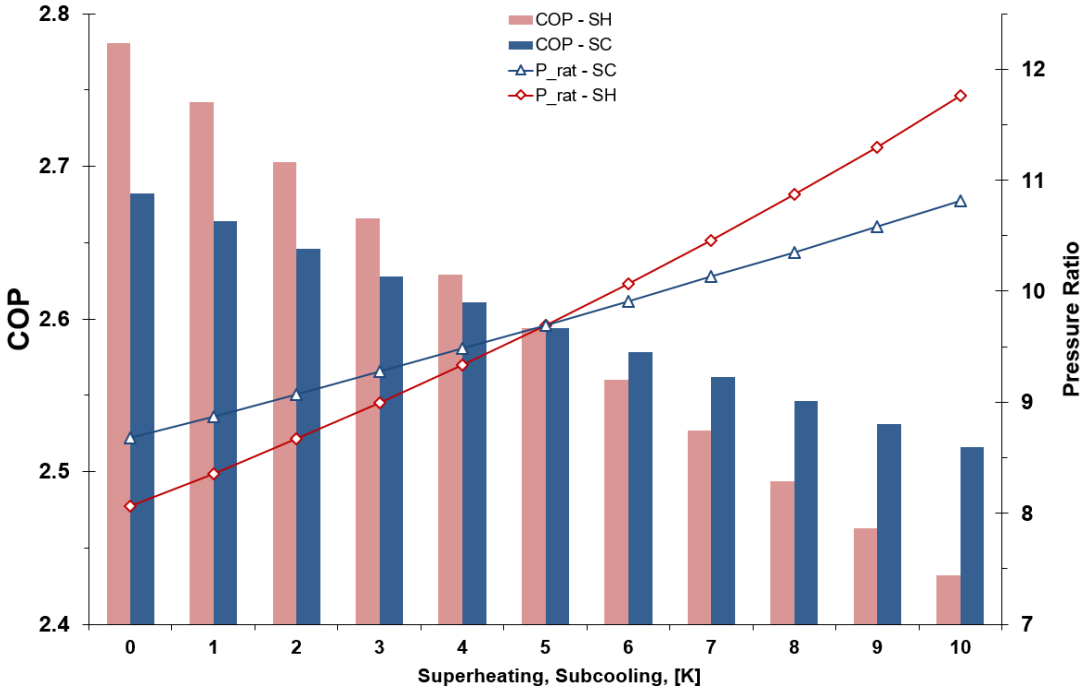


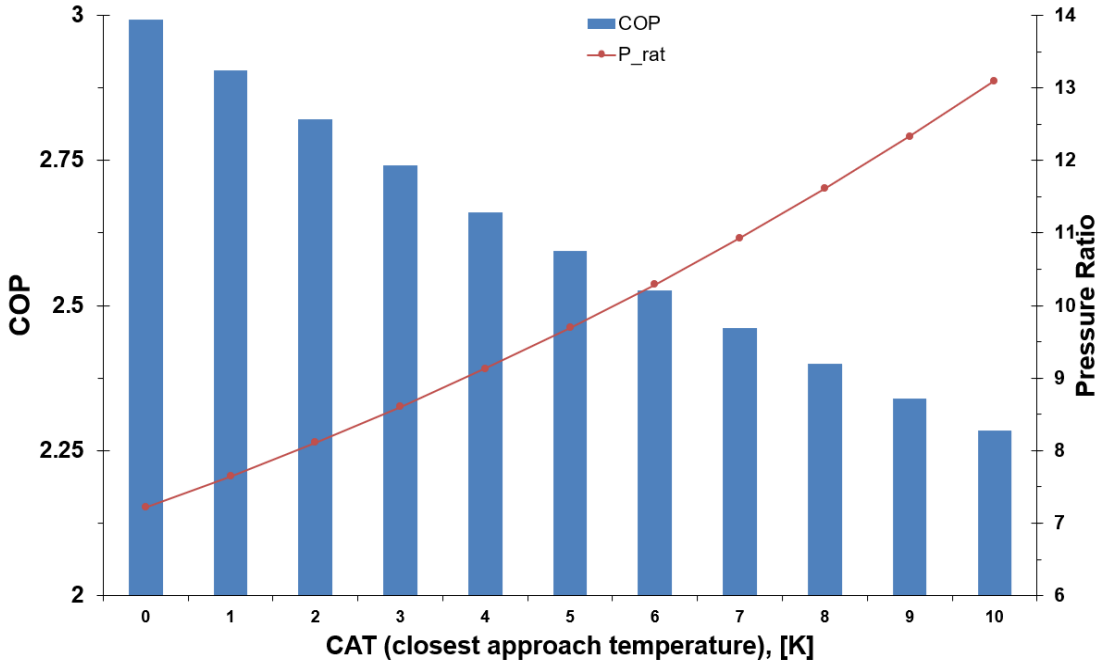
$T_{amb} = -10\ C$




q cond
lgp
K
3
3'
2'
2
p c
v 1
t 2
4
p ev
1'
1
t 1
h
q ev
w comp


T1 = Tamb + CAT
1
2
Tamb = −10 C
Compressor
Condenser
Air ambient
evaporator
4
3
TEV


COP - SH
COP - SC
P_rat - SC
P_rat - SH
COP
Pressure Ratio
Superheating, Subcooling, [K]


COP
P_rat
COP
Pressure Ratio
CAT (closest approach temperature), [K]

Нәтижелері

Compressor: **2.8 kW** input power, 7 kW heat capacity;
Evaporator: **4.7 kW** heat capacity;
Condenser: **7 kW** heat capacity.

Mass rate: 0.0336 kg/s; Max. T: **115 C**; Min. T: **-20 C**;
Max. P: **38 bar**; Min. P: **4 bar.**

T_amb	eta_comp	Sh-Sb	COP	P_ratio	W_comp	Q_evap	Q_cond
-15	0.8	5	2.311	11.67	3000	4000	7000
-10			2.463	9.623	2800	4200	
-5			2.636	8.005	2700	4300	
0			2.836	6.71	2500	4500	
5			3.067	5.665	2300	4700	
10			3.339	4.815	2100	4900	
15			3.662	4.118	1900	5100	

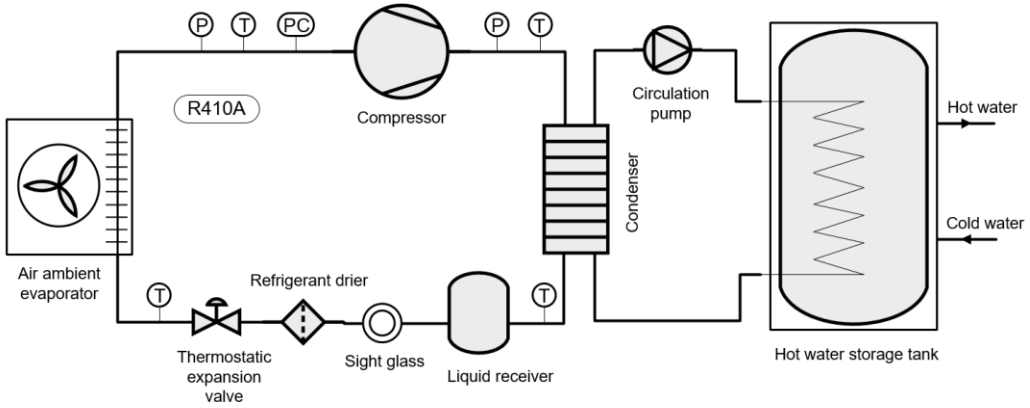
Ауа жылу насосы

Q_{cond} = 7 кВт

COP = 2.0-3.5

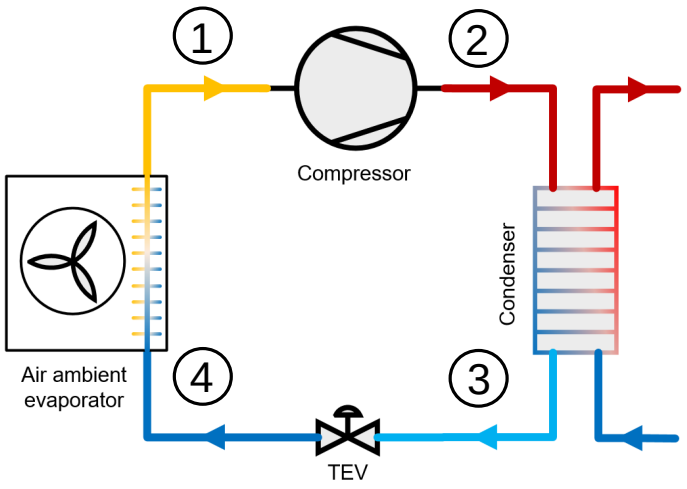
T_{amb} = -10 ℃

T_{del} = +50 ℃




GREE

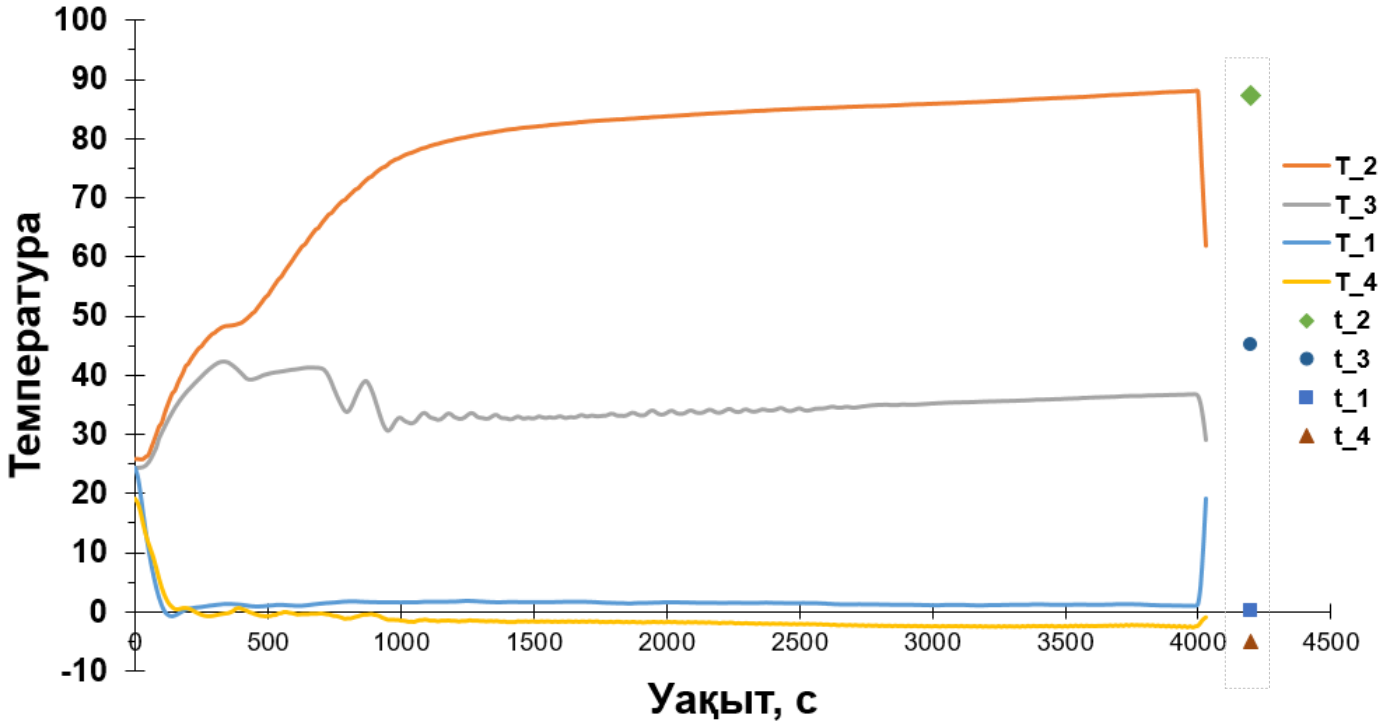
Тәжірибе нәтижесі



Модель:

T_{amb} = 5 C
T_{del} = 40 C
Supcooling = 5 C
Superheating = 5 C
CAT = 5 C
$\eta_{comp} = 0.8$

COP = 2,86

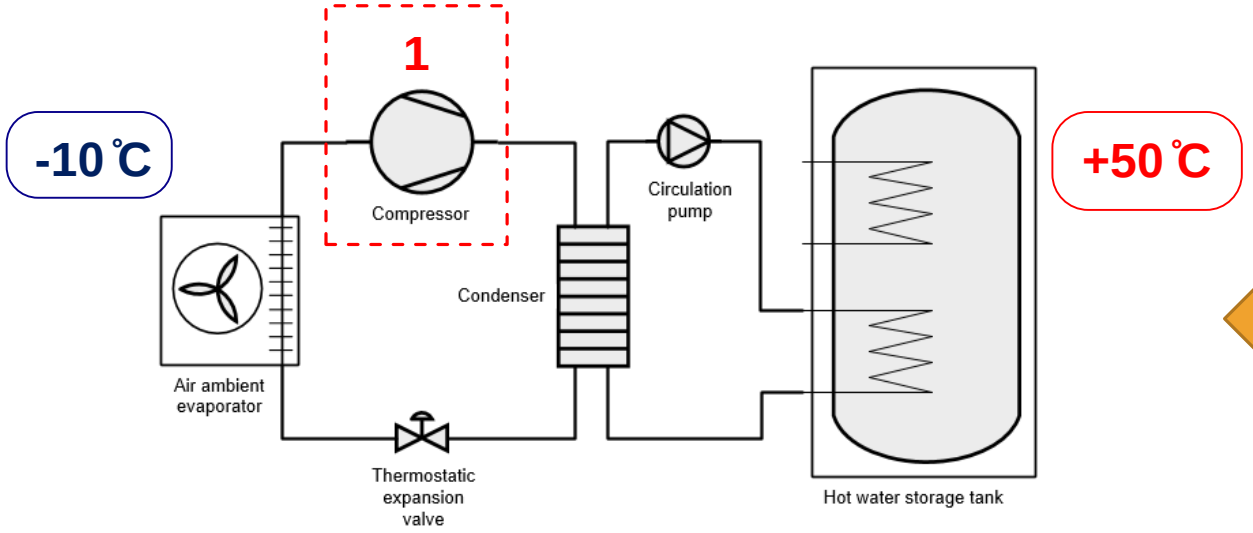


Тәжірибе:

18.01.19ж, сағат 17:30-18:30
T_{amb} = 0-2 C
T_{del} = 38-42 C

COP = 2 – 2,75

2. Каскадты жылу насосы

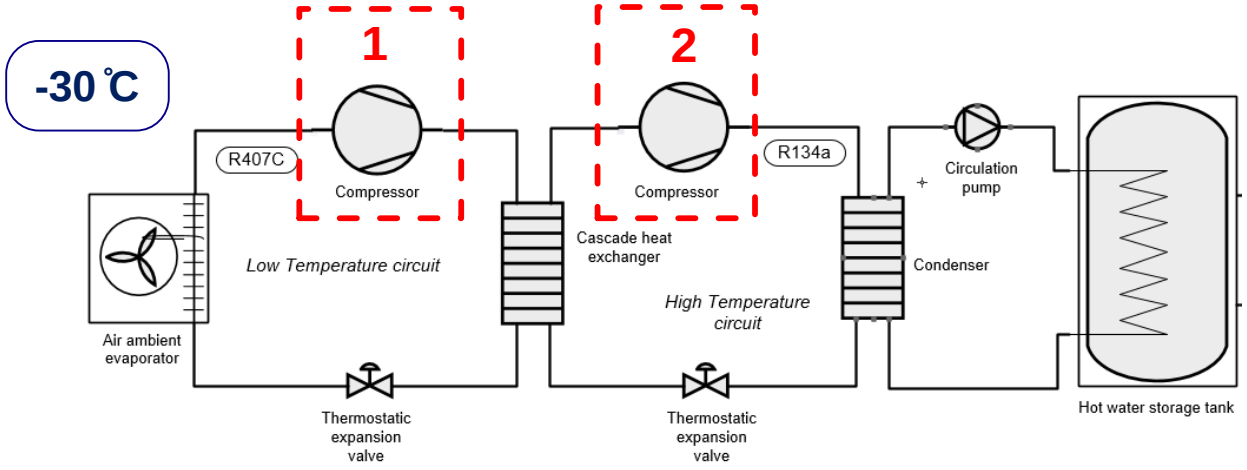


Ауа жылу насосы:

COP = 2.0-3.5

Қоршаған орта темп. **-10 ℃**

Жылыту контуры **+50 ℃**



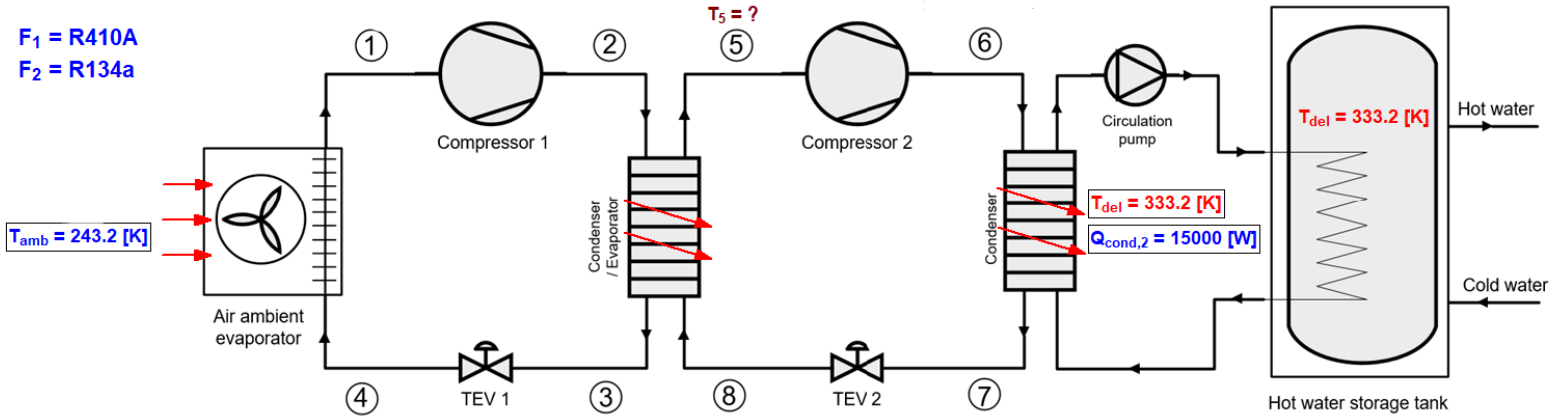
Каскадты ауа жылу насосы:

COP = 1.7-3.0

Қоршаған орта темп. **-30 ℃**

Жылыту контуры **+60 ℃**

2.Каскадты жылу насосы



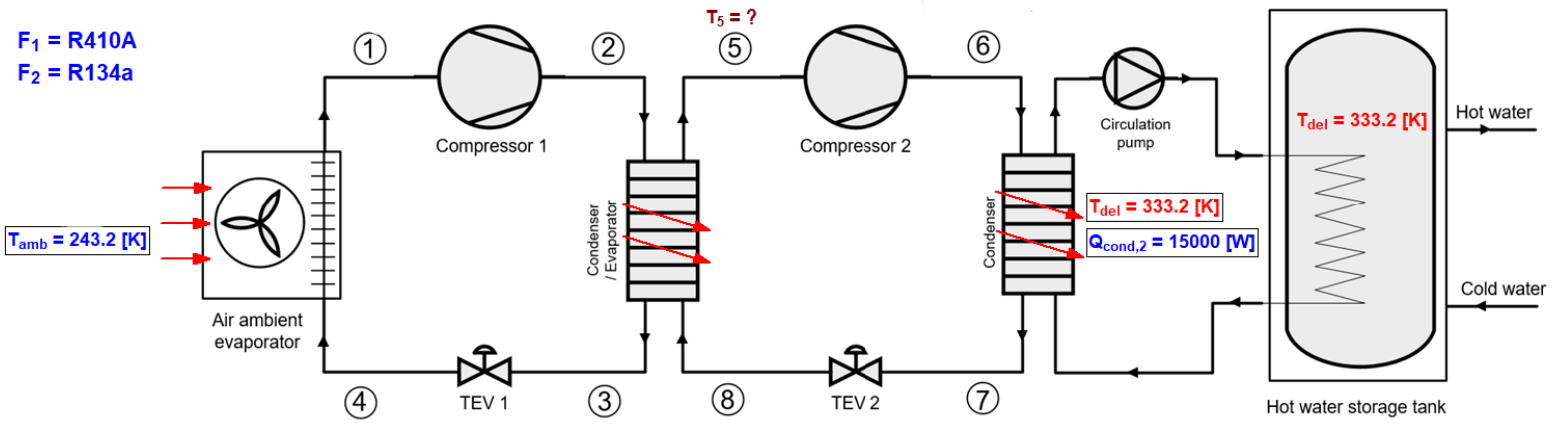
① $T_1 = T_{amb} - CAT$ $P_1 = P(T_1 - Sup_{heat}; x_1)$ $h_1 = h(T_1; P_1)$ $s_1 = s(T_1; P_1)$	② $P_2 = P_3$ $h_2 = ?$ $h_2 = h(T_2; P_2)$ $s_2 = s(T_2; P_2)$	⑤ $T_5 = ?$ $P_5 = P(T_5 - Sup_{heat}; x_5)$ $h_5 = h(T_5; P_5)$ $s_5 = s(T_5; P_5)$	⑥ $P_6 = P_7$ $h_6 = ?$ $h_6 = h(T_6; P_6)$ $s_6 = s(T_6; P_6)$
④ $P_4 = P_1$ $h_4 = h_3$ $T_4 = T(P_4; h_4)$ $s_4 = s(P_4; h_4)$	③ $T_3 = T_5 + CAT$ $P_3 = P(T_3 + Sub_{cool}; x_3)$ $h_3 = h(T_3; P_3)$ $s_3 = s(T_3; P_3)$	⑧ $P_8 = P_5$ $h_8 = h_7$ $T_8 = T(P_8; h_8)$ $s_8 = s(P_8; h_8)$	⑦ $T_7 = T_{del} + CAT$ $P_7 = P(T_7 + Sub_{cool}; x_7)$ $h_2 = h(T_2; P_2)$ $s_2 = s(T_2; P_2)$

$T_{amb} = -30\ C$
$Sup_{heat} = 5\ C$
$x_1 = 1$

$Sub_{cool} = 5\ C$
$x_3 = 0$

$T_5 = !$
$x_5 = 1$

$T_{del} = +60\ C$
$x_7 = 0$



$$Q_{ev,1} = \dot{m}_I(h_1 - h_4)$$

Evaporators:

$$Q_{ev,2} = \dot{m}_{II}(h_5 - h_8)$$

$$W_{comp,1} = \dot{m}_I(h_2 - h_1)$$
$$W_{comp,1} = \dot{m}_I(h_{s,2} - h_1)/\eta_{comp}$$
$$h_{s,2} = h(P_2; s_1)$$

Compressors:

$$W_{comp,2} = \dot{m}_{II}(h_6 - h_5)$$
$$W_{comp,2} = \dot{m}_{II}(h_{s,6} - h_5)/\eta_{comp}$$
$$h_{s,6} = h(P_6; s_5)$$

$$Q_{cond,1} = \dot{m}_I(h_2 - h_3)$$
$$Q_{cond,1} = Q_{ev,2}$$

Condensers:

$$Q_{cond} = \dot{m}_{II}(h_6 - h_7)$$

$$COP = \frac{Q_{cond}}{W_{comp,1} + W_{comp,2}}$$

$$P_{ratio,1} = \frac{P_2}{P_1}$$
$$P_{ratio,2} = \frac{P_6}{P_5}$$

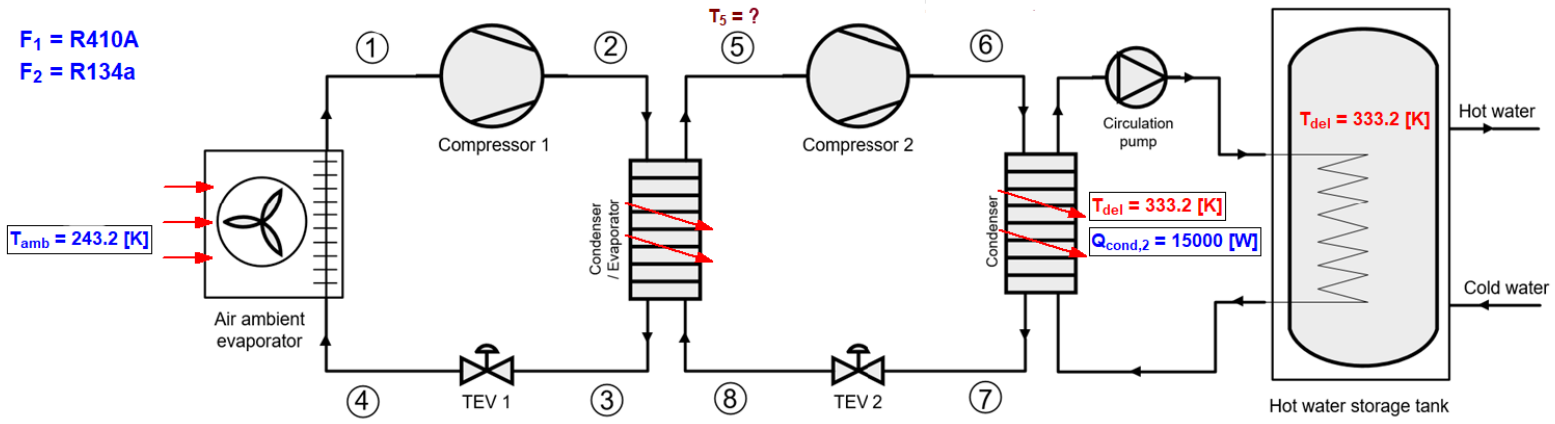
$$h_2 = ?$$
$$h_6 = ?$$
$$T_5 = ?$$

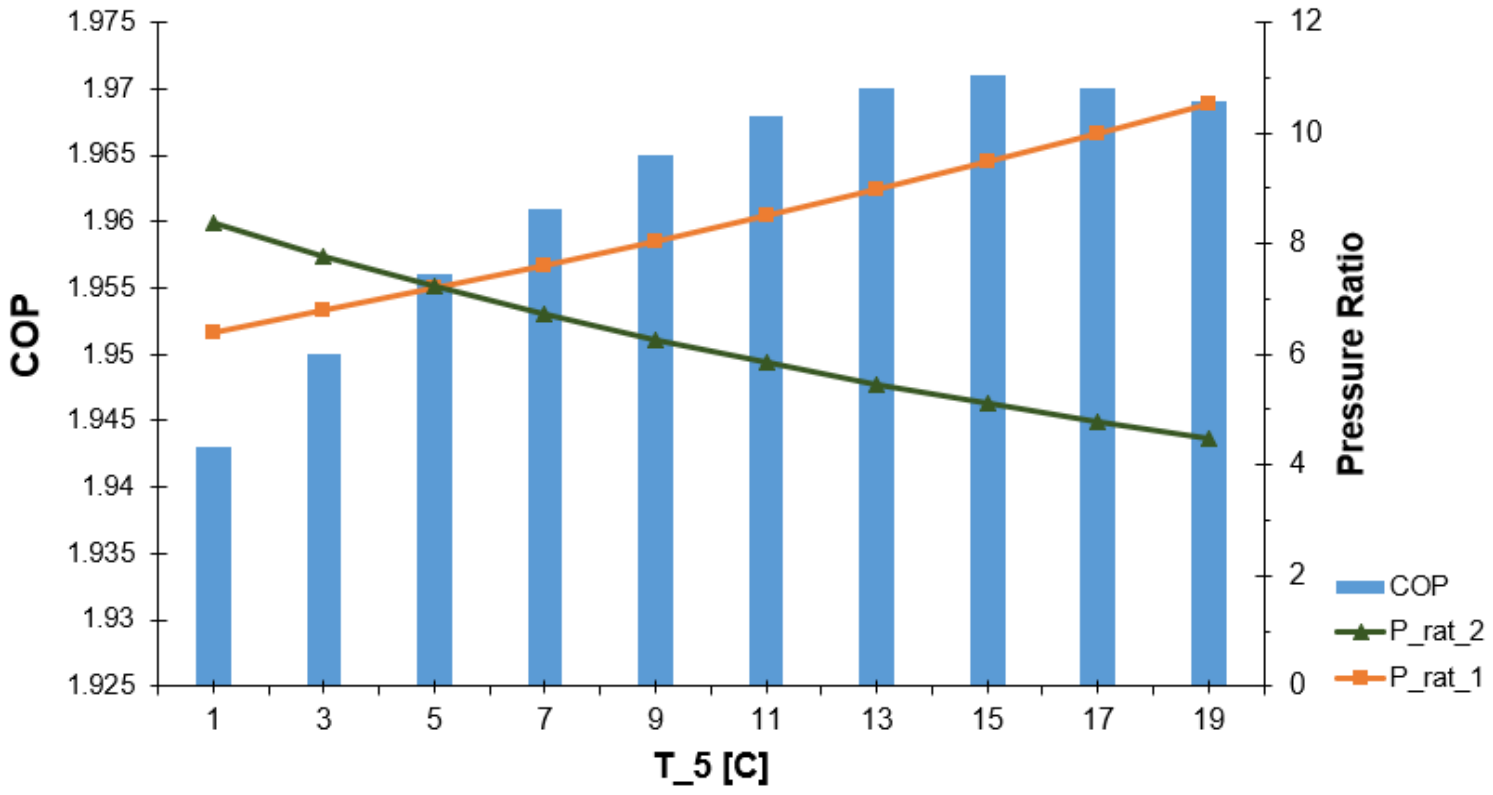
$$\eta_{comp} = 0.8$$

$$Q_{cond} = 15\ kW$$

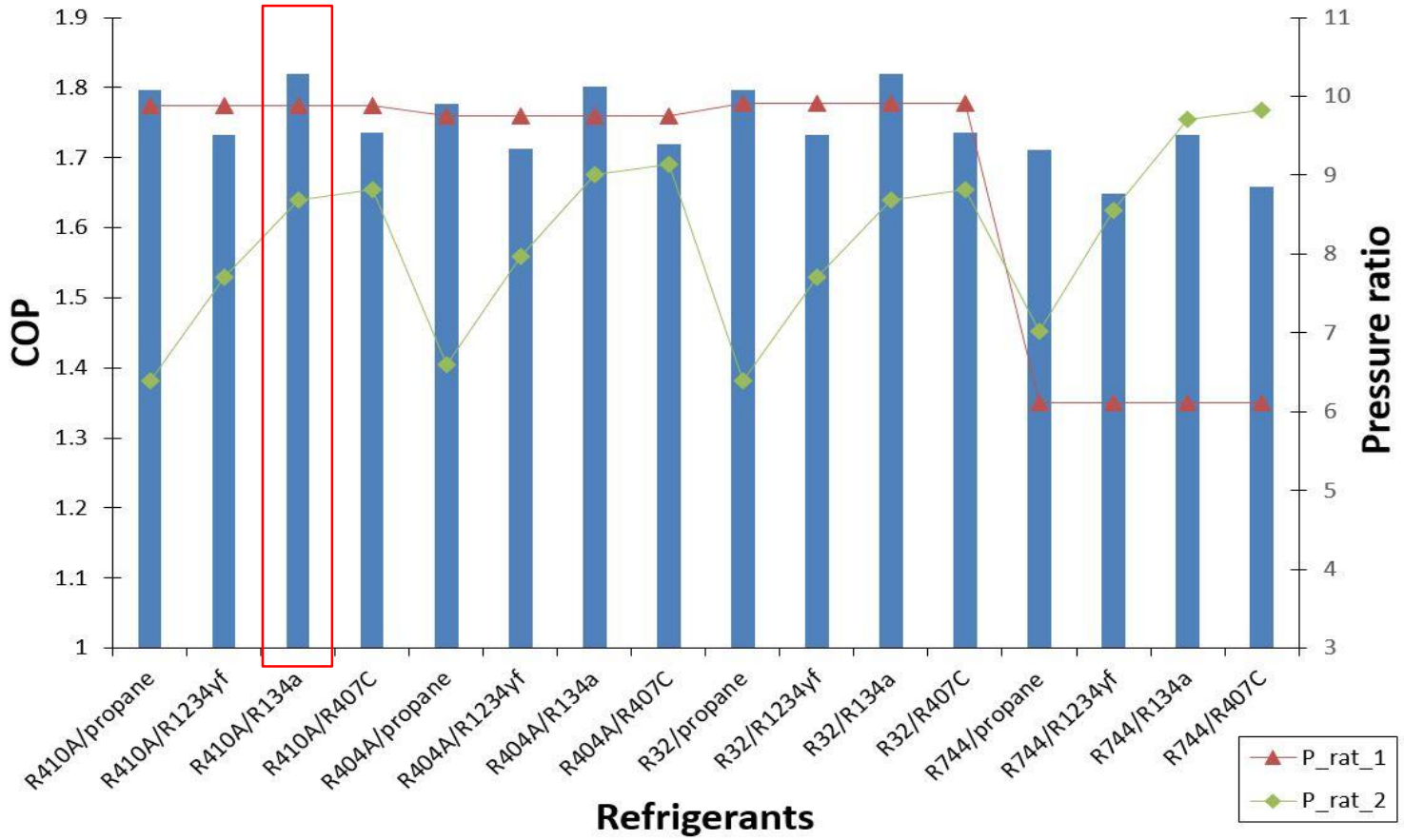
$$\begin{cases} T_{amb} < T_5 < T_{del} \\ Max(COP) \\ P_{ratio,1} < 10 \\ P_{ratio,2} < 10 \end{cases}$$

Нәтижелерді талдау





Нәтижелерді талдау



Low temperature	High temperature
R32	R290
	R1234yf
	R134a
	R407C
R410A	R290
	R1234yf
	R134a
	R407C
R404A	R290
	R1234yf
	R134a
	R407C
R744	R290
	R1234yf
	R134a
	R407C

T_{amb} = **-30 C**; T_{del} = **60 C;** Q_{cond} = **15 kW**)

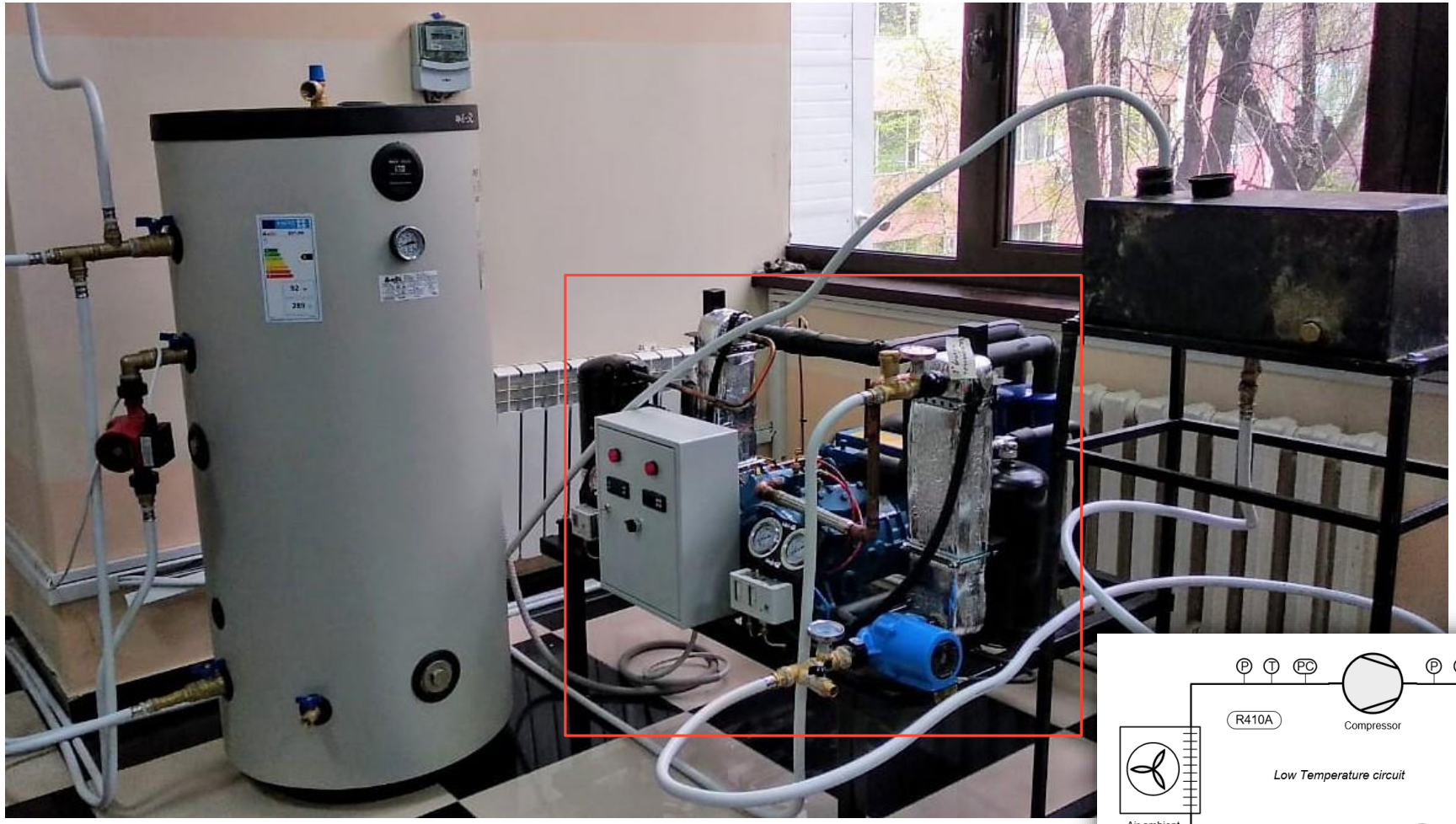
Evaporator: **9 kW** heat capacity;
Heat Exchanger: **11.6 kW** heat capacity;
Condenser: **15 kW** heat capacity.

Compressor 1: **3.3 kW** input power, 11.6 kW heat capacity;
Mass rate I: 0.04153 kg/s; Max. T: **85 C**; Min. T: **-40 C**;
Max. P: **25 bar**; Min. P: **1.5 bar.**

Compressor 2: **4.3 kW** input power, 15 kW heat capacity;
Mass rate II: 0.09571 kg/s; Max. T: **90 C**; Min. T: **5 C**;
Max. P: **22 bar**; Min. P: **4 bar.**

T_amb	eta_comp	Sh-Sb	COP	P_ratio_1	P_ratio_2	W_comp_1	W_comp_2	Q_evap	Q_med	Q_cond
-35	0.8	5	1.895	9.88	6.494	3300	4700	7100	10300	15000
-30			1.97	8.983	5.461	3300	4300	7400	10700	
-25			2.049	7.802	4.939	3300	4100	7700	11000	
-20			2.134	6.487	4.778	3100	4000	8000	11000	
-15			2.227	5.588	4.476	2900	3800	8300	11200	
-10			2.33	4.98	4.067	2800	3600	8600	11400	
-5			2.442	4.249	3.941	2600	3500	8900	11500	
0			2.567	3.84	3.59	2600	3300	9200	11700	
5			2.705	3.323	3.482	2300	3200	9500	11800	
10			2.86	3.039	3.181	2300	3000	9800	12000	
15			3.034	2.728	2.999	2100	2800	10100	12200	

Каскадты жылу насосы

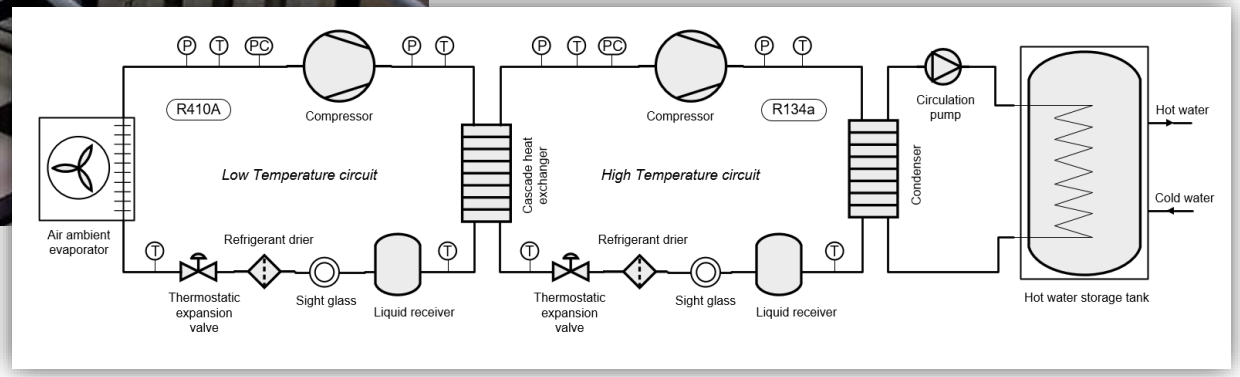


Q_{cond} = 15 кВт

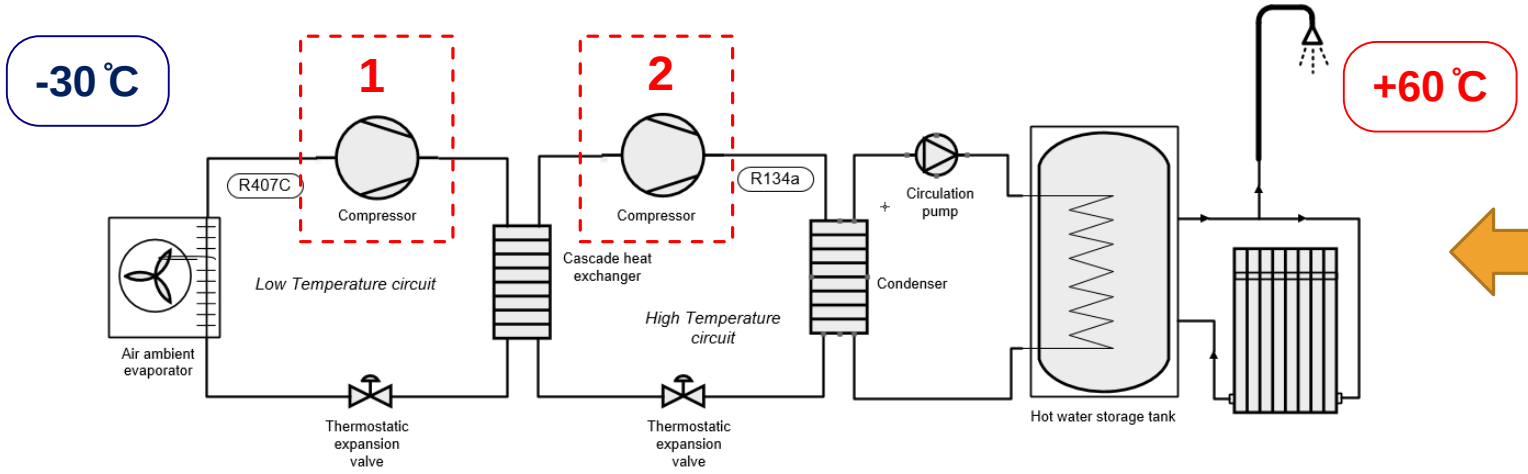
COP = 2.0-3.5

T_{amb} = -30 ℃

T_{del} = +60 ℃



3. Автокаскадты жылу насосы

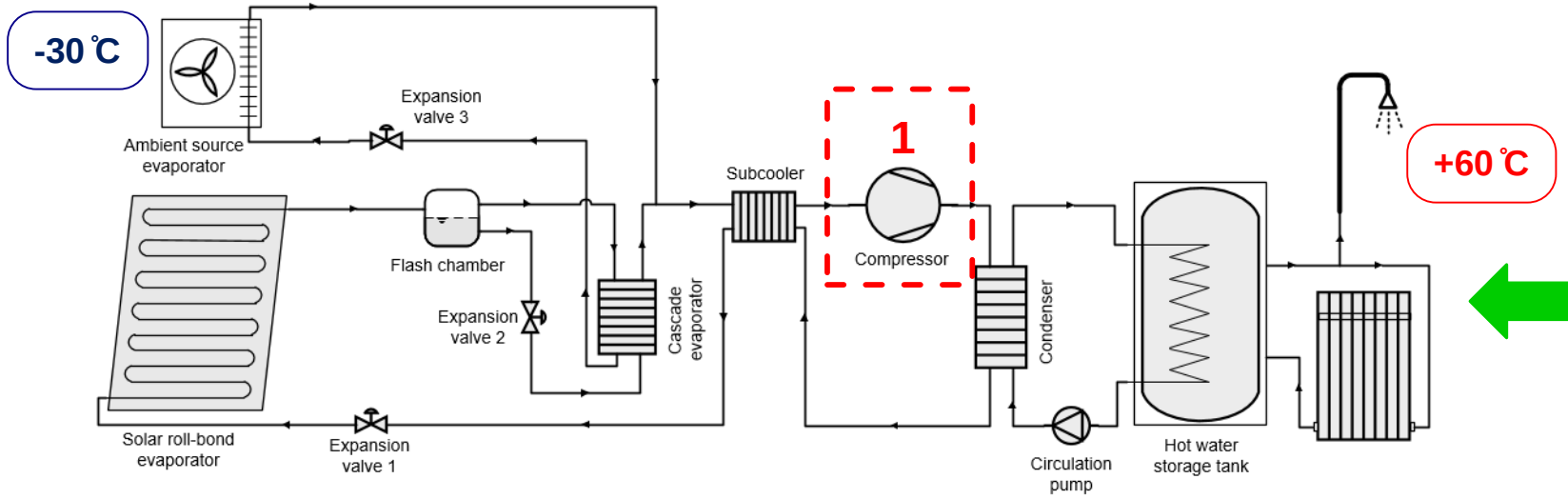


Каскадты ауа жылу насосы:

COP = 1.7-3.0

Қоршаған орта темп. **-30 ℃**

Жылыту контуры **+60 ℃**



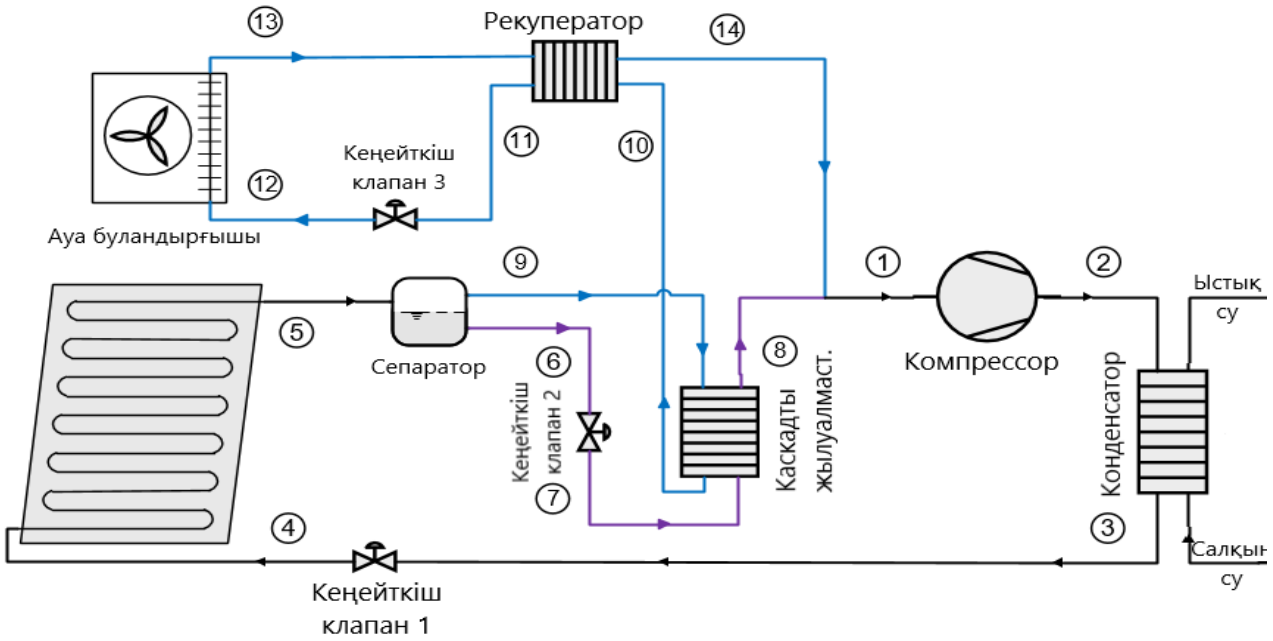
Автокаскадты жылу насосы:

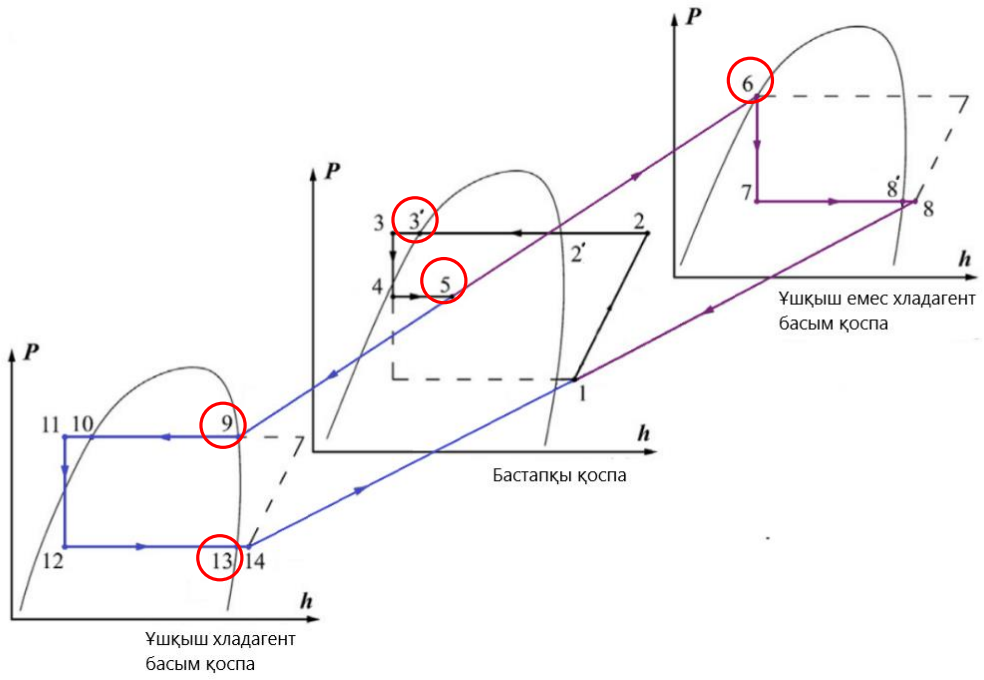
COP = 2.0-4.0

Қоршаған орта темп. **-30 ℃**

Жылыту контуры **+60 ℃**

3. Автокаскадты жылу насосы





High pressure

$$T_{cond} = T_{del} + \text{CAT}$$

$$x_3 = 0$$

$$P_{high} = P(T_{cond} + Sub_{cool}; x_3;\ w_{o,1})$$

Low pressure

$$T_{LTE} = T_{amb} - \text{CAT}$$

$$x_{13} = 1$$

$$P_{low} = P(T_{LTE} - Sup_{LTE}; x_{13};\ w_{mv,1})$$

Medium pressure

$$x_9 = 1$$

$$x_6 = 0$$

$$T_{sol} = T(P_{med}; x_9;\ w_{mv,1})$$

$$T_{sol} = T(P_{med}; x_6;\ w_{lv,1})$$

$$x_{sol} * w_{mv,1} + (1 - x_{sol}) * w_{lv,1} = w_{o,1}$$

$$P_{ratio} = \frac{P_{high}}{P_{low}}$$

$$\boldsymbol{w_{o,1} = 0.55}$$

$$T_{amb} = -10\ C$$

$$T_{del} = 40\ C$$

$$x_{sol} = 0.45$$

$$T_{sol} = 5\ C$$

Зеотропты қоспаны анықтау

$$P_{ratio} = \frac{P_{high}}{P_{low}}$$

$w_{o,1} = 0.55$

$T_{amb} = -10\ C$

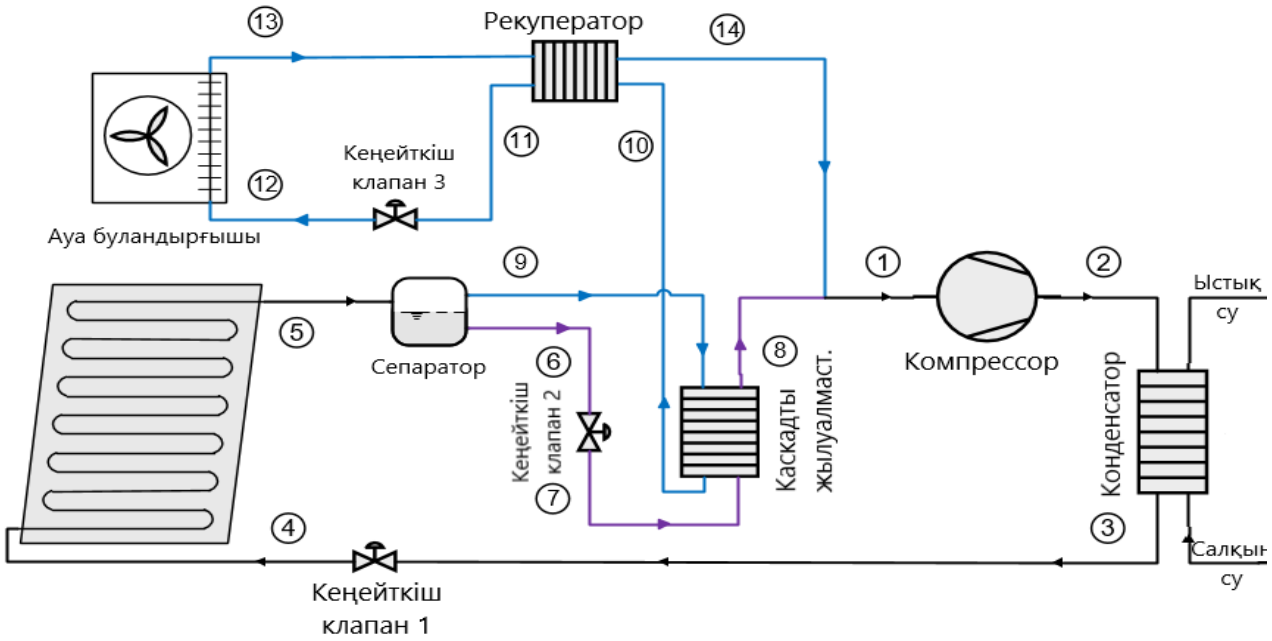
$T_{del} = 40\ C$

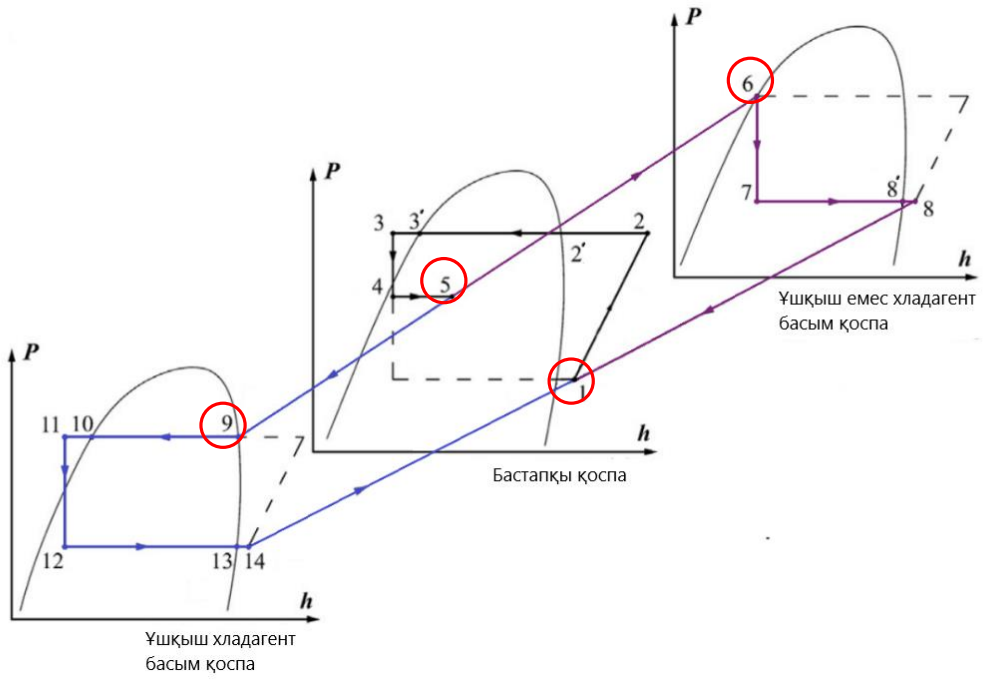
$x_{sol} = 0.45$

$T_{sol} = 5\ C$

	R32/R600a		R32/R134a		R32/R1234yf		R32/R1234ze		R32/R245fa	
$w_{o,1}$	$w_{mv,1}$	$w_{lv,1}$	$w_{mv,1}$	$w_{lv,1}$	$w_{mv,1}$	$w_{lv,1}$	$w_{mv,1}$	$w_{lv,1}$	$w_{mv,1}$	$w_{lv,1}$
0.7	0.79	0.62	0.79	0.63	0.8	0.62	0.79	0.62	0.9	0.54
0.65	0.78	0.54	0.75	0.57	0.75	0.56	0.75	0.56	0.87	0.47
0.6	0.77	0.48	0.7	0.51	0.71	0.51	0.715	0.51	0.85	0.4
0.55	0.765	0.37	0.66	0.46	0.66	0.46	0.67	0.45	0.82	0.33
0.5	0.76	0.29	0.61	0.41	0.61	0.41	0.64	0.39	0.79	0.26
0.45	0.74	0.21	0.56	0.36	0.55	0.36	0.59	0.34	0.75	0.205
0.4	0.7	0.15	0.51	0.31	0.5	0.32	0.54	0.28	0.7	0.15

3. Автокаскадты жылу насосты





Liquid out from solar collector (5-6)

$$\dot{m}_{lv} = (1 - x_5)\dot{m}_o$$

Vapor out from solar collector (5-9)

$$\dot{m}_{mv} = x_5\dot{m}_o$$

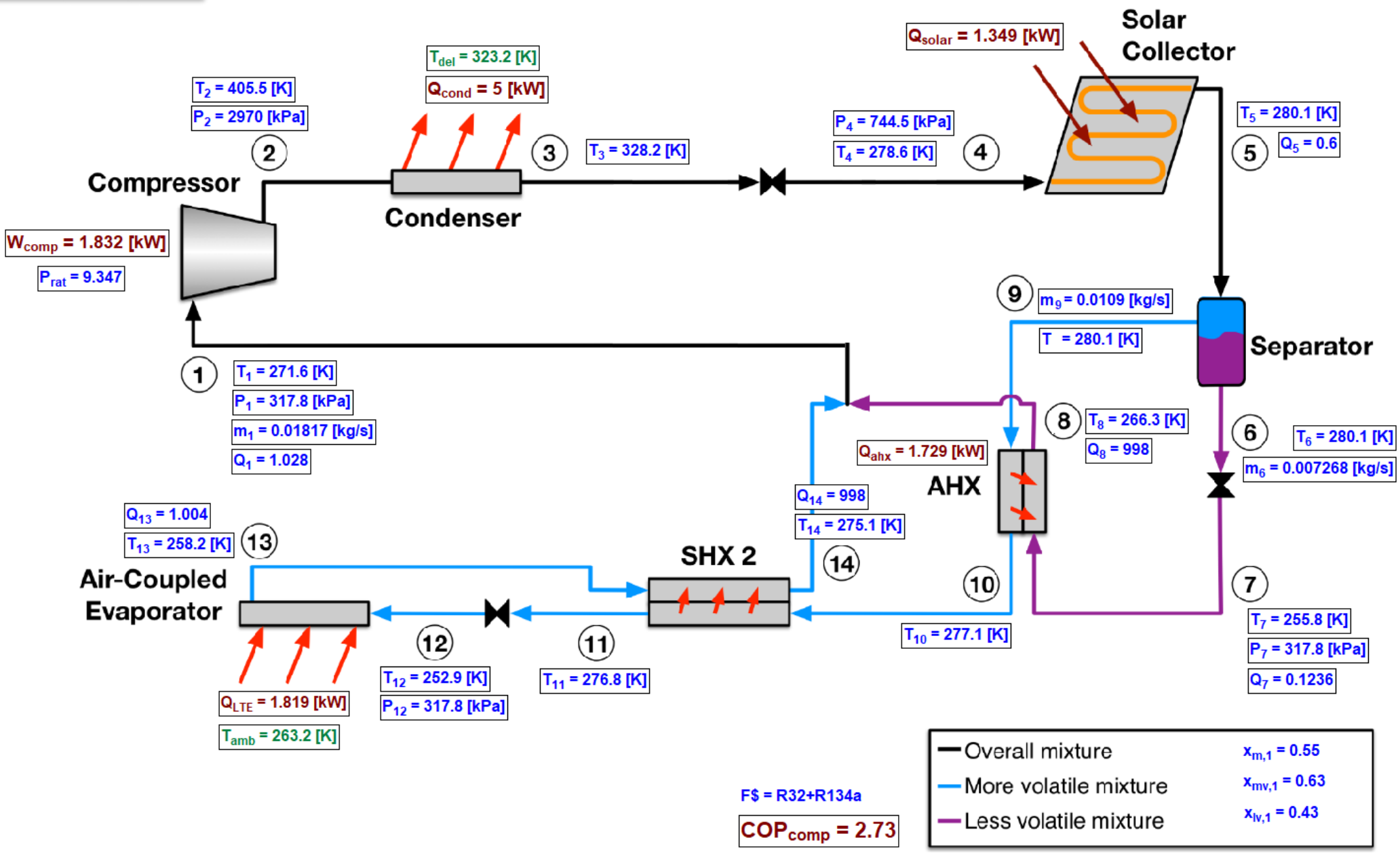
Solar collector outlet (5)

$$x_{sol} * w_{mv,1} + (1 - x_{sol}) * w_{lv,1} = w_{o,1}$$

Mixed stream (1)

$$\dot{m}_o h_1 = \dot{m}_{mv} h_{14} + \dot{m}_{lv} h_8$$

Нәтижелері

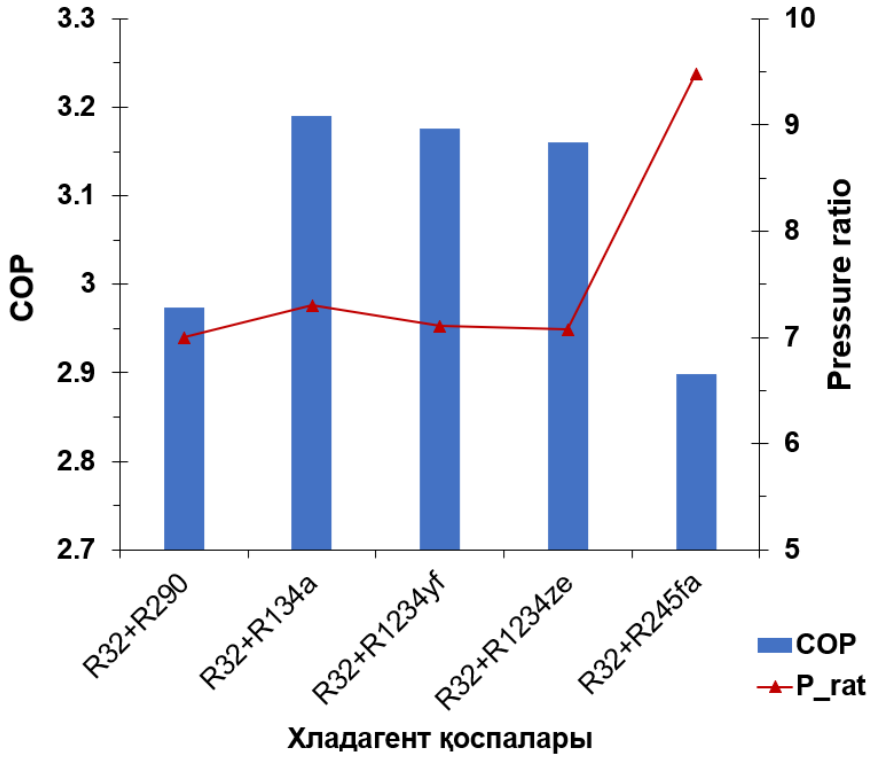

Solar Collector
Q_{solar} = 1.349 [kW]
T_{del} = 323.2 [K]
Q_{cond} = 5 [kW]
T_2 = 405.5 [K]
P_2 = 2970 [kPa]
2
3
T_3 = 328.2 [K]
P_4 = 744.5 [kPa]
T_4 = 278.6 [K]
4
T_5 = 280.1 [K]
Q_5 = 0.6
5
Compressor
Condenser
W_{comp} = 1.832 [kW]
P_{rat} = 9.347
9
m_9 = 0.0109 [kg/s]
T = 280.1 [K]
Separator
1
T_1 = 271.6 [K]
P_1 = 317.8 [kPa]
m_1 = 0.01817 [kg/s]
Q_1 = 1.028
8
T_8 = 266.3 [K]
Q_8 = 998
6
T_6 = 280.1 [K]
m_6 = 0.007268 [kg/s]
Q_{ahx} = 1.729 [kW]
AHX
Q_{14} = 998
T_{14} = 275.1 [K]
Q_{13} = 1.004
T_{13} = 258.2 [K]
13
SHX 2
14
Air-Coupled Evaporator
10
7
T_{10} = 277.1 [K]
T_7 = 255.8 [K]
P_7 = 317.8 [kPa]
Q_7 = 0.1236
12
11
T_{12} = 252.9 [K]
P_{12} = 317.8 [kPa]
T_{11} = 276.8 [K]
Q_{LTE} = 1.819 [kW]
T_{amb} = 263.2 [K]
Overall mixture
More volatile mixture
Less volatile mixture
$x_{m,1}$ = 0.55
$x_{mv,1}$ = 0.63
$x_{lv,1}$ = 0.43
F$ = R32+R134a
COP_{comp} = 2.73

Нәтижелерді талдау

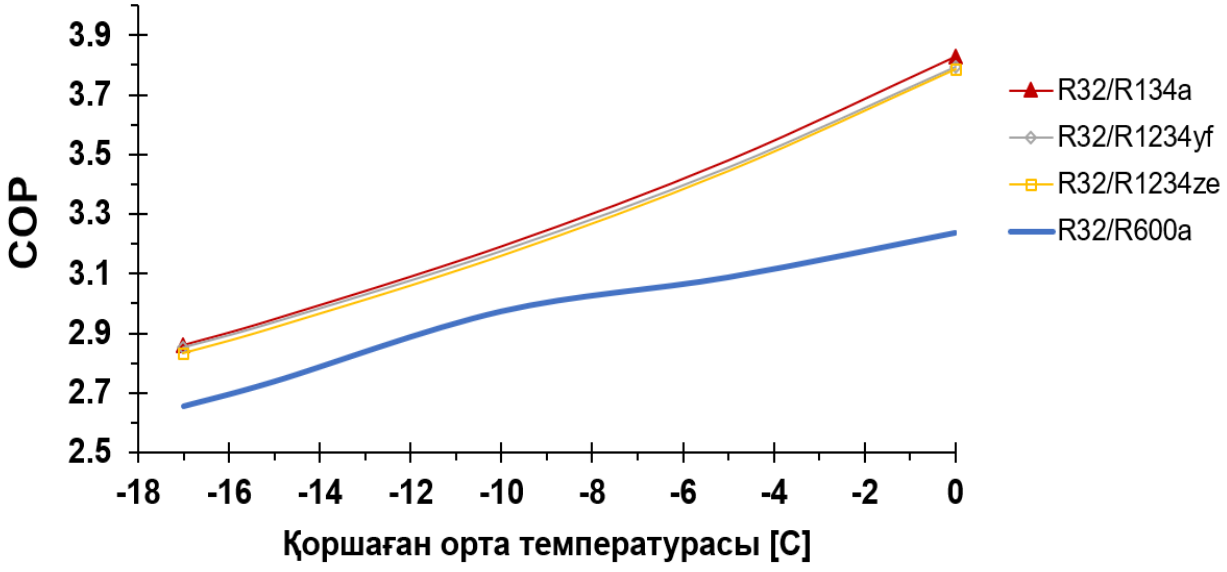
$$w_{o,1} = 0.55$$

$$T_{amb} = -10\ C$$

$$T_{del} = 40\ C$$



$$T_{del} = 40\ C$$



Қорытынды

1. **Ауа жылу насосы**
   - ✓ Математикалық модель құру (энергиялық, эксергиялық баланс);
   - ✓ Сандық/Тәжірибелік зерттеулер (эксергия);
   - ✓ Нәтижелерді талдау (эксергиялық ПӘК, COP).
2. **Каскадты ауа жылу насосы**
   - ✓ Математикалық модель құру;
   - ✓ Сандық/Тәжірибелік зерттеулер;
   - ✓ Нәтижелерді талдау.
3. **Автокаскадты күн жылу насосы**
   - ✓ Математикалық модель құру;
   - ✓ Сандық зерттеулер;
   - ➢ Нәтижелерді талдау.

1. Yerdesh Ye. B., Belyayev Ye. K., Baiseitov D., Murugesan M., Modeling two-phase flow in pipe in the solar collector // International Journal of Mathematics and Physics 9, №1 (12), 2018, pp. 12-19.
2. Yerdesh Ye., Belyayev Ye., Kaltayev A. Study of capillary tube as the expansion device in heat pump system // Vestnik KazNRTU. – Almaty: KazNRTU (Satbayev University), №4 (128), 2018, pp. 212-217.
3. Yerdesh Ye., Abdulina Z., Aliuly A., Belyayev Ye., Mohanraj M., Kaltayev A. Numerical assessment of combi solar PV/T and cascade air source heat pump performance for heating application in continental climate // Alternative Energy Sources, Materials & Technologies (AESMT'18), Plovdiv, Bulgaria.
4. Yerdesh Ye., Abdulina Z., Baimbetov D., Belyayev Ye., Mohanraj M. Numerical simulation of R290 as possible alternative to R22 in air source heat pumps // Proceedings of International Conference cum Exhibition on: THERMAL ANALYSIS AND ENERGY SYSTEMS (ICTAES 2018). – Coimbatore, India, 2018, pp. 27-31(RACHP-04)
5. Yerdesh Ye., Abdulina Z., Aliuly A, Belyayev Ye., Mohanraj M., Kaltayev A. Numerical simulation on solar collector and cascade heat pump combi water heating systems in Kazakhstan climates // Renewable energy. **(IF 4.9)** (With Editor)
6. Инновационный патент - Авторы: Беляев Е., Калтаев А., Моханрадж М., Ердеш Е. Шакир Е.; Название ОИС: Комбинированный солнечно-воздушный каскадный тепловой насос; Патент №33339, 11.12.2018; Уд. автора №106426.
7. Инновационный патент - Авторы: Беляев Е., Абдулина З., Ердеш Е., Калтаев А., Моханрадж М., Раттнер А.; Название ОИС: Автокаскадный солнечный тепловой насос; Регистрационный номер документа: 2019/0375.1; Дата подачи 23.03.2019

Назарларыңызға рахмет!!!

Пайдаланылған әдебиеттер тізімі

1. Mohanraj M., Belyayev Ye., Jayaraj S., Kaltayev A., Research and developments on solar assisted compression heat pump systems - A comprehensive review (Part A: Modeling and modifications) // Renewable and Sustainable Energy Reviews, vol. 83(2018), pp 90-123.
2. Mohanraj M., Belyayev Ye., Jayaraj S., Kaltayev A., Research and developments on solar assisted compression heat pump systems - A comprehensive review (Part-B: Applications) // Renewable and Sustainable Energy Reviews, vol. 83(2018), pp 124-155.
3. Zafer Utlu, Devrim Aydın, Olcay Kıncay, Comprehensive thermodynamic analysis of a renewable energy sourced hybrid heating system combined with latent heat storage // Energy Conversion and Management, vol. 84, 2014, pp. 311–325.
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5. Song Y., Li D., Cao F., Wang X., Theoretical investigation on the combined and cascade CO2/R134a heat pump systems for space heating, Applied Thermal Engineering, vol. 124 (2017), pp 1457–1470.
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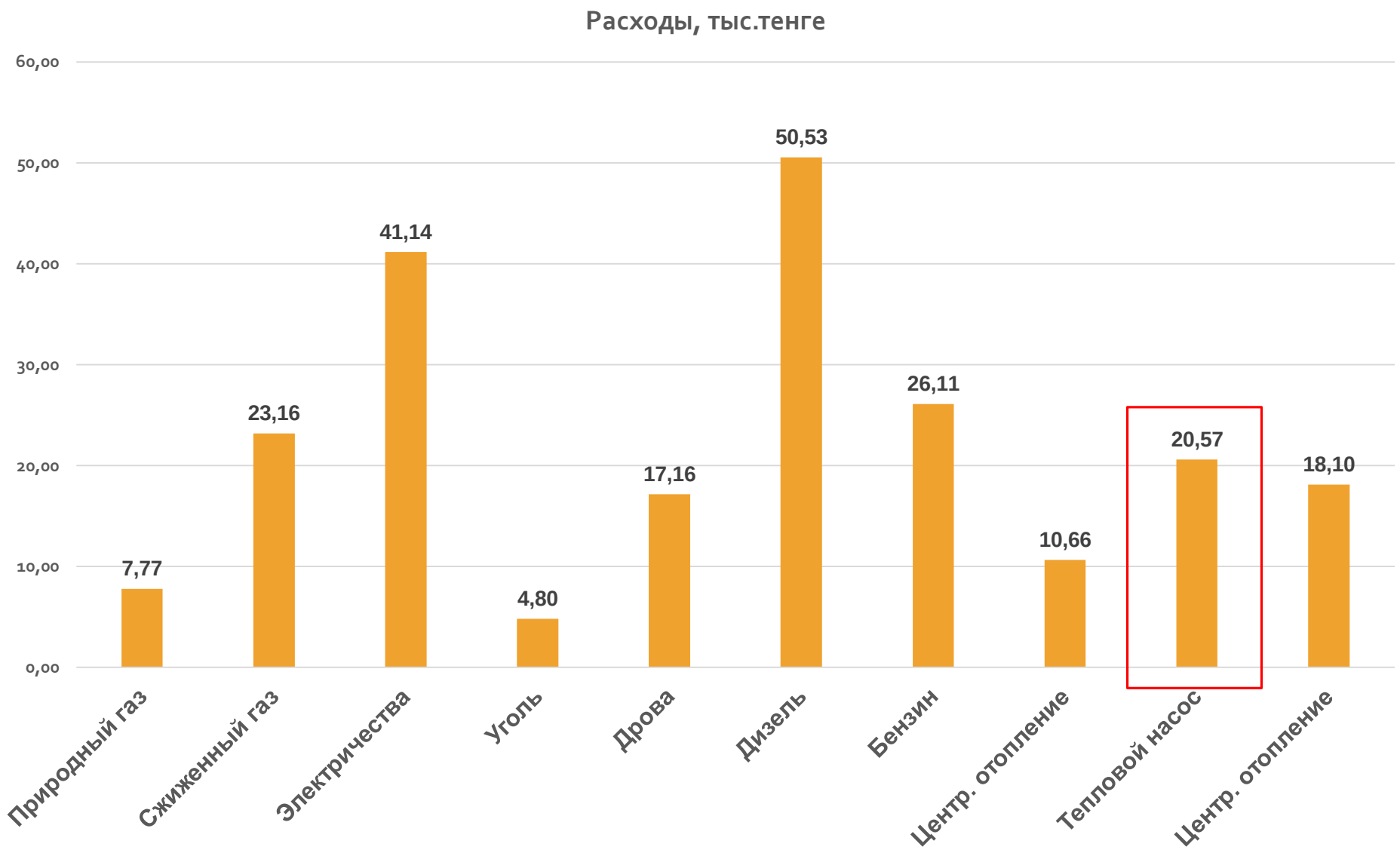
10. Sivakumar M., Somasundaram P., Exergy and energy analysis of three stage auto refrigerating cascade system using Zeotropic mixture for sustainable development, Energy Conversion and Management, vol. 84 (2014), pp 589–596.

ASHP – 7 kW (-10 C)


Расходы, тыс.тенге
60,00
50,00
40,00
30,00
20,00
10,00
0,00
7,77
23,16
41,14
4,80
17,16
50,53
26,11
10,66
20,57
18,10
Природный газ
Сжиженный газ
Электричества
Уголь
Дрова
Дизель
Бензин
Центр. отопление
Тепловой насос
Центр. отопление

CASHP – 15 kW (-30 C)