FEATURES OF RESEARCH AND EVALUATION OF EFFICIENCY OF HEAT PUMP CYCLES WITH USING THE SOLKANE[®] PROGRAMS

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Abstract

The analysis of features of research and an estimation of efficiency of cycles of heat pumps with use of the Solkane® programs at training of experts in a specialty "heat power engineering" was carried out. The capabilities of the programi can be used for training specialists in the specialty "heat power engineering", which aims to study, design and evaluate the effectiveness of energy supply systems with heat pump installations, optimization of modes of operation of energy supply systems with heat pumps.

Key words: efficiency, cycle, heat pump, Solkane®, refrigerant.

Introduction

When training specialists in the specialty "heat power engineering" there is a need to study, design and evaluate the effectiveness of energy supply systems with heat pump installations (HPI), optimization of modes of operation of energy supply systems with heat pumps.

Calculations of heat pump efficiency indicators are performed using the specialized programs «SOLKANE® Refrigerants» and «SOLKANE® Software» [1 – 2], designed by science company «Solvay». «SOLKANE® Refrigerants» and «SOLKANE® Software» are the free powerful specialized programs for calculating the thermophysical properties of refrigerants and calculating the cycles of HPI. These programs calculates the thermodynamic properties of all Solkane refrigerants and a number of CFCs, contains modules for calculating various processes and cycles, as well as calculations of refrigerant pipelines.

"SOLKANE® Refrigerants" and "SOLKANE® Software" are used by a number of European higher education institutions to train specialists in the fields of heat, refrigeration and cryogenic technology, food and processing industries [3 - 10].

Presentation of the materials

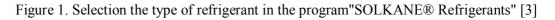
We will illustrate the possibilities of research in the program "SOLKANE® Refrigerants" on specific examples. To illustrate the capabilities of the program used materials from [3] and illustrations by the author. At the beginning of work with the program "SOLKANE® Refrigerants" it is necessary to choose the type of refrigerant from the offered in program. The choice of refrigerant is illustrated in Fig. 1.

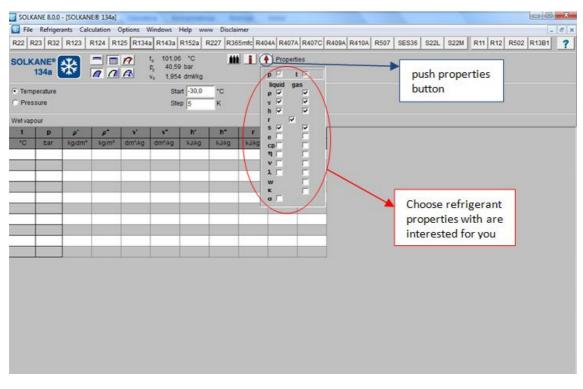
The program "SOLKANE® Refrigerants" allows to select the thermophysical, and thermodynamic properties of the refrigerant for different phase (see Fig. 2): density ρ , specific volume v, specific enthalpy h, enthalpy difference r, specific entropy s, specific exergy e, specific heat capacity Cp, dynamic viscosity η , kinematic viscosity v, heat conductivity λ , acoustic velocity w, adiabatic exponent κ , surface tension σ . As is known from thermodynamics, these properties depend on saturation parameters: temperature t and pressure p.

The next step in working with the program"SOLKANE® Refrigerants" is to select the ranges of saturation temperatures (or saturation pressures), as well as the step of changing them to determine the properties of a particular refrigerant (see Fig. 3). Based on the entered data, the program generates a table of thermophysical and thermodynamic properties of the refrigerant for different phase (see Fig. 3).

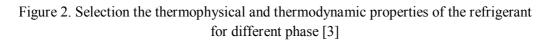
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Source: [3].





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30,00	0,84	1,389	4,43	160,77	380,31	219,54	0,8480	1,7515	1,2723	107,05	15,853	
25.00	1,06	1,374	5,51	167,13	383,42	216,29	0,8741	1,7460	1,2821	104,91	15,117	2. choose step between
20,00	1,33	1,359	6,79	173,56	386,51	212,95	0,6999	1,7412	1,2925	102,77	14,383	successive temperature
15,00	1,64	1,343	8,29	180,00	389,56	209,51	0,9254	1,7369	1,3035	100,03	13,652	
10,00	2,01	1,327	10,05	186,63	392,58	205,95	0,9505	1,7331	1,3152	98,49	12,925	
5,00	2,43	1,311	12,08	193,27	395,56	202,29	0,9754	1,7297	1,3277	96,35	12,202	
00,	2,93	1,295	14,43	200,00	398,49	198,49	1,0000	1,7267	1,3410	94,21	11,486	
.00	3,50	1,278	17,14	206,79	401,37	194,58	1.0243	1,7241	1,3553	92,07	10,776	
0,00	4,15	1,261	20,23	213,65	404,19	190,54	1,0484	1,7217	1,3707	89.93	10,074	
5,00	4,88	1,243	23,76	220,58	406,94	186,35	1,0723	1,7196	1,3874	87,79	9,379	
0,00	5,72	1,225	27,78	227,59	409,61	182,02	1,0960	1,7176	1,4056	85,65	8,694	
5,00	6,65	1,206	32,35	234,67	412,20	177,53	1,1195	1,7158	1,4255	83,51	8,020	Second March 1997
0,00	7,70	1,187	37,53	241,83	414,69	172,85	1,1429	1,7141	1,4475	81,37	7,356	•
5,00	8,87	1,167	43,40	249,08	417,07	168,00	1,1663	1,7124	1,4719	79,24	6,704	
00,00	10,17	1,145	50.06	256,43	419,33	162,90	1,1897	1,7107	1,4994	77,10	6,064	3. choose the start
5,00	11,60	1,125	57,62	263.90	421,44	157,54	1,2132	1,7090	1,5307	74.96	5,438	
00,00	13,18	1,102	66,21	271,52	423,38	151,86	1,2367	1,7071	1,5668	72.82	4,827	
5,00	14,92	1.078	76.03	279,32	425,12	145,80	1,2605	1,7049	1,6093	70.68	4,231	
0,00	16,82	1,053	87,28	287.33	426,63	139,30	1,2845	1,7024	1,6601	68,54	3,651	
55,D0	18.90	1.026	100,27	295.60	427,84	132,24	1,3089	1,6994	1,7229	NN	3,089	
70.00	21,17	0.996	115,42	304,18	428,70	124,52	1,3337	1,6957	1,8030	NN	2,544	

Source: [3].

Figure 3. The table of thermophysical and thermodynamic properties of the refrigerant for different phase, based on the entered data [3]

The refrigeration (or heat pump) cycle selection in the program "SOLKANE® Refrigerants" is shown in Fig.4. In Fig. 5 shows the input of initial data for the calculation of heat pump (or refrigeration) efficiency indicators for the selected type of cycle: the values of temperatures of evaporation and condensation, values of pressure drop, superheating and subcooling values, refrigerating capacity, isentropic efficiency of compressor, parameters on suction and discharge lines. For beginning of the calculation of heat pump (or refrigeration) efficiency indicators can be pressed «calculation» button (see Figs. 5, 6).

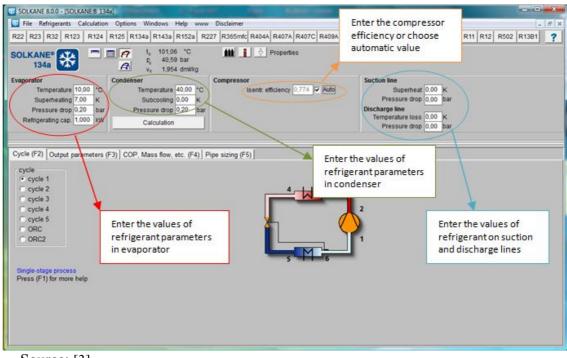
As a results of calculations of refrigeration (or heat pump) cycle are determined: output parameters for characteristic points of cycle (pressure p, temperature t, specific enthalpy h, specific entropy s and measure of dryness x (see Fig. 6)). These parameters also can be found in characteristic points of cycle on «pressure – enthalpy» diagram (Fig. 7).

As a results of calculations of refrigeration (or heat pump) cycle also are determined such indicators of cycle efficiency (see Fig.8): *COP* (Coefficient of Performance, that is characterized the ratio of heating capacity to the electrical capacity that consumption of heat pump), thermal power capacity of evaporator and condenser, electrical power capacity of compressor, pressure difference, capacity ratio, etc.

	Press this button to choose kind of circu	it
SOLKANE 8.0.0 - (SOLKANE 8 1344)		
File Refrigerants Calculation Options Windows Help www	Disclaimer	- 0 X
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SOLKANE* C . 101.06 °C . 40.59 bar 134a	1 OProperties	
Evaporator Temperature 10.00 "C Superfinating 7.00 K Pressure drop 0.00 bar Refrigerating cap 1.000 KW Calculation	Compressor Isent: efficiency 0.800 C Auto	Suction line Superhead Discharge line Temperature toss Discharge line Dis
Cycle (F2) Output parameters (F3) COP. Mass flow, etc. (F4) P cycle - - - cycle 1 - - - cycle 2 - - - cycle 3 - - - cycle 5 - - - proces - - - Press (F1) for more help - choose kind		1

Source: [3].

Figure 4. Selection of refrigeration (or heat pump) cycle in the program "SOLKANE® Refrigerants" [3]



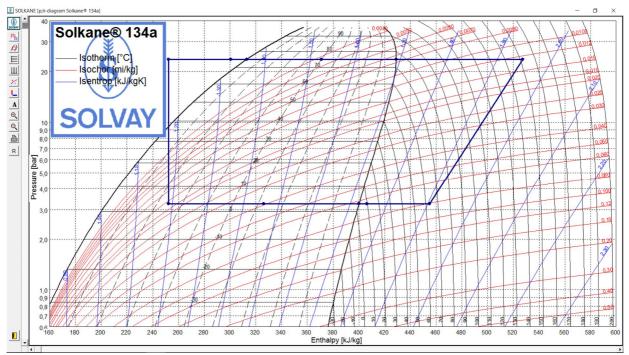
Source: [3].

Figure 5. The input of initial data for the calculation of heat pump (or refrigeration) efficiency indicators for the selected type of cycle [3]

	ANE [®]		■ A A	F. 40	1,06 °C 0,59 bar 954 dmil/kg		Properties		
F	tor Temperatur Superheatin Pressure dro Igerating cap	g 7.00 K p 0,20 bi	ar P		op 0,20 ba		Isentr. efficiency 0.735 ♥ Auto	Support Supperheat 0.00 K Pressure drop 0.00 bar Discharge line 0.00 K Temperature loss 0.00 K Pressure drop 0.00 bar	
Cycle (F2) Output	parameter	s (F3) COP	Mass flo	w.etc (F4)	Pipe sizing	(F5)		
	P	1	٧	h	8	×	Single-stage process		
oint	bar	'C	dm'ukg	kJag	k.LikgK		4	Press second lap	
~	4,15	17,00	51,28 21,31	410,67	1,7443				
5	10,17	49,72	22,14	436,99	1,7443			2	
-	10.17	56,21	22.14	436.99	1,7657				
-	10.17	40.00	19.98	419.33	1,7107				
4'm	10.07	39.63		337,33	1,4485			1	
	9,97	39.26	0.87	255.34	1,1863				
5	9,97	39.26	0.87	255.34	1,1863		5 6		
-	4,35	11,42	10,53	255,34	1,1949	0,210			
5°m	4,24	10,71	29,98	329,76	1,4583				
	4,15	10,00	49,43	404,19	1,7217				
	4,15	17.00	51,28	410.67	1,7443				

Source: [3].

Figure 6. Heat Pump Cycle calculation results (parameters of circuit characteristic points) [3]



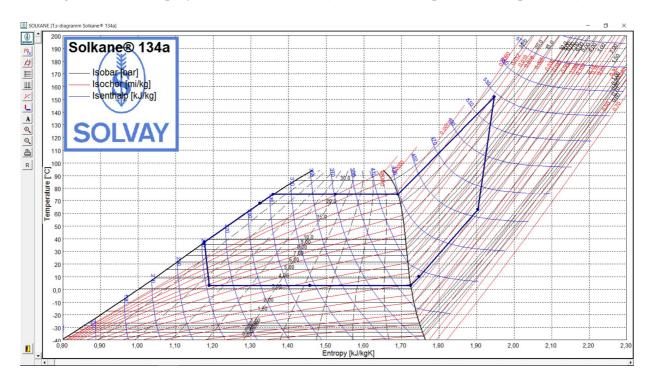
Source: author's data.

The parameters of refrigerant in the program "SOLKANE® Refrigerants" also can be found in characteristic points of cycle on «temperature – entropy» diagram (Fig. 9).

Figure 7. Heat Pump Cycle on diagram «pressure - enthalpy» in the program"SOLKANE® Refrigerants"

SOLKANE 8.0.0 - [SOLKANE® 134		daug Mala				- 6
			R365mfc R404A R407A R407C R409A R4	10A R507 SES36 S22L S22M	R11 R12 R502 R1381 7	(-)(*
		101,06 °C 40,59 bar	🗰 🧴 Properties			
Evaporator Temperature 10.00 °C Superheating 7.00 K Pressure drop 0.20 bar Refrigerating cap 1.00 KW	Condenser Temp Subi Pressu	and the second	npressor Isent: efficiency 0.735 v Auto	Suction line Superheat 0.00 K Pressure drop 0.00 bar Discharge line Temperature loss 0.00 K Pressure drop 0.00 bar		
Cycle (F2) Output parameters (F3) COP, Mas	s flow, etc. (F4) Pipe s	izing (F5)			
Power Single-stage proce	55					
Evaporator	1,00 kW	Pressure ratio	2,45			
Condenser	1,17 kW	Pressure difference	6,02 bar		1	
Compressor	0,17 kW	Mass flow Volume flow (Suction II	6,438 g/s ne) 1,19 mil/h		Press third lap	
		Volum: capacity	3029 kJ/mł		i i coo cini a lap	
Suction line	0.000 KW	COP	5.90			
Discharge line	0,000 kW		0,00			

Source: [3]. Figure 8. Heat Pump Cycle calculation results (COP, mass flow, power consumption, etc.) [3]



Source: author's data. Figure 9. Heat Pump Cycle on diagram «temperature – entropy» in the program "SOLKANE® Refrigerants"

In this paper, we analyzed features of research and evaluation of efficiency of heat pump cycles using the SOLKANE® programs. The capabilities of the program can be used for training specialists in the specialty "heat power engineering", which aims to study, design and evaluate the effectiveness of energy supply systems with heat pump installations, optimization of modes of operation of energy supply systems with heat pumps.

Conclusion

The analysis of features of research and an estimation of efficiency of cycles of heat pumps with use of the Solkane® programs at training of experts in a specialty "heat power engineering" was carried out.

Calculations of heat pump efficiency indicators are performed using the specialized programs «SOLKANE® Refrigerants» and «SOLKANE® Software» [1-2], designed by science company «Solvay». «SOLKANE® Refrigerants» and «SOLKANE® Software» are the free powerful specialized programs for calculating the thermophysical properties of refrigerants and calculating the cycles of HPI. These programs calculates the thermodynamic properties of all Solkane refrigerants and a number of CFCs, contains modules for calculating various processes and cycles, as well as calculations of refrigerant pipelines.

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We have illustrated the possibilities of research in the program "SOLKANE® Refrigerants" on specific examples. It is illustrated that as a results of calculations of refrigeration (or heat pump) cycle in "SOLKANE® Refrigerants" are determined: output parameters for characteristic points of cycle (pressure p, temperature t, specific enthalpy h, specific entropy s and measure of dryness x), *COP* (Coefficient of Performance, that is characterized the ratio of heating capacity to the electrical capacity that consumption of heat pump), thermal power capacity of evaporator and condenser, electrical power capacity of compressor, pressure difference, capacity ratio, etc.

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