

Program Options and Input/Output Information

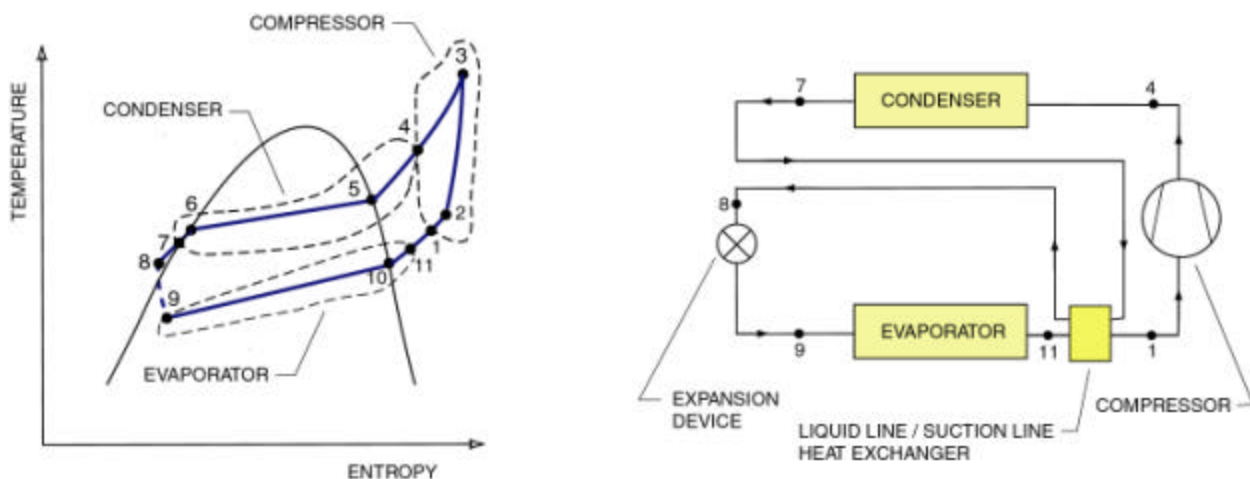
CYCLE-11_UA is a semi-theoretical cycle simulation model for the preliminary evaluation of performance of refrigerants and refrigerant mixtures in the vapor compression cycle. The UA version evolved from the DT version, which for the most part is described in Domanski and McLinden (1992). The current UA version incorporates a few changes to the version discussed in the paper and employs REFPROP 6.01 property routines (McLinden et al. 1998). A short explanation is given below regarding the data input.

The UA version of CYCLE-11 is a somewhat hardware-oriented model in comparison to the DT version. In the UA version, the evaporator and condenser are defined in terms of UA values, as opposed to the ΔT representation in the original DT model. The evaporator and condenser can have counter-flow, cross-flow, and parallel-flow configurations. The UA version requires as input a compressor swept volume, compressor speed (RPM), and electric-motor efficiency, η_{em} . (For open compressors specify $\eta_{em}=1$, since the electric-motor heat goes to the suction vapor.) Note, that if unrealistically small UA values are specified in relation to the compressor swept volume, excessive ΔT s may be required. This may cause the simulation to move the condenser temperature above the critical temperature and the evaporator temperature below zero on the Kelvin scale, resulting in a simulation crash.

In addition to the efficiency-based compressor representation explained above, the model has the option to account for a refrigerant pressure drop and temperature change between the compressor shell inlet and the cylinder, and between the cylinder and the compressor shell outlet. The pressure and temperature changes are calculated using simplified pressure-drop and heat-transfer correlations, which involve thermodynamic properties of the refrigerant and pressure-drop and heat-transfer parameters. These pressure and heat-transfer parameters are provided to the model as input and should be established by running the program for a reference refrigerant (most conveniently, a refrigerant commonly used in a given application) to ensure that the resulting refrigerant pressure drops and temperature changes are within the expected range. Simulations for other refrigerants and mixtures should be conducted using the same parameters.

CYCLE-11_UA can account for transport properties in representing performance of the evaporator, condenser, and liquid-line/suction-line heat exchanger (LLSL-HX) on relative bases (Domanski et al., 1994). To use this option, the user first has to execute a simulation run with imposed pressure drops, UA values, and LLSL-HX effectiveness so the program could calculate pressure drop and heat transfer parameters and save them for subsequent simulation runs.

The input to the program includes the inlet and outlet temperatures for heat transfer fluids (HTFs). However, the program provides the option under which the exit HTF temperatures are calculated on relative bases. To have this option available, the user first has to execute the program with imposed exit temperatures, which



Thermodynamic loop and system schematic and showing 11 key locations considered by CYCLE-11

allows for calculating and saving HTF capacity rates (products of specific heats and mass flow rates). Then CYCLE-11-UA uses these HTF capacity rates for simulating HTF exit temperatures in the subsequent simulations.

During execution, the program establishes a thermodynamic loop, which satisfies the input data. If the refrigerant temperature at any point in the evaporator or condenser is within 0.05 K of the temperature of the heat-transfer fluid (HTF), a warning message, "Evaporator is pinched" or "Condenser is pinched," is printed. For simulations using the efficiency-based compressor representation, the program calculates entropy production information for the evaporator, condenser, and complete system as explained in Domanski et al. 1993. A printout from a simulation results file for such a case is attached.

Program Execution

CYCLE-11 is a research model and was developed for internal use by the Thermal Machinery Group of NIST. For this reason the model has not been equipped with a visual interface and may be burdensome to use at the beginning for persons not familiar with the program. CYCLE-11 can be executed from the Window Explorer by clicking with a mouse on the executable element CYC-11UA.EXE. An MS-DOS dialog window will open in which the program will solicit input data and display information related to the simulation run. The program also solicits the name of the file to which it will write simulation results. It is convenient to provide a name with the .txt affix (e.g., run1.txt). This way the user can open the file by clicking on it with a mouse when the simulation run is completed and the dialog window disappears.

The program uses the MS-DOS dialog window to warn the user when intermediate convergence problems occur either in the CYCLE-11 original code or REFPROP property routines. Most of the time the simulation will continue until CYCLE_D successfully converges and writes a file with simulation results, however, occasionally these problems may result in a crash of the simulation. In case of REFPROP-related problems, CYCLE_D also writes detailed REFPROP diagnostic information into file error.txt. These diagnostic messages are explain in McLinden et al. 1998.

To facilitate the use of CYCLE-11, it is recommended that beginner users start with simulations that do not involve transport properties and heat transfer and pressure drop in the compressor. The model has been developed in FORTRAN 77 using standard options and can be executed on any PC computer.

References

Domanski P.A. and McLinden M.O., 1992. "A Simplified Cycle Simulation Model for the Performance Rating of Refrigerants and Refrigerant Mixtures", International Journal of Refrigeration, Vol. 15, No. 2, pp. 81-88.

Domanski, P.A., Mulroy, W.J., and Didion, D.A., 1993. "Glide Matching With Binary and Ternary Zeotropic Part 2. A Computer Simulation, Proceedings from the IIR International Conference on Energy Efficiency in Refrigeration and Global Warming Impact at Univ. of Ghent, Belgium, pp. 220-230, Int. Inst. Refrig., Paris, France. Also, Int. J. Refrig., Volume 17, No. 4, 1994, pp. 226-230.

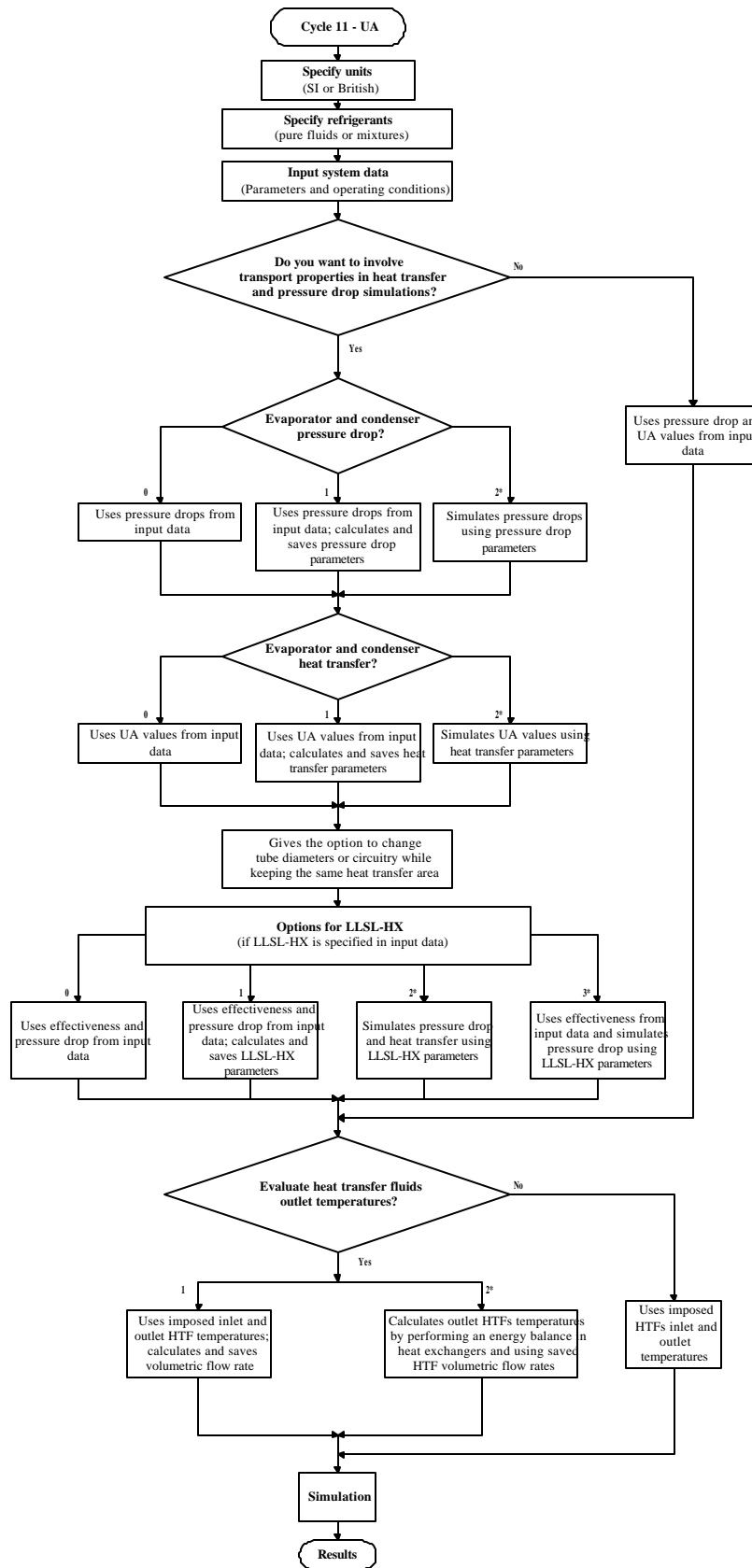
Domanski, P.A., Didion, D.A., Mulroy, W.J., and Parise, J.A.R., 1994. "A Simulation Model and Study of Hydrocarbon Refrigerants for Residential Heat Pump Systems", IIR Conference on New Applications of Natural Working Fluids in Refrigeration and Air Conditioning, Germany, pp. 339-354.

McLinden, M.O., Klein, S.A., Lemmon, E.W., and Peskin, A.P., 1998. "NIST Thermodynamic and Transport Properties of Refrigerants and Refrigerant Mixtures – REFPROP", (Version 6.01), NIST Standard Reference Database 23, National Institute of Standards and Technology, Gaithersburg, MD. (<http://www.nist.gov/srd/webguide/nist23/23v6.htm>)

Contact information

Piotr A. Domanski
National Institute of Standards and Technology
Building 226, Room B114
100 Bureau Drive, Stop 8631
Gaithersburg, MD 20899-8631

tel:(301) 975-5877
fax:(301) 208-0485
e-mail: Piotr.Domanski@NIST.gov



*Note: These options are available if reference data was saved during a previous simulation run

Flowchart for CYCLE-11-UA

An Example of CYCLE-11 Simulation Results

Cycle analysis by CYCLE-11, Version UA of June 15, 2000

INPUT DATA:

Refrigerant and weight composition

R32 .200; R600a .800;

HX stream temps: Source (in, out): -17.8, -21.7 C Counter flow HX
 Sink (in, out): 32.2, 37.8 C Counter flow HX

Compressor RPM = 1800.0 Compressor ambient temperature = 32.2 C
 El. motor eff = .900; Polytropic eff = .850; Vswept = .0001699 m³
 HTC for processes 1-2 & 3-4: .0000 .0000 (kJ/K)^{.66}/[kg^{.46} m^{.6}]
 DPC for processes 1-2 & 3-4: .0000 .0000 m²/s²

UA (kW/K).....: Evaporator = .3164 Condenser = .2110
 Evaporator superheat = .0 C Condenser subcooling = .0 C
 Imposed pressure drops (kPa).: Evap = .0 Cond = .0

RESULTS:

Avg. eff. temperature differences (cond, evap): 18.89 7.29 C
 Superheat due to h.t. with liquid line = 28.3 C
 Liquid line subcooling = 16.9 C
 Q (liquid line/suction line) = 39.92 kJ/kg Effectiveness = .500
 DPsl = 5.000 kPa DPll = 5.000 kPa
 Entropy production: Evap = 3.175E-02 Cond = 1.354E-01 Tot = 1.671E-01 kJ/kg K
 Source = -1.005E+00 Sink = 1.427E+00 Tot = 4.221E-01 kJ/kg K
 Condenser is pinched !

State	T HTF	(C) REF	P (kPa)	H (kJ/kg)	V (m ³ /kg)	S (kJ/kg K)	XQ
1 SHELL IN	n/a	4.7	74.3	447.0	5.36E-1	1.89020	1.000
2 CYLIND IN	n/a	17.0	74.3	465.0	5.62E-1	1.95391	1.000
3 CYLIND OUT	n/a	128.9	1515.0	632.1	3.40E-2	2.02221	1.000
4 COND IN	37.8	128.9	1515.0	632.1	3.40E-2	2.02221	1.000
5 COND SATV	36.3	71.7	1515.0	513.1	2.55E-2	1.70285	1.000
6 COND SATL	32.2	34.9	1515.0	192.4	1.78E-3	.73064	.000
7 COND OUT	32.2	34.9	1515.0	192.4	1.78E-3	.73064	.000
8 EXPAN IN	n/a	18.0	1510.0	152.4	1.69E-3	.59741	.000
9 EVAP IN	-21.7	-35.0	79.3	152.4	1.66E-1	.69313	.373
10 EVAP SATV	-17.8	-23.6	79.3	407.1	4.46E-1	1.72967	1.000
11 EVAP OUT	-17.8	-23.6	79.3	407.1	4.46E-1	1.72967	1.000

Performance: Cycle System

Work: 185.59 kJ/kg 1.682 kW RMS (kg/s) = .9063E-02

Refrig. capacity: 254.63 kJ/kg 2.308 kW COPr = 1.372

Heating capacity: 439.70 kJ/kg 3.985 kW COPh = 2.369

General performance data: Refrigerating Heating

Vol. capacity @ EffV = 1.000 452.8 kJ/m³ 781.8 kJ/m³

Vol. capacity @ EffV = .344 155.8 kJ/m³ 269.1 kJ/m³

Evap sup ht = .0% Cond sup ht = 8.8% Cond sub cool = .0%

Pressure Ratio = 20.40

Gliding temp. (C).: Evap = 11.5; Cond = 94.0; Cond superheat = 57.2 C