PUREZ -- THE MARK V ORNL HEAT PUMP DESIGN MODEL FOR CHLORINE-FREE, PURE AND NEAR-AZEOTROPIC REFRIGERANT ALTERNATIVES

Documentation Package

Version 0.95B

C. K. Rice and W. L. Jackson

Oak Ridge National Laboratory

November 1994

Table of Contents For PUREZ Documentation Notes

Listing of Text Documents Included On Disk:

README_V.DOC	List of References
HISTORY.DOC	Versions of ORNL HPDM
REFRIGS.DOC	Refrigerant ID Specifications in Mark V Data File
READMETO.RUN	Overview of Files and Subdirectories on Disk
HPDFILES.DOC	Description of Additional Heat Pump Configuration Files
HPDLINES.DOC	Description of HPDATA Input
HPDFORM.DOC	Free Formatted Input Data Format for the Mark V Model; Programmers Notes on the HFC Version Free Formatting Option
HPDCONV.DOC	Converting Data Files from Mark III to Mark IV (MODCON) and Mark V (PUREZ) Versions
TUNECOMP.DOC	Compressor Tuning for the Mark IV and V Models
TUNEMODL.DOC	Compressor and HX Model Tuning for the Mark IV and V Models
CHANGES.95B	Changes from Version 95a to 95b

PUREZ -- THE MARK V ORNL HEAT PUMP DESIGN MODEL

FOR CHLORINE-FREE, PURE AND NEAR-AZEOTROPIC

REFRIGERANT ALTERNATIVES

Overview Of New Capabilities

The PUREZ program (pronounced "pures") is an updated version of the ORNL Heat Pump Design Model that includes a number of pure and near-azeotropic chlorine-free refrigerants. Eight pure chlorine-free and five near-azeotropic HFC mixtures are included. These are:

pure—R-32, R-123, R-124, R-125, R-134a, R-143a, R-152a, and R-290 (propane);
mixtures—AZ-20 and AZ-50 (preliminary and official compositions), and HP-62.

The primary intended application remains air-to-air heat pumps and air conditioners. Candidate R-22 replacements included are R-134a, AZ-20, R-32, R-290 (propane). Candidate R-502 replacements are R-125, R-143a, AZ-50, and HP-62. The remaining HFC refrigerants included are candidate replacements for R-11, R-114, R-12, and R-502. Information on how to specify the new refrigerants is provided in the attachment "Refrigerant ID Specifications in Mark V Heat Pump Data File" (file REFRIGS.DOC).

Other new features of Mark V are:

Free-format, annotated input data files and flexible refrigerant selection;

New options for:

using ARI 540-91 compressor map curve-fit representations (10-term coefs),

holding heat pump output capacity constant,

specifying nominal refrigerant pressure drops of auxiliary components,

conducting parametrics of tube diameter and thickness; and

TUNECOMP program to calibrate compressor map representations using system operating data.

The options of using ARI compressor curve-fits and maintaining a constant design capacity are based on improvements made by G. Rosenquist of LBL at the request of the ARI MODCON Working Group. That work was done in preparation for the use of MODCON (Mark IV) in engineering analyses in support of the next round of NAECA minimum efficiency standards.

Further improvements are planned for PUREZ in the near future such as updating refrigerant heat transfer correlations and heat exchanger and flow control algorithms. Work is also in progress on a separate version of the program capable of properly modeling heat pump systems with zeotropic refrigerant mixtures such as AC-9000.

Although the input data for Mark V is free-format, Mark III and Mark IV data files are forward-compatible so that only the new Mark V data lines must be added. See “Converting Data Files from Mark III to Mark IV (MODCON) and Mark V (PUREZ) Versions” (file HPDCONV.DOC) for further specifics.

While PUREZ models the thermodynamic and transport properties of the listed chlorine-free refrigerants, proper system modeling requires that the user have compressor maps for the specific refrigerants they wish to simulate. A few data files have been provided that include compressor maps for R-22, R-134a, and AZ-20; these are described in HPDFILES.DOC.

Warning: At present, the program does not check that the compressor map data is for the same refrigerant that is being modeled in the system. (Future versions will prevent this potential misuse of the program). Use of a compressor map with the wrong refrigerant will give meaningless system results. If the user needs to run the program for a number of refrigerants without compressor data on each, the efficiency and loss model is the recommended approach at present.

The new parametrics of tube diameter and thickness are specified as independent design variables #’s 53-54 and 55-56, respectively in the CONCHZ input file. ID #’s 53 and 54 denote tube inner diameters DERI and DERO for the indoor and outdoor coils. ID #’s 55 and 56 denote tube thicknesses THKTBI and THKTBO for the indoor and outdoor coils. The tube outer diameters are adjusted to be consistent with the tube inner diameter and thickness values.

The combination of the option to maintain a constant output capacity in conjunction with the design parametrics capability provides a convenient means to identify design variable combinations that give maximum COP at constant capacity. Such an analysis is most appropriate at the design cooling condition where the desired cooling capacity is usually known and COP is to be maximized or the cost minimized. Care should be taken to not use compressor displacement as a parametric variable when the constant capacity option is used—as displacement is the parameter adjusted to maintain the desired capacity.

REFRIGERANT ID SPECIFICATIONS IN MARK V DATA FILE

The Mark V version of the ORNL HPDM includes thirteen chlorine-free refrigerants --eight pure refrigerants and five near-azeotropic mixtures. Different mixture versions (constituting the preliminary and official compositions) of the two-component refrigerant near-azeotropes, AZ-20 and AZ-50, are included. Representations for the chlorine-free, pure and the two-component near-azeotropic refrigerants were provided by Allied-Signal. Dupont provided property representations for HP-62--the near-azeotrope ternary that is an R-502 alternative.

The desired refrigerant can be identified in the input data in a variety of ways.The refrigerant ID specification is relatively free format. The "R" or "R-" preceding a refrigerant number is optional. For refrigerants R-134a, R-143a and R-152a, the "a" is optional. For C-318, the "C-" is optional. For binary mixtures, the official composition percentages are assumed if omitted. AZ-20 may besubstituted for R-32/R-125. AZ-50 may be substituted for R-143a/R-125. R-507 is equivalent to R-143a/R-125(50/50), etc. (The full names with composition percentages typed as shown below can be included in the input data if desired.)

For example, AZ-50 can be specified in the input line as AZ-50, AZ50, 50, R-507, 507, R-143a/R-125(50/50), 143/125(50/50), 143/125 or 143125.

The following refrigerants are represented, in full (thermodynamically and thermophysically) or in part (transport properties only) in the Mark V model:

Version	Refrigerant ID	Ref. No.	Alternative Names	Candidate Replacement For
3	R-12	12		
3	R-22	22		
3	R-114	114		
3	R-502	502		
4	R-134a	134		R-12, R-22
5	R-32	32		R-22
5	R-123	123		R-11
5	R-124	124		R-114
5	R-125	125		R-502
5	R-143a	143		R-502
5	R-152a	152		R-12
5	R-290	290	propane	R-22
5	R-32/R-125(50/50)	32125	AZ-20	R-22
5	R-32/R-125(60/40)	3212560	prelim. AZ-20	R-22
5	R-143a/R-125(50/50)	143125	AZ-50, R-507	R-502
5	R-143a/R-125(55/45)	14312555	prelim. AZ-50	R-502
5	R-143a/R-125/R-134a (52/44/4)	14312552	HP-62	R-502
*	(R-11)	(11)		
*	(R-13)	(13)		
*	(R-14)	(14)		
*	(R-21)	(21)		
*	(R-23)	(23)		
*	(R-113)	(113)		
*	(C-318)	(318)		
*	(R-500)	(500)		
*	(R-729)	(729)	(air)	

3 refrigerants included in the Mark III and earlier versions of the ORNL HPDM

version of the ORNL HPDM where newer refrigerants first appeared—Mark IV MODCON(4) or Mark V PUREZ(5) version. **References:Allied-Signal, Dupont.**

* denotes refrigerants ( ) for which only thermophysical (transport) properties are built into the model. The thermodynamic (equation-of-state) properties for these can be modeled by adding published "Downing" coefficients to the TABLES subroutine. **Reference: R. L. Downing, "Refrigerant Equations", ASHRAE Transactions, Vol. 80, Part 2, 1974.**

References for Mark V Thermodynamic Properties

R. L. Downing, 1974. "Refrigerant Equations", ASHRAE Transactions, Vol. 80, Part 2, 1974.
(Mark I-III refrigerants)

Allied-Signal, 1993. “Propane”, *Thermodynamic Tables,* Version 1.0.
(Propane in Mark V)

Allied-Signal, 1994. *Genetron Refrigerant Software: GENIE*, *Program GR100.2,* June.
(Mark IV and V new refrigerants)

References for Mark V Transport Properties

ASHRAE, 1976. *Thermophysical Properties of Refrigerants*, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, GA.
(Mark I-III refrigerants and propane in Mark V)

Allied-Signal, 1991 to 1993. Personal communication, M. Spatz.
(Mark IV and V new refrigerants)

Allied transport properties for pure refrigerants were determined from internally generated correlations.

For a few pure refrigerants and refrigerant mixtures, the following references were also used in conjunction with component properties:

L. P. Filippov, 1955. Vest. Mosk. Univ., *Ser. Fiz. Mat. Estestv. Nauk*., Vol. 8, pp. 67-69.
(Liquid thermal conductivity of mixtures)

D. S. Jung and D. A. Didion, 1990. “A Mixing Rule For Liquid Viscosities of Refrigerant Mixtures”, *International Journal of Refrigeration*, Vol. 13, pp. 243-247.
(Liquid viscosity of mixtures)

A. Kumagi and S. Takashashi, 1991. “Viscosity of Saturated Fluid Fluorocarbon Refrigerants from 273 to 353 K”, *International Journal of Thermophysics*, Vol. 12, No. 1.
(Liquid viscosity of R-143a)

K. Nagaoka, Y. Tanaka, H. Kubota, and T. Makita, 1986. “A New Correlation for Viscosity of Gaseous Fluorocarbon Refrigerants”, *International Journal of Thermophysics*, Vol. 7, No. 5, pp. 1023-1031.
(Vapor viscosity of pure and mixed refrigerants)

DuPont, 1993. *Transport Properties of SUVA Refrigerants: HP62, HP80, HP81;* SUVA Refrigerants Product Information, ART-18, May, p. 19.
(HP-62 in Mark V)

Transport Properties Predicted By PUREZ

for R-22 and Alternatives R-134a, Propane, and AZ-20

R-22

SAT. LIQ./VAP. SPECIFIC HEAT, VISCOSITY, & THERMAL CONDUCTIVITY

Temp (F)	P_{sat} (psia)	CP_l (Btu/lbm-R)	CP_{gs} (Btu/lbm-R)	MU_l (cP)	MU_{gs} (cP)	K_l (Btu/h-ft-R)	K_{gs} (Btu/h-ft-R)
-40	15.22	0.2617	0.1458	0.3300	0.01011	0.0693	0.00399
-35	17.29	0.2626	0.1473	0.3212	0.01024	0.0685	0.00409
-30	19.57	0.2636	0.1488	0.3129	0.01037	0.0677	0.00419
-25	22.09	0.2646	0.1503	0.3050	0.01050	0.0669	0.00429
-20	24.84	0.2657	0.1517	0.2974	0.01063	0.0661	0.00439
-15	27.86	0.2668	0.1532	0.2902	0.01075	0.0653	0.00449
-10	31.16	0.2679	0.1547	0.2833	0.01088	0.0645	0.00459
-5	34.75	0.2691	0.1563	0.2767	0.01101	0.0637	0.00469
0	38.66	0.2704	0.1579	0.2704	0.01113	0.0629	0.00479
5	42.89	0.2717	0.1596	0.2644	0.01126	0.0621	0.00489
10	47.46	0.2742	0.1613	0.2587	0.01139	0.0613	0.00499
15	52.41	0.2758	0.1632	0.2532	0.01152	0.0605	0.00509
20	57.73	0.2774	0.1652	0.2479	0.01165	0.0597	0.00519
25	63.45	0.2790	0.1673	0.2428	0.01178	0.0589	0.00529
30	69.59	0.2805	0.1696	0.2379	0.01192	0.0582	0.00539
35	76.17	0.2820	0.1720	0.2333	0.01206	0.0574	0.00549
40	83.21	0.2836	0.1746	0.2288	0.01220	0.0566	0.00559
45	90.72	0.2852	0.1774	0.2245	0.01234	0.0558	0.00569
50	98.73	0.2869	0.1804	0.2203	0.01248	0.0550	0.00579
55	107.25	0.2887	0.1837	0.2163	0.01263	0.0542	0.00589
60	116.31	0.2906	0.1871	0.2125	0.01278	0.0534	0.00599
65	125.93	0.2927	0.1908	0.2088	0.01294	0.0526	0.00609
70	136.12	0.2949	0.1948	0.2052	0.01310	0.0518	0.00619
75	146.92	0.2974	0.1991	0.2017	0.01326	0.0510	0.00629
80	158.33	0.3000	0.2037	0.1984	0.01343	0.0502	0.00639
85	170.38	0.3029	0.2085	0.1952	0.01361	0.0494	0.00649
90	183.09	0.3060	0.2137	0.1921	0.01379	0.0486	0.00659
95	196.50	0.3094	0.2193	0.1891	0.01397	0.0478	0.00669
100	210.60	0.3131	0.2252	0.1858	0.01416	0.0470	0.00679
105	225.45	0.3171	0.2314	0.1840	0.01436	0.0462	0.00689
110	241.04	0.3215	0.2381	0.1818	0.01456	0.0454	0.00699
115	257.42	0.3262	0.2452	0.1794	0.01476	0.0446	0.00709
120	274.60	0.3314	0.2526	0.1766	0.01498	0.0439	0.00719
125	292.62	0.3369	0.2605	0.1735	0.01520	0.0431	0.00729
130	311.50	0.3429	0.2689	0.1701	0.01543	0.0423	0.00739
135	331.26	0.3494	0.2777	0.1663	0.01567	0.0415	0.00749
140	351.95	0.3563	0.2870	0.1623	0.01591	0.0407	0.00759
145	373.58	0.3637	0.2968	0.1579	0.01616	0.0399	0.00769
150	396.20	0.3717	0.3071	0.1532	0.01642	0.0391	0.00779
155	419.83	0.3802	0.3179	0.1481	0.01669	0.0383	0.00789
160	444.53	0.3893	0.3292	0.1427	0.01697	0.0375	0.00799

R-134a

SAT. LIQ./VAP. SPECIFIC HEAT, VISCOSITY, & THERMAL CONDUCTIVITY

Temp (F)	P_{sat} (psia)	CP_l (Btu/lbm-R)	CP_{gs} (Btu/lbm-R)	MU_l (cP)	MU_{gs} (cP)	K_l (Btu/h-ft-R)	K_{gs} (Btu/h-ft-R)
-40	7.49	0.2842	0.1601	0.4711	0.00915	0.0616	0.00475
-35	8.64	0.2858	0.1620	0.4519	0.00927	0.0610	0.00489
-30	9.92	0.2873	0.1641	0.4338	0.00940	0.0603	0.00504
-25	11.35	0.2888	0.1661	0.4168	0.00952	0.0597	0.00518
-20	12.95	0.2904	0.1681	0.4008	0.00965	0.0590	0.00532
-15	14.72	0.2921	0.1702	0.3857	0.00977	0.0584	0.00547
-10	16.67	0.2939	0.1723	0.3714	0.00990	0.0577	0.00561
-5	18.83	0.2959	0.1745	0.3579	0.01002	0.0571	0.00576
0	21.20	0.2981	0.1766	0.3451	0.01015	0.0564	0.00590
5	23.81	0.3004	0.1788	0.3330	0.01027	0.0558	0.00605
10	26.65	0.3029	0.1810	0.3215	0.01040	0.0551	0.00619
15	29.76	0.3056	0.1832	0.3107	0.01052	0.0545	0.00633
20	33.14	0.3084	0.1855	0.3003	0.01065	0.0538	0.00648
25	36.81	0.3114	0.1877	0.2905	0.01077	0.0532	0.00662
30	40.79	0.3145	0.1900	0.2812	0.01090	0.0525	0.00677
35	45.09	0.3177	0.1923	0.2723	0.01102	0.0519	0.00691
40	49.74	0.3209	0.1947	0.2638	0.01115	0.0512	0.00706
45	54.74	0.3241	0.1970	0.2558	0.01127	0.0506	0.00720
50	60.13	0.3274	0.1994	0.2481	0.01140	0.0499	0.00735
55	65.90	0.3306	0.2018	0.2407	0.01152	0.0493	0.00749
60	72.09	0.3338	0.2042	0.2337	0.01165	0.0486	0.00763
65	78.72	0.3369	0.2067	0.2270	0.01177	0.0480	0.00778
70	85.79	0.3399	0.2091	0.2206	0.01190	0.0474	0.00792
75	93.33	0.3428	0.2116	0.2144	0.01202	0.0467	0.00807
80	101.37	0.3457	0.2141	0.2085	0.01215	0.0461	0.00821
85	109.92	0.3485	0.2166	0.2029	0.01227	0.0454	0.00836
90	118.99	0.3512	0.2192	0.1975	0.01240	0.0448	0.00850
95	128.62	0.3539	0.2217	0.1923	0.01253	0.0441	0.00864
100	138.83	0.3566	0.2243	0.1873	0.01265	0.0435	0.00879
105	149.63	0.3593	0.2269	0.1825	0.01278	0.0428	0.00893
110	161.04	0.3621	0.2295	0.1779	0.01290	0.0422	0.00908
115	173.10	0.3651	0.2321	0.1735	0.01303	0.0415	0.00922
120	185.82	0.3683	0.2348	0.1692	0.01315	0.0409	0.00937
125	199.24	0.3720	0.2375	0.1651	0.01328	0.0402	0.00951
130	213.36	0.3761	0.2402	0.1612	0.01340	0.0396	0.00966
135	228.23	0.3809	0.2430	0.1574	0.01353	0.0389	0.00980
140	243.86	0.3864	0.2457	0.1537	0.01365	0.0383	0.00994
145	260.29	0.3929	0.2486	0.1501	0.01378	0.0376	0.01009
150	277.54	0.4006	0.2514	0.1467	0.01390	0.0370	0.01023
155	295.64	0.4097	0.2544	0.1434	0.01403	0.0363	0.01038
160	314.64	0.4204	0.2573	0.1403	0.01415	0.0357	0.01052

R-290 (Propane)

SAT. LIQ./VAP. SPECIFIC HEAT, VISCOSITY, & THERMAL CONDUCTIVITY

Temp (F)	P_{sat} (psia)	CP_l (Btu/lbm-R)	CP_{gs} (Btu/lbm-R)	MU_l (cP)	MU_{gs} (cP)	K_l (Btu/h-ft-R)	K_{gs} (Btu/h-ft-R)
-40	16.09	0.5360	0.3644	0.2002	0.00763	0.0741	0.00669
-35	18.13	0.5389	0.3690	0.1943	0.00763	0.0734	0.00690
-30	20.35	0.5420	0.3737	0.1887	0.00763	0.0726	0.00711
-25	22.78	0.5451	0.3784	0.1833	0.00763	0.0718	0.00732
-20	25.43	0.5483	0.3831	0.1781	0.00763	0.0710	0.00753
-15	28.31	0.5516	0.3879	0.1732	0.00763	0.0703	0.00773
-10	31.42	0.5549	0.3928	0.1685	0.00763	0.0695	0.00793
-5	34.80	0.5584	0.3978	0.1640	0.00763	0.0687	0.00813
0	38.44	0.5619	0.4029	0.1597	0.00763	0.0680	0.00833
5	42.36	0.5655	0.4081	0.1556	0.00763	0.0672	0.00853
10	46.58	0.5692	0.4135	0.1517	0.00763	0.0664	0.00873
15	51.10	0.5730	0.4190	0.1479	0.00763	0.0657	0.00893
20	55.95	0.5769	0.4248	0.1443	0.00763	0.0649	0.00913
25	61.12	0.5809	0.4308	0.1408	0.00763	0.0641	0.00933
30	66.65	0.5850	0.4370	0.1374	0.00763	0.0634	0.00954
35	72.55	0.5892	0.4435	0.1342	0.00763	0.0626	0.00974
40	78.81	0.5935	0.4502	0.1311	0.00763	0.0618	0.00994
45	85.48	0.5972	0.4573	0.1281	0.00788	0.0611	0.01015
50	92.54	0.6019	0.4646	0.1253	0.00810	0.0603	0.01036
55	100.03	0.6068	0.4723	0.1225	0.00829	0.0595	0.01057
60	107.96	0.6121	0.4803	0.1198	0.00845	0.0588	0.01078
65	116.34	0.6178	0.4888	0.1173	0.00858	0.0580	0.01099
70	125.18	0.6240	0.4976	0.1148	0.00870	0.0572	0.01121
75	134.51	0.6306	0.5068	0.1124	0.00880	0.0565	0.01144
80	144.34	0.6377	0.5165	0.1101	0.00888	0.0557	0.01166
85	154.68	0.6454	0.5266	0.1079	0.00896	0.0549	0.01189
90	165.56	0.6537	0.5371	0.1058	0.00903	0.0542	0.01213
95	176.99	0.6626	0.5482	0.1037	0.00910	0.0534	0.01237
100	188.98	0.6722	0.5598	0.1017	0.00918	0.0526	0.01261
105	201.56	0.6824	0.5719	0.0998	0.00925	0.0518	0.01286
110	214.74	0.6935	0.5846	0.0979	0.00934	0.0511	0.01312
115	228.54	0.7053	0.5978	0.0961	0.00944	0.0503	0.01338
120	242.99	0.7180	0.6117	0.0944	0.00955	0.0495	0.01365
125	258.09	0.7315	0.6261	0.0927	0.00969	0.0488	0.01392
130	273.88	0.7459	0.6412	0.0910	0.00985	0.0480	0.01421
135	290.37	0.7613	0.6569	0.0894	0.01004	0.0472	0.01450
140	307.58	0.7776	0.6733	0.0879	0.01025	0.0465	0.01479
145	325.53	0.7950	0.6904	0.0864	0.01050	0.0457	0.01510
150	344.26	0.8134	0.7081	0.0850	0.01079	0.0449	0.01541
155	363.78	0.8329	0.7266	0.0836	0.01112	0.0442	0.01573
160	384.11	0.8536	0.7459	0.0822	0.01150	0.0434	0.01606

R-32/R-125(50/50) (AZ-20)

SAT. LIQ./VAP. SPECIFIC HEAT, VISCOSITY, & THERMAL CONDUCTIVITY

Temp (F)	P_{sat} (psia)	CP_l (Btu/lbm-R)	CP_{gs} (Btu/lbm-R)	MU_l (cP)	MU_{gs} (cP)	K_l (Btu/h-ft-R)	K_{gs} (Btu/h-ft-R)
-40	24.80	0.2952	0.1846	0.3205	0.01033	0.0636	0.00536
-35	28.20	0.2997	0.1866	0.3106	0.01045	0.0629	0.00544
-30	31.94	0.3043	0.1886	0.3012	0.01057	0.0621	0.00552
-25	36.05	0.3090	0.1906	0.2921	0.01068	0.0614	0.00560
-20	40.55	0.3137	0.1927	0.2834	0.01080	0.0606	0.00568
-15	45.46	0.3185	0.1948	0.2750	0.01092	0.0598	0.00577
-10	50.81	0.3234	0.1970	0.2669	0.01104	0.0591	0.00585
-5	56.62	0.3284	0.1992	0.2591	0.01115	0.0583	0.00593
0	62.91	0.3334	0.2014	0.2516	0.01127	0.0576	0.00601
5	69.70	0.3386	0.2037	0.2443	0.01139	0.0568	0.00610
10	77.04	0.3438	0.2060	0.2373	0.01150	0.0561	0.00618
15	84.92	0.3490	0.2083	0.2304	0.01162	0.0553	0.00627
20	93.39	0.3544	0.2107	0.2238	0.01173	0.0546	0.00635
25	102.47	0.3599	0.2131	0.2173	0.01185	0.0538	0.00644
30	112.19	0.3654	0.2155	0.2110	0.01197	0.0531	0.00653
35	122.57	0.3710	0.2180	0.2049	0.01208	0.0523	0.00661
40	133.63	0.3767	0.2205	0.1989	0.01219	0.0516	0.00670
45	145.42	0.3825	0.2230	0.1931	0.01231	0.0508	0.00679
50	157.95	0.3884	0.2255	0.1874	0.01242	0.0501	0.00687
55	171.27	0.3943	0.2281	0.1818	0.01254	0.0493	0.00696
60	185.39	0.4004	0.2307	0.1764	0.01265	0.0485	0.00705
65	200.35	0.4065	0.2333	0.1710	0.01276	0.0478	0.00714
70	216.19	0.4128	0.2360	0.1657	0.01288	0.0470	0.00723
75	232.93	0.4191	0.2386	0.1606	0.01299	0.0463	0.00732
80	250.62	0.4255	0.2413	0.1555	0.01310	0.0455	0.00741
85	269.29	0.4321	0.2441	0.1505	0.01322	0.0448	0.00750
90	288.99	0.4387	0.2469	0.1455	0.01333	0.0440	0.00759
95	309.75	0.4455	0.2497	0.1406	0.01344	0.0433	0.00769
100	331.61	0.4523	0.2526	0.1358	0.01355	0.0425	0.00778
105	354.62	0.4592	0.2555	0.1310	0.01366	0.0418	0.00787
110	378.83	0.4663	0.2585	0.1262	0.01378	0.0410	0.00796
115	404.29	0.4735	0.2616	0.1214	0.01389	0.0403	0.00806
120	431.05	0.4807	0.2648	0.1167	0.01400	0.0395	0.00815
125	459.17	0.4881	0.2680	0.1119	0.01411	0.0388	0.00825
130	488.70	0.4956	0.2715	0.1070	0.01422	0.0380	0.00834
135	519.71	0.5032	0.2751	0.1021	0.01433	0.0372	0.00843
140	552.26	0.5110	0.2789	0.0970	0.01444	0.0365	0.00853
145	586.43	0.5188	0.2831	0.0918	0.01455	0.0357	0.00863
150	622.28	0.5268	0.2879	0.0861	0.01466	0.0350	0.00872
155	659.90	0.5349	0.2937	0.0798	0.01477	0.0342	0.00882
160	699.36	0.5431	0.3023	0.0716	0.01488	0.0335	0.00891

Transport Properties Predicted By PUREZ

for R-502 and Alternatives HP-62 and AZ-50

R-502

SAT. LIQ./VAP. SPECIFIC HEAT, VISCOSITY, & THERMAL CONDUCTIVITY

Temp	P_{sat}	CP_l	CP_{gs}	MU_l	MU_{gs}	K_l	K_{gs}
(F)	(psia)	(Btu/lbm-R)		(cP)	(cP)	(Btu/h-ft-R)	
-40	18.80	0.2585	0.1488	0.3570	0.01009	0.0519	0.00460
-35	21.23	0.2599	0.1508	0.3452	0.01024	0.0513	0.00469
-30	23.90	0.2614	0.1525	0.3341	0.01039	0.0507	0.00478
-25	26.82	0.2629	0.1540	0.3235	0.01053	0.0500	0.00487
-20	30.01	0.2644	0.1554	0.3135	0.01066	0.0494	0.00496
-15	33.48	0.2659	0.1567	0.3040	0.01079	0.0488	0.00505
-10	37.26	0.2675	0.1578	0.2950	0.01092	0.0481	0.00514
-5	41.35	0.2690	0.1589	0.2865	0.01105	0.0475	0.00523
0	45.78	0.2706	0.1600	0.2784	0.01118	0.0469	0.00532
5	50.55	0.2723	0.1610	0.2707	0.01130	0.0463	0.00541
10	55.70	0.2739	0.1621	0.2633	0.01143	0.0456	0.00550
15	61.23	0.2756	0.1632	0.2563	0.01155	0.0450	0.00559
20	67.16	0.2773	0.1644	0.2497	0.01168	0.0444	0.00568
25	73.50	0.2790	0.1656	0.2433	0.01181	0.0438	0.00577
30	80.29	0.2808	0.1671	0.2313	0.01194	0.0431	0.00586
35	87.52	0.2825	0.1686	0.2269	0.01207	0.0425	0.00595
40	95.23	0.2843	0.1704	0.2223	0.01221	0.0419	0.00604
45	103.42	0.2861	0.1724	0.2173	0.01235	0.0412	0.00613
50	112.12	0.2880	0.1747	0.2122	0.01250	0.0406	0.00622
55	121.34	0.2899	0.1772	0.2069	0.01265	0.0400	0.00631
60	131.10	0.2917	0.1800	0.2015	0.01281	0.0394	0.00640
65	141.43	0.2937	0.1832	0.1960	0.01297	0.0387	0.00649
70	152.32	0.2956	0.1867	0.1905	0.01314	0.0381	0.00658
75	163.81	0.2976	0.1906	0.1849	0.01332	0.0375	0.00667
80	175.92	0.2996	0.1950	0.1793	0.01351	0.0368	0.00676
85	188.66	0.3016	0.1998	0.1737	0.01371	0.0362	0.00685
90	202.06	0.3036	0.2051	0.1681	0.01392	0.0356	0.00694
95	216.13	0.3057	0.2108	0.1627	0.01414	0.0350	0.00703
100	230.89	0.3078	0.2172	0.1572	0.01436	0.0343	0.00712
105	246.38	0.3099	0.2241	0.1519	0.01461	0.0337	0.00721
110	262.61	0.3120	0.2316	0.1466	0.01486	0.0331	0.00730
115	279.61	0.3142	0.2397	0.1415	0.01513	0.0325	0.00739
120	297.41	0.3163	0.2471	0.1365	0.01541	0.0318	0.00748
125	316.05	0.3186	0.2585	0.1316	0.01570	0.0312	0.00788
130	335.54	0.3208	0.2722	0.1268	0.01601	0.0306	0.00811
135	355.95	0.3230	0.2884	0.1221	0.01634	0.0299	0.00823
140	377.30	0.3253	0.3075	0.1176	0.01668	0.0293	0.00830
145	399.65	0.3276	0.3300	0.1132	0.01704	0.0287	0.00836
150	423.06	0.3300	0.3561	0.1089	0.01741	0.0281	0.00847
155	447.61	0.3323	0.3861	0.1047	0.01781	0.0274	0.00866
160	473.39	0.3347	0.4205	0.1007	0.01822	0.0268	0.00900

R-143a/R-125/R-134a(52/44/4) (HP-62)

SAT. LIQ./VAP. SPECIFIC HEAT, VISCOSITY, & THERMAL CONDUCTIVITY

Temp (F)	P_{sat} (psia)	CP_l (Btu/lbm-R)	CP_{gs} (Btu/lbm-R)	MU_l (cP)	MU_{gs} (cP)	K_l (Btu/h-ft-R)	K_{gs} (Btu/h-ft-R)
-40	19.62	0.2826	0.1796	0.3196	0.01040	0.0525	0.00588
-35	22.15	0.2868	0.1815	0.3068	0.01041	0.0519	0.00594
-30	24.94	0.2905	0.1835	0.2944	0.01043	0.0514	0.00601
-25	28.00	0.2938	0.1855	0.2826	0.01046	0.0508	0.00608
-20	31.35	0.2967	0.1875	0.2713	0.01049	0.0502	0.00615
-15	35.01	0.2993	0.1896	0.2606	0.01054	0.0497	0.00623
-10	38.99	0.3017	0.1917	0.2503	0.01060	0.0491	0.00631
-5	43.32	0.3039	0.1939	0.2404	0.01066	0.0486	0.00640
0	48.01	0.3060	0.1962	0.2310	0.01074	0.0480	0.00650
5	53.09	0.3080	0.1985	0.2220	0.01083	0.0474	0.00660
10	58.57	0.3100	0.2009	0.2134	0.01092	0.0469	0.00671
15	64.48	0.3121	0.2033	0.2053	0.01103	0.0464	0.00682
20	70.84	0.3143	0.2059	0.1975	0.01115	0.0458	0.00694
25	77.66	0.3167	0.2086	0.1900	0.01128	0.0453	0.00707
30	84.98	0.3193	0.2114	0.1829	0.01142	0.0447	0.00720
35	92.81	0.3223	0.2143	0.1761	0.01158	0.0442	0.00734
40	101.17	0.3256	0.2174	0.1696	0.01175	0.0436	0.00749
45	110.08	0.3293	0.2207	0.1634	0.01193	0.0431	0.00764
50	119.57	0.3335	0.2242	0.1574	0.01212	0.0425	0.00781
55	129.66	0.3382	0.2279	0.1517	0.01233	0.0419	0.00798
60	140.37	0.3436	0.2319	0.1462	0.01256	0.0414	0.00816
65	151.72	0.3496	0.2362	0.1410	0.01280	0.0408	0.00835
70	163.74	0.3564	0.2408	0.1359	0.01305	0.0402	0.00855
75	176.44	0.3639	0.2459	0.1310	0.01333	0.0396	0.00877
80	189.85	0.3723	0.2515	0.1263	0.01362	0.0391	0.00899
85	203.99	0.3816	0.2578	0.1217	0.01393	0.0385	0.00922
90	218.88	0.3918	0.2647	0.1172	0.01426	0.0379	0.00947
95	234.53	0.4031	0.2726	0.1129	0.01461	0.0373	0.00973
100	250.98	0.4155	0.2817	0.1086	0.01499	0.0366	0.01000
105	268.24	0.4290	0.2921	0.1044	0.01538	0.0360	0.01029
110	286.34	0.4437	0.3045	0.1003	0.01581	0.0354	0.01060
115	305.28	0.4597	0.3192	0.0962	0.01625	0.0347	0.01091
120	325.09	0.4770	0.3372	0.0921	0.01673	0.0341	0.01125
125	345.80	0.4957	0.3596	0.0880	0.01724	0.0334	0.01160
130	367.41	0.5159	0.3884	0.0839	0.01778	0.0327	0.01198
135	389.95	0.5376	0.4265	0.0797	0.01835	0.0320	0.01237
140	413.43	0.5608	0.4792	0.0755	0.01895	0.0313	0.01278
145	437.87	0.5857	0.5566	0.0713	0.01960	0.0306	0.01322
150	463.29	0.6123	0.6802	0.0669	0.02028	0.0298	0.01368
155	489.71	0.6406	0.9083	0.0624	0.02101	0.0291	0.01417
160	517.13	0.6707	1.4936	0.0579	0.02179	0.0283	0.01468

R-143a/R-125(50/50) (AZ-50)

SAT. LIQ./VAP. SPECIFIC HEAT, VISCOSITY, & THERMAL CONDUCTIVITY

Temp (F)	P_{sat} (psia)	CP_l (Btu/lbm-R)	CP_{gs}	MU_l (cP)	MU_{gs} (cP)	K_l (Btu/h-ft-R)	K_{gs}
-40	20.18	0.3701	0.1774	0.2935	0.00979	0.0512	0.00475
-35	22.86	0.3569	0.1794	0.2843	0.00990	0.0505	0.00483
-30	25.80	0.3483	0.1815	0.2754	0.01001	0.0499	0.00492
-25	29.02	0.3434	0.1835	0.2669	0.01012	0.0493	0.00500
-20	32.54	0.3415	0.1856	0.2587	0.01023	0.0487	0.00509
-15	36.37	0.3420	0.1876	0.2509	0.01034	0.0480	0.00517
-10	40.53	0.3443	0.1897	0.2433	0.01046	0.0474	0.00526
-5	45.04	0.3476	0.1918	0.2360	0.01057	0.0468	0.00535
0	49.91	0.3517	0.1940	0.2290	0.01068	0.0462	0.00544
5	55.18	0.3559	0.1961	0.2222	0.01079	0.0456	0.00552
10	60.85	0.3599	0.1983	0.2157	0.01090	0.0449	0.00561
15	66.94	0.3635	0.2004	0.2094	0.01101	0.0443	0.00570
20	73.48	0.3664	0.2026	0.2033	0.01112	0.0437	0.00579
25	80.48	0.3683	0.2048	0.1975	0.01123	0.0431	0.00588
30	87.97	0.3693	0.2070	0.1918	0.01133	0.0424	0.00597
35	95.97	0.3691	0.2092	0.1863	0.01144	0.0418	0.00606
40	104.50	0.3678	0.2114	0.1810	0.01155	0.0412	0.00616
45	113.59	0.3654	0.2137	0.1758	0.01166	0.0406	0.00625
50	123.26	0.3622	0.2159	0.1708	0.01177	0.0400	0.00634
55	133.53	0.3582	0.2182	0.1660	0.01188	0.0393	0.00643
60	144.44	0.3537	0.2204	0.1612	0.01198	0.0387	0.00653
65	156.01	0.3491	0.2227	0.1567	0.01209	0.0381	0.00662
70	168.28	0.3447	0.2250	0.1522	0.01220	0.0375	0.00672
75	181.26	0.3410	0.2273	0.1478	0.01230	0.0368	0.00681
80	195.00	0.3384	0.2296	0.1436	0.01241	0.0362	0.00691
85	209.53	0.3375	0.2320	0.1394	0.01252	0.0356	0.00700
90	224.88	0.3390	0.2344	0.1353	0.01262	0.0350	0.00710
95	241.10	0.3435	0.2367	0.1313	0.01273	0.0344	0.00719
100	258.22	0.3518	0.2392	0.1274	0.01284	0.0337	0.00729
105	276.28	0.3647	0.2416	0.1234	0.01294	0.0331	0.00739
110	295.34	0.3830	0.2441	0.1196	0.01305	0.0325	0.00749
115	315.44	0.4078	0.2467	0.1157	0.01315	0.0319	0.00758
120	336.63	0.4401	0.2493	0.1118	0.01326	0.0312	0.00768
125	358.97	0.4807	0.2521	0.1079	0.01336	0.0306	0.00778
130	382.50	0.5311	0.2549	0.1040	0.01347	0.0300	0.00788
135	407.30	0.5922	0.2579	0.0999	0.01357	0.0294	0.00798
140	433.44	0.6654	0.2610	0.0956	0.01368	0.0288	0.00808
145	460.97	0.7519	0.2645	0.0911	0.01378	0.0281	0.00818
150	489.97	0.8532	0.2685	0.0860	0.01389	0.0275	0.00828
155	520.53	0.9707	0.2735	0.0797	0.01399	0.0269	0.00838
160	520.53	0.9707	0.2695	0.0797	0.01409	0.0269	0.00848

Text Documents Included On Disk

README_V.DOC

HISTORY.DOC

REFRIGS.DOC

READMETO.RUN

HPDFILES.DOC

HPDLINES.DOC

HPDFORM.DOC

HPDCONV.DOC

TUNECOMP.DOC

TUNEMODL.DOC

CHANGES.95B

FILE: README_V.DOC

```
C ******************************************************************************
C ******************************__PUREZ__***************************************
C **************************          THE            ****************************
C **********************              MARK V              ***********************
C ******************         ORNL HEAT PUMP DESIGN MODEL          ******************
C ***********           FOR CHLORINE-FREE, PURE AND AZEOTROPIC          ************
C ********   REFRIGERANT ALTERNATIVES TO R-22, R-502, R-12, AND R-114  *********
C ******************************************************************************
C
C                      DEVELOPED FOR THE DEPARTMENT OF ENERGY
C                         OFFICE OF BUILDING TECHNOLOGIES
C                                      BY
C                          OAK RIDGE NATIONAL LABORATORY
C
C                           PRINCIPAL PROGRAM DEVELOPER
C                                  C. K. RICE
C                                     ORNL
C
C                          DISTRIBUTION VERSION 0.95B
C                                November 1994
C
C ******************************************************************************
C     DOCUMENTATION:
C
C       C. K. RICE AND W. L. JACKSON, PUREZ -- THE MARK V ORNL HEAT PUMP
C          DESIGN MODEL FOR CHLORINE-FREE, PURE AND AZEOTROPIC REFRIGERANT
C          ALTERNATIVES, Documentation Package, Version 0.95B, November 1994.
C
C       C. K. RICE, THE ORNL MODULATING HEAT PUMP DESIGN TOOL -- USER'S GUIDE,
C          ORNL-CON-343, DRAFT JUNE 1991
C
C       S. K. FISCHER, C. K. RICE, AND W. L. JACKSON, THE OAK RIDGE
C         HEAT PUMP DESIGN MODEL: MARK III VERSION PROGRAM DOCUMENTATION,
C         ORNL/TM-10192, MARCH 1988.
C
C       S. K. FISCHER AND C. K. RICE, THE OAK RIDGE HEAT PUMP MODELS: I.
C         A STEADY-STATE COMPUTER DESIGN MODEL FOR AIR-TO-AIR HEAT PUMPS,
C         ORNL/CON-80/R1, AUGUST 1983.
C
C ******************************************************************************
C     RELATED REPORTS AND PAPERS (1985 TO DATE)
C
C       C. K. RICE, BENCHMARK PERFORMANCE ANALYSIS OF AN ECM-MODULATED
C         AIR-TO-AIR HEAT PUMP WITH A RECIPROCATING COMPRESSOR, ASHRAE
C         TRANSACTIONS, VOL. 98, PT. 1, 1992
C
C       C. K. RICE, "CAPACITY MODULATION COMPONENT CHARACTERIZATION
C         AND DESIGN TOOL DEVELOPMENT", THE SECOND DOE/ORNL HEAT PUMP
C         CONFERENCE: RESEARCH AND DEVELOPMENT ON HEAT PUMPS FOR
C         CONDITIONING APPLICATIONS, WASHINGTON, D. C., APRIL 17-20, 1988.
C
C       C.K. RICE, EFFICIENCY CHARACTERISTICS OF SPEED-MODULATED DRIVES
C         AT PREDICTED TORQUE CONDITIONS FOR AIR-TO-AIR HEAT PUMPS, ASHRAE
C         TRANSACTIONS, VOL. 94, PT. 1, 1988, PP. 892-921.
C
C       C.K. RICE, THE EFFECT OF VOID FRACTION CORRELATION AND HEAT FLUX
C         ASSUMPTION ON REFRIGERANT CHARGE INVENTORY PREDICTION, ASHRAE
C         TRANSACTIONS, VOL. 93, PT. 1, 1987, PP. 341-367.
C
C       C. K. RICE, S. K. FISCHER, AND C. J. EMERSON, THE OAK RIDGE
C         HEAT PUMP MODELS: II. AN ANNUAL PERFORMANCE FACTOR / LOADS MODEL
C         FOR RESIDENTIAL AIR-SOURCE HEAT PUMPS, ORNL/CON-160, 1985.
C
C       S. K. FISCHER AND C. K. RICE, SYSTEM DESIGN OPTIMIZATION AND VALIDATION
C         FOR SINGLE-SPEED HEAT PUMPS, ASHRAE TRANSACTIONS, VOL. 91, PT. 2B,
C         1985, PP. 509-523.
C
C ******************************************************************************
```

FILE: HISTORY.DOC

VERSIONS OF ORNL HPDM
(Heat Pump Design Model)

```
1982 Mark I   - First distribution version (magnetic tape).


1985 Mark III - First distribution PC version, Input/Output schematics onscreen,
                Compressor map fitting routine.


1986          - ADL/ORNL Mixed Refrigerant Version of Mark III
                (limited distribution version for binary CFC mixtures)


1991 Mark IV  - Modulating version with charge inventory and design parametrics,
    (MODCON)    Improved air-side heat transfer correlations,
                Modulating compressor map fitting routine,
                Compressor and HX calibration multipliers,
                R-134a capability added, and
                EXMOD input data menu.


1993 Mark V   - 8 pure and 5 near-azeotropic chlorine-free refrigerant
    (PUREZ)     candidates for R-11, R-114, R-12, R-22, and R-502 replacement.

                Free-format input data and flexible refrigerant selection.

                New options for:
                  using ARI compressor map curve-fit representations (10-term
                  coefs), holding heat pump output capacity constant,
                  specifying nominal refrigerant pressure drops of auxiliary
                    components, and
                  conducting parametrics of tube diameter and thickness.

                TUNECOMP program to calibrate compressor map representations
                with system operating data

                       Version 0.95a (July 1994), Version 0.95b (November 1994)
```

FILE: REFRIGS.DOC

REFRIGERANT ID SPECIFICATIONS IN MARK V DATA FILE

The Mark V version of the ORNL HPDM includes thirteen chlorine-free refrigerants --eight pure refrigerants and five near-azeotropic mixtures. Different mixture versions (constituting the preliminary and official compositions) of the two-component refrigerant near-azeotropes, AZ-20 and AZ-50, are included. Representations for the chlorine-free, pure and the two-component near-azeotropic refrigerants were provided by Allied-Signal. Dupont provided property representations for HP-62--the near-azeotrope ternary that is an R-502 alternative.

The desired refrigerant can be identified in the input data in a variety of ways. The refrigerant ID specification is relatively free format. The "R" or "R-" preceding a refrigerant number is optional. For refrigerants R-134a, R-143a and R-152a, the "a" is optional. For C-318, the "C-" is optional. For binary mixtures, the official composition percentages are assumed if omitted. AZ-20 may be substituted for R-32/R-125. AZ-50 may be substituted for R-143a/R-125. R-507 is equivalent to R-143a/R-125(50/50), etc. (The full names with composition percentages typed as shown below can be included in the input data if desired.)

For example, AZ-50 can be specified in the input line as AZ-50, AZ50, 50, R-507, 507,R-143a/R-125(50/50),143/125(50/50), 143/125 or 143125.

The following refrigerants are represented, in full (thermodynamically and thermophysically) or in part (transport properties only) in the Mark V model:

Ver.	Refrigerant ID	Ref. No.	Alternative Names	Candidate Replacement For
3	R-12	12		
3	R-22	22		
3	R-114	114		
3	R-502	502		
4	R-134a	134		R-12, R-22
5	R-32	32		R-22
5	R-123	123		R-11
5	R-124	124		R-114
5	R-125	125		R-502
5	R-143a	143		R-502
5	R-152a	152		R-12
5	R-290 (propane)	290		R-22
5	R-32/R-125(50/50)	32125	AZ-20	R-22
5	R-32/R-125(60/40)	3212560		R-22
5	R-143a/R-125(50/50)	143125	AZ-50, R-507	R-502
5	R-143a/R-125(55/45)	14312555		R-502
5	R-143a/R-125/R-134a (52/44/4)	14312552	HP-62	R-502

Ver.	Refrigerant ID	Ref. No.	Alternative Names	Candidate Replacement For
*	(R-11)	(11)		
*	(R-13)	(13)		
*	(R-14)	(14)		
*	(R-21)	(21)		
*	(R-23)	(23)		
*	(R-113)	(113)		
*	(C-318)	(318)		
*	(R-500)	(500)		
*	(R-729) (air)	(729)		

3 - refrigerants included in the Mark III and earlier versions of the ORNL HPDM
- version of the ORNL HPDM where newer refrigerants first appeared
-- Mark IV MODCON (4) or Mark V PUREZ(5) version.
References: Allied-Signal, Dupont.
* - denotes refrigerants () for which only thermophysical (transport) properties are built into the model. The thermodynamic (equation-of-state) properties for these can be modeled by adding published "Downing" coefficients to the TABLES subroutine.
Reference: R. L. Downing, "Refrigerant Equations", ASHRAE Transactions, Vol. 80, Part 2, 1974.

FILE: READMETO.RUN

```
To run the model, Type 'PUREZ' and respond to the interactive queries.
The program will run faster if you copy the executable file
and the accompanying default input data sets to your hard disk.
The program will run whether or not your PC has a math coprocessor
but will execute 30 to 60 (or more) times faster with one.

THE MAIN DIRECTORY OF THIS DISK CONTAINS THE FOLLOWING FILES:

PUREZ.EXE    executable code for ORNL PUREZ Heat Pump Design Model

FOR06.COM    print utility to add form feeds to output file
FOR06.DOC    instructions on how to use FOR06.COM

COMPRESS.COM utility to set   printer to compressed mode (132 character width)
RESET.COM    utility to reset printer to standard   mode ( 80 character width)

Default Input Data Sets:

CONCHZ.DAT    sample data file to skip parametrics
HPDATA.DAT    sample heat pump configuration file

Default Output Data Set:

OUTPUT.DAT    sample heat pump performance results
OUTPUT.PRT    sample heat pump performance results after use of FOR06.COM

Documentation Files:

READMETO.RUN  this overview of files and subdirectories contained on the disk

README_V.DOC  listing of program credits and documentation references

HPDFILES.DOC  description of additional heat pump configuration files

CHANGES.95b   listing of changes since last printed documentation

--DOCS        directory containing documentation files on new features of PUREZ
              (Mark V) model

THE MAIN DIRECTORY OF THIS DISK CONTAINS THE FOLLOWING SUBDIRECTORIES:

--ARIFIT      directory containing the companion compressor mapfitting program
              for the  ARI Standard 540-91 mapfitting approach (10-coef. curve
              fits)

--MAPFIT      directory containing the companion compressor mapfitting program
              for the ORNL mapfitting approach (6-coefficient curve fits)

--HPD_ARI     directory containing heat pump data files with ARI compressor maps

--HPD_VAL     directory containing heat pump data files for a sample validation
              case

--TUNECOMP    directory containing the companion compressor tuning program

--SOURCE      directory containing compressed FORTRAN source code for the ORNL
              PUREZ program

--RECOMPIL    directory containing utility files to assist users in recompiling
              and relinking the FORTRAN code
```

FILE: HPDFILES.DOC

SAMPLE DATA FILES

--in subdirectory HPD_ARI

HPs with Scroll Compressor ARI-format Maps For Specific Refrigerants,
R-22, R-134a, AZ-20 (50/50 composition), and R-290 (propane)

S22.DAT
S134A.DAT
S32125.DAT
S290.DAT

HPs with Recip Compressor ARI-format Maps For R-22

R22.DAT

-- in subdirectory HPD_VAL

Validation Data Sets For R-22 Using Allied Test Data
(Zheng And Spatz,1993 International CFC And Halon Alternatives Conference)
And ORNL MAPFIT-Format Maps To A Recip Compressor

A82.DAT	Data Sets With No Calibration, 82 F cooling
A95.DAT	Data Sets With No Calibration, 95 F cooling
B82.DAT	Data Sets With Compressor Calibration, 82 F cooling
B95.DAT	Data Sets With Compressor Calibration, 95 F cooling
C82.DAT	Data Sets With Compressor and HX Calibration, 82 F cooling
C95.DAT	Data Sets With Compressor and HX Calibration, 95 F cooling

Validation Data Sets For AZ-20 (60/40 Composition) Using Allied Test Data
(Zheng And Spatz,1993 International CFC And Halon Alternatives Conference)
And ORNL MAPFIT-Format Maps To A Recip Compressor

C82_AZ20.DAT	Data Sets With Compressor and HX Calibrations From R-22 Tests, 82 F cooling
C95_AZ20.DAT	Data Sets With Compressor and HX Calibrations From R-22 Tests, 95 F cooling

FILE: HPDLINES.DOC

Description of HPDATA Input

LINE #1 Same description as Line #1 in MODCON User's Guide.

LINE #2 Same description as Line #2 in MODCON User's Guide.

LINE #3 NEW INPUT LINE

ICAPFLAG Indicator for capacity iteration
=0, for no iteration
=1, for iteration

CAPACITY Fixed output capacity (cooling or heating) of unit (Btu/h).

EPSILON Acceptable tolerance on capacity (Btu/h).

LINE #4 Same description as Line #3 in MODCON User's Guide.

LINE #5 Same description as Line #4 in MODCON User's Guide.

LINE #6 Same description as Line #5 in MODCON User's Guide.

LINE #7 Same description as Line #6 in MODCON User's Guide.

LINE #8 Same description as Line #7 in MODCON User's Guide.

LINE #9 Same description as Line #8 in MODCON User's Guide.

COMPRESSOR DATA FOR EFFICIENCY-AND-LOSS MODEL:
(Lines 10.0 and 10.1)

LINE #10.0 Same description as Line #9.0 in MODCON User's Guide.

LINE #10.1 Same description as Line #9.1 in MODCON User's Guide.

MAP-BASED COMPRESSOR MODEL INPUT DATA:
(Alternative Lines 10.0 and 10.1)

LINE #10.0 Same description as Line #9.0 in MODCON User's Guide.

LINE #10.1 MODIFIED INPUT LINE

MODEDT Switch indicating type of compressor data representation.
=1, curve fits to compressor input power and refrigerant mass flow rate for ORNL map-fit compressor model
=2, curve fits to compressor shell isentropic and volumetric efficiencies
=*3, curve fits to compressor input power and refrigerant mass flow rate for ARI map-fit compressor model*

Remaining input variables are described according to the definitions found on Line #9.1 in MODCON User's Guide.

LINE #10.2 Same description as Line #9.2 in MODCON User's Guide.

LINE #10.3 Same description as Line #9.3 in MODCON User's Guide.

LINE #10.4 MODIFIED INPUT LINE

CPOWER or CPOWERA Coefficients for fit to compressor power as a function of compressor inlet (suction) and outlet (discharge) saturation temperatures (deg F), TSICMP and TSOCMP.

if MODEDT=1, then 6 coefficients are used to describe the power-fit (in kW) in the ORNL MAPFIT program representation of --

```
POWER(IHZ) = CPOWER (1,IHZ) * TSOCMP**2       +
             CPOWER (2,IHZ) * TSOCMP          +
             CPOWER (3,IHZ) * TSICMP**2       +
             CPOWER (4,IHZ) * TSICMP          +
             CPOWER (5,IHZ) * TSOCMP * TSICMP +
             CPOWER (6,IHZ)
```

if MODEDT=3, then 10 coefficients are used to describe the power-fit (in Watts) in the ARI 540-91 representation of --

```
POWER(IHZ) = CPOWERA (1,IHZ)                      +
             CPOWERA (2,IHZ) * TSICMP             +
             CPOWERA (3,IHZ) * TSOCMP             +
             CPOWERA (4,IHZ) * TSICMP**2          +
             CPOWERA (5,IHZ) * TSOCMP * TSICMP    +
             CPOWERA (6,IHZ) * TSOCMP**2          +
             CPOWERA (7,IHZ) * TSICMP**3          +
             CPOWERA (8,IHZ) * TSOCMP * TSICMP**2 +
             CPOWERA (9,IHZ) * TSICMP * TSOCMP**2 +
             CPOWERA(10,IHZ) * TSOCMP**3
```

LINE #10.5 MODIFIED INPUT LINE

CMASSF or CMASSFA — Coefficients for fit to compressor mass flow rate (lbm/hr) as a function of compressor inlet (suction) and outlet (discharge) saturation temperatures (deg F), TSICMP and TSOCMP.

if MODEDT=1, then 6 coefficients are used to describe the mass flow-fit in the ORNL MAPFIT program representation of --

```
XMR(IHZ) =      CMASSF (1,IHZ) * TSOCMP**2   +
        CMASSF (2,IHZ) * TSOCMP              +
        CMASSF (3,IHZ) * TSICMP**2           +
        CMASSF (4,IHZ) * TSICMP              +
        CMASSF (5,IHZ) * TSOCMP * TSICMP     +
        CMASSF (6,IHZ)
```

if MODEDT=3, then 10 coefficients are used to describe the mass flow-fit in the ARI 540-91 representation of --

```
XMR(IHZ) =      CMASSFA (1,IHZ)              +
        CMASSFA (2,IHZ) * TSICMP             +
        CMASSFA (3,IHZ) * TSOCMP             +
        CMASSFA (4,IHZ) * TSICMP**2          +
        CMASSFA (5,IHZ) * TSOCMP * TSICMP    +
        CMASSFA (6,IHZ) * TSOCMP**2          +
        CMASSFA (7,IHZ) * TSICMP**3          +
        CMASSFA (8,IHZ) * TSOCMP * TSICMP**2 +
        CMASSFA (9,IHZ) * TSICMP * TSOCMP**2 +
        CMASSFA(10,IHZ) * TSOCMP**3
```

LINE #10.6 Same description as Line #9.6 in MODCON User's Guide.

LINE #10.7 Same description as Line #9.7 in MODCON User's Guide.

LINE #10.8 Same description as Line #9.8 in MODCON User's Guide.

LINES #11-#23 Same description as Lines #10 thru #22 in MODCON User's Guide.

LINE #24 HEAT TRANSFER AND AUXILIARY LINE PRESSURE DROPS IN REFRIGERANT LINES:

Heat transfer values QSUCLN, QDISLN, and QLIQLN are the same as in Line #23 in the MODCON User's Guide.

New optional values are nominal pressure drops (psi) in the suction, discharge, and liquid lines, DPSLN, DPDLN, and DPLLN at a nominal mass flow rate (lbm/hr) XMRNOM

LINES #25-#27 Same description as Lines # thru #25 in MODCON User's Guide.

FILE: HPDFORM.DOC

Free Formatted Input Data Format for the Mark V Model

The Mark V program has been modified to read three input files (HPDATA, CONCHZ and CONTRL) with comment lines added. Also, the data in the input files may now be entered in a free format (FORTRAN list directed READ) without the restriction to fixed format positions.

The comment lines must have an asterisk, "*", as the first non-blank character. There is no limit to the number of comment lines that may be included. A data preprocessor will strip away the comment lines before the data are read by the MODCON routines.

The free format, which applies to all of the numeric input data, allows the numbers to be entered in any column on the input lines, separated by one or more spaces. Numbers may be adjacent (no spaces) if a sign, "+" or "-", is the first character of each subsequent number. Character input for titles and headings always begins in the first column of the line. In the "CONCHZ" data file, the character data for dependent variable descriptions may start in any column.

For each of the input data files, the data preprocessor creates a temporary file which contains the data with all comments stripped away. This file is not used, but may be copied after a run for use with Mark III or older versions of MODCON that do not allow comments or free format. See the explanation for converting data files from the Mark III to IV or V format to determine which data must be removed. Also, numbers may need to be put into specific columns for Mark III or IV. The temporary files will be named HPDATA.TMP, CONCHZ.TMP or CONTRL.TMP for the HPDATA, CONCHZ or CONTRL input files, respectively.

Programmers Notes on the Mark V Free Formatting Option

For each of the input data files, the data preprocessor creates two files. The first is a temporary file which contains the data with all comments stripped away. This file is not used, but may be copied after a run for use with Mark IV versions that do not allow comments. The temporary files will be named HPDATA.TMP, CONCHZ.TMP or CONTRL.TMP for the HPDATA, CONCHZ or CONTRL input files, respectively. The second file created by the preprocessor is a scratch file which has a slash, "/", added at the end of each free-formatted line to assure termination of list directed IO if data values are omitted. This file is read by the Mark V routines and deleted when the program terminates.

The following new COMMON blocks were put into the model wherever the Input/Output Unit numbers for the free format preprocessed files:

```
      COMMON / IOUNIT / IOCHZP, IOCHZQ, IOCHZR, IOCNTP, IOCNTQ, IOCNTR,
     &                  IOCONW, IOSSP, IOCONP
      COMMON / IOHPDT / IOHPDP, IOHPDQ, IOHPDR, IOHPDW
```

The following unit numbers for input and output were assigned for the free format preprocessing routines:

Unit	Variable	Description
10	IOHPDP	FOR READING INPUT 'HPDATA' DATA FILE
11	IOHPDQ	FOR WRITING TEMPORARY PREPROCESSED 'HPDATA' DATA FILE
12	IOHPDR	FOR PREPROCESSING SCRATCH 'HPDATA' DATA FILE
13	IOCHZP	FOR READING INPUT 'CONCHZ' DATA FILE
14	IOCHZQ	FOR WRITING TEMPORARY PREPROCESSED 'CONCHZ' DATA FILE
15	IOCHZR	FOR PREPROCESSING SCRATCH 'CONCHZ' DATA FILE
16	IOCNTP	FOR READING INPUT 'CONTRL' DATA FILES (OPTIONAL)
17	IOCNTQ	FOR WRITING TEMPORARY PREPROCESSED 'CONTRL' DATA FILES
18	IOCNTR	FOR PREPROCESSING SCRATCH 'CONTRL' DATA FILES
19	IOSSP	FOR PUNCHING STEADY-STATE PERFORMANCE DATA FILE OF THE FORM REQUIRED FOR THE ORNL ANNUAL PERFORMANCE FACTOR MODEL
20	IOCONP	FOR PUNCHING THE CONTOUR DATA FILE 'CONGEN' OR 'CONSPD'
6	IOCONW	FOR PRINTING THE INPUT ECHO AND THE OUTPUT LISTING
6	IOHPDW	FOR PRINTING THE INPUT ECHO AND THE OUTPUT LISTING

The data preprocessor is composed of the following subroutines:

PREFIL - Strips comments from an input file to a temporary file which may be saved for future reference. Also creates a scratch file which has comments stripped and is set up for free formatted (list-directed) input for the Mark V program.
UNFIX - Inserts spaces between numbers for list directed input.
ITRIM - Returns length of character string with trailing blanks removed.
LTRIM - Returns the position of the first non-blank in a character string.

The following routines are used by CONDRV to locate the the character data for dependant variable descriptions:

PARM - Find specified or next parameter in a character string.
SKPD - Skip delimeters in a character string.
NXTD - Find next delimeter in a character string.

FILE: HPDCONV.DOC

Converting Data Files from Mark III to Mark IV (MODCON) and Mark V (PUREZ) Versions

The Mark III input data files may be modified to work with the Mark IV (MODCON) and Mark V (PUREZ) models by adding new data in specific sections within the same input data file. The rest of the input data remain essentially unchanged and are forward-compatible.

Data need to be added in the following categories to convert Mark III data for the MODCON input file:

CHARGE INVENTORY
1) Charge inventory data for refrigerant mass calculations,
COMPRESSOR
3) Compressor map parameters for different compressor speeds and nominal design parameters (map-based compressor model only),
2) Coefficients for volumetric efficiency calculations (efficiency-and-loss compressor model only),
BLOWERS
4) Additional parameters for indoor blower,
HEAT EXCHANGERS
5) Fin patternation data for indoor coil,
6) Heat transfer and pressure drop multipliers for indoor coil,
7) REPEAT OF 4), 5), and 6) for outdoor blower and coil
8) Iteration convergence parameters.

To go from Mark IV to Mark V model data format, the following additional data category must be included:

1) Specified capacity for fixed capacity runs.

Except for the additional data required when converting Mark III data to Mark IV and V data, both Mark III and IV data sets are forward compatible with the new free-format input for the Mark V model. This is true even for the compressor map coeffieients where there are no spaces from one coefficient to the next.

Comment lines utilize the Mark V version's free format option which ignores any line which begins with an asterisk (*). The numbers may be entered in a free format, separated by one or more spaces. Numbers may be adjacent (no spaces) if a sign, "+" or "-", is the first character of each subsequent number. (This allows some of the fixed format compressor map curve fits to be used without modification.)

The two following tables exemplify the changes needed to convert HPDATA data sets from Mark III to Mark V version format. Table 1 is for the Map-Based compressor model. Table 2 is a data set for the Loss & Efficiency compressor model.

The Mark III and V columns contain the line numbers from the respective versions as listed in the documentation. The Data column is the data in the MARK V version format, complete with comment lines.

Lines marked with a "+" in the X column are new for the MARK IV+ version and have no corresponding input data from the Mark III version. Lines marked with an "x" have been changed in some way, usually by adding some new variables which may be identified by three plus signs, "+++", above the variable names in the comment lines. In Table 1, there are two exceptions to this rule (changes in definition or shifting of data from one line to another) for the Map-Based compressor data. First, in MARK IV+ Line # 8, CMPSPD was redefined from speed (RPM) to drive frequency (HZ). Second, Line 9.2 in the MARK IV+ versions now contains the two variables, DISPLB and SUPERB, that were previously at the end of MARK III Line 8 (Line 9.4 in Mark IV+ versions).

TABLE 1 - Conversion from Mark III to Mark V
for Map_Based Compressor Model

```
X Mark  HFC  Data
   III
- ---- ----  -------------------------------------------------------------------------------
             * ITITLE
     1    1  TEST HP: MAP-BASED COMPRESSOR MODEL, COOLING MODE -- 82 F AMBIENT
             *
             *   LPRINT
     2    2           1
             *    NCORH        NR
     3    3           1        22
             *
             *  ICAPFLG  CAPACITY   EPSILON
+                     0       0.0       0.0
             *
             *   ICHRGE     SUPER    REFCHG     MVOID
             *                                    +++
x    4    4           0      26.7       0.0         0
             *
             *    IMASS    VOLCMP    ACCHGT    ACCDIA    OILDIA    UPPDIA    HOLDIS  ATBDIA
+         5           0       0.0       0.0       0.0       0.0       0.0       0.0     0.0
             *
             *    IREFC     DTROC
     5    6           0      16.0
             *
             *   TSICMP    TSOCMP
     6    7        38.2     121.1
             *
             *    ICOMP     DISPL    CMPSPD      QCAN    CANFAC
             *                           xxx
x    7    8           2     3.150      60.0       0.0     0.099
             *
             * CTITLE
+       9.0  Map-Based Compressor Model
             *
             *   MODEDT    ICMPDT    ICDVCH    CSIZMT    CFRQNM    CVLTNM    CVLHZM
+       9.1           1         2         2       3.0      60.0     210.0       1.0
             *
             *      NHZ    DISPLB    SUPERB    CSIZMB    CFRQNB    CVLTNB
x    8  9.2           1 3.150E+00  20.0E+00       3.0      60.0     210.0
             *
             *  Lines 9.3 - 9.6 repeat for IHZ <= NHZ
             *    HZVAL    RPMVAL    VLTVAL    POWADJ    XMRADJ ---> (IHZ)
+       9.3        60.0     3450.     210.0       1.0       1.0
             *
             * CPOWER(1,IHZ) - CPOWER(6,IHZ)
x    8  9.4  -2.375E-05 1.349E-02-1.112E-04-4.530E-03 2.396E-04 6.408E-01
             *
             * CMASSF(1,IHZ) - CMASSF(6,IHZ)
     9  9.5  -2.625E-03 1.394E-01 6.125E-02 7.062E+00-2.156E-02 1.899E+02
```

TABLE 1 - continued

```
                *
                *    TAIII      RHII
     10   10         80.0       0.50
                *                                                       IRFIDF
                *   FRQIDF     FRQNMI      QANMI     SIZMTI     FANEFI  ^ ICHIDF      DDUCT  FIXCAP
                *      +++        +++                   +++              +++  +++
x    11   11           1.0       60.0     1200.0        0.0      410.0   -1    -1       6.0     0.0
                *
                *     AAFI        NTI     NSECTI        WTI        STI       RTBI
     12   12         3.802        4.0       6.00      0.625       1.00      104.0
                *
                *   FINTYI        FPI     DELTAI       DEAI       DERI       XKFI       XKTI  HCONTI
     13   13           2.0       13.0     0.0100     0.3325     0.3085      128.3      225.0   100.0
                *
                *     NDUM       XDUM
+         14             0        0.0
                *
                *   HTRMLI     PDRMLI     HTAMLI     PDAMLI     CABMLI
+         15           1.0        1.0        1.0        1.0        1.0
                *
                *    TAIIO       RHIO
     14   16          82.0       0.40
                *                                                       IRFODF
                *   FRQODF     FRQNMO      QANMO     SIZMTO     FANEFO  ^ ICHODF     MFANFT
                *      +++        +++                   +++              +++  +++
x    15   17           1.0       60.0     3000.0        0.0      230.0   -1    -1          0
                *
                *     AAFO        NTO     NSECTO        WTO        STO       RTBO
     16   18        14.713        1.0       3.00       .866       1.00       21.0

                *   FINTYO        FPO     DELTAO       DEAO       DERO       XKFO       XKTO  HCONTO
     17   19           2.0       20.0     0.0050     0.3950     0.3710      128.3      225.0   100.0
                *
                *     NDUM       XDUM
+         20             0        0.0
                *
                *   HTRMLO     PDRMLO     HTAMLO     PDAMLO     CABMLO
+         21           1.0        1.0        1.0        1.0        1.0
                *
                *   MCMPOP     MFANIN     MFANOU
     18   22             2          2          2
                *
                *   QSUCLN     QDISLN     QLIQLN      DPSLN      DPDLN      DPLLN     XMRNOM
                *                                       +++        +++        +++        +++
     19   23           0.0        0.0        0.0        0.0        0.0        0.0        0.0
                *
                *      DLL     XLEQLL     DLRVIC     XLRVIC     DLRVOC     XLRVOC
     20   24        0.2885      30.00     0.7260      30.00     0.7260       2.00
                *
                *    DSLRV     XLEQLP      DDLRV     XLEQHP
     21   25        0.7260       5.00     0.4760       2.00
                *
                *   AMBCON     CNDCON     FLOCON     EVPCON     CONMST     CMPCON       TOLH    TOLS
+         26           0.0        0.0        0.0        0.0        0.0        0.0        0.0     0.0
```

TABLE 2 - Conversion from Mark III to Mark V
for Efficiency & Loss Compressor Model

```
X Mark  HFC  Data
   III
- ---- ----  ------------------------------------------------------------------------------
             * ITITLE
     1    1  TEST AC: EFFICIENCY & LOSS COMP. MODEL, COOLING MODE -- 82 F AMB.
             *
             *   LPRINT
     2    2         1
             *    NCORH         NR
     3    3         1         22
             *
             *  ICAPFLG  CAPACITY   EPSILON
+                   0        0.0       0.0
             *
             *   ICHRGE      SUPER    REFCHG     MVOID
             *                                     +++
x    4    4         0       21.0       0.0         0
             *
             *    IMASS     VOLCMP    ACCHGT    ACCDIA    OILDIA    UPPDIA    HOLDIS  ATBDIA
+         5         0        0.0       0.0       0.0       0.0       0.0       0.0     0.0
             *
             *    IREFC      DTROC
     5    6         0       20.0
             *
             *   TSICMP     TSOCMP
     6    7      38.2      121.1
             *
             *    ICOMP      DISPL    CMPSPD      QCAN    CANFAC
     7    8         1      1.820   3450.00       0.0     0.099
             *
             *       VR     EFFMMX    ETAISN    ETAMEC    ETAVLA    ETAVLB
             *                                            +++       +++
x    8    9       .01       0.90      0.88      0.90     -0.01      0.08
             *
             *   MTRCLC      FLMOT     QHILO    HILOFC
     9  9.1         0        3.0       300       1.0

             *
```

TABLE 2 - continued

```
             *
             *     TAIII      RHII
    10   10        80.0      0.50
             *                                                IRFIDF
             *   FRQIDF    FRQNMI     QANMI    SIZMTI    FANEFI  ^ ICHIDF     DDUCT  FIXCAP
             *      +++       +++                 +++            +++  +++
x   11   11         1.0      60.0    1200.0       0.0     410.0   -1   -1       6.0     0.0
             *
             *     AAFI       NTI    NSECTI       WTI       STI      RTBI
    12   12       3.802       4.0      6.00     0.625    0.8660     104.0
             *
             *   FINTYI       FPI    DELTAI      DEAI      DERI      XKFI      XKTI  HCONTI
    13   13         2.0      13.0    0.0100    0.2700    0.2460     128.3     225.0   100.0
             *
             *     NDUM      XDUM
+        14           0       0.0
             *
             *   HTRMLI    PDRMLI    HTAMLI    PDAMLI    CABMLI
+        15         1.0       1.0       1.0       1.0       1.0
             *
             *    TAIIO      RHIO
    14   16        82.0      0.40
             *                                                IRFODF
             *   FRQODF    FRQNMO     QANMO    SIZMTO    FANEFO  ^ ICHODF    MFANFT
             *      +++       +++                 +++            +++  +++
x   15   17         1.0      60.0    3000.0       0.0     230.0   -1   -1         0
             *
             *     AAFO       NTO    NSECTO       WTO       STO      RTBO
    16   18      14.713       1.0      2.00      .866     0.866      21.0

             *   FINTYO       FPO    DELTAO      DEAO      DERO      XKFO      XKTO  HCONTO
    17   19         2.0      20.0    0.0050    0.3325    0.3085     128.3     225.0   100.0
             *
             *     NDUM      XDUM
+        20           0       0.0
             *
             *   HTRMLO    PDRMLO    HTAMLO    PDAMLO    CABMLO
+        21         1.0       1.0       1.0       1.0       1.0
             *
             *   MCMPOP    MFANIN    MFANOU
    18   22           2         2         2
             *
             *   QSUCLN    QDISLN    QLIQLN     DPSLN     DPDLN     DPLLN    XMRNOM
             *                                    +++       +++       +++       +++
    19   23         0.0       0.0       0.0       0.0       0.0       0.0       0.0
             *
             *      DLL    XLEQLL    DLRVIC    XLRVIC    DLRVOC    XLRVOC
    20   24      0.2885     30.00    0.7260     30.00    0.7260      2.00
             *
             *    DSLRV    XLEQLP     DDLRV    XLEQHP
    21   25      0.7260      5.00    0.4760      2.00
             *
             *   AMBCON    CNDCON    FLOCON    EVPCON    CONMST    CMPCON      TOLH    TOLS
+        26         0.0       0.0       0.0       0.0       0.0       0.0       0.0     0.0
```

FILE: TUNECOMP.DOC

TUNECOMP - Compressor Tuning for the Mark IV and V Models

The compressor tuning model, TUNECOMP, calculates adjustment factors for power, refrigerant mass flow rate, overall isentropic and volumetric efficiencies.

Input to TUNECOMP comes from two sources:

1) a control file (or keyboard input) which provides file names for compressor data and printed results, the measured power and refrigerant mass flow rate, and the measured compressor suction and discharge conditions.
2) the compressor data file named in the above input file.

Output is written to the specified output file.

The control file may contain a line for each set of operating conditions so that the same compressor may be analyzed for multiple tests. Input to the control file is as follows:

1) option to use specified input/output files instead of default names.
2) input file name.
3) output file name.
4) operating conditions (as many lines as desired.

The operating condition variables are entered on one line in free format as follows:

```
POW_X  - measured power, excluding fan power (W)
XMR_X  - measured refrigerant mass flow rate (lb/m)
TRICMP - measured suction refrigerant temperature (F)
PIN_G  - measured suction pressure (psi gauge)
POU_G  - measured discharge pressure (psi gauge)
```

A sample operating conditions input file is in Fig. 1.

The compressor data file may be extracted from a heat pump data file for the Mark IV or V version model. The new file will begin with a title line followed by the LPRINT and NCORH, NR lines from the heat pump data. Next, the heat pump data lines starting with ICOMP and ending with the last compressor data line (just before the TAIII, RHII line) are copied in. Finally, the last line from the heat pump data which has tolerances for the various iterations is brought over. Sample heat pump data and compressor data files are shown in Figs. 2 and 3.

The resulting output file echoes the operating conditions and calculated refrigerant state point conditions based on the input values and lists the specified (input values), calculated, adjustment factor and percent difference results for the following:

```
POW    - power (excluding fan power),
XMR    - refrigerant mass flow rate,
ETATOT - overall isentropic efficiency,
ETAVOL - overall volumetric efficiency.
```

Fig. 4 is a sample output file.

The appropriate pair of adjustment factors (power and refrigerant mass flow rate or overall isentropic and volumetric efficiencies, depending on the compressor model being used) may be used by the Mark IV or V versions for runs at the corresponding outdoor/indoor conditions. As an approximation, such corrections can be used for other conditions as well, but preferably for only the same mode of operation (heating or cooling) as the tested data because of the possible effects of different air temperatures over the compressor shell.

Figure 1 - Sample operating conditions input file.

```
y
compaz20.dat
compaz20.out
*
* AZ-20 (60/40 mix), 82 F
*    power = 3054 - 513 = 2541W
* POW_X, XMR_X, TRICMP, PIN_G, POU_G
   2541,   456,   66.9, 129.3, 371.8
*
* AZ-20 (60/40 mix), 95 F
*    power = 3335 - 513 = 2822W
* POW_X, XMR_X, TRICMP, PIN_G, POU_G
   2822,   441,   70.4, 134.1, 432.0
```

Figure 2 - Sample heat pump data file.

```
*   ITITLE
TEST HP: RECIPROCATING COMPRESSOR, 82 F, Adj HTA's & Line Sizes
*
*   LPRINT
        1
*
*    NCORH         NR
        1   3212560
        0       0.0       0.0
        0      23.1       0.0         0
        0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
        0      13.0
     38.2     121.1
*
*    ICOMP     DISPL    CMPSPD      QCAN    CANFAC
        2     2.135     60.00       0.0     0.099
*
*   CTITLE
Map-Based Compressor Model, R-32/R-125 (60/40)
*
*   MODEDT    ICMPDT    ICDVCH    CSIZMT    CFRQNM    CVLTNM    CVLHZM
        1         2         2       3.0      60.0     210.0       1.0
*
*      NHZ    DISPLB    SUPERB    CSIZMB    CFRQNB    CVLTNB
        1 2.135E+00  20.0E+00      3.0      60.0     210.0
*
*    HZVAL    RPMVAL    VLTVAL    ETIADJ    ETVADJ
     60.0     3450.     210.0       1.0       1.0
*
*   CPOWER(6) ...
-8.750E-05 2.026E-02-2.233E-04-2.471E-02 4.651E-04 5.435E-01
*
*     CXMR(6) ...
-2.373E-02 3.617E+00 4.837E-02 5.783E+00-9.609E-03 2.076E+01
     80.0      0.50
      1.0      60.0    1200.0       0.0     293.0   -1   -1       6.0       0.0
    3.118       4.0      6.00     0.625      1.00     104.0
      2.0      13.0    0.0100    0.3325    0.3085     128.3     225.0     100.0
        0       0.0
      1.0       1.0       1.0       1.0       1.0
     82.0      0.40
      1.0      60.0    3000.0       0.0     220.0   -1   -1         0
   20.500       1.0      3.00      .866      1.00      21.0
      2.0      20.0    0.0050    0.3950    0.3710     128.3     225.0     100.0
        0       0.0
      1.0       1.0       1.0       1.0       1.0
        2         2         2
      0.0       0.0       0.0
   0.2885     30.00    0.6100     30.00    0.4125      45.00
   0.7260      5.00    0.4760      2.00
*
*   AMBCON    CNDCON    FLOCON    EVPCON    CONMST    CMPCON      TOLH      TOLS
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
```

Figure 3 - Sample compressor data file.

```
*   ITITLE
Reciprocating Compressor Used In Validation Tests, R-32/R-125 (60/40)
*
*   LPRINT
         3
*
*    NCORH         NR
         1   3212560
*
*    ICOMP      DISPL    CMPSPD      QCAN    CANFAC
         2      2.135     60.00       0.0     0.099
*
*   CTITLE
Map-Based Compressor Model, R-32/R-125 (60/40)
*
*   MODEDT    ICMPDT    ICDVCH    CSIZMT    CFRQNM    CVLTNM    CVLHZM
         1         2         2       3.0      60.0     210.0       1.0
*
*      NHZ    DISPLB    SUPERB    CSIZMB    CFRQNB    CVLTNB
         1 2.135E+00  20.0E+00       3.0      60.0     210.0
*
*    HZVAL    RPMVAL    VLTVAL    POWADJ    XMRADJ
      60.0     3450.     210.0    1.0000    1.0000
*
*   CPOWER(6) ...
-8.750E-05 2.026E-02-2.233E-04-2.471E-02 4.651E-04 5.435E-01
*
*     CXMR(6) ...
-2.373E-02 3.617E+00 4.837E-02 5.783E+00-9.609E-03 2.076E+01
*
*   AMBCON    CNDCON    FLOCON    EVPCON    CONMST    CMPCON      TOLH      TOLS
       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
```

Figure 4 - Sample output file.

```
***** INPUT DATA *****

      Reciprocating Compressor Used In Validation Tests, R-32/R-125 (60/40)

Level of printed output: 3
      COOLING MODE OF OPERATION
      THE REFRIGERANT IS R-32/R-125(60/40)

      COMPRESSOR CHARACTERISTICS:
        OPERATING FREQUENCY                       60.000 HZ
        TOTAL DISPLACEMENT                         2.135 CUBIC INCHES

        Map-Based Compressor Model, R-32/R-125 (60/40)

        DRIVE TYPE OF INPUT COMPRESSOR DATA IS    SINE-WAVE-DRIVEN

        SELECTED MOTOR SIZE IS                      3.00 HP
        NOMINAL FREQUENCY FOR      MOTOR RATING AT  60.0 HZ
        NOMINAL VOLTAGE   FOR      MOTOR RATING AT 210.0 VOLTS
        SELECTED OPERATING VOLTS/HERTZ MULTIPLIER    1.0

        BASE SUPERHEAT    FOR COMPRESSOR MAP      20.000 F
        BASE DISPLACEMENT FOR COMPRESSOR MAP       2.135 CU IN

        BASE     MOTOR SIZE IS                      3.00 HP
        NOMINAL FREQUENCY FOR BASE MOTOR RATING AT  60.0 HZ
        NOMINAL VOLTAGE   FOR BASE MOTOR RATING AT 210.0 VOLTS


***** INPUT DATA *****


        -- USER PROVIDED COEFFICIENTS FOR COMPRESSOR POWER AND MASS FLOW RATE AT DISCRETE FREQUENCIES --

        CURVE FIT REPRESENTATIONS AT  1 DISCRETE FREQUENCIES

        CURVE FIT COEFFICIENTS AT  60.0 HZ FREQUENCY    NOMINAL SPEED OF  3450.0 RPM    DRIVE VOLTAGE OF   210.0 VOLTS
        POWER CONSUMPTION=    -8.750E-05*CONDENSING  TEMPERATURE**2 +  2.026E-02*CONDENSING  TEMPERATURE
                            + -2.233E-04*EVAPORATING TEMPERATURE**2 + -2.471E-02*EVAPORATING TEMPERATURE
                            +  4.651E-04*CONDENSING  TEMPERATURE*EVAPORATING TEMPERATURE +  5.435E-01 KW
        MASS FLOW RATE=       -2.373E-02*CONDENSING  TEMPERATURE**2 +  3.617E+00*CONDENSING  TEMPERATURE
                            +  4.837E-02*EVAPORATING TEMPERATURE**2 +  5.783E+00*EVAPORATING TEMPERATURE
                            + -9.609E-03*CONDENSING  TEMPERATURE*EVAPORATING TEMPERATURE +  2.076E+01 LBM/HR

        HEAT REJECTED FROM COMPRESSOR SHELL IS  .099 TIMES THE COMPRESSOR POWER

        SUPERHEAT CORRECTION TERMS (SET IN BLOCK DATA):
          SUCTION GAS HEATING FACTOR                 .330
          VOLUMETRIC EFFICIENCY CORRECTION FACTOR    .750
          SUCTION SUPERHEAT HEAT TRANSFER FACTOR     .050
          SUCTION GAS HEAT PICKUP FRACTION           .750

      ITERATION TOLERANCES :
        AMBCON    .200 F     CMPCON    .050 BTU/LBM     TOLH     .00100 BTU/LBM
        CNDCON    .200 F     FLOCON    .200 F           TOLS     .00005 BTU/LBM-R
        EVPCON    .500 F     CONMST    .003 F
```

Figure 4 - Sample output file (continued)

```
--- Input Parameters ---
     POW       XMR    TRICMP     PIN_G     POU_G
  2541.0    456.00     66.90    129.30    371.80
--- Compressor I/O States ---
  TRICMP    PINCMP    POUCMP    TSICMP    TSOCMP     SUPER
   66.90    144.00    386.50     43.76    110.71     23.14

CMPMAP: SATURATION TEMPERATURE LEAVING  EVAPORATOR      .000 F    PRESSURE DROP IN SUCTION LINE        .000 PSI
      SATURATION TEMPERATURE ENTERING COMPRESSOR    43.756 F    PRESSURE ENTERING COMPRESSOR      144.000 PSIA
      SATURATION TEMPERATURE LEAVING  COMPRESSOR   110.715 F    PRESSURE LEAVING  COMPRESSOR      386.500 PSIA
      SATURATION TEMPERATURE ENTERING CONDENSER       .000 F    PRESSURE DROP IN DISCHARGE LINE      .000 PSI

      SUPERHEAT   LEAVING  EVAPORATOR      .000 F
      SUPERHEAT   ENTERING COMPRESSOR    23.144 F    HEAT GAIN IN SUCTION LINE             .00 BTU/H
      TEMPERATURE LEAVING  COMPRESSOR   176.457 F    HEAT LOSS FROM COMPRESSOR SHELL    832.90 BTU/H
      TEMPERATURE ENTERING CONDENSER       .000 F    HEAT LOSS IN   DISCHARGE LINE         .00 BTU/H

      SUPERHEAT CORRECTION TERMS
        BASE POWER PER UNIT MASS FLOW    19.539 BTU/LBM
        POWER     CORRECTION FACTOR       1.003
        MASS FLOW CORRECTION FACTOR        .993

      SELECTED COMPRESSOR/MOTOR :
        DRIVE FREQUENCY            60.000 HZ
        COMPRESSOR INPUT POWER      2.465 KW        OVERALL ISENTROPIC EFFICIENCY       .6911
        REFRIGERANT FLOW RATE     426.384 LBM/H     VOLUMETRIC         EFFICIENCY       .8241
        OPERATING MOTOR SPEED    3466.512 RPM       COMPRESSOR PRESSURE RATIO         2.6840
        % OF NOMINAL FREQUENCY     100.00 %
        INDUCTION MOTOR VOLTAGE   210.000 VOLTS

        MOTOR TORQUE               70.315 OZ-FT     MOTOR/DRIVE EFFICIENCY              .8773
        PERCENT OF NOMINAL TORQUE  96.226 %         SUPERHEAT EFFICIENCY                .9679
        TORQUE SUPERHEAT EFFECT    1.0000           SUCTION GAS HEATING FACTOR           .125
        BASE SUPERHEAT DELTA-T      9.507 F         ADJUSTED SUPERHEAT DELTA-T         9.507 F
        BASE SUPERHEAT DELTA-HISEN 14.089 BTU/LBM   ADJUSTED SUPERHEAT DELTA-HISEN    14.089 BTU/LBM
        SUPERHEAT FLOW MULTIPLIER   1.000           SUPERHEAT EFFICIENCY MULTIPLIER    1.000
        DRIVE FLOW RATE MULTIPLIER  1.000           DRIVE EFFICIENCY MULTIPLIER        1.000

      BASE COMPRESSOR/MOTOR :
        DRIVE FREQUENCY            60.000 HZ        OVERALL ISENTROPIC EFFICIENCY       .6904
        OPERATING MOTOR SPEED    3466.512 RPM       NOMINAL VOLUMETRIC EFFICIENCY       .8251
        PERCENT OF NOMINAL TORQUE  96.226 %         MOTOR/DRIVE EFFICIENCY              .8773
        INDUCTION MOTOR VOLTAGE   210.000 VOLTS

--- Experimental Values Versus Calibration Results ---
                   POW       XMR    ETATOT    ETAVOL
Experimental:     2541.0    456.00     .7171     .8814
Calculated:       2465.0    426.38     .6911     .8241
Map Adjustment:   1.0308    1.0695    1.0375    1.0695
Diff (%):          -2.99     -6.49     -3.61     -6.49
```

Figure 4 - Sample output file (continued)

```
 --- Input Parameters ---
     POW       XMR    TRICMP     PIN_G     POU_G
  2822.0    441.00     70.40    134.10    432.00
--- Compressor I/O States ---
  TRICMP    PINCMP    POUCMP    TSICMP    TSOCMP     SUPER
   70.40    148.80    446.70     45.73    121.99     24.67

CMPMAP: SATURATION TEMPERATURE LEAVING  EVAPORATOR      .000 F    PRESSURE DROP IN SUCTION LINE        .000 PSI
      SATURATION TEMPERATURE ENTERING COMPRESSOR    45.727 F    PRESSURE ENTERING COMPRESSOR      148.800 PSIA
      SATURATION TEMPERATURE LEAVING  COMPRESSOR   121.991 F    PRESSURE LEAVING  COMPRESSOR      446.700 PSIA
      SATURATION TEMPERATURE ENTERING CONDENSER       .000 F    PRESSURE DROP IN DISCHARGE LINE      .000 PSI

      SUPERHEAT   LEAVING  EVAPORATOR      .000 F
      SUPERHEAT   ENTERING COMPRESSOR    24.673 F    HEAT GAIN IN SUCTION LINE             .00 BTU/H
      TEMPERATURE LEAVING  COMPRESSOR   194.340 F    HEAT LOSS FROM COMPRESSOR SHELL    919.55 BTU/H
      TEMPERATURE ENTERING CONDENSER       .000 F    HEAT LOSS IN   DISCHARGE LINE         .00 BTU/H

      SUPERHEAT CORRECTION TERMS
        BASE POWER PER UNIT MASS FLOW    21.982 BTU/LBM
        POWER     CORRECTION FACTOR       1.004
        MASS FLOW CORRECTION FACTOR        .990

      SELECTED COMPRESSOR/MOTOR :
        DRIVE FREQUENCY             60.000 HZ
        COMPRESSOR INPUT POWER       2.721 KW       OVERALL ISENTROPIC EFFICIENCY       .6861
        REFRIGERANT FLOW RATE      416.443 LBM/H    VOLUMETRIC         EFFICIENCY       .7863
        OPERATING MOTOR SPEED     3452.229 RPM      COMPRESSOR PRESSURE RATIO         3.0020
        % OF NOMINAL FREQUENCY      100.00 %
        INDUCTION MOTOR VOLTAGE    210.000 VOLTS

        MOTOR TORQUE                77.319 OZ-FT    MOTOR/DRIVE EFFICIENCY              .8702
        PERCENT OF NOMINAL TORQUE  105.811 %        SUPERHEAT EFFICIENCY                .9624
        TORQUE SUPERHEAT EFFECT     1.0000          SUCTION GAS HEATING FACTOR           .130
        BASE SUPERHEAT DELTA-T      11.160 F        ADJUSTED SUPERHEAT DELTA-T        11.160 F
        BASE SUPERHEAT DELTA-HISEN  15.902 BTU/LBM  ADJUSTED SUPERHEAT DELTA-HISEN    15.902 BTU/LBM
        SUPERHEAT FLOW MULTIPLIER    1.000          SUPERHEAT EFFICIENCY MULTIPLIER    1.000
        DRIVE FLOW RATE MULTIPLIER   1.000          DRIVE EFFICIENCY MULTIPLIER        1.000

      BASE COMPRESSOR/MOTOR :
        DRIVE FREQUENCY             60.000 HZ       OVERALL ISENTROPIC EFFICIENCY       .6847
        OPERATING MOTOR SPEED     3452.229 RPM      NOMINAL VOLUMETRIC EFFICIENCY       .7825
        PERCENT OF NOMINAL TORQUE  105.811 %        MOTOR/DRIVE EFFICIENCY              .8702
        INDUCTION MOTOR VOLTAGE    210.000 VOLTS

--- Experimental Values Versus Calibration Results ---
                   POW       XMR    ETATOT    ETAVOL
Experimental:     2822.0    441.00     .7007     .8326
Calculated:       2721.5    416.44     .6861     .7863
Map Adjustment:   1.0369    1.0590    1.0212    1.0590
Diff (%):          -3.56     -5.57     -2.08     -5.57
```

FILE: TUNEMODL.DOC

Compressor and HX Model Tuning for the Mark IV and V Models

1) Run the TUNECOMP model with specified power, refrigerant mass flow rate, suction temperature, suction pressure and discharge pressure. These values come from experimental test data at particular outdoor and indoor conditions.

   This provides adjustment factors to the compressor performance representations for power, refrigerant mass flow rate and overall isentropic and volumetric efficiencies at one system test condition.

2) In Mark IV and V, use the appropriate pair of adjustment factors (power and refrigerant mass flow rate or overall isentropic and volumetric efficiencies, depending on the compressor model being used) to create a base run at the outdoor and indoor conditions from the test data.

3) Iterate on Eq. Lengths for liquid, suction & discharge lines until connecting lines pressure drops match the test data (if available).

```
             Cooling Mode         Heating Mode
             ----------------     ----------------
PD liql = f(XLEQLL)             f(XLEQLL)
PD sucl = f(XLEQLP+XLRVIC)      f(XLEQLP+XLRVOC)
PD disl = f(XLEQHP+XLRVOC)      f(XLEQHP+XLRVIC)
```

   (This was the approach taken for the example validations. These validations were done before the capability was added of including nominal pressure drops in Line #23 of the heat pump input data. This latter approach is more preferable because it is more direct and also it maintains the correct line lengths for use in charge inventory calculations.)

4) Iterate on HX pressure drop multipliers until HX pressure drops are in reasonable agreement with test results.

```
             Cooling Mode         Heating Mode
             ----------------     ----------------
PD evap = f(PDRMLI,NSECTI)      f(PDRMLO,NSECTO)
PD cond = f(PDRMLO,NSECTO)      f(PDRMLI,NSECTI)
```

   Note: If you vary the number of circuits (NSECTO or NSECTI) as well, the refrigerant-side heat transfer will also change.

5) Iterate on heat transfer multipliers until evaporator and condenser saturation temperatures match at the measurement points. If known multipliers are available for air or refrigerant side, adjust only the remaining multipliers.

```
               Cooling Mode         Heating Mode
               ----------------     ----------------
Tsat evap = f(HTRMLI,HTAMLI)      f(HTRMLO,HTAMLO)
Tsat cond = f(HTRMLO,HTAMLO)      f(HTRMLI,HTAMLI)
```

6) To validate Mark IV or V for other operating conditions, re-run the TUNECOMP model (see step 1) with a compressor map appropriate for the new refrigerant to get new adjustment factors for the compressor at the appropriate refrigerant conditions, but continue to use the HX adjustment factors and multipliers calculated in steps 3, 4 and 5 from the original base run in step 2.

   This procedure allows any intrinsic error in the compressor map to be identified and corrected for conditions where test data are available. (If the compressor adjustment factors vary somewhat from one condition to another, this may be due to the effects of different air temperatures over the compressor or -- if the compressor is insulated -- this might indicate problems with the compressor, use of a different viscosity oil, or a non-representative compressor map.) The validations can then test how well the single-point calibrated HX models perform at other operating conditions.

   NOTE THAT COMPRESSOR MAP REPRESENTATIONS DEVELOPED FOR ONE REFRIGERANT SHOULD NOT BE USED WITH A DIFFERENT REFRIGERANT. The loss and efficiency model is more appropriate for use in cases where one needs to model system performance of different refrigerants and compressor maps for each refrigerant are not available.

FILE: CHANGES.95B

November 1994

PUREZ (MARK V) ORNL Heat Pump Model
Changes From Version 0.95 to Version 0.95b

Version 0.95a

Corrected energy balance problem with condenser heat rejection. The energy in the condenser superheated region where the wall temp was above condensation was not being accounted for properly. This had been working properly in Mark III but a logic change in Mark IV caused the problem to appear. This problem was noted independently by two HVAC researchers.

Version 0.95b

Fixed a related problem where the code would fail to converge in EXCH. Traced this to faulty logic path in superheated region iterations.

Found problems with parametrics options that adjust two or three variables simultaneously while trying to maintain constant total HX area. Found that the HX adjustment multipliers used were not working exactly as intended. The errors occurred in subroutine TRNVAL and involved parametric variables greater than ID number 44 in Table A.2 of the MODCON documentation.

Modified CONDRV and APFDRV to correct some I/O problems when using the CONTROL data option and to print out screen information on parametric analysis progress. Added header describing current version at beginning of output file. Header says "PUREZ (Mark V) -- Version 0.95b".

Found that the mass flow rate coefficients for the scroll compressor using R134a (S134.DAT in subdirectory HPD_ARI) were incorrect as received from the manufacturer. Refit the original ARI AREP data (from report #30) using the ARI curve fitting procedure and replaced the corresponding ARI coefficients in file S134.DAT.

Added data set for propane (S290.DAT) to subdirectory HPD_ARI. Corrected values of NR in S134.DAT and S32125.DAT from R-22 to R-134a and R-32125, respectively, and reran cases. (...a good example of why we need to include a way to ensure that the compressor map is suitable for the selected refrigerant!)

Observed some convergence problems with superheat in the evaporator when the refrigerant side pressure drop is large (such as small tube diameter cases). Haven't investigated closely but suspect that iteration is more unstable under such conditions. Suggest that users loosen the tolerance on EVPCON from 0.5 to 1 deg F in such cases.

Found some problems in the way the fan power conversions were working when specifying a reference fan power value. Problems that were identified involved ECM drives.

Listing Of Files Changed In This Update --

APFDRV.95b

CONDRV.95b

COND.95b

EVAPR.95b

EXCH.95b

TRNVAL.95b