APPENDIX A

Information on the SEER, EER, and HSPF of residential air conditioners and heat pumps was obtained from the California Energy Commission databases.[i] The information is for units under 65,000 BTU/h, (5.4 tons). Plots of EER vs. SEER for residential split system and packaged air conditioners and heat pumps and of SEER vs. HSPF and EER vs. HSPF for residential split system and packaged heat pumps are shown in Figures 1, 2, and 3.

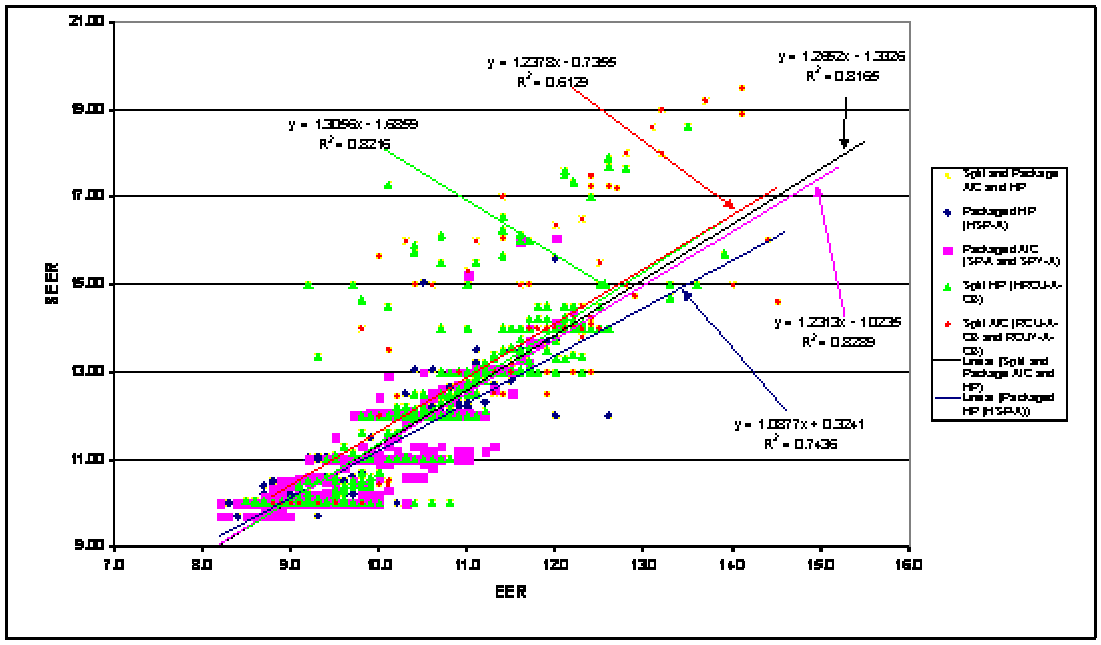

Figure 1: SEER versus EER for Residential Packaged and Split Systems ≤ 65,000 Btu/h

Source: California Energy Commission Appliance Database, Central Air. URL: http://www.energy.ca.gov/appliances/appliance/excel_based_files/central_air/. February 23, 2004.

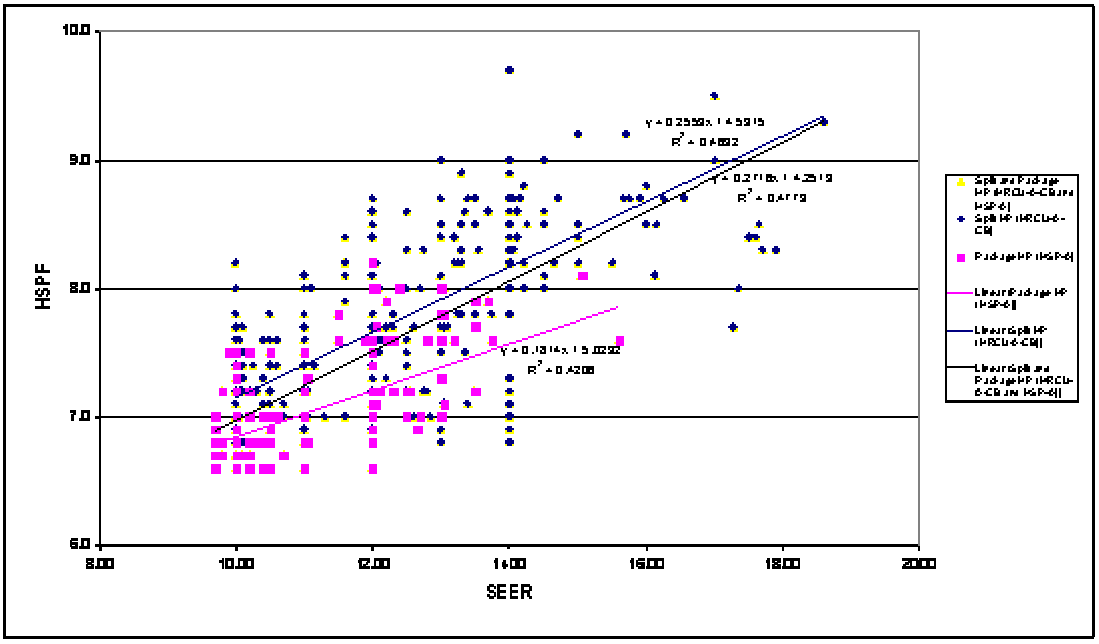

Figure 2: SEER versus HSPF for Residential Packaged and Split System Heat Pumps ≤ 65,000 Btu/h

Source: California Energy Commission Appliance Database, Central Air. URL: http://www.energy.ca.gov/appliances/appliance/excel_based_files/central_air/. February 23, 2004.

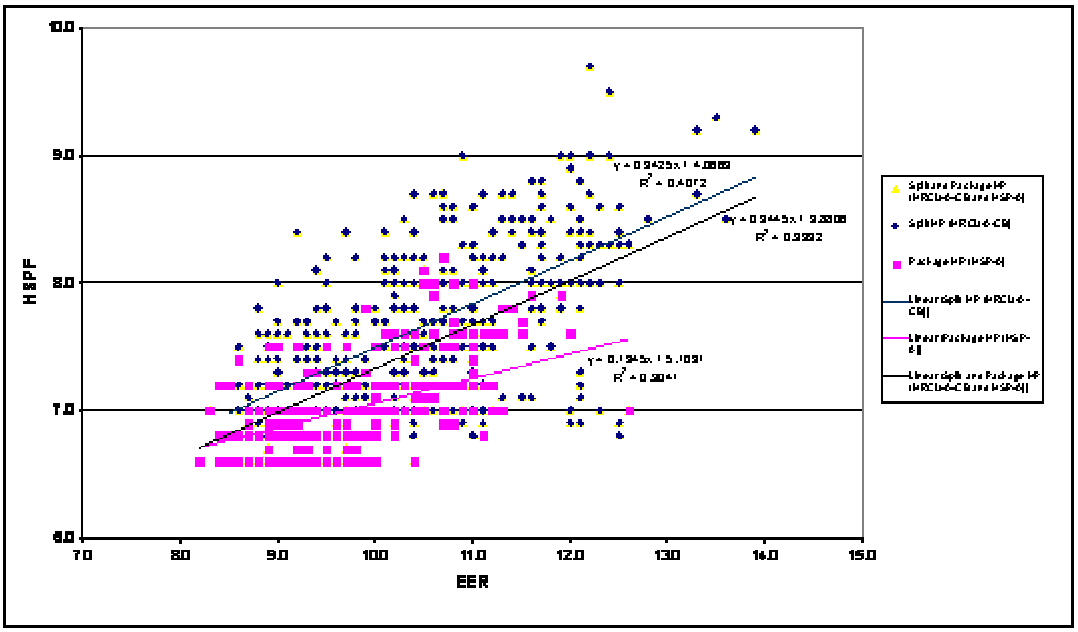

Figure 3: EER versus HSPF for Residential Packaged and Split System Heat Pumps ≤ 65,000 Btu/h

Source: California Energy Commission Appliance Database, Central Air. URL: http://www.energy.ca.gov/appliances/appliance/excel_based_files/central_air/. February 23, 2004

Though there is a cost impact of using TXVs, their use has benefits that result in better field performance, as discussed in the commercial unitary AC and HP TSD.[ii] Better control of the refrigerant at part load or off-load operating conditions is one such benefit. The TXV has no EER benefit in a properly designed and charged A/C unit, but experience with residential split systems has shown that 62% of units are improperly charged in the field.[iii] According to a CEC report[iv], improperly charged refrigerant and low airflow cause a seasonal efficiency reduction of 9% and 8%, respectively. Performance in a system with a TXV is less affected by this undercharging and low airflow than in a fixed orifice or capillary tube system, where the SEER will degrade by 16% with the combination of these problems. Without fixing these problems, using a TXV will increase the SEER by 11%. Though a TXV has no immediate benefit in systems with proper refrigerant charge and airflow, these systems will develop charge and airflow problems eventually because of small leaks and dirt buildup in the fan and coil systems. Over the lifetime of a system, a TXV will alleviate these problems.

As shown in Figure 4, nearly all systems with a SEER of 15 or higher use a TXV and it is quite common for 13 and 14 SEER systems. Therefore, mandating the use of a TXV seems to offer some modest benefits in an Energy Star Specification.

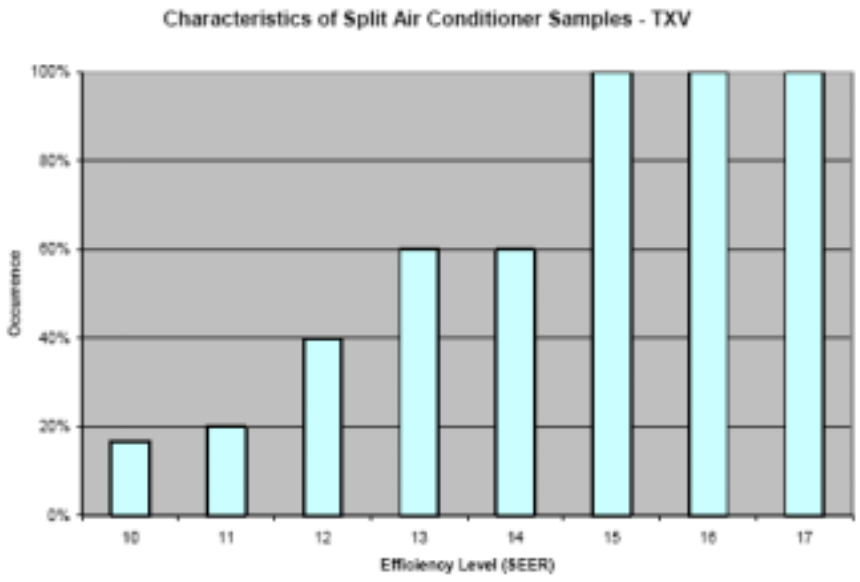

Figure 4: Characteristics of Expansion Devices for Split System Air Conditioners ≤ 65,000 Btu/h (1998)

[i] California Energy Commission Appliance Database, Central Air. URL: http://www.energy.ca.gov/appliances/appliance/excel_based_files/central_air/. February 23, 2004.
[ii] ibid.

[iii] Proctor Engineering Group, LTD. April 6, 2003. AC Performance Associated with AB970 [Online]. Presentation in file 2000-11-28_PROCTOR.PPT in URL: http://www.energy.ca.gov/ab970_standards/documents/presentations/

[iviv] California Energy Commission. March 20, 2001. Split System Space Cooling Refrigerant Charge and Airflow Measurement. Document number P400-01-014.l

Appendix B

Table B1 Papers Investigating System Sizing

Study	State	New / Existing	Sample Size	Avg. % Oversized	Avg. Tons Oversized	% Savings Potential Min	% Savings Potential Max
Blasnik et al 1995a	Nevada	New	30	33		2	10
Blasnik et al 1996	Arizona	New	22	48	1.21	2	10
Giolma et al 1985	Texas	Both		64		2	10
James at al 1997	Florida	New	368	23	0.61	2	10
Katz 1997	Carolinas	New	50		0.81	2	10
Kemper 1994	Iowa	New	125	56	0.98	2	10
Lucas 1992	Pacific NW	Existing	60	44	0.68	2	10
Neme et al 1997	Maryland	New	46	59	1.11	2	10
Sherman & Hildebrandt 1998	California	Existing	40	16	0.3	2	10
VEIC/PEG 1997	New Jersey	New	52	60	1.58	2	10
XENERGY 1998	New Jersey	Existing	45	70		2	10
		Total	838				
		Average		47.3	0.91	2	10

Table B2 Papers Investigating Refrigerant Charge

Study	State	New / Existing	Sample Size	% Overcharge	% Undercharge	% Energy Savings
Blasnik et al 1995a	Nevada	New	30	5	59	17
Blasnik et al 1995a	California	New	10			8
Blasnik et al 1996	Arizona	New	22	4	78	21
Farzad & O'Neal 1993						5
Farzad & O'Neal 1994						17
Hammarlund et al 1992	California	New	12			12
Hammarlund et al 1992	California	New	66	61	8	12
Katz 1997	Maryland	New	22	64	23	
Proctor & Pernick 1992	California	Existing	175	33	23	
Proctor 1991	California	Existing	15			
Proctor et al 1995a	California	New	30	33	56	
Proctor et al 1997a	New Jersey	New	52			13
Rodriguez et al 1995						5
Rodriguez et al 1995						15
		Total	43.4			
		Average		33.3	41.2	12.5

Table B3 Papers Investigating Evaporator Coil Airflow

Study	State	New / Existing	Sample Size	Avg. Airflow	% Energy Savings
Blasnik et al 1995a	Nevada	New	30	345	8
Blasnik et al 1995a	California	New	10	319	
Blasnik et al 1996	Arizona	New	22	344	10
Hammarlund et al 1992	California	New	12		10
Hammarlund et al 1992	California	New	66		12
Neme et al 1997	Maryland	New	25	340	
Palani et al 1992					4
Parker et al 1997	Florida	Both	27	270	10
Proctor & Pernick 1992	California	Existing	175		
Proctor 1991	California	Existing	15		
Proctor et al 1995a	California	Existing	30	300	
Rodriguez et al 1995					2
Rodriguez et al 1995					10
VEIC/PEG 1997	New Jersey	New	52	372	7
		Total	464.0		
		Average		327.1	8.1

Table B4 Papers Investigating Duct Leakage

Study	State	New / Existing	Sample Size	Duct Leakage to outside @ cfm	% Energy Savings
Blasnik et al 1995a	Nevada	New	30	253	26
Blasnik et al 1995a	California	New	10	292	25
Blasnik et al 1996	Arizona	New	22	193	11
Cummings et al 1990	Florida	Existing	24		18
Hammarlund et al 1992	California	New	12		24
Hammarlund et al 1992	California	New	66		6
Jump et al 1996	California	Existing	24		18
Katz 1997	Carolinas	New	96	360	
Modera & Jump 1995	California	Existing	3		19
Neme et al 1997	Maryland	New	25	204	12
Pamiter & Francisco 1994	Northwest	Existing	22	287	16
Penn 1993	Florida	Existing	10620		17
Proctor & Pernick 1992	California	Existing	1000	246	18
Proctor 1991	California	Existing	15	276	18
Proctor et al 1995a		Existing	30	397	
Proctor et al 1997a	New Jersey	New	52	299	20
Siegel et al 1996	Oregon	Existing	8	241	16
Treidler & Modera 1996	Maryland		4		9
Vigil 1993	North Carolina	Existing	82	188	13
		Total	12,145		
		Average		269.7	16.8

References

Blasnik, Michael et al. 1995a. *Assessment of HVAC Installations in New Homes in Nevada Power Company's Service Territory.* Palo Alto, Calif.: Electric Power Research Institute.

_____. 1996. *Assessment of HVAC Installations in New Homes in APS Service Territory*. Prepared for the Arizona Public Service Company. Palo Alto, Calif.: Electric Power Research Institute.

Cummings, James B., et al. 1990. "Impacts of Duct Leakage on Infiltration rates, Space Conditioning Energy Use, and Peak Electrical Demand in Florida Homes. In *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings,* 9.65-9.76. Washington, D.C. American Council for an Energy-Efficient Economy.

Farzad, Mohsen, and Dennis L. O'Neal. 1993. "Inference of the Expansion Device on Air-Conditioner System Performance Characteristics under a Range of Charging Conditions." *ASHRAE Transactions: Research:* 3-13.

Giolma, J., et al. 1985. *Effects of Downsizing Residential Air Conditioners on Aggregate Peak Demand.* Prepared for Austin Electric Utility Department and American Public Power Association. San Antonio, Tex.: Trinity University.

Hammarlund, Jeff, et al. 1992. "Enhancing the Performance of HVAC and Distribution Systems in Residential New Construction." In *Proceedings of the ACEEE 1992 Summer Study on Energy Efficiency in Buildings,* 2.85-2.87. Washington, D.C.: American Council for an Energy Efficient Economy.

James, Patrick, et al. 1997. "The Effect of Residential Equipment Capacity on Energy Use, Demand and Run-Time." Paper presented at the 1997 ASHRAE Winter Meeting.

Jump, David, et al. 1996. "Field Measurements of Efficiency and Duct Retrofit Effectiveness in Residential Forced Air Distribution Systems." In *Proceedings of the ACEEE 1996 Summer Study on Energy Efficiency in Buildings,* 1.147-1.155. Washington, D.C.: American Council for an Energy Efficient Economy.

Katz, Arnie. 1997. "What's Being Built Out There? Performance Tests on 100 New Homes." *Home Energy,* September/October: 29-34.

Kemper [Kemper Management Services, Inc. and Southern Electric International]. 1994. *Residential new Construction Baseline Survey.* Prepared for the Iowa Joint Utilities Task Force.

Lucas, Robert G. 1992. "Analysis of Residential Air Conditioning Equipment Using Monitored Data." In *Proceedings of the ACEEE 1992 Summer Study on Energy Efficiency in Buildings,* 2.157-2.165. Washington, D.C.: American Council for an Energy Efficient Economy.

Modera, Mark and David Jump. 1995. "Field Measurement of the Interaction between Heat Pumps and Attic Duct Systems in Residential Buildings." Paper Presented at the ASME International Solar Energy Conference, March 19-24.

Neme, Chris, et al. 1997. *Southern Maryland Electric Cooperative Power Saver Home Program Impact Evaluation.* Burlington, Vt.: Vermont Energy Investment Corporation.

Palani, Manivannan, Dennis O'Neal, and Jeff Haberl. 1992. "The Effect of Reduced Evaporator Air Flow on the Performance of a Residential Central Air Conditioner." In *the Eighth Symposium on Improving Building Systems in Hot and Humid Climates,* 20-26. Dallas, Tex.

Palmiter, Larry and Paul W. Francisco. 1994. "Measured Efficiency of Forced-Air Distribution Systems in 24 Homes." In *Proceedings of the ACEEE 1994 Summer Study on Energy Efficiency in Buildings*, 3.177-3.187. Washington, D.C.: American Council for an Energy Efficient Economy.

Parker, D.S., et al. 1997. *Impact of Evaporator Coil Air Flow in Residential Air Conditioning Systems.* FSEC-PF-321-97. Florida Solar Energy Center.

Penn, Cyril. 1993. "Duct Fixing in America." *Home Energy*, September/October: 50-52.

Proctor, John. 1991. *Pacific Gas and Electric Appliance Doctor Pilot Project: Summer 1990 Activity.* San Rafael, Calif.: Proctor Engineering Group.

Proctor, John and Ronald Pernick. 1992. "Getting it Right the Second Time: Measured Savings and Peak Reduction from Duct and Appliance Repairs." In *Proceedings of the ACEEE 1992 Summer Study on Energy Efficiency in Buildings*, 2.217-2.224. Washington, D.C.: American Council for an Energy Efficient Economy.

Proctor, John, et al. 1995a. *Southern California Edison Coachella Valley Duct and HVAC Retrofit Efficiency Improvement Pilot Project (Draft).* Prepared for Southern California Edison. San Rafael, Calif.: Proctor Engineering Group.

_____. 1997a. "Assessment of Energy Savings and kW reduction Potential from Air Conditioner and Duct Improvements for New Homes in PSE&G Service Territory (Summary)." Prepared for the Public Service Electric and Gas and Vermont Energy Investment Corporation. San Rafael, Calif.: Proctor Engineering Group.

Rodriguez, Angel G., et al. 1995. *The Effect of Refrigerant Charge, Duct Leakage, and Evaporator Air Flow on the High Temperature Performance of Air Conditioners and Heat Pumps.* Prepared for the Electric Power Research Institute. College Station, Tex.: Texas A&M University, Department of Mechanical Engineering.

Sherman, Craig and Eric Hildebrandt. 1998. "Efficient Cooling: Making It Happen." *Home Energy*, March/April: 35-39.

Siegel, Jeff, et al. 1996. *Measured Heating System Efficiency Retrofits in Eight Manufactured (HUD-Code) Homes.* Prepared for the Electric Power Research Institute and the Eugene Water and Electric Board. Seattle, Wash.: Ecotope.

Treidler, Burke and Mark Modera. 1996. "Thermal Performance of Residential Duct Systems in Basements." *ASHRAE Transactions 1996.* AT-96-13-1. Atlanta, Ga.: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

VEIC/PEG [Vermont Energy Investment Corporation and Proctor Engineering Group]. 1997. *PSE&G Baseline Survey of Residential New Construction.* Burlington, Vt.:

Vermont Energy Investment Corporation and San Rafael, Calif.: Proctor Engineering Group.

Vigil, Frank. 1993. "Duke Power's Success." *Home Energy*, September/October: 45-47.

XENERGY, Inc. 1998. *Direct Load Control Evaluation.* Prepared for the Public Service Electric and Gas. Madison, Wisc.: XENERGY, Inc.