



Lawrence Berkeley Laboratory

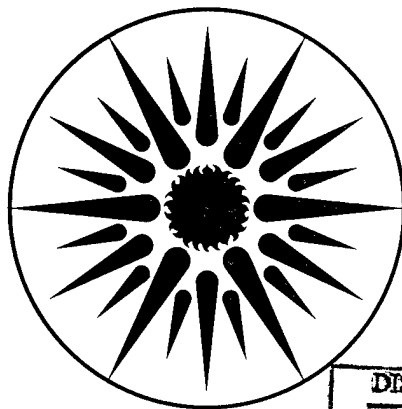
UNIVERSITY OF CALIFORNIA

ENERGY & ENVIRONMENT DIVISION

**End-use Energy Characterization and Conservation
Potentials at DoD Facilities: An Analysis of Electricity
Use at Fort Hood, Texas**

H. Akbari and S. Konopacki

May 1995



**ENERGY
AND ENVIRONMENT
DIVISION**

DISTRIBUTION STATEMENT 1

Approved for public release;
Distribution Unlimited

DTIC QUALITY INSPECTED 3

19961008 082

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor The Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or The Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof, or The Regents of the University of California.

Available to DOE and DOE Contractors
from the Office of Scientific and Technical Information
P.O. Box 62, Oak Ridge, TN 37831
Prices available from (615) 576-8401

Available to the public from the
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, VA 22161

Lawrence Berkeley Laboratory is an equal opportunity employer.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave Blank)		2. REPORT DATE May 1995		3. REPORT TYPE AND DATES COVERED Final	
4. TITLE AND SUBTITLE End-use Energy Characteristics and Conservation Potentials at DoD Facilities: An Analysis of Electricity Use at Fort Hood, Texas				5. FUNDING NUMBERS MIPR E529W221 dated 14 May 1993	
6. AUTHOR(S) H. Akbari and S. Konopacki					
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Construction Engineering Research Laboratories (USACERL) P.O. Box 9005 Champaign, IL 61826-9005				8. PERFORMING ORGANIZATION REPORT NUMBER TM 96/100	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Executive Director, SERDP Office 901 N. Stuart Street, Suite 303 Arlington, VA 22203				10. SPONSORING / MONITORING AGENCY REPORT NUMBER LBL-36974 UC-000	
11. SUPPLEMENTARY NOTES Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.					
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.				12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) This report discusses the application of the Lawrence Berkeley Laboratory's End-use Disaggregation Algorithm (EDA) to a Department of Defense (DOD) installation and presents hourly reconciled end-use data for all major building types and end uses. The goals of the project were to: (1) develop an energy database by building type and by end use for DOD facilities and (2) to enhance the DOD energy office's ability to track energy use by end use. The project was pilot tested at Fort Hood, Texas, which was determined to have representative samples of nearly all the major building types in use on DOD installations. The EDA was applied to 10 separate feeders from the three substations at the Fort. The results from the analyses of these 10 feeders were extrapolated to estimate energy use by end use for the entire installation and validate the results with the independent Texas Utility billing data for electricity use for the installation. The results show, among other findings, that administration, residential, and barracks buildings are the largest consumers of electricity for a total of 250 GWh per year (74 percent of the Fort's annual consumption of 330 GWh).					
14. SUBJECT TERMS energy conservation Ft. Hood, TX facility management military facilities				15. NUMBER OF PAGES 256	
				16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified		20. LIMITATION OF ABSTRACT SAR	

**End-use Energy Characterization and Conservation
Potentials at DoD Facilities: An Analysis of Electricity
Use at Fort Hood, Texas**

May 1995

H. Akbari and S. Konopacki

Energy & Environment Division
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

A Report Prepared for
Lee DeBaillie and Larry Lister
U. S. Army Construction Engineering Research Laboratory
P. O. Box 9005
Champaign, IL 61826

This work was supported by a grant from the Strategic Environmental Research and Development Program (SERDP) and managed by the U. S. Army Construction Engineering Research Laboratory (CERL) through the U. S. Department of Energy, under contract DE-AC0376SF00098.

Acknowledgement

This work was sponsored by the U.S. Army Construction Engineering Research Laboratories (CERL) through the U.S. Department of Energy, Under contract DE-AC0376SF00098. Funding was provided by the Strategic Environmental Research and Development Program (SERDP). Public Law 101-510 established SERDP as a multi-agency program funded through the Department of Defense. SERDP seeks to identify, develop, and demonstrate technologies in the areas of pollution prevention and cleanup, energy and resource conservation and global environmental change. SERDP responds to the environmental requirements of the Department of Defense (DoD) and is undertaken in cooperation with other government agencies, including the Department of Energy (DoE), the National Institutes of Science and Technology (NIST), the National Oceanographic and Atmospheric Administration (NOAA), the National Institutes of Health (NIH), the U.S. Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA).

Abstract

This report discusses the application of the LBL's End-use Disaggregation Algorithm (EDA) to a DoD installation and presents hourly reconciled end-use data for all major building types and end uses. The goals of the project were: 1) to develop an energy database by building type and by end use for DoD facilities and 2) to enhance the DoD energy office's ability to track energy use by end use.

The project initially focused on achieving these objectives and pilot-testing the methodology at Fort Hood, Texas. Fort Hood is located near the town of Killeen, and with over 5000 buildings was determined to have representative samples of nearly all of the major building types in use on DoD installations. These building types at Fort Hood include: office, administration, vehicle maintenance, shop, hospital, grocery store, retail store, car wash, church, restaurant, single-family detached housing, two and four-plex (both single- and double-story) housings, and apartment building. Up to 11 end uses were developed for each prototype, consisting of 9 electric and 2 gas; however, only the electric end uses were reconciled against known data and weather conditions. The electric end uses are space cooling, ventilation (air-handling units, fans, chilled and hot water pumps), cooking, miscellaneous/plugs, refrigeration, exterior lighting, interior lighting, process loads, and street lighting. The gas end uses are space heating and hot water heating. Space heating energy-use intensities were simulated only.

The EDA was applied to 10 separate feeders from the three substations at Fort Hood. The results from the analyses of these ten feeders were extrapolated to estimate energy use by end use for the entire installation, and validate the results with the independent Texas Utility billing data for electricity use for the installation. The results show that administration, residential, and the barrack buildings are the largest consumers of electricity for a total of 250GWh per year (74% of the Fort Hood annual consumption of 330 GWh). By end use, cooling, ventilation, miscellaneous, and indoor lighting consume almost 84% of total electricity use. The contribution to the peak power demand is highest by residential sector (35%, 24 MW out of 70 MW), followed by administration buildings (30%), and barrack (14%). For the entire Fort Hood installation, cooling is 54% of the peak demand (38 MW out of 70 MW), followed by interior lighting at 18%, and miscellaneous end uses by 12%.

Table of Contents

Table of Contents	v
List of Figures	vii
List of Tables	xvii
Executive Summary	xix
1. Introduction	1
Background	1
Objectives	1
Project Description	1
Overview of the Report	2
2. Input Data	4
IFS Building Inventories	4
Model Energy Installation Project (MEIP) Onsite Survey Data of 25 Non- residential Buildings	4
Model Energy Installation Project (MEIP) Onsite Survey Data of 11 Residential Buildings	7
Chiller Survey Data	7
Mechanical Equipment Survey Data	7
Feeder Short-Interval (Hourly) Electric Load Data	7
Feeder to Building Assignment Data	8
Previously Developed LBL Prototypes	8
Hourly Weather Data	8
Texas Utility Hourly Electric Load Data	8
3. Methodology	11
EDA Description	11
Feeder Data Analysis	11
Prototype Development	18
Feeder to Prototype Assignment	23
EDA Application	23

Post EDA Data Analysis	26
4. Results	28
Prototype Selection by Feeder	28
DOE-2 Simulated Electric and Gas End-use Annual EUIs	28
EDA Reconciled Electric End-use Annual EUIs by Feeder	28
EDA Reconciled Total Electric Annual EUIs by Feeder	33
Weighted EDA Reconciled Electric End-use Annual EUIs	33
Simulated and EDA Reconciled Street Lighting Annual EUIs	33
EDA Validation	33
Electronic Data	39
5. Conclusion	40
Accuracy of the Results	40
Recommendations	41
Extrapolation of the Results to Other DoD Installations	42
Bibliography	43
Appendix A - Feeder Data Analysis	45
Appendix B - Prototype Characteristics and DOE-2 Simulated End-use Load Shapes	103
Appendix C - EDA Reconciled End-use Load Shapes by Prototype	164

List of Figures

Figure	Description	Page
Figure EX-1.	Annual Electricity Use and Peak Power Demand at Fort Hood, TX...	xiv
Figure 2-1.	Texas Utility Annual Hourly Electricity Use.	10
Figure 3-1.	Fort Hood End-Use Characterization Methodology.	12
Figure 3-2.	Fort Hood End-Use Characterization Methodology - Feeder Data Analysis.	13
Figure 3-3.	Feeder 2 Data.	14
Figure 3-4.	Feeder 2 Data Analysis - Feeder Load vs. Outdoor Drybulb Temperature Winter - Standard Day.	16
Figure 3-5.	Feeder 2 Data Analysis - Feeder Load vs. Outdoor Drybulb Temperature Summer - Standard Day.	17
Figure 3-6.	Large Administration Load Shapes for Standard Day - Summer.	21
Figure 3-7.	Fort Hood End-Use Characterization Methodology - Prototype Development.	22
Figure 3-8.	Fort Hood End-Use Characterization Methodology - Feeder to Prototype Assignment Analysis.	24
Figure 3-9.	Fort Hood End-Use Characterization Methodology - Post EDA Data Analysis.	27
Figure 4-1.	EDA Annual Hourly Electricity Use (Upper) Difference of Texas Utility and EDA (Lower).	38
Figures A-1.	Feeder 2 Data.	48
Figures A-2.	Scatterplots of Feeder 2 Hourly Load vs. Drybulb Temperature for Standard Winter Days.	49
Figures A-3.	Scatterplots of Feeder 2 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days.	50
Figures A-4.	Scatterplots of Feeder 2 Hourly Load vs. Drybulb Temperature for Standard Summer Days.	51
Figures A-5.	Scatterplots of Feeder 2 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days.	52
Figures A-6.	Feeder 3 Data.	53
Figures A-7.	Scatterplots of Feeder 3 Hourly Load vs. Drybulb Temperature for Standard Winter Days.	54
Figures A-8.	Scatterplots of Feeder 3 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days.	55
Figures A-9.	Scatterplots of Feeder 3 Hourly Load vs. Drybulb Temperature for Standard Summer Days.	56
Figures A-10.	Scatterplots of Feeder 3 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days.	57

List of Figures

Figure	Description	Page
Figures A-11.	Feeder 4 Data.	58
Figures A-12.	Scatterplots of Feeder 4 Hourly Load vs. Drybulb Temperature for Standard Winter Days.	59
Figures A-13.	Scatterplots of Feeder 4 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days.	60
Figures A-14.	Scatterplots of Feeder 4 Hourly Load vs. Drybulb Temperature for Standard Summer Days.	61
Figures A-15.	Scatterplots of Feeder 4 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days.	62
Figures A-16.	Feeder 5 Data.	63
Figures A-17.	Scatterplots of Feeder 5 Hourly Load vs. Drybulb Temperature for Standard Winter Days.	64
Figures A-18.	Scatterplots of Feeder 5 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days.	65
Figures A-19.	Scatterplots of Feeder 5 Hourly Load vs. Drybulb Temperature for Standard Summer Days.	66
Figures A-20.	Scatterplots of Feeder 5 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days.	67
Figures A-21.	Feeder 9 Data.	68
Figures A-22.	Scatterplots of Feeder 9 Hourly Load vs. Drybulb Temperature for Standard Winter Days.	69
Figures A-23.	Scatterplots of Feeder 9 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days.	70
Figures A-24.	Scatterplots of Feeder 9 Hourly Load vs. Drybulb Temperature for Standard Summer Days.	71
Figures A-25.	Scatterplots of Feeder 9 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days.	72
Figures A-26.	Feeder 10 Data.	73
Figures A-27.	Scatterplots of Feeder 10 Hourly Load vs. Drybulb Temperature for Standard Winter Days.	74
Figures A-28.	Scatterplots of Feeder 10 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days.	75
Figures A-29.	Scatterplots of Feeder 10 Hourly Load vs. Drybulb Temperature for Standard Summer Days.	76
Figures A-30.	Scatterplots of Feeder 10 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days.	77
Figures A-31.	Feeder 12 Data.	78

List of Figures

Figure	Description	Page
Figures A-32.	Scatterplots of Feeder 12 Hourly Load vs. Drybulb Temperature for Standard Winter Days.....	79
Figures A-33.	Scatterplots of Feeder 12 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days.....	80
Figures A-34.	Scatterplots of Feeder 12 Hourly Load vs. Drybulb Temperature for Standard Summer Days.	81
Figures A-35.	Scatterplots of Feeder 12 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days.	82
Figures A-36.	Feeder 15 Data.	83
Figures A-37.	Scatterplots of Feeder 15 Hourly Load vs. Drybulb Temperature for Standard Winter Days.....	84
Figures A-38.	Scatterplots of Feeder 15 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days.....	85
Figures A-39.	Scatterplots of Feeder 15 Hourly Load vs. Drybulb Temperature for Standard Summer Days.	86
Figures A-40.	Scatterplots of Feeder 15 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days.	87
Figures A-41.	Feeder W4 Data.	88
Figures A-42.	Scatterplots of Feeder W4 Hourly Load vs. Drybulb Temperature for Standard Winter Days.....	89
Figures A-43.	Scatterplots of Feeder W4 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days.....	90
Figures A-44.	Scatterplots of Feeder W4 Hourly Load vs. Drybulb Temperature for Standard Summer Days.	91
Figures A-45.	Scatterplots of Feeder W4 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days.	92
Figures A-46.	Feeder W5 Data.	93
Figures A-47.	Scatterplots of Feeder W5 Hourly Load vs. Drybulb Temperature for Standard Winter Days.....	94
Figures A-48.	Scatterplots of Feeder W5 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days.....	95
Figures A-49.	Scatterplots of Feeder W5 Hourly Load vs. Drybulb Temperature for Standard Summer Days.	96
Figures A-50.	Scatterplots of Feeder W5 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days.	97
Figures A-51.	Feeder W6 Data.	98
Figures A-52.	Scatterplots of Feeder W6 Hourly Load vs. Drybulb	

List of Figures

Figure	Description	Page
	Temperature for Standard Winter Days.....	99
Figures A-53.	Scatterplots of Feeder W6 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days.....	100
Figures A-54.	Scatterplots of Feeder W6 Hourly Load vs. Drybulb Temperature for Standard Summer Days.	101
Figures A-55.	Scatterplots of Feeder W6 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days.	102
Figures B-1.	DOE-2 Simulated End-use Load Shapes for Hammerhead Barrack.....	134
Figures B-2.	DOE-2 Simulated End-use Load Shapes for Rolling Pin Barrack.....	135
Figures B-3.	DOE-2 Simulated End-use Load Shapes for Modular Barrack.	136
Figures B-4.	DOE-2 Simulated End-use Load Shapes for Small Barrack.....	137
Figures B-5.	DOE-2 Simulated End-use Load Shapes for Dining Hall.....	138
Figures B-6.	DOE-2 Simulated End-use Load Shapes for Gymnasium.	139
Figures B-7.	DOE-2 Simulated End-use Load Shapes for Large Administration.	140
Figures B-8.	DOE-2 Simulated End-use Load Shapes for Small Administration (Old w/ Split DX).....	141
Figures B-9.	DOE-2 Simulated End-use Load Shapes for Small Administration (Old w/ Chiller).	142
Figures B-10.	DOE-2 Simulated End-use Load Shapes for Small Administration (New w/ Split DX).....	143
Figures B-11.	DOE-2 Simulated End-use Load Shapes for Small Administration (New w/ Chiller).....	144
Figures B-12.	DOE-2 Simulated End-use Load Shapes for Small Vehicle Maintenance (No AC).	145
Figures B-13.	DOE-2 Simulated End-use Load Shapes for Large Vehicle Maintenance (Split DX).	146
Figures B-14.	DOE-2 Simulated End-use Load Shapes for Large Vehicle Maintenance (Chiller).....	147
Figures B-15.	DOE-2 Simulated End-use Load Shapes for Hangar.	148

List of Figures

Figure	Description	Page
Figures B-16.	DOE-2 Simulated End-use Load Shapes for Hospital.....	149
Figures B-17.	DOE-2 Simulated End-use Load Shapes for Detached Residential.....	150
Figures B-18.	DOE-2 Simulated End-use Load Shapes for Two-Plex Residential.....	151
Figures B-19.	DOE-2 Simulated End-use Load Shapes for Four-Plex Residential.....	152
Figures B-20.	DOE-2 Simulated End-use Load Shapes for Large Retail.....	153
Figures B-21.	DOE-2 Simulated End-use Load Shapes for Warehouse (No AC).....	154
Figures B-22.	DOE-2 Simulated End-use Load Shapes for Warehouse (Split DX).....	155
Figures B-23.	DOE-2 Simulated End-use Load Shapes for Bowling Center.....	156
Figures B-24.	DOE-2 Simulated End-use Load Shapes for Church.....	157
Figures B-25.	DOE-2 Simulated End-use Load Shapes for Grocery Store.....	158
Figures B-26.	DOE-2 Simulated End-use Load Shapes for Library.....	159
Figures B-27.	DOE-2 Simulated End-use Load Shapes for Fastfood Restaurant.....	160
Figures B-28.	DOE-2 Simulated End-use Load Shapes for Sitdown Restaurant.....	161
Figures B-29.	DOE-2 Simulated End-use Load Shapes for Small Retail.....	162
Figures B-30.	DOE-2 Simulated End-use Load Shapes for Youth Center.....	163
Figures C-1.	EDA Reconciled End-use Load Shapes for Hammerhead Barrack (Feeder 3).....	166
Figures C-2.	EDA Reconciled End-use Load Shapes for Hammerhead Barrack (Feeder 10).....	167
Figures C-3.	EDA Reconciled End-use Load Shapes for Hammerhead Barrack (Feeder 15).....	168
Figures C-4.	EDA Reconciled End-use Load Shapes for Hammerhead Barrack (Weighted 3,10,15).....	169

List of Figures

Figure	Description	Page
Figures C-5.	EDA Reconciled End-use Load Shapes for Rolling Pin Barrack (Feeder 3).....	170
Figures C-6.	EDA Reconciled End-use Load Shapes for Rolling Pin Barrack (Feeder 10).....	171
Figures C-7.	EDA Reconciled End-use Load Shapes for Rolling Pin Barrack (Weighted 3,10).....	172
Figures C-8.	EDA Reconciled End-use Load Shapes for Modular Barrack (Feeder 2).	173
Figures C-9.	EDA Reconciled End-use Load Shapes for Modular Barrack (Feeder 5).	174
Figures C-10.	EDA Reconciled End-use Load Shapes for Modular Barrack (Feeder 15).	175
Figures C-11.	EDA Reconciled End-use Load Shapes for Modular Barrack (Feeder W6).....	176
Figures C-12.	EDA Reconciled End-use Load Shapes for Modular Barrack (Weighted 2,5,15).....	177
Figures C-13.	EDA Reconciled End-use Load Shapes for Small Barrack (Feeder 10).....	178
Figures C-14.	EDA Reconciled End-use Load Shapes for Dining Hall (Feeder 3).....	179
Figures C-15.	EDA Reconciled End-use Load Shapes for Dining Hall (Feeder 5).....	180
Figures C-16.	EDA Reconciled End-use Load Shapes for Dining Hall (Feeder 10).....	181
Figures C-17.	EDA Reconciled End-use Load Shapes for Dining Hall (Feeder 15).....	182
Figures C-18.	EDA Reconciled End-use Load Shapes for Dining Hall (Weighted 3,5,10,15).	183
Figures C-19.	EDA Reconciled End-use Load Shapes for Gymnasium (Feeder 2).	184
Figures C-20.	EDA Reconciled End-use Load Shapes for Gymnasium (Feeder 15).	185
Figures C-21.	EDA Reconciled End-use Load Shapes for Large Administration (Feeder 2).	186
Figures C-22.	EDA Reconciled End-use Load Shapes for Large Administration (Feeder 5).	187
Figures C-23.	EDA Reconciled End-use Load Shapes for Large Administration (Weighted 2,5).	188

List of Figures

Figure	Description	Page
Figures C-24.	EDA Reconciled End-use Load Shapes for Small Administration (Old w/ Split DX) (Feeder 2).	189
Figures C-25.	EDA Reconciled End-use Load Shapes for Small Administration (Old w/ Split DX) (Feeder 10).	190
Figures C-26.	EDA Reconciled End-use Load Shapes for Small Administration (Old w/ Split DX) (Feeder 15).	191
Figures C-27.	EDA Reconciled End-use Load Shapes for Small Administration (Old w/ Split DX) (Weighted 2,10).	192
Figures C-28.	EDA Reconciled End-use Load Shapes for Small Administration (Old w/ Chiller) (Feeder 2).	193
Figures C-29.	EDA Reconciled End-use Load Shapes for Small Administration (Old w/ Chiller) (Feeder 3).	194
Figures C-30.	EDA Reconciled End-use Load Shapes for Small Administration (Old w/ Chiller) (Feeder 10).	195
Figures C-31.	EDA Reconciled End-use Load Shapes for Small Administration (Old w/ Chiller) (Feeder 15).	196
Figures C-32.	EDA Reconciled End-use Load Shapes for Small Administration (Old w/ Chiller) (Weighted 3,10,15).....	197
Figures C-33.	EDA Reconciled End-use Load Shapes for Small Administration (New w/ Split DX) (Feeder 2).....	198
Figures C-34.	EDA Reconciled End-use Load Shapes for Small Administration (New w/ Split DX) (Feeder 10).....	199
Figures C-35.	EDA Reconciled End-use Load Shapes for Small Administration (New w/ Split DX) (Weighted 2,10).....	200
Figures C-36.	EDA Reconciled End-use Load Shapes for Small Administration (New w/ Chiller) (Feeder 2).....	201
Figures C-37.	EDA Reconciled End-use Load Shapes for Small Administration (New w/ Chiller) (Feeder W6).	202
Figures C-38.	EDA Reconciled End-use Load Shapes for Small Vehicle Maintenance (No AC) (Feeder 3).	203
Figures C-39.	EDA Reconciled End-use Load Shapes for Small Vehicle Maintenance (No AC) (Feeder 10).	204
Figures C-40.	EDA Reconciled End-use Load Shapes for Small Vehicle Maintenance (No AC) (Weighted 3,10).....	205
Figures C-41.	EDA Reconciled End-use Load Shapes for Large Vehicle Maintenance (Split DX) (Feeder 3).	206
Figures C-42.	EDA Reconciled End-use Load Shapes for Large Vehicle Maintenance (Split DX) (Feeder 10).	207

List of Figures

Figure	Description	Page
Figures C-43.	EDA Reconciled End-use Load Shapes for Large Vehicle Maintenance (Split DX) (Feeder 15).	208
Figures C-44.	EDA Reconciled End-use Load Shapes for Large Vehicle Maintenance (Split DX) (Feeder W6).....	209
Figures C-45.	EDA Reconciled End-use Load Shapes for Large Vehicle Maintenance (Split DX) (Feeder 3,10,15).	210
Figures C-46.	EDA Reconciled End-use Load Shapes for Large Vehicle Maintenance (Chiller) (Feeder 15).....	211
Figures C-47.	EDA Reconciled End-use Load Shapes for Large Vehicle Maintenance (Chiller) (Feeder W6).....	212
Figures C-48.	EDA Reconciled End-use Load Shapes for Hangar (Feeder 15)	213
Figures C-49.	EDA Reconciled End-use Load Shapes for Hospital (Feeder 9)	214
Figures C-50.	EDA Reconciled End-use Load Shapes for Detached Residential (Feeder 5).....	215
Figures C-51.	EDA Reconciled End-use Load Shapes for Detached Residential (Feeder 12).....	216
Figures C-52.	EDA Reconciled End-use Load Shapes for Detached Residential (Feeder W4).....	217
Figures C-53.	EDA Reconciled End-use Load Shapes for Detached Residential (Feeder 5,12,W4).....	218
Figures C-54.	EDA Reconciled End-use Load Shapes for Two-Plex Residential (Feeder 5).....	219
Figures C-55.	EDA Reconciled End-use Load Shapes for Two-Plex Residential (Feeder 12).....	220
Figures C-56.	EDA Reconciled End-use Load Shapes for Two-Plex Residential(Feeder W4)	221
Figures C-57.	EDA Reconciled End-use Load Shapes for Two-Plex Residential(Feeder W5)	222
Figures C-58.	EDA Reconciled End-use Load Shapes for Two-Plex Residential (Feeder 5,12,W4)	223
Figures C-59.	EDA Reconciled End-use Load Shapes for Four-Plex Residential(Feeder 3).....	224
Figures C-60.	EDA Reconciled End-use Load Shapes for Four-Plex Residential(Feeder 12).....	225
Figures C-61.	EDA Reconciled End-use Load Shapes for Four-Plex Residential (Feeder 3,12).....	226

List of Figures

Figure	Description	Page
Figures C-62.	EDA Reconciled End-use Load Shapes for Large Retail (Feeder W5).....	227
Figures C-63.	EDA Reconciled End-use Load Shapes for Warehouse (No AC) (Feeder 3)	228
Figures C-64.	EDA Reconciled End-use Load Shapes for Warehouse (Split DX) (Feeder W6).....	229
Figures C-65.	EDA Reconciled End-use Load Shapes for Miscellaneous (Feeder 2)	230
Figures C-66.	EDA Reconciled End-use Load Shapes for Miscellaneous (Feeder 3)	231
Figures C-67.	EDA Reconciled End-use Load Shapes for Miscellaneous (Feeder 5)	232
Figures C-68.	EDA Reconciled End-use Load Shapes for Miscellaneous (Feeder 10)	233
Figures C-69.	EDA Reconciled End-use Load Shapes for Miscellaneous (Feeder 15)	234

List of Tables

Table	Description	Page
Table EX-1.	Final EDA Reconciled Electric End-use Annual EUIs [kWh/ft ² /yr].	xiii
Table 1-1.	Project Scope.	3
Table 2-1.	IFS Building Inventory Classified by Prototype.....	5
Table 2-2.	IFS Building Inventory Catcod Classified by Prototype.	6
Table 2-3.	Monthly Weather Data Summary - Waco, Texas 1993.....	9
Table 3-1.	Hospital Prototype Characteristics.....	19
Table 4-1.	Prototype Selection by Feeder.	29
Table 4-2.	DOE-2 Simulated Electric and Gas Enduse Annual EUIs.....	31
Table 4-3.	EDA Reconciled Electric Enduse Annual EUIs by Feeder.	32
Table 4-4.	EDA Reconciled Total Electric Annual EUIs by Feeder.	34
Table 4-5.	Weighted EDA Reconciled Electric Enduse Annual EUIs.	35
Table 4-6.	Simulated and EDA Reconciled Street Lighting Annual EUIs.	35
Table 4-7.	EDA Predicted Annual Energy Consumption by Prototype.....	37
Table 4-8.	EDA Predicted Annual Energy Consumption by Enduse.	37
Table B-1.	Hammerhead Barrack - Prototype Characteristics.....	104
Table B-2.	Rolling Pin Barrack - Prototype Characteristics.....	105
Table B-3.	Modular Barrack - Prototype Characteristics.	106
Table B-4.	Small Barrack - Prototype Characteristics.....	107
Table B-5.	Dining Hall Prototype Characteristics.	108
Table B-6.	Gymnasium Prototype Characteristics.....	109
Table B-7.	Large Administration Prototype Characteristics.	110
Table B-8.	Small Administration - Old w/Split DX Prototype Characteristics.....	111
Table B-9.	Small Administration - Old w/Chiller Prototype Characteristics.	112
Table B-10.	Small Administration - New w/Split DX Prototype Characteristics.	113
Table B-11.	Small Administration - New w/Chiller Prototype Characteristics.	114
Table B-12.	Vehicle Maintenance - Small w/No AC - Prototype Characteristics.....	115
Table B-13.	Vehicle Maintenance - Large w/Split DX - Prototype Characteristics.....	116
Table B-14.	Vehicle Maintenance - Large w/Chiller - Prototype Characteristics.....	117
Table B-15.	Hangar Prototype Characteristics.	118
Table B-16.	Hospital Prototype Characteristics.....	119
Table B-17.	Detached Residential Prototype Characteristics.....	120
Table B-18.	Two-Plex Residential Prototype Characteristics.	121
Table B-19.	Four-Plex Residential Prototype Characteristics.	122
Table B-20.	Large Retail Prototype Characteristics.	123

List of Tables

Table	Description	Page
Table B-21.	Warehouse w/No AC - Prototype Characteristics.	124
Table B-22.	Warehouse w/Split DX - Prototype Characteristics.	125
Table B-23.	Bowling Center Prototype Characteristics.....	126
Table B-24.	Church Prototype Characteristics.	127
Table B-25.	Library Prototype Characteristics.	128
Table B-26.	Grocery Store Prototype Characteristics.....	129
Table B-27.	Fastfood Restaurant Prototype Characteristics.	130
Table B-28.	Sitdown Restaurant Prototype Characteristics.....	131
Table B-29.	Small Retail Prototype Characteristics.	132
Table B-30.	Youth Center Prototype Characteristics.	133
Table C-1.	EDA Hourly Load Smoothing Summary.....	165

Executive Summary

Defense Energy Program Policy Memorandum (DEPPM) 91-2 requires, through energy efficiency strategies, Department of Defense (DoD) facilities to reduce energy consumption and costs by 20% from 1985 to 2000. The strategies include both improved operation and maintenance and enhanced energy efficiency measures.

The proper analytical tools, methodologies, and a database of energy consumption by end use for DoD facilities are not readily available. Historically, DoD has addressed analysis of energy efficiencies programs by conducting energy audits of the installations and by developing prototypical buildings and assessing conservation potentials through building energy simulations. Although prototypical studies can result in some general understanding of energy consumption by end use, they must be reconciled against *measured* energy use for reliable estimates. The End-use Disaggregation Algorithm (EDA) developed at Lawrence Berkeley Laboratory (LBL) was designed specifically for this purpose. In EDA, computer simulations are reconciled hourly against measured energy consumption in order to obtain end-use consumption data.

The objectives of this project were:

- to develop an energy database by building type and by end use for DoD facilities;
- to enhance the DoD energy office's ability to track energy use by end use;
- to establish a vehicle for transferring the analytical methodologies for end-use energy analysis developed at LBL to the U.S. Army Construction Engineering Research Laboratory (CERL).

This project has initially focused on achieving these objectives and pilot-testing the methodology at one DoD installation: Fort Hood, Texas. It is anticipated that the methodology and much of the database developed for Fort Hood can be easily transferred to other installations. The future work for other installations will be built up on the results of this project.

The project was designed in seven tasks:

- Task 1: Development of a detailed workplan
- Task 2: Database preparation and integration
- Task 3: Development of DOE-2 prototypes
- Task 4: Short-term end-use metering
- Task 5: Refinement of end-use disaggregation algorithm
- Task 6: Reconciliation of end-use energy intensities
- Task 7: Final report and transfer of data and methodology

The building types at Fort Hood cover a wide spectrum of commercial and residential buildings. The commercial buildings include: office, administration, vehicle maintenance, shop, hospital, grocery store, retail store, car wash, church, restaurant, etc. The residential buildings include: single family detached unit, two and four-plex (both single and double story) units, and apartment building. Up to 11 enduses were developed for each prototype, consisting of 9 electric and 2 gas; however, only the electric enduses were reconciled. The electric enduses are space cooling, ventilation (AHU, fans, chilled and hot water pumps), cooking, miscellaneous/plugs, refrigeration, exterior lighting, interior lighting, process loads, and street lighting. The gas enduses are space heating and hot water heating. Space heating EUIs were simulated only.

The EDA was applied to 10 feeders in Fort Hood. The results from the analyses of these ten feeders were extrapolated to estimate energy use by end-use for the entire installation, and validate the results with the

independent Texas Utility billing data for electricity use for the installation. **Table EX-1** summarizes the final EDA reconciled electric end use annual EUIs.

The extrapolation of the EDA results to the entire Fort Hood installation is shown in **Figure EX-1**, where electricity use and peak power demand are depicted by both building type and end use. Clearly, administration, residential, and the barrack prototypes are the largest consumers of electricity for a total of 250GWh per year (74% of the Fort Hood annual consumption of 330 GWh). By end use, cooling, ventilation, miscellaneous, and indoor lighting consume almost 84% of total electricity use. The contribution to the peak power demand is highest by residential sector (35%, 24 MW out of 70 MW), followed by administration buildings (30%), and barrack (14%). For the entire Fort Hood installation, cooling is 54% of the peak demand (38 MW out of 70 MW), followed by interior lighting at 18%, and miscellaneous end uses by 12%.

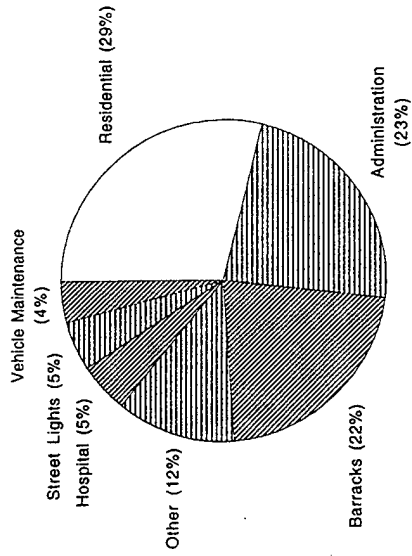
With existing technologies, energy efficiency programs can be designed to reduce energy and peak demand use by 30% with a payback time of less than 2 years. Such a program at Fort Hood can result in savings of over 100 GWh per year in energy and 20 MW in peak power demand.

In the second phase of this project, we plan to extend these analyses to other installations and characterize energy use by end use for all DoD facilities within the U.S.

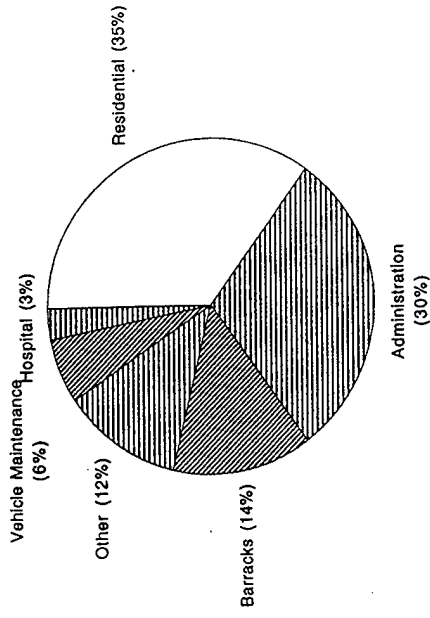
Table EX-1. Final EDA Reconciled Electric Enduse Annual EUIs [kWh/ft²/yr]

Prototype	Cool	Fan	Cook	Misc	Ref	Ex_Lit	In_Lit	Prss	Total
Barrack									
Hammer Head	3.41	1.40	0.28	1.73	2.05	0.19	1.83	-	10.90
Rolling Pin	4.31	3.51	0.31	0.86	2.03	0.12	1.35	-	12.48
Modular	3.75	1.15	0.30	2.63	2.29	0.15	2.50	-	12.76
Small	5.10	1.36	0.16	0.99	1.16	0.19	1.03	-	9.99
Dining Hall	5.28	2.09	5.94	-	4.60	0.13	3.69	-	21.72
Gymnasium	2.32	0.90	-	0.60	-	0.19	5.85	0.09	9.95
Administration									
Large	2.85	3.18	-	9.05	-	0.12	4.87	-	20.06
Small - Old w/ Split DX	8.39	2.66	-	1.47	-	0.14	4.98	-	17.63
Small - Old w/ Chiller	4.98	4.65	-	1.37	-	0.12	4.61	-	15.75
Small - New w/ Split DX	6.30	1.93	-	1.45	-	0.13	4.92	-	14.75
Small - New w/ Chiller	4.35	4.02	-	1.74	-	0.18	5.92	-	16.21
Vehicle Maintenance									
Small No AC	-	0.48	-	0.45	-	0.26	1.82	0.04	3.03
Large w/ Split DX	0.57	0.28	-	0.50	-	0.29	2.05	0.04	3.74
Large w/ Chiller	0.47	0.43	-	0.57	-	0.34	2.33	0.05	4.19
Hangar	1.71	1.32	-	0.25	-	0.07	3.49	0.04	6.88
Hospital	6.24	1.72	0.68	11.81	0.61	0.33	9.40	-	30.80
Residential									
Detached	5.03	0.44	0.21	3.71	0.83	0.37	0.78	-	11.37
Two Plex	4.65	0.40	0.21	3.59	0.80	0.35	0.75	-	10.76
Four Plex	6.45	0.44	0.19	2.92	0.70	0.31	0.64	-	11.67
Other									
Retail - Large	9.00	8.74	1.16	5.29	5.74	1.53	29.09	-	60.54
Warehouse									
No AC	-	0.16	-	0.44	-	0.22	1.67	-	2.49
AC	2.41	0.53	-	0.75	-	0.43	2.78	-	6.90

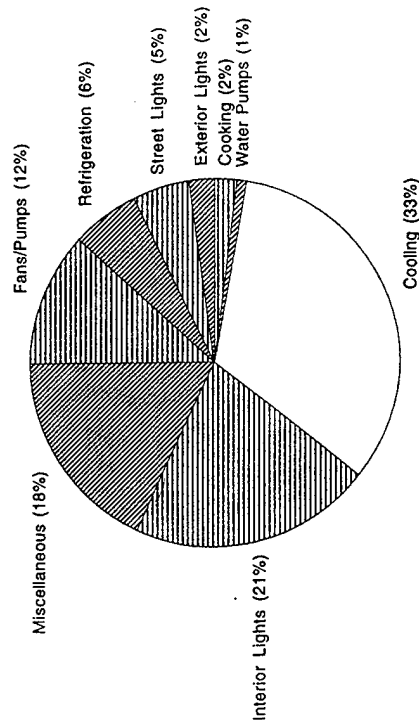
a) Electricity use by building type



b) Peak power demand by building type

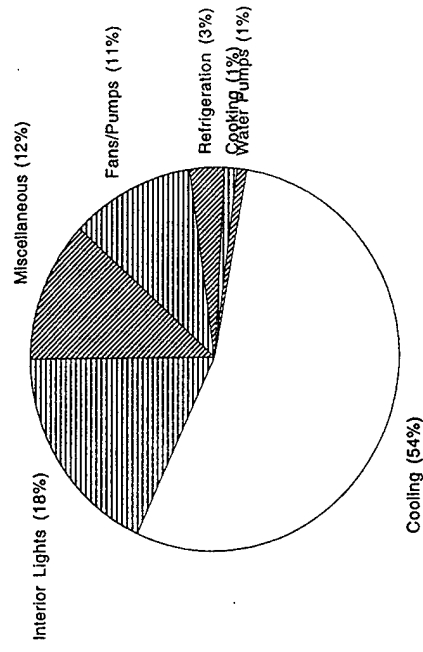


c) Electricity use by end use



Total 330 GWh/yr

d) Peak power demand by end use



Total 70 MW

Figure EX-1. Annual Electricity Use and Peak Power Demand at Fort Hood, TX.

Chapter 1

Introduction

Background

Defense Energy Program Policy Memorandum (DEPPM) 91-2 requires, through energy efficiency strategies, Department of Defense (DoD) facilities to reduce energy consumption and costs by 20% from 1985 to 2000. The strategies include both improved operation and maintenance and enhanced energy efficiency measures.

The proper analytical tools, methodologies, and a database of energy consumption by end use for DoD facilities are not readily available to implement energy efficiency programs. The Model Energy Installation Program (MEIP) was developed to prove the concept that DoD could cost-effectively save energy while simultaneously improving both working and living conditions at DoD facilities. Tools are required to perform end-use energy analysis, to predict and forecast future energy scenarios, and to evaluate and recommend cost-effective energy conservation technologies and opportunities.

Historically, DoD has addressed these objectives by energy audits of the installations and by development of prototypical buildings and assessment of conservation potentials through building energy simulations. Although prototypical studies can result in some general understanding of energy consumption by end use, they must be reconciled against *measured* energy use for reliable estimates. The End-use Disaggregation Algorithm (EDA) developed at Lawrence Berkeley Laboratory (LBL) was designed specifically for this purpose. In EDA, computer simulations are reconciled hourly against measured energy consumption in order to obtain end-use consumption data (Akbari, 1995).

In addition, DoD and government agencies have developed numerous energy analysis tools and energy analysis techniques on a "piecemeal" basis or for specific applications, and have compiled property databases for facilities management (real property databases). This project has drawn upon and brought together these disparate sources of information into an integrated form that can be used for DoD-wide energy end-use characterization.

Objectives

The objectives of this project were:

- to develop an energy database by building type and by end use for DoD facilities;
- to enhance the DoD energy office's ability to track energy use by end use;
- to establish a vehicle for transferring the analytical methodologies for end-use energy analysis developed at LBL to the U.S. Army Construction Engineering Research Laboratory (CERL).

This project has initially focused on achieving these objectives and pilot-testing the methodology at one DoD installation: Fort Hood, Texas. It is anticipated that the methodology and much of the database developed for Fort Hood can be easily transferred to other installations. The future work for other installations will be built up on the results of this project.

Project Description

The project involved detailed analysis of existing DoD data on facilities' energy use and characteristics, in conjunction with other data bases, and application of a previously developed reconciliation model to estimate end-use load shapes and intensities. We have first analyzed the databases for consistency and completeness. Implementation and validation of the methodology are the heart of this project. We have refined the previously developed model to meet the requirements of the new application. We then applied

the refined method to the above databases to extract end-use load shape information from them.

Although the goal of this project was to analyze electrical energy end use DoD-wide, the amount of repetition at the building level (as well as at the installation level) allows the number of installations analyzed to be limited. Fort Hood, Texas, the site of an ongoing energy demonstration has been identified as the first installation to be analyzed. We plan to use the methodology and much of the database developed for Fort Hood to analyze energy use characteristics in other installations. Future work for other installations will build upon the results of this project.

The project was designed in seven tasks:

- Task 1: Development of a detailed workplan
- Task 2: Database preparation and integration
- Task 3: Development of DOE-2 prototypes
- Task 4: Short-term end-use metering
- Task 5: Refinement of end-use disaggregation algorithm
- Task 6: Reconciliation of end-use energy intensities
- Task 7: Final report and transfer of data and methodology

The Detailed Workplan (Akbari, 1994) discusses the elements of these tasks in detail. After preparation of the Detailed Workplan, however, it was decided that Task 4 (Short-term end-use metering) would not to be carried out in this phase of the project.

The building types at Fort Hood cover a wide spectrum of commercial and residential buildings. The commercial buildings include: office, administration, vehicle maintenance, shop, hospital, grocery store, retail store, car wash, church, restaurant, etc. The residential buildings include: single family detached unit, two and four-plex (both single and double story) units, and apartment building. In addition, there are barracks that combine the commercial and residential functions. Some buildings have dedicated air-conditioning systems and some have central systems.

Given the complexity of the building types, we decided to analyze energy end-use characteristics of buildings by functions of buildings or building groups. Based on visual inspection of the facilities at Fort Hood and discussion with CERL project manager, we developed the list of building types and end-uses for analysis as shown in **Table 1-1**. For each building in the scope we developed a prototype.

Up to 11 end uses were developed for each prototype, consisting of 9 electric and 2 gas; however, only the electric end uses were reconciled. The electric end uses are space cooling, ventilation (AHU, fans, chilled and hot water pumps), cooking, miscellaneous/plugs, refrigeration, exterior lighting, interior lighting, process loads, and street lighting. The gas end uses are space heating and hot water heating. Space heating EUIs were simulated only. Hot water heating EUIs were taken from previous LBL studies and the MEIP surveys.

Overview of the Report

This final report (Task 7) is organized in five chapters and three appendices. Chapter 2, provides an overview of input data and analysis performed (Task 2). In Chapter 3, we discuss our methodology for analysis of data, development of building prototypes, and an approach to end-use data analysis (Tasks 3 and 5). In Chapter 4, we summarize the simulation results and EDA reconciliation analyses (Tasks 3 and 6). Chapter 5 summarizes the major conclusions from the project. In Appendix A, the graphical results of the Feeder Data Analysis are presented. Appendix B contains the prototype characteristics and DOE-2 simulated load shapes. Appendix C presents the EDA reconciled load shapes.

Table 1-1. Project Scope

Prototype	Cool	Fan/Vent†	Cook	Misc/Plug	Refrig	Ex_Lit	In_Lit	Prcss	Heat‡	Hot Water‡
Barrack										
Hammer Head	X	X	X	X	X	X	X		X	X
Rolling Pin	X	X	X	X	X	X	X		X	X
Modular	X	X	X	X	X	X	X		X	X
Small	X	X	X	X	X	X	X		X	X
Dining Hall	X	X	X		X	X	X		X	X
Gymnasium	X	X		X		X	X	X	X	X
Administration										
Large	X	X		X		X	X		X	X
Small - Old w/ Split DX	X	X		X		X	X		X	X
Small - Old w/ Chiller	X	X		X		X	X		X	X
Small - New w/ Split DX	X	X		X		X	X		X	X
Small - New w/ Chiller	X	X		X		X	X		X	X
Vehicle Maintenance										
Small w/ No AC		X		X		X	X	X	X	
Large w/ Split DX	X	X		X		X	X	X	X	
Large w/ Chiller	X	X		X		X	X	X	X	
Hangar	X	X		X		X	X	X	X	
Hospital	X	X	X	X	X	X	X		X	X
Residential										
Detached	X	X	X	X	X	X	X		X	X
Two Plex	X	X	X	X	X	X	X		X	X
Four Plex	X	X	X	X	X	X	X		X	X
Other										
Retail - Large	X	X	X	X	X	X	X		X	X
Warehouse										
w/ No AC		X		X		X	X		X	
w/ Split DX	X	X		X		X	X		X	
Miscellaneous§										
Bowling Center	X	X		X		X	X		X	
Church	X	X		X		X	X		X	
Grocery Store	X	X	X	X	X	X	X		X	X
Library	X	X		X		X	X		X	
Restaurant - Fastfood	X	X	X	X	X	X	X		X	X
Restaurant - Sitdown	X	X	X	X	X	X	X		X	X
Retail - Small	X	X	X	X	X	X	X		X	X
Youth Center	X	X		X		X	X		X	
Water Pump∞										
Street Lighting						X				

† The Fan/Vent end use includes chilled and heated water pumps.

‡ Space heating and hot water heating are gas end uses and are not reconciled.

§ The end-use characterization for the miscellaneous prototypes are provided by simulations only.

∞ EDA is not applied to the water pump prototype only measured load data is available.

Chapter 2 **Input Data**

Numerous data bases were available for use in this project, which include onsite surveys, measured electrical load data, building inventory data, and weather data. The primary source of these data was CERL. LBL supplied supplementary information from previous EDA studies carried out at LBL.

The data were carefully inspected and reviewed by LBL with advice from CERL. It was then decided which data would be used in the project. The data bases outlined below were integrated for use in the project.

- IFS Building Inventories
- Model Energy Installation Project (MEIP) Onsite Survey Data of 25 Nonresidential Buildings
- Model Energy Installation Project (MEIP) Onsite Survey Data of 11 Residential Buildings
- Chiller Survey Data
- Mechanical Equipment Survey Data
- Feeder Short-Interval (Hourly) Electric Load Data
- Feeder to Building Assignment Data
- Previously Developed LBL Prototypes
- Hourly Weather Data
- Texas Utility Hourly Electrical Load Data

IFS Building Inventories

The IFS building inventory data base (Army) surveys 40 characteristics of 5,122 buildings, which represents all the buildings in Fort Hood. The pertinent data include building category code, floor area, number of floors, year of construction, and HVAC system type. The category code identifies the buildings function or use, as defined by the Army. In previous work, CERL classified all the buildings into groups based on the category code. In this project, the buildings were classified into prototypes based on the category code, CERL's initial building classification, discussions with CERL following inspection of the data by LBL, floor area, year of construction, and HVAC system type. The prototypes have been grouped into CERL's classification strategy as barrack, administration, vehicle maintenance, hospital, residential, and other categories. The prototype classifications are shown in **Table 2-1** and each are discussed in Chapter 3 under Prototype Development. Note in **Table 2-1** that the group titled 'Other' contains non-building, utility, water pump, and fuel station. These represent less than 1% of the total floor area of Fort Hood building stock and are not modeled; however, some measured water pump load data were available and analyzed. **Table 2-2** categorizes the prototypical buildings by IFS category code (catcod) and building identification number.

MEIP Onsite Survey Data of 25 Nonresidential Buildings

The MEIP study is a detailed onsite survey of 25 non-residential buildings in Fort Hood. The types of buildings surveyed are small and large administration, hangar, barrack, gymnasium, vehicle maintenance shop, and dining hall. Data included in the survey are floor area, shell construction, interior loads and schedules, HVAC system types and schedules, and plant parameters and schedules. Some of the buildings are modeled in greater detail than others. This ranges from buildings with multiple zones with

Table 2-1. IFS Building Inventory Classified by Prototype

Group	Prototype	Number	Total Floor Area (ft ²)	Avg Floor Area (ft ²)	Weight
Barrack	Hammer Head	32	1066798	33337	0.042
	Rolling Pin	28	1810654	64666	0.071
	Modular	49	1647994	33633	0.065
	Small	83	403967	4867	0.016
	Dining Hall	116	505877	4361	0.020
	Gymnasium	9	223595	24844	0.008
	Total	317	5658885	-	0.222
Administration	Large	4	674113	168528	0.026
	Small Old w/ Split DX	230	1153551	5015	0.045
	Small Old w/ Chiller	317	2029777	6403	0.080
	Small New w/ Split DX	59	373706	6334	0.015
	Small New w/ Chiller	81	356215	4398	0.014
	Total	691	4587362	-	0.180
Vehicle Maintenance	Small w/ No AC	218	1034912	4747	0.040
	Large w/ Split DX	40	1037480	25937	0.040
	Large w/ Chiller	10	446072	44607	0.017
	Hangar	18	743895	41328	0.029
	Total	286	3262359	-	0.126
Hospital	Hospital	1	504202	504202	0.020
Residential	Detached	856	1141815	1334	0.045
	Two Plex	1680	4936284	2938	0.194
	Four Plex	368	2490464	6772	0.098
	Total	2904	8568563	-	0.337
Other	Retail Large	2	256116	128058	0.010
	Warehouse w/ No AC	423	1137313	2689	0.045
	Warehouse w/ Split DX	28	283407	10122	0.011
	Miscellaneous	131	909865	6946	0.036
	Non-Building	193	155347	805	0.006
	Utility	142	132248	931	0.005
	Water Pump	73	16150	221	0.001
	Fuel Station	34	31983	941	0.001
	Total	1026	2922429	-	0.115
Fort Hood	Total	5122	25503800	-	1.000

Table 2-2. IFS Building Inventory Catcod Classified by Prototype

For some Catcods there are tens of buildings; Building ID numbers for these Catcods are not listed.

Prototype	IFS Catcod (Building ID†)
Barrack	
Hammer Head	72111 (092, 094, 100, 140)
Rolling Pin	72111 (120, 160, 210, 270, 310, 340, 370, 410)
Modular	72111 (290, 360, 390, 870, 890, 900, 910)
	72410 (057, 360)
	74032 (001)
Small	72111 (018, 210, 211, 044)
	72114 (564)
	72410 (563)
	72411 (068)
	74032 (023, 201)
Dining Hall	72210, 74047, 74048
Gymnasium	74028
Administration	
Large	61011 (01001)
	61012 (00410, 28000)
	61060 (91012)
Small Old w/ Split DX	13130, 13160, 13165, 13170, 13320, 14111, 14112, 14131, 14182, 14183, 14184, 14185, 17120, 17130, 17150, 17160, 51020, 53020, 53040, 55010, 55030, 61021, 61023, 61024, 61026, 61027, 61028, 61031, 61040, 61041, 61050, 61060, 72330, 72335, 72360, 73028, 74014, 74025, 74065
Small Old w/ Chiller	13110, 13320, 13640, 14110, 14112, 14131, 14180, 14182, 14183, 14185, 17120, 17123, 17130, 17150, 17160, 17174, 53040, 54010, 55010, 61022, 61025, 61026, 61050, 61060, 72330, 72335, 72360, 74065
Small New w/ Split DX	13120, 13360, 14110, 14112, 14131, 14180, 14183, 14185, 17120, 17130, 17160, 51020, 53020, 54010, 55010, 61021, 61028, 61040, 61050, 72330, 74014, 74065
Small New w/ Chiller	13320, 13640, 14112, 14114, 14131, 14140, 14182, 14183, 17120, 17123, 17139, 17150, 53040, 54010, 61031, 72330, 72335, 74014, 74065
Vehicle Maintenance	
Small w/ No AC	21130, 21210, 21410, 21430, 21452, 21540, 21612, 21710, 21740, 21810, 21850, 21870, 21880, 21882, 21883, 21885, 21887, 21888, 21889, 21910, 21920, 74031
Large w/ Split DX	21410, 21430, 21540, 21710, 21920
Large w/ Chiller	17110, 17112, 17182, 21420, 21430, 21710, 21885
Hangar	21110, 21112
Hospital	51010 (36000)
Residential	
Detached	71111, 71112, 71113, 71114, 71115, 71121, 71122, 71123, 71124, 71125, 71135
Two Plex	71113, 71114, 71115, 71123, 71124, 71125, 71135
Four Plex	71114, 71115, 71135
Other	
Retail Large	74021 (50001)
	74053 (50004)
Warehouse	
w/ No AC	21470, 42250, 43210, 43230, 44210, 44220, 44222, 44240, 44245, 44261, 44270, 44275, 44285, 44286
w/ Split DX	41186, 43210, 44220, 44226, 44270, 44285
Miscellaneous	73010, 73015, 73018, 73019, 73020, 73030, 73073, 74009, 74011, 74021, 74022, 74024, 74030, 74033, 74037, 74040, 74041, 74043, 74050, 74051, 74052, 74056, 74057, 74062, 74066, 74067, 74068, 74069, 74070, 74071, 74074, 74077, 74078, 74081, 74084, 76010
Non-Building	71410, 71420, 73055, 87220, 87230, 87235, 87240
Utility	17124, 17170, 72320, 72321, 73075, 74007, 81160, 81180, 81321, 82116, 82150, 83311, 84150, 89046, 89080
Water Pump	83231, 84131, 84142, 84220, 84580
Fuel Station	12111, 12121, 12310, 12320, 12324, 12530, 12531, 12540, 12565, 12585, 12661, 12666, 12680

† For barrack first 3 digits of 5 digit building id are shown.

descriptions of it as a single zone, to buildings with multiple zones detailing each zone. These data were utilized to define the prototypes.

An appendix to the MEIP report provides data for monthly electric and gas data for these 25 buildings; however, 4 of the buildings (10001, 30015, 39004, and 39044) that were included in the main text of the report were not in the appendix (buildings 4501, 7051, 17041, and 87017 were instead). Electric and gas consumption were given for 1990, 1991, and 1992 with large gaps of missing data. The gas data are questionable, as some of them lack continuity between adjacent heating months. The data from this appendix were not utilized.

Another appendix is a survey of motor nameplates of the 25 buildings selected in the main text of the study. Again, these data were not utilized.

MEIP Onsite Survey Data of 11 Residential Buildings

This MEIP study is a detailed onsite survey of 11 residential buildings each in a different village of Fort Hood. Data included in the survey are floor area, shell construction, interior loads, and HVAC system types. The survey characterizes the villages of Fort Hood by number of units, number of bedrooms, officer quarters versus enlisted, original construction dates, and air conditioning system type and tonnage. These data were used to define the residential prototypes.

Chiller Survey Data

The Chiller survey is a CERL visual inspection/recording of installed chiller nameplate data of 463 chillers. The chiller data includes manufacturer, model number, building number, number of chillers, tonnage, airflow, air handler power, and condenser power (note the condenser data is scarce). The chiller data for the hospital has been used in specifying the hospital prototype, otherwise these data were used for cross checking other data bases.

Mechanical Equipment Survey Data

The Mechanical equipment survey is a CERL visual inspection/recording of installed motor and equipment nameplate data of 1127 motors and equipment for about 230 buildings. The motor data includes building number, location, manufacturer, application, model number, serial number, power, speed, frequency, voltage, phase, amperage, and efficiency. The equipment include pumps, cooling towers, air handlers, boilers, and domestic water heaters. The equipment data includes model number, serial number, power, and airflow (note the equipment data base is scarce).

This data base has been compared with the MEIP motor survey for 7 of the 25 buildings described previously (12020, 14022, 23001, 34008, 34010, 37017, and 39004). These data bases show frequent differences in quantity, application, and rating of motors. For some of the buildings the MEIP survey shows more motors than this data base, and for others the reverse is true. These data were utilized for cross checking with other data bases.

Feeder Short-Interval (Hourly) Electric Load Data

Fort Hood receives electrical power from 3 substations: main, west, and north substations. These substations distribute the power through 16 feeders connected to the main substation, 6 to the west, and 3 to the north. Pacific Northwest Labs (PNL) monitored the power on these feeders for the period of September 1992 through December 1993.

Feeder hourly electric load data is available for the main and west substations for the period of September 1992 through December 1993, and for the north substation for September 1992 through March 1993. Feeder data were analyzed for the 1993 calendar year, therefore the north substation was omitted because of lack of data. The load data were measured by PNL on each of three phases for each feeder. Subsequently, the phases were summed by feeder to determine the total load in kW. Of the 16 feeders connected to the main substation, Feeder 8 was not monitored, Feeders 6, 11, and 13 each were missing 6 months of data, and Feeders 1, 7, 14, and 16 each were missing the month of June. Of the 6 feeders connected to the west substation, Feeders W1, W2, and W3 each were missing the month of August. All together 11 feeders were analyzed, and the results are presented in Appendix A.

The feeder data were prepared by removing bad data (data represented by -999) and duplicate data. Short interval missing data (~3 consecutive hours or less) were imputed by linear interpolation, and long interval missing data were copied from periods of similar load behavior. Any data abnormalities were replaced similarly to the missing data as just described. The data were then adjusted to Central Standard and Central Daylight Time from Pacific Standard Time.

Feeder to Building Assignment Data

The feeder to building assignment data base lists the buildings connected to each feeder. This data base is available for the main and west substations except for Feeders 6 and 13. However, there appears to be some questionable assignments concerning Feeders 2, 14, 16, W5, and W6. Table 4-1 (in Chapter 4) lists the prototypes selected for each feeder.

Feeder 2 was remapped based on a visual inspection by LBL of the electrical distribution and city layout drawings. This added 27 buildings to Feeder 2, including a division headquarters building (#28000). The buildings added to Feeder 2 were removed from Feeder 14. Feeder 16 appears to feed the west end of Fort Hood as seen on the map, however this data base suggests it feeds buildings on the west and east ends of the base. Feeder W5 is questionable because the EDA results reveal annual electric consumption to be excessively high, therefore, we think some buildings may be missing from this feeder. There appears to be similar problems with Feeder W6 as with W5, but not as extreme.

Previously Developed LBL Prototypes

LBL has developed a variety of prototypes from previous studies with PG&E (Pacific Gas & Electric Company) and SCE (Southern California Edison Company) (Akbari, et al. 1993), which were utilized when prototype information was unavailable from the data supplied by CERL. These prototypes were simulated with DOE-2.1D with 1993 Waco, Texas weather data. The previously developed LBL prototypes used were the hospital, library, small and large retail stores, sitdown and fastfood restaurants, grocery store, and warehouse.

Hourly Weather Data

We obtained 1993 Waco, Texas hourly weather data from the National Climatic Data Center in Airways Surface Observations (TD1440) format. Table 2-3 summarizes the monthly 1993 weather data from Waco, Texas.

Texas Utility Hourly Electrical Load Data

Texas Utility (TU) 1993 annual hourly electrical use data for the main and west substations are presented in Figure 2-1. These data are used to validate the EDA predicted results for the entire installation, since

feeder electrical use data doesn't exist for all feeders. The TU data were measured on the high side of the transformer, where the PNL feeder data were on the low side.

Table 2-3. Monthly Weather Data Summary - Waco, Texas 1993

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Avg Temp Drybulb (°F)	45.7	50.2	56.6	63.7	71.8	80.8	85.3	86.3	77.6	64.0	51.0	49.6	65.3
Avg Temp Wetbulb (°F)	42.2	45.4	50.4	56.9	64.7	73.5	74.5	72.9	67.6	58.5	46.3	45.0	58.2
Avg Temp Day (°F)	48.2	53.0	60.0	67.2	76.0	84.4	88.4	89.9	82.2	68.0	54.4	53.2	70.4
Avg Temp Night (°F)	44.2	48.4	53.9	60.4	67.2	76.7	81.9	82.7	73.5	60.7	48.6	47.3	61.0
Avg Temp Daily Max (°F)	55.3	59.5	66.8	74.3	83.1	91.4	95.2	97.2	90.4	74.5	62.0	59.4	75.9
Avg Temp Daily Min (°F)	37.3	41.2	47.1	53.3	61.0	72.0	75.9	75.8	65.4	54.5	41.2	40.1	55.5
Temp Max (°F)	75	76	88	87	93	97	100	100	97	89	83	73	100
Temp Min (°F)	27	28	30	38	50	57	73	70	52	26	24	27	24
Avg Rel Hum													
4am	85.1	79.9	82.0	81.6	88.2	88.4	82.0	71.3	80.8	86.6	83.8	82.9	82.7
10am	83.1	76.5	71.2	69.2	70.6	74.4	67.3	59.3	68.3	80.4	76.1	75.6	72.6
4pm	63.7	56.0	53.3	51.7	52.4	54.3	43.2	35.8	41.2	52.9	54.2	52.9	50.9
10pm	78.7	73.4	68.6	70.2	75.3	76.6	59.0	54.6	62.8	77.3	75.7	78.2	70.8
Heating Deg Days													
(Base 65)	580.0	410.0	273.0	113.5	8.5	0.0	0.0	0.0	0.5	157.0	422.0	477.0	2441.5
(Base 60)	425.5	276.0	160.0	43.5	1.0	0.0	0.0	0.0	0.0	87.5	291.0	339.0	1623.5
(Base 55)	280.5	154.5	79.5	9.5	0.0	0.0	0.0	0.0	0.0	43.0	170.5	218.0	955.5
(Base 50)	151.0	66.5	30.5	0.0	0.0	0.0	0.0	0.0	0.0	25.0	87.0	118.5	478.5
Cooling Deg Days													
(Base 80)	0.0	0.0	0.0	0.0	0.0	74.5	173.0	201.5	50.5	0.0	0.0	0.0	499.5
(Base 75)	0.0	0.0	0.0	1.0	19.0	207.0	328.0	356.5	134.0	21.5	0.0	0.0	1067.0
(Base 70)	0.0	0.0	4.5	21.5	99.5	352.0	483.0	511.5	251.0	72.0	6.0	0.0	1801.0
(Base 65)	0.0	0.0	23.5	77.0	227.0	502.0	638.0	666.5	388.0	143.0	20.0	4.5	2689.5
Heating Deg Hrs/24													
(Base 65)	603.5	421.9	309.7	146.3	38.5	1.5	0.0	0.0	26.2	176.0	443.3	489.7	2656.7
(Base 60)	456.2	300.0	199.7	79.7	13.0	0.2	0.0	0.0	8.0	116.0	320.0	360.3	1853.0
(Base 55)	319.3	193.4	114.4	37.9	2.8	0.0	0.0	0.0	0.8	74.0	213.2	246.0	1201.7
(Base 50)	198.5	109.1	57.2	13.4	0.0	0.0	0.0	0.0	0.0	43.2	132.6	152.2	706.2
Cooling Deg Hrs/24													
(Base 80)	0.0	0.0	2.3	4.0	25.8	103.3	189.5	217.4	99.2	13.5	0.3	0.0	655.4
(Base 75)	0.0	0.1	8.0	19.0	71.2	198.5	319.8	352.2	179.9	34.9	2.1	0.0	1185.7
(Base 70)	1.2	1.6	21.7	51.4	144.7	329.5	474.3	505.7	283.9	77.2	8.2	1.2	1900.5
(Base 65)	4.5	7.8	48.5	108.5	250.3	475.9	629.3	660.7	404.5	144.0	23.2	11.0	2768.1

Main and West Substations - 1993

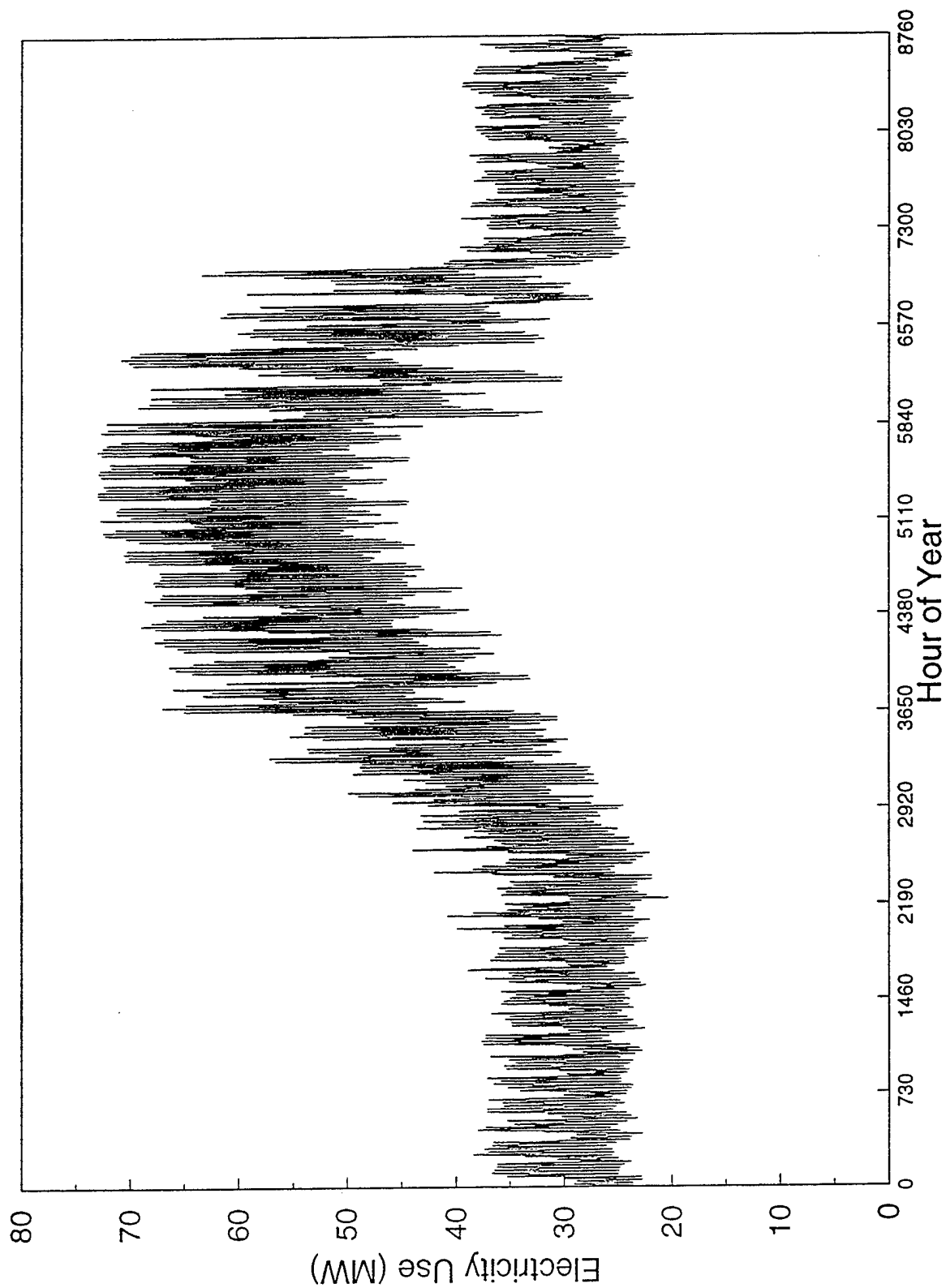


Figure 2-1. Texas Utility Annual Hourly Electricity Use

Chapter 3 Methodology

The methodology is an integrated technique for the estimation of hourly end-use energy consumption, which relies explicitly on measured feeder short-interval (hourly) electric load data to reconcile preliminary engineering estimates from DOE-2 building energy simulations. The method consists of five steps as observed in **Figure 3-1**. In this chapter, we will provide an overview of EDA followed by a description of the five steps in EDA application.

EDA Description

The End-Use Disaggregation Algorithm (EDA) is a tool designed to improve the hourly estimates of building electric energy consumption from that of prorations from simulations. In EDA, the sum of the end uses is constrained, at hourly intervals, to be equal to the measured whole-building load. This constraint provides a reality check that is not possible with pure simulation.

EDA is a deterministic method that primarily utilizes the statistical characteristics of the measured, hourly feeder load and its inferred dependence on temperature. Simulation is only used to supply information that is not evident from the load/temperature relationship, which are the ratios of one end use to another by hour and the temperature independent cooling load. In addition, the load/temperature relationship helps to characterize the conditioning end use, providing an additional constraint on the remaining end uses and preventing some of the errors possible with simple proration. EDA can give more weight to any given end use for any scheduled hour with use of a confidence factor. For example, if lighting was metered, confidence in that end use would be very high, so EDA would not alter the initial estimate. The reconciliation is done hourly, for two seasons (winter and summer), and for two daytypes (standard and nonstandard).

In its original form EDA was limited to reconcile end-use data for a single building. The technique was documented and validated with end-use metered data from an office building and a retail store (Akbari, 1995). The next generation of EDA was applied to prototypical buildings (Akbari, et al. 1989, 1991, and 1993), where the characteristics and measured whole-building electrical load data from many buildings of a similar type were averaged. The prototype simulations were reconciled with the average whole-building measured load. In this project, EDA was refined so that it reconciles several prototypes on a given feeder with feeder electrical load data.

The present generation of EDA is implemented using the hourly measured load for the feeder and the estimated temperature-independent and temperature-dependent components, the initial estimated end-use loads from the simulations, and the feeder to prototype assignment as input to obtain reconciled end-use hourly loads for all prototypes on the feeder. Confidence factors were not used because information did not exist that provided more confidence in one end use over another.

Feeder Data Analysis

The measured feeder load data are prepared as discussed in Chapter 2 and then analyzed as shown in **Figure 3-2**. A complete presentation of the data and analysis are shown in Appendix A. As an example, the original annual hourly load for Feeder 2 is shown in **Figure 3-3(a)**. Notice, the data logger produced inconsistent data for two weeks in September. The inconsistent data were modified as discussed in Chapter 2. The modified annual hourly load for Feeder 2 is shown in **Figure 3-3(b)**, which were the data used in the analysis. Two regions are represented in **Figure 3-3(b)**, temperature-independent and temperature-dependent. The temperature-independent region is defined as the winter season and runs

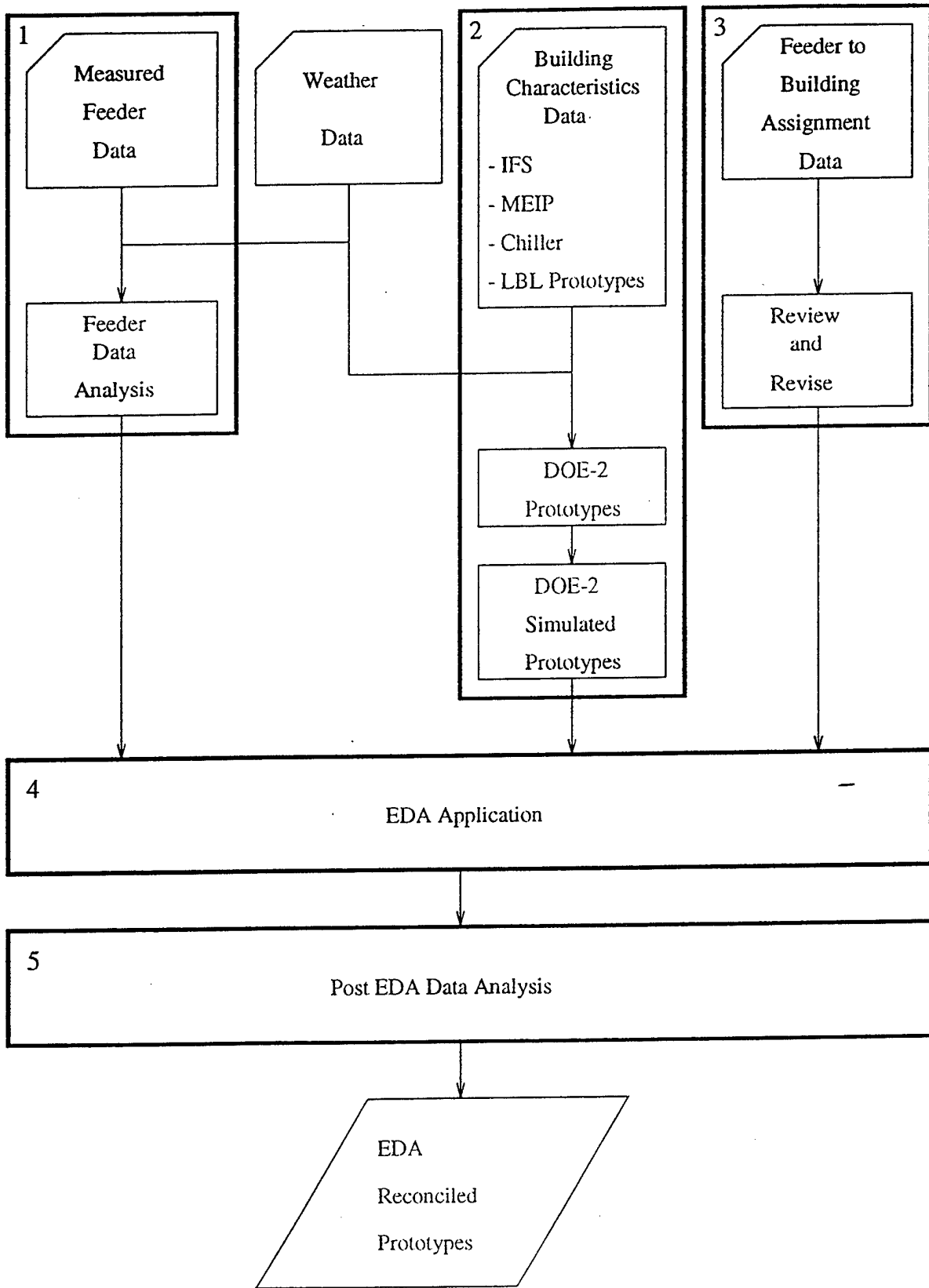


Figure 3-1. Fort Hood End-Use Characterization Methodology

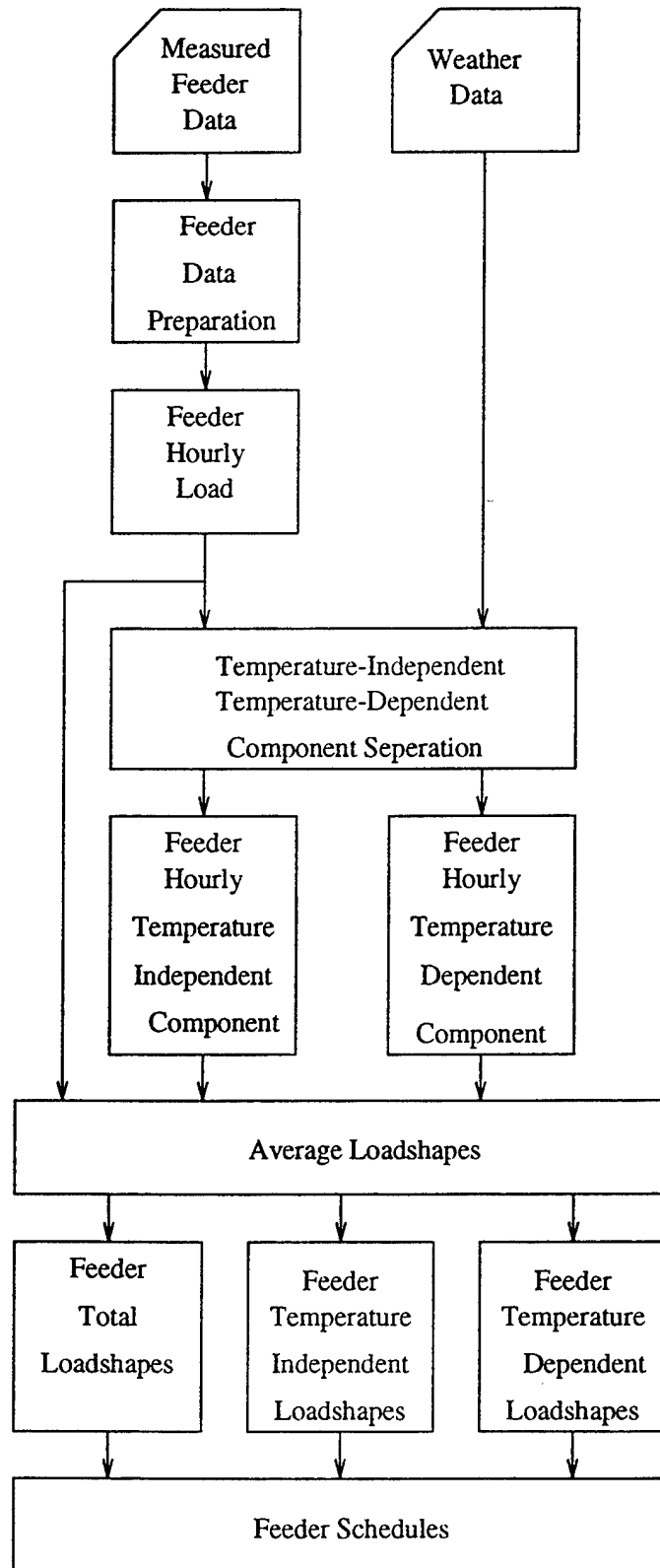


Figure 3-2. Fort Hood End-Use Characterization Methodology - Feeder Data Analysis

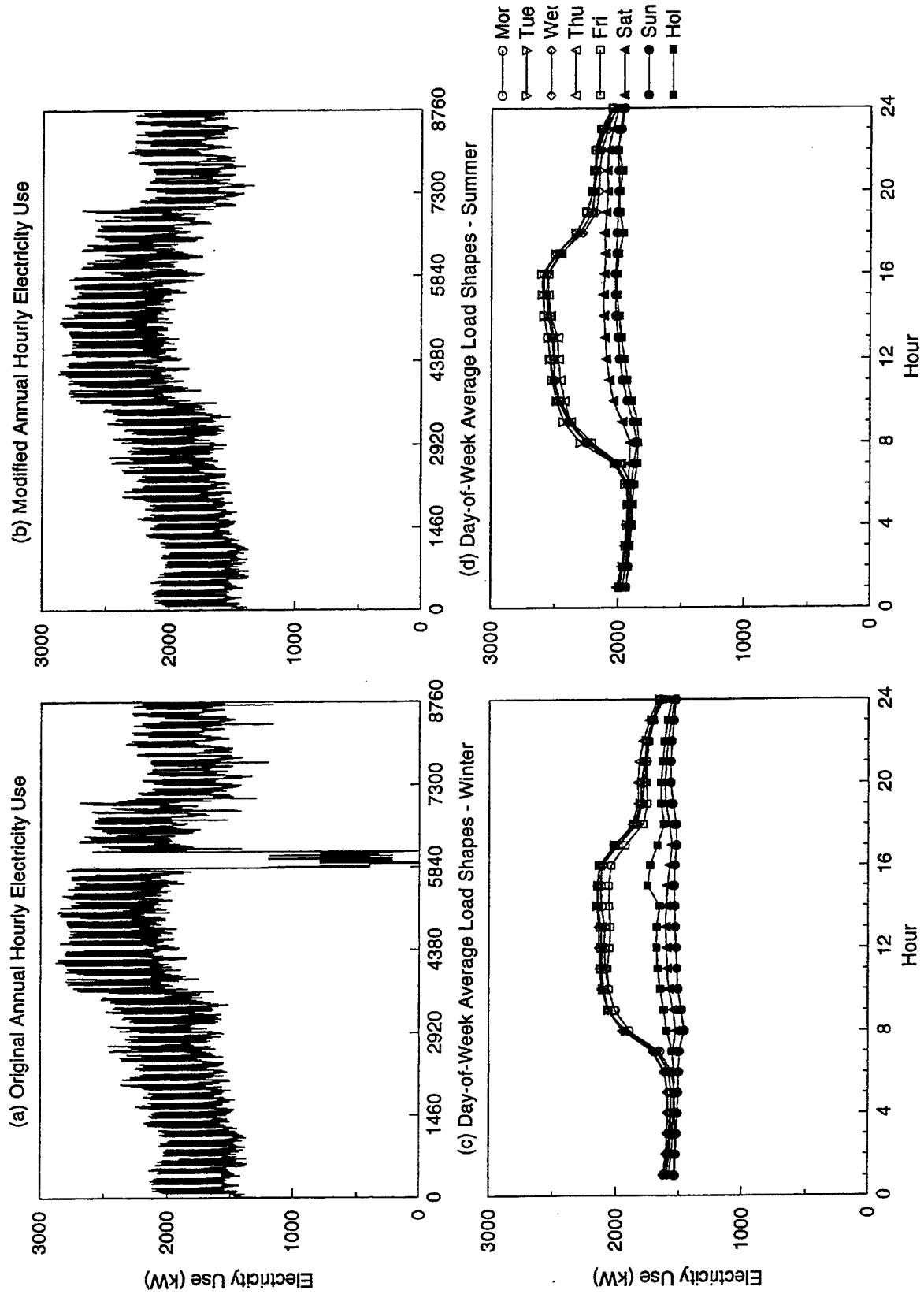


Figure 3-3. Feeder 2 Data

from January 1 through April 10 and October 23 through December 31. The temperature-dependent region is defined as the summer season and runs from April 11 through October 22.

From the feeder modified (original, if no modification necessary) annual hourly load the arithmetic mean average is plotted for day-of-week (Sunday through Saturday and Holidays) and season (winter and summer). The average, day-of-week, seasonal plots for Feeder 2 are illustrated in **Figures 3-3(c) and 3-3(d)** for winter and summer, respectively. Observed in these plots are the feeder seasonal schedules, which can help to define prototype seasonal schedules. Also, seen in the plots are the daytypes, which characterize the average daily load shapes. All of the feeders are characterized by two daytypes, weekday (standard day) and weekend/holiday (nonstandard day) for each season.

Next, scatter plots of feeder load versus outdoor drybulb temperature are developed by daytype (standard and nonstandard days) and season, by hour-of-day. Feeder 2 standard day load versus outdoor drybulb temperature scatter plots for winter and summer are displayed in **Figures 3-4 and 3-5**, respectively. In the winter plot the temperature-independence of the load is easily seen, except for a few data points it remains constant for the entire season. However, the summer plot illustrates a strong positive relationship between feeder load and outdoor drybulb temperature.

The summer load is then subdivided into temperature-independent (ti) and temperature-dependent (td) loads through a multi-variable regression by hour and daytype. The technique regresses feeder summer load versus outdoor drybulb temperature, and assumes a single slope adequately represents the 24 hourly slopes. In **Figure 3-5** the 24 hourly plots show slopes of equal magnitude. This was the case with all the feeders and the basis for the single slope assumption. The assumption is also made that the winter temperature-independent load does not equal the summer temperature-independent load. The summer temperature-independent load is defined as 5% of the summer load average range added to the summer average minimum load (by hour and daytype). The value of 5% was selected based on analysis of the relative difference in the nighttime load between the winter and summer scatter plots.

$$\text{Feeder_Load}_{\text{Sum,ti}} = \text{Feeder_Load}_{\text{Sum,min,avg}} + 0.05 (\text{Feeder_Load}_{\text{Sum,max,avg}} - \text{Feeder_Load}_{\text{Sum,min,avg}}) \quad [1]$$

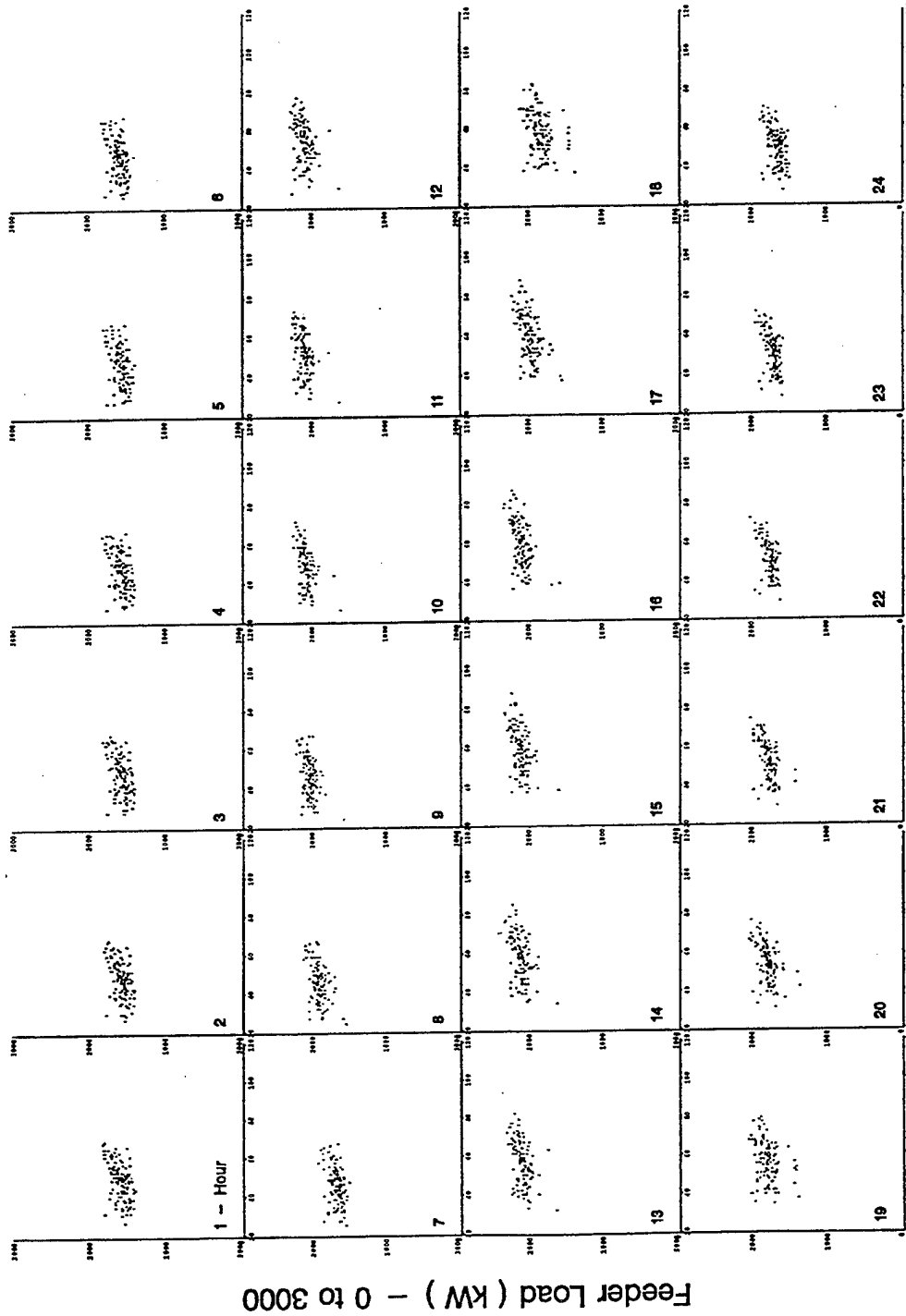
The regression results in a single slope [kW/°F], 24 zero intercepts [kW], and 24 base temperatures [°F] describing the linear relationship between summer feeder load and outdoor drybulb temperature. The base temperature is defined at the temperature that the feeder summer load equals the temperature-independent load, and is found hourly and by daytype from the following relation.

$$\text{Temperature}_{\text{Base}} = \frac{(\text{Feeder_Load}_{\text{Sum,ti}} - \text{Zero_Intercept})}{\text{Slope}} \quad [2]$$

The temperature-dependent load is calculated from the product of the regression slope and the hourly outdoor drybulb temperature differential.

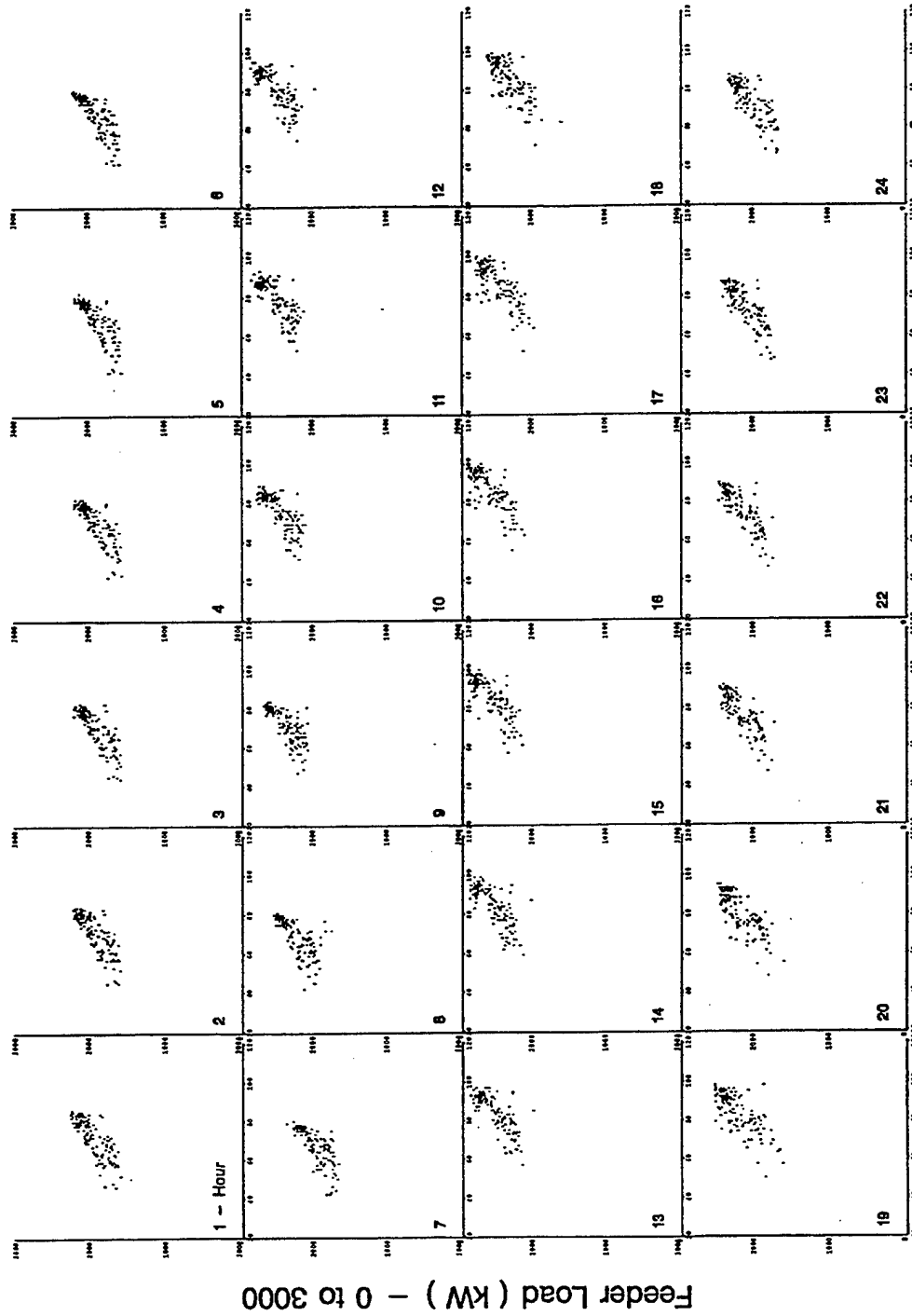
$$\text{Feeder_Load}_{\text{Sum,td}} = \text{Slope} (\text{Temperature}_{\text{Outdoor,db}} - \text{Temperature}_{\text{Base}}) \quad [3]$$

An attempt to improve the regression statistics was made by regressing the feeder load against drybulb temperature and absolute humidity. This yielded no significant improvement in the regression statistics, due to the colinearity of drybulb temperature and absolute humidity. This finding is consistent with an



Outdoor Drybulb Temperature (Degrees Fahrenheit) — 20 to 120

Figure 3-4. Feeder 2 Data Analysis - Feeder Load vs. Outdoor Drybulb Temperature - Winter - Standard Day



Outdoor Drybulb Temperature (Degrees Fahrenheit) - 20 to 120

Figure 3-5. Feeder 2 Data Analysis - Feeder Load vs. Outdoor Drybulb Temperature - Summer - Standard Day

earlier study (Akbari, et. at. 1995).

The feeder hourly load data has been separated into temperature-independent winter, temperature-independent summer, and temperature-dependent summer seasons, and is ready as input data for the EDA application.

Prototype Development

The 5,122 buildings of Fort Hood have been grouped into 23 prototypes based on the functions and characteristics of the facilities as shown in **Table 2-1**. These prototypes were developed from the IFS Building Inventory, MEIP Onsite Surveys, Chiller Survey, Previously Developed LBL Prototypes, and Feeder Schedule data bases as described in Chapter 2. A prototype is described by floor area from IFS data; shell characteristics, interior loads, HVAC system characteristics, and schedules from either MEIP or LBL prototypes, and additional schedule information from the feeder analysis. The hospital prototype also uses the chiller survey data. Tables describing these prototypes are provided in Appendix B. As an example, the prototype characteristics for the hospital are shown in **Table 3-1**, where the third column identifies the data source for each prototypical characteristic. Commercial and residential building types are represented at Fort Hood and each will be discussed briefly.

The barrack group consists of 4 types of billets (barrack) , a dining hall, and a gymnasium, where the billets are classified as hammerhead, rolling pin, modular, or small. The modular and small billets function as residential units. The hammerhead and rolling pin billets function as commercial units as well as residential, since they include administrative zones in addition to billeting. All the prototypes are heated with natural gas hot water boilers. The gymnasium and small billet are cooled by packaged direct expansion units, and the dining hall and remaining billets by central chillers with cooling towers.

The administrative group is made up of 5 prototypes a large and 4 small varieties. The large administrative prototype is modeled as 3 floors of 168,500 ft² building with a central chiller with cooling tower and hot water boiler. The 4 small administrative prototypes are either of old or modern construction with a packaged direct expansion or chilled water cooling system. They are modeled as single story with ~5000 ft².

The vehicle maintenance group consists of 4 prototypes; a small shop, 2 large shops, and a hangar. Each of these prototypes are modeled with an office zone and a bay zone, where the office is about 5% of the total floor area. The bay zones are not cooled, but are heated with gas-fired unit heaters. The office zones are heated with a hot water boiler. The small vehicle maintenance shop is modeled without an air-conditioned office. The large vehicle maintenance shops have air-conditioned offices, which are cooled with either a packaged direct expansion unit or a chiller. The hangar has office cooling provided by a chiller. Also, these prototypes have a process (air compressor) load.

There is only one major hospital (Darnell) at Fort Hood and it is individually modeled as a prototype. Dental clinics, which for all practical purposes, are operated like office buildings with well defined schedules and a similar working environment, are modeled as administrative prototypes.

The residential group consists of 3 prototypes, detached, two-plex, and four-plex, of 1,330, 2,940, and 6,770 ft², respectively. All are modeled as single story units heated with a gas-fired furnace and cooled with central air direct expansion units.

The other building group includes a large retail store, two warehouses, and a miscellaneous category. The large retail store is modeled as a single story of 128,000 ft², where cooling is provided by a chiller/cooling tower and heating by a hot water boiler. The warehouses are modeled with an office space and a storage space, where the office is about 5% of the total floor area. The storage zone has no cooling, but is heated with a gas-fired unit heater. The office is heated with a hot water boiler. One warehouse is

Table 3-1a. Hospital Prototype Characteristics

Construction		
Floor Area (ft ²)	504202	IFS
Number of Floors	6	
Floor Materials	4" Light Weight Concrete Carpet w/ Pad	LBL
Roof Materials	3/8" Built-up Roofing 6" Light Weight Concrete 2" Roof Insulation Air Layer 1/2" Acoustical Tile	
Slab Material	6" Heavy Weight Concrete	
Wall Materials	12" Concrete Block Filled 3 1/2" R-11 Insulation Air Layer 5/8" Gypsum	
Window Characteristics		
Number of Panes	1	
Shading Coefficient	0.90	
Non-HVAC Loads		
Exterior Lights (W/ft ²)	0.1	
Refrigeration (W/ft ²)	0.1	
HVAC System		
Distribution	Central Air / Variable Volume	
Economizer	Inactive	
Cooling		
Type	Herm Cent Chiller / Cooling Tower (3)	Chiller
Capacity (Tons)	417	
COP	4.55	LBL
Setpoint (°F)	73	
Availability	Jan 1 - Dec 31	Feeder
Heating		
Type	Hot Water Boiler / Natural Gas	LBL
Setpoint (°F)	73	
Availability	Jan 1 - Dec 31	Feeder
Loads / System Schedule		
Standard Days	Monday - Friday	
On Hours	7 - 23	
Nonstandard Days	Saturday, Sunday, Holiday	
On Hours	7 - 23	

Table 3-1b. Hospital Prototype Zonal Characteristics (Source LBL Prototype)

	Clinic	Core	Perimeter	Kitchen	Hallway	Total
Floor Area (% total)	25	35	15	5	20	100
Occupancy (ft ² /person)	289	289	150	321	578	-
Outside Air (ACH)	-	-	-	1.8	-	-
Outside Air / Person (CFM)	15	15	15	-	15	-
Interior Lights (W/ft ²)	2.1	1.6	1.6	2.1	0.8	1.6
Miscellaneous (W/ft ²)	4.0	1.3	1.3	9.0	-	2.1
Cooking (W/ft ²)	-	-	-	4.0	-	0.2
System Type	DD	VAV	FPFC	SZRH	VAV	

modeled without office cooling and the other is cooled with a packaged direct expansion unit. The miscellaneous category consists of a bowling center, church, grocery store, library, restaurants (fastfood and sitdown), small retail store, and youth center, which are considered low priority by CERL and only DOE-2 simulated results are presented.

Up to 11 end uses are simulated for each prototype, consisting of 9 electric and 2 gas; however, only the electric end uses are reconciled. The electric end uses are space cooling, ventilation (AHU, fans, chilled and hot water pumps), cooking, miscellaneous/plugs, refrigeration, exterior lighting, interior lighting, process loads, and street lighting. The gas end uses are space heating and hot water heating. Space heating EUIs are simulated only. Hot water heating EUIs are taken from previous LBL studies and the MEIP surveys. The end uses listed by prototype are displayed in **Table 1-1**.

A single street light pole was assumed to consist of a mixture of single and double lamps, with 1.3 lamps per pole, and where each lamp is rated at 150 W. These poles are placed every 50 feet. The street length for each feeder was estimated from the Fort Hood Base Map. This provided the initial estimate for the EDA application.

EDA requires initial estimates of end-use hourly loads for each prototype. For HVAC end uses (cooling and fans), initial estimates result from simulation of the prototype using the DOE-2.1D (BESG, 1990) building energy simulation program with Waco, Texas weather data. For non-HVAC end uses (miscellaneous equipment, refrigeration, cooking, process, exterior and interior lighting), the estimates are generated with the Non-HVAC Load Generator, also known as NELDIG (Akbari, et. al. 1989). NELDIG combines the peak intensity for each end use (equipment/lighting/etc) with a fraction derived from prototypical schedules. This results in an annual hourly load profile for each non-HVAC end use. The simulated load shapes are presented in Appendix B. As an example, the simulated summer standard day load shapes for the large administration prototype are displayed in **Figure 3-6(a)**. The prototype development procedure is illustrated in **Figure 3-7**.

During the summer the total cooling and fan loads can be attributed to temperature-independent (base) and temperature-dependent demands. The cooling and fan temperature-independent and temperature-dependent loads are estimated from the hourly cooling and fan results of the DOE-2 simulation, respectively. The base cooling load is determined by averaging (by daytype and hour) the simulated summer cooling hourly load whenever the outdoor drybulb temperature is in the range of 65 or below. The base temperature of 65 is selected based on the visual inspection of data.

$$DOE2_Cool_Load_{Sum,base,proto,i} = \left(\frac{1}{N}\right) \sum_1^N DOE2_Cool_Load_{Sum,65below,proto,i} \quad [4]$$

The base fan load is assumed initially to be 1/3 of the base cooling load, which is based on a previous LBL study (Akbari, et al. 1993).

$$DOE2_Fan_Load_{Sum,base,proto,i} = 0.33 DOE2_Cool_Load_{Sum,base,proto,i} \quad [5]$$

Simulated temperature-dependent hourly cooling is found by subtracting the base cooling from the total simulated hourly cooling. The same is done for fans.

$$DOE2_Cool_Load_{Sum,td,proto,i} = DOE2_Cool_Load_{Sum,proto,i} - DOE2_Cool_Load_{Sum,base,proto,i} \quad [6]$$

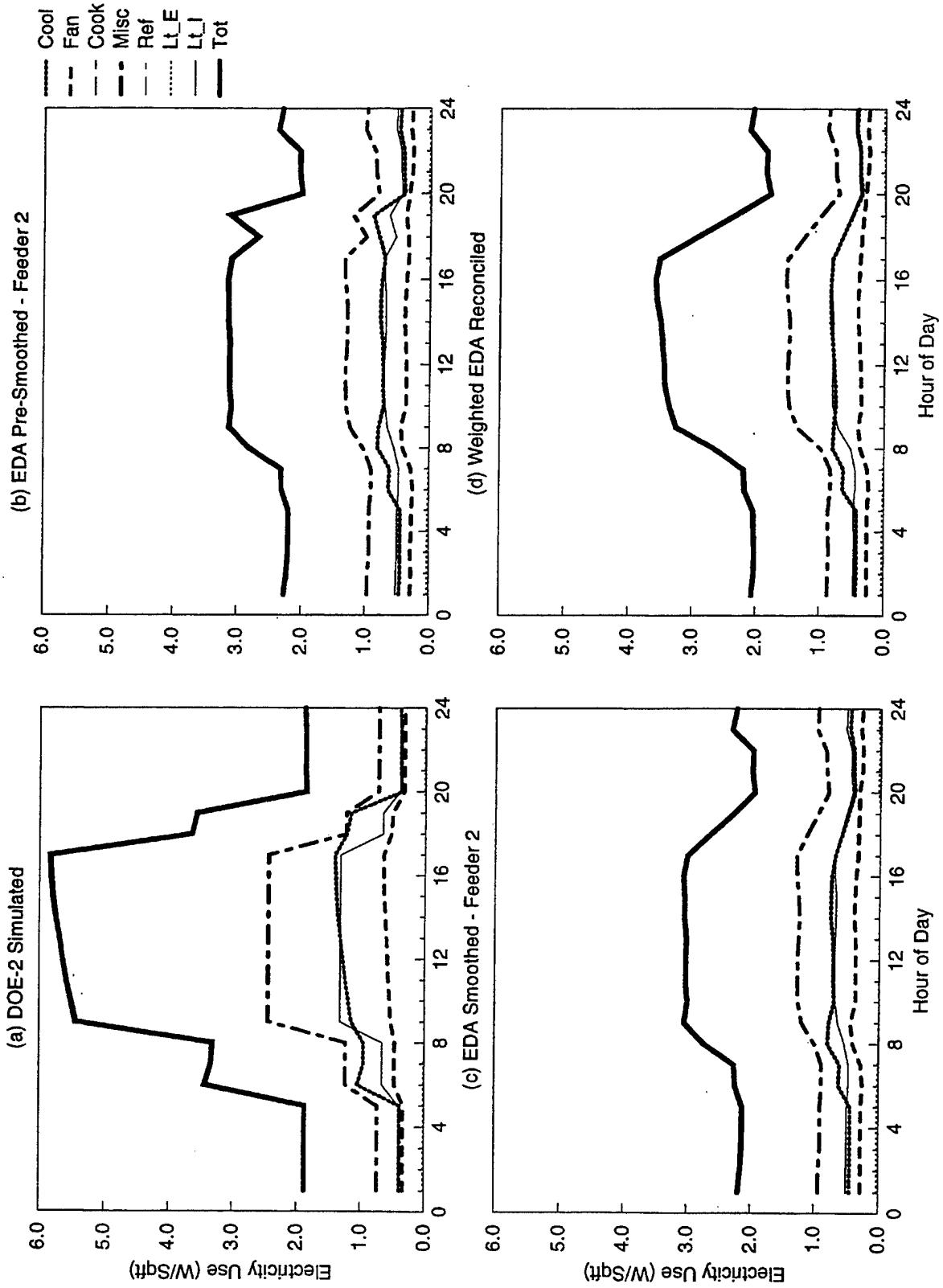


Figure 3-6. Large Administration Load Shapes for Standard Day - Summer.

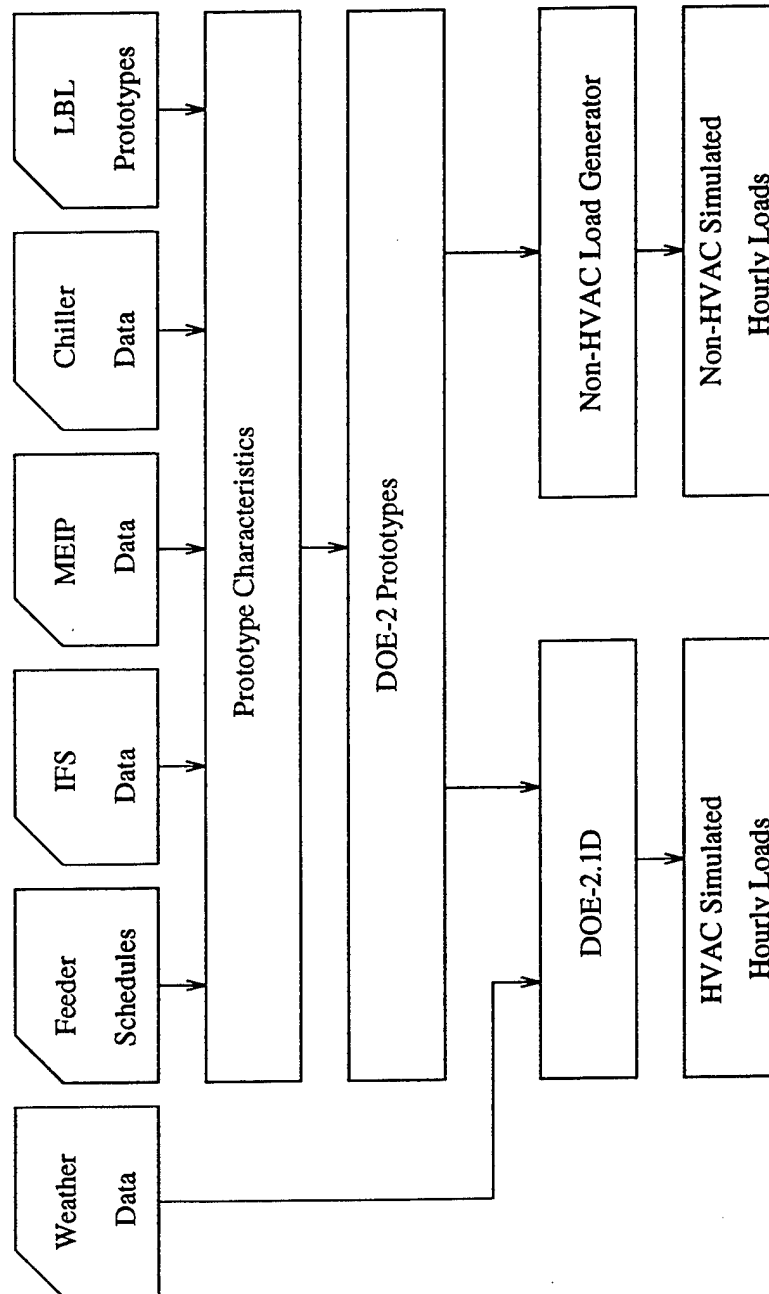


Figure 3-7. Fort Hood End-Use Characterization Methodology - Prototype Development

$$\text{DOE2_Fan_Load}_{\text{Sum,td,proto}_i} = \text{DOE2_Fan_Load}_{\text{Sum,proto}_i} - \text{DOE2_Fan_Load}_{\text{Sum,base,proto}_i} \quad [7]$$

The base and temperature-dependent cooling and fan hourly loads are used as input to EDA.

Feeder to Prototype Assignment

The feeder to building assignment data base was reviewed (and revised as discussed in Chapter 2) and integrated with the IFS building inventories data to determine the floor area per prototype on each feeder (see **Figure 3-8**). The feeders were assigned the prototypes that cover 90-100% of the floor area of the feeder. This ranged from 1 prototype (Feeder 9, hospital) to 10 prototypes (Feeders 10 and 15). The remaining 5-10% of the floor area was composed of prototypes that each represented less than 1% or 2% of the floor area (in most cases less than 1%). The feeder to prototype assignment was then used as input to EDA, see **Table 4-1** for these assignments.

EDA Application

The first step was to disaggregate the winter temperature-independent hourly component from the feeder data analysis into end uses for each prototype. Cooling had been set equal to zero for the winter season, since the measured load data suggested there was no temperature-dependent component and the MEIP survey indicated cooling systems were off during winter (the exception is for the hospital on Feeder 9). The winter fan and pump load was attributed to moving heated and ventilation air and hot water. The winter hourly component was distributed proportionally based on the initial simulated end use hourly loads for each prototype and street lighting.

$$\text{EDA_Cool_Load}_{\text{Win,proto}_i} = 0 \quad [8]$$

$$\text{EDA_Fan_Load}_{\text{Win,proto}_i} = \left(\frac{\text{DOE2_Fan_Load}_{\text{Win,proto}_i}}{\sum_1^N \text{DOE2_Total_Load}_{\text{Win,proto}_i}} \right) \text{Feeder_Load}_{\text{Win}} \quad [9]$$

$$\text{EDA_Non_HVAC_Load}_{\text{Win,proto}_i} = \left(\frac{\text{DOE2_Non_HVAC_Load}_{\text{Win,proto}_i}}{\sum_1^N \text{DOE2_Total_Load}_{\text{Win,proto}_i}} \right) \text{Feeder_Load}_{\text{Win}} \quad [10]$$

The second step was to disaggregate the summer temperature-dependent and temperature-independent hourly components into end uses for each prototype. The temperature-dependent cooling was determined by prorating the estimated temperature-dependent hourly component by the initial simulated cooling hourly loads. The same was done to estimate temperature-dependent hourly loads for fans.

$$\text{EDA_Cool_Load}_{\text{Sum,td,proto}_i} = \left(\frac{\text{DOE2_Cool_Load}_{\text{Sum,td,proto}_i}}{\sum_1^N \text{DOE2_Cool_Fan_Load}_{\text{Sum,td,proto}_i}} \right) \text{Feeder_Load}_{\text{Sum,td}} \quad [11]$$

$$\text{EDA_Fan_Load}_{\text{Sum,td,proto}_i} = \left(\frac{\text{DOE2_Fan_Load}_{\text{Sum,td,proto}_i}}{\sum_1^N \text{DOE2_Cool_Fan_Load}_{\text{Sum,td,proto}_i}} \right) \text{Feeder_Load}_{\text{Sum,td}} \quad [12]$$

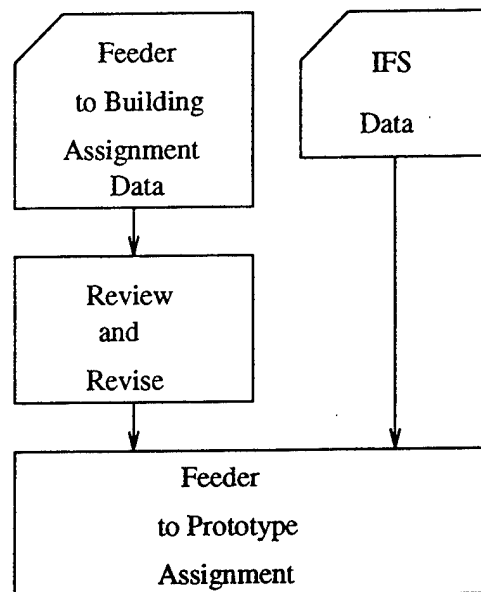


Figure 3-8. Fort Hood End-Use Characterization Methodology - Feeder to Prototype Assignment Analysis

The temperature-independent (base) cooling and fan hourly loads were calculated by prorating the summer temperature-independent hourly component with the Non-HVAC end uses and simulated base cooling and fans (ti in equations 13 and 14 represents the sum of the Non-HVAC end uses and simulated base cooling and fans).

$$EDA_Cool_Load_{Sum,base,proto,i} = \left(\frac{DOE2_Cool_Load_{Sum,base,proto,i}}{\sum_i DOE2_ti_Load_{Sum,proto,i}} \right) Feeder_Load_{Sum,ti} \quad [13]$$

$$EDA_Fan_Load_{Sum,base,proto,i} = \left(\frac{DOE2_Fan_Load_{Sum,base,proto,i}}{\sum_i DOE2_ti_Load_{Sum,proto,i}} \right) Feeder_Load_{Sum,ti} \quad [14]$$

The total cooling load was the sum of the hourly temperature-dependent cooling and the base cooling, likewise for fans.

$$Pre_EDA_Cool_Load_{Sum,proto,i} = EDA_Cool_Load_{Sum,base,proto,i} + EDA_Cool_Load_{Sum,td,proto,i} \quad [15]$$

$$Pre_EDA_Fan_Load_{Sum,proto,i} = EDA_Fan_Load_{Sum,base,proto,i} + EDA_Fan_Load_{Sum,td,proto,i} \quad [16]$$

The summer temperature-independent hourly component was then adjusted by subtracting out the base cooling and fan hourly loads.

$$Feeder_Load_{Sum,ti,adj} = Feeder_Load_{Sum,ti} - \sum_i Pre_EDA_Cool_Fan_Load_{Sum,base,proto,i} \quad [17]$$

The non-HVAC end use hourly loads were found by proportionally distributing the adjusted summer temperature-independent hourly component.

$$Pre_EDA_Non_HVAC_Load_{Sum,proto,i} = \left(\frac{DOE2_Non_HVAC_Load_{Sum,proto,i}}{\sum_i DOE2_Total_Non_HVAC_Load_{Sum,proto,i}} \right) Feeder_Load_{Sum,ti,adj} \quad [18]$$

Then the difference (Error) between the total measured feeder hourly load and the sum of the estimated temperature-dependent and temperature-independent hourly components was distributed. This was done for summer only (except for Feeder 9).

$$Error = Feeder_Load_{Sum,measured} - (Feeder_Load_{Sum,td} + Feeder_Load_{Sum,ti}) \quad [19]$$

If the error was greater than zero (regression under-estimate), then it was distributed proportionally based on the relative floor area of the prototype to the feeder. However, if the error was less than zero (regression over-estimate), the error was still distributed proportionally, but if this distribution caused any end use to become less than zero, then the error was redistributed with the relative floor area decreased by 50% for any end use less than zero. This process was repeated until all reconciled end-use hourly loads were greater than zero. The error was then added to the previously calculated summer end use hourly

loads.

$$EDA_End-Use_Load_{Sum,proto,i} = Pre_EDA_End-Use_Load_{Sum,proto,i} + (Error \left(\frac{Floor_Area_{Proto,i}}{Floor_Area_{Feeder}} \right)) \quad [20]$$

At the completion of this step the raw EDA reconciled hourly loads by end use and prototype were determined. These raw EDA reconciled hourly loads were then averaged by season and daytype to produce average load shapes. The winter and summer hourly load files were combined into a single annual file. The data in both the hourly and average daily forms were utilized in the Post EDA Data Analysis.

Post EDA Data Analysis

The steps involved in the Post EDA Data Analysis are shown in **Figure 3-9**. The raw EDA reconciled hourly loads, annual EUIs, and load shapes were inspected for acceptance. If they were not accepted, then the feeder to prototype assignment were adjusted (see Chapter 2) based on a remapping of buildings to feeders, and EDA must be rerun. If they were accepted, then the raw EDA reconciled hourly loads were scaled down by the fraction of floor area utilized by the feeder. **Table 4-1** shows the floor area fraction by which the raw hourly loads are scaled.

$$EDA_End-Use_Load_{Scaled,proto,i} = Floor_Area_Fraction_{Feeder} \times EDA_End-Use_Load_{Proto,i} \quad [21]$$

Next, the load shapes were examined for unrealistic behavior in the shoulder hours. Because the prototype schedules do not ideally reflect the load behavior in the reconciled load shapes, the shoulder hours periodically exhibited spikes for some end uses. These spikes were smoothed with a linear fit within the scaled EDA reconciled hourly loads for whatever end uses it was necessary. **Figure 3-6(b)** exhibits the reconciled summer standard day load shapes for the large administration prototype on Feeder 2 that require smoothing for hours 17 through 20. The smoothed version is shown in **Figure 3-6(c)**. The smoothed load shapes for all feeders analyzed are presented in Appendix C by prototype.

At this point the scaled and smoothed annual EUIs and load shapes were examined for a final time to determine which would be implemented in the final weighting step. The prototypes accepted were combined into a final weighted reconciled prototype based on the relative floor area of like prototypes from different feeders. **Figure 3-6(d)** displays the final weighted load shapes of the large administration prototype for summer standard days, which is a weighted combination from Feeders 2 and 5. The final weighted load shapes are displayed in Appendix C.

$$EDA_End-Use_Load_{Final,proto,i} = \frac{\sum_1^N EDA_End-Use_Load_{Scaled,smoothed,proto,i} \times Floor_Area_{Proto,i}}{\sum_1^N Floor_Area_{Proto,i}} \quad [22]$$

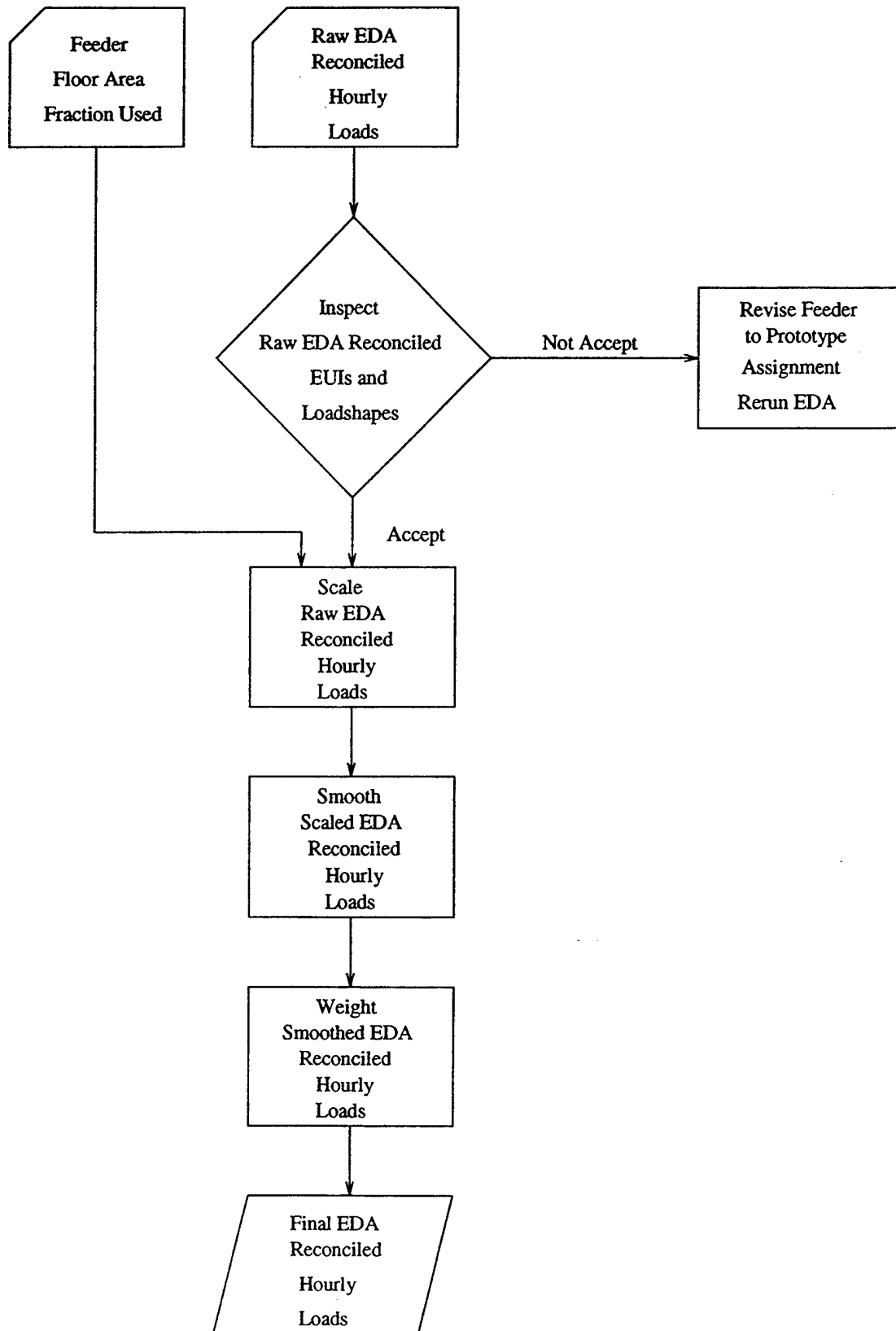


**Figure 3.9. Fort Hood End-Use Characterization Methodology
Post EDA Data Analysis**

Chapter 4

Results

The EDA was applied to 10 feeders in Fort Hood; Feeders 2, 3, 5, 9, 10, 12, 15, W4, W5, and W6. The results for these 10 feeders are presented in the order listed below.

- Prototype Selection by Feeder
- DOE-2 Simulated Electric and Gas Enduse Annual EUIs
- EDA Reconciled Electric Enduse Annual EUIs by Feeder
- EDA Reconciled Total Electric Annual EUIs by Feeder
- Weighted EDA Reconciled Electric Enduse Annual EUIs
- Simulated and EDA Reconciled Street Lighting Annual EUIs
- EDA Validation
- Electronic Data

Prototype Selection by Feeder

Table 4-1 lists the prototypes selected by feeder. Note, that the quantity in the fourth column of **Table 4-1** indicates the fraction of total prototype floor area to total feeder floor area. Except, in the cases of Feeder 4 (water pump), Feeder 9 (hospital), and Feeder W5 (two-plex residential and large retail), the total prototype floor area did not sum to 100% of the total feeder floor area. The remaining 5-10% of the floor area was composed of prototypes that each represented less than 1% or 2% of the floor area (in most cases less than 1%). Executing EDA on prototypes representing a very small fraction of floor area was deemed impractical because of the instability of the EDA load shapes for these prototypes. The floor area fraction is the quantity that the raw EDA hourly end use loads are scaled down by in Equation [21]. For Feeders 2, 3, 5, 10, and 15 a miscellaneous prototype is shown, these are a floor area weighted combination of the miscellaneous building types listed for each of the feeders.

DOE-2 Simulated Electric and Gas Enduse Annual EUIs

Table 4-2 summarizes the DOE-2 simulated annual EUIs for each prototype and end use identified in **Table 1-1**. The electric end uses are space cooling, ventilation (AHU, fans, chilled and hot water pumps), cooking, miscellaneous/plugs, refrigeration, exterior lighting, interior lighting, and process loads listed in columns 2 through 9, respectively. The total electric EUI is displayed in column 10. The gas end uses are space heating and hot water heating and are listed in columns 11 and 12, respectively.

EDA Reconciled Electric Enduse Annual EUIs by Feeder

Table 4-3 summarizes the EDA reconciled annual electric EUIs for all of the feeders, identified by feeder, prototype, and end use. These are the results obtained after scaling and smoothing the raw EDA hourly loads. Feeders are identified by the suffix following the prototype name. Note, the large administration prototypes EUI for the miscellaneous end use includes computer operation. The end-use EUIs for the residential two-plex prototype on Feeder W5 are much greater than those of the other residential two-plex prototypes. This is likely due to errors in the feeder-to-building assignment data base as discussed in Chapter 2.

Table 4-1. Prototype Selection by Feeder

Feeder	Prototype	Floor Area (ft ²)	Floor Area Fraction
2	Administration - Large	463000	0.489
	Miscellaneous	124686	0.132
	Youth Center	63634	0.067
	Bowling Center	30984	0.033
	Retail - Small	11541	0.012
	Church	11238	0.012
	Library	7289	0.008
	Administration - Small - Old w/ Split DX	118884	0.126
	Gymnasium	62000	0.066
	Administration - Small - New w/ Chiller	49320	0.052
	Administration - Small - New w/ Split DX	44474	0.047
	Barrack - Modular	30649	0.032
	Administration - Small - Old w/ Chiller	26780	0.028
	Total	919793	0.972
3	Residential - Four Plex	482481	0.266
	Barrack - Hammer Head	454958	0.251
	Administration - Small - Old w/ Chiller	319723	0.176
	Vehicle Maintenance - Small w/ No AC	195941	0.108
	Miscellaneous	67233	0.037
	Retail - Small	23588	0.013
	Library	19975	0.011
	Youth Center	15260	0.008
	Church	8410	0.005
	Barrack - Rolling Pin	66942	0.037
	Warehouse w/ No AC	60974	0.034
	Vehicle Maintenance - Large w/ Split DX	55430	0.031
	Dining Hall	37197	0.020
	Total	1740879	0.960
4	Water Pump	4442	1.000
5	Residential - Two Plex	942943	0.533
	Residential - Detached	460130	0.260
	Administration - Large	124817	0.071
	Barrack - Modular	92000	0.052
	Miscellaneous	69981	0.040
	Church	32228	0.018
	Retail - Small	30438	0.017
	Library	4320	0.003
	Youth Center	2995	0.002
	Dining Hall	34661	0.020
	Total	1724532	0.976
9	Hospital	504202	1.000

Table 4-1. Prototype Selection by Feeder - Continued

Feeder	Prototype	Floor Area (ft ²)	Floor Area Fraction
10	Barrack - Rolling Pin	710044	0.307
	Administration - Small - Old w/ Chiller	303107	0.131
	Vehicle Maintenance - Small w/ No AC	261947	0.113
	Administration - Small - Old w/ Split DX	186219	0.081
	Barrack - Hammer Head	175632	0.076
	Miscellaneous	135768	0.059
	Retail - Small	90342	0.039
	Library	33014	0.014
	Church	7492	0.004
	Youth Center	4920	0.002
	Vehicle Maintenance - Large w/ Split DX	135445	0.059
	Dining Hall	98033	0.042
	Barrack - Small	84960	0.037
	Administration - Small - New w/ Split DX	75361	0.033
	Total	2166516	0.938
12	Residential - Two Plex	384520	0.540
	Residential - Four Plex	203939	0.286
	Residential - Detached	62291	0.087
	Total	650750	0.913
15	Barrack - Hammer Head	436208	0.269
	Administration - Small - Old w/ Chiller	322972	0.199
	Barrack - Modular	232704	0.143
	Hangar	170010	0.105
	Vehicle Maintenance - Large w/ Split DX	111024	0.068
	Miscellaneous	73299	0.045
	Youth Center	48254	0.030
	Retail - Small	18386	0.011
	Church	6659	0.004
	Vehicle Maintenance - Large w/ Chiller	58080	0.036
	Administration - Small - Old w/ Split DX	51012	0.031
	Dining Hall	48769	0.030
	Gymnasium	41960	0.026
	Total	1546038	0.952
W4	Residential - Two Plex	1915823	0.843
	Residential - Detached	219173	0.096
	Total	2134996	0.939
W5	Residential - Two Plex	284688	0.526
	Retail - Large	256116	0.474
	Total	540804	1.000
W6	Vehicle Maintenance - Large w/ Split DX	205615	0.399
	Vehicle Maintenance - Large w/ Chiller	183244	0.356
	Warehouse w/ Split DX	56800	0.110
	Administration - Small - New w/ Chiller	41331	0.080
	Barrack - Modular	17550	0.034
	Total	504540	0.979

Table 4-2. DOE-2 Simulated End-use Annual EUIs [kWh/ft² yr for electric end-uses] - [kBtu/ft² yr for gas end-uses]

Prototype	Cool	Fan	Cook	Misc	Ref	Ex_Lit	In_Lit	Prss	Total Elec	Heat†	Hot Water†
Barrack											
Hammer Head	3.91	1.33	0.39	2.73	2.98	0.22	3.01	-	14.57	2.72	18.5
Rolling Pin	5.01	3.72	0.45	1.35	3.00	0.13	2.17	-	15.82	9.45	16.6
Modular	3.05	0.88	0.33	3.09	2.54	0.13	2.93	-	12.95	13.47	24.8
Small	3.62	1.62	0.21	1.44	1.65	0.22	1.50	-	10.26	14.21	11.0
Dining Hall	5.62	1.93	8.87	-	6.13	0.13	5.50	-	28.18	7.35	24.1
Gymnasium	1.64	0.69	-	0.78	-	0.18	9.21	0.01	12.50	23.55	11.0
Administration											
Large	3.86	3.79	-	10.71	-	0.09	5.77	-	24.23	0.18	4.4
Small - Old w/ Split DX	6.84	3.32	-	2.41	-	0.13	8.25	-	20.95	8.55	2.9
Small - Old w/ Chiller	5.59	4.80	-	2.41	-	0.13	8.25	-	21.19	5.40	2.9
Small - New w/ Split DX	4.97	2.42	-	2.41	-	0.13	8.25	-	18.19	11.87	2.9
Small - New w/ Chiller	5.01	4.06	-	2.41	-	0.13	8.25	-	19.86	9.81	2.9
Vehicle Maintenance											
Small w/ No AC	-	0.61	-	0.67	-	0.35	3.48	0.01	5.13	41.36	-
Large w/ Split DX	0.48	0.24	-	0.67	-	0.35	3.48	0.01	5.23	29.08	-
Large w/ Chiller	0.37	0.33	-	0.67	-	0.35	3.48	0.01	5.21	28.75	-
Hangar	1.69	1.01	-	0.27	-	0.04	5.00	0.01	8.03	24.44	-
Hospital	9.50	2.83	1.01	15.82	0.88	0.44	12.59	-	43.06	5.80	1.9
Residential											
Detached	6.94	0.51	0.22	4.23	0.86	0.39	0.88	-	14.03	12.63	11.0
Two Plex	6.55	0.50	0.22	4.23	0.86	0.39	0.88	-	13.64	11.90	11.0
Four Plex	6.02	0.55	0.22	4.23	0.86	0.39	0.88	-	13.15	10.88	11.0
Other											
Retail - Large	4.12	3.46	0.43	1.95	1.88	0.44	10.67	-	22.95	0.41	0.9
Warehouse											
w/ No AC	-	0.18	-	0.75	-	0.35	3.48	-	4.75	18.03	-
w/ Split DX	0.72	0.30	-	0.75	-	0.35	3.48	-	5.59	11.02	-
Miscellaneous											
Bowling Center	2.61	0.75	-	5.08	-	0.22	5.15	-	13.80	0.93	-
Church	2.46	0.74	-	0.93	-	0.22	5.61	-	9.96	10.19	-
Grocery Store	4.74	2.38	0.37	4.57	11.49	0.91	8.88	-	33.35	51.44	1.3
Library	3.47	1.06	-	3.01	-	0.22	10.24	-	17.99	5.28	-
Restaurant- Fastfood	21.70	3.58	4.12	7.74	9.10	3.29	12.45	-	61.98	37.73	8.8
Restaurant- Sitdown	15.57	2.70	3.12	4.68	5.55	1.17	5.41	-	38.20	40.80	8.8
Retail - Small	4.51	1.19	0.05	1.87	0.49	0.44	9.34	-	17.89	5.62	0.5
Youth Center	3.02	0.92	-	2.00	-	0.22	6.82	-	12.98	10.88	-

† Space heating and hot water heating are gas end uses.

Table 4-3. EDA Reconciled Electric Enduse Annual EUIs by Feeder [kWh/ft² yr]

Prototype	Cool	Fan	Cook	Misc	Ref	Ex_Lit	In_Lit	Press	Total
Barrack									
Hammer Head - 3	2.56	1.07	0.23	1.40	1.64	0.15	1.48	-	8.53
Hammer Head - 10	3.25	1.40	0.28	1.76	2.05	0.19	1.87	-	10.79
Hammer Head - 15	4.36	1.76	0.33	2.07	2.49	0.23	2.18	-	13.40
Rolling Pin - 3	3.51	2.74	0.26	0.71	1.66	0.10	1.08	-	10.06
Rolling Pin - 10	4.38	3.58	0.31	0.87	2.07	0.12	1.37	-	12.71
Modular - 2	2.77	1.14	0.35	3.35	2.71	0.18	3.20	-	13.69
Modular - 5	2.65	1.02	0.30	2.76	2.43	0.13	2.65	-	11.94
Modular - 15	4.31	1.21	0.28	2.49	2.18	0.15	2.34	-	12.96
Modular - W6	6.16	1.89	0.41	3.69	2.88	0.16	3.38	-	18.58
Small - 10	5.10	1.36	0.16	0.99	1.16	0.19	1.03	-	9.99
Dining Hall - 3	4.02	1.53	4.48	-	3.47	0.10	2.79	-	16.39
Dining Hall - 5	4.83	2.09	7.87	-	5.89	0.13	4.85	-	25.66
Dining Hall - 10	5.01	2.04	5.48	-	4.28	0.12	3.42	-	20.35
Dining Hall - 15	7.09	2.60	6.60	-	5.20	0.15	4.11	-	25.75
Gymnasium - 2	1.32	0.80	-	0.67	-	0.23	7.90	0.05	10.97
Gymnasium - 15	2.32	0.90	-	0.60	-	0.19	5.85	0.09	9.95
Administration									
Large - 2	2.80	3.21	-	8.73	-	0.12	4.70	-	19.57
Large - 5	2.97	3.08	-	9.86	-	0.09	5.31	-	21.32
Small - Old w/ Split DX - 2	4.60	2.61	-	1.74	-	0.18	5.92	-	15.05
Small - Old w/ Split DX - 10	9.81	2.67	-	1.37	-	0.12	4.62	-	18.59
Small - Old w/ Split DX - 15	17.10	3.58	-	1.62	-	0.15	5.47	-	27.92
Small - Old w/ Chiller - 2	4.98	4.83	-	1.74	-	0.18	5.92	-	17.65
Small - Old w/ Chiller - 3	3.75	3.47	-	1.11	-	0.10	3.73	-	12.16
Small - Old w/ Chiller - 10	4.78	4.57	-	1.37	-	0.12	4.62	-	15.47
Small - Old w/ Chiller - 15	6.40	5.91	-	1.62	-	0.15	5.47	-	19.56
Small - New w/ Split DX - 2	3.32	1.88	-	1.74	-	0.18	5.92	-	13.04
Small - New w/ Split DX - 10	7.21	1.95	-	1.37	-	0.12	4.62	-	15.27
Small - New w/ Split DX - 15	4.35	4.02	-	1.74	-	0.18	5.92	-	16.21
Small - New w/ Chiller - W6	10.12	8.32	-	1.82	-	0.16	6.18	-	26.59
Vehicle Maintenance									
Small w/ No AC - 3	-	0.41	-	0.40	-	0.23	1.62	0.03	2.69
Small w/ No AC - 10	-	0.52	-	0.48	-	0.28	1.97	0.04	3.29
Large w/ Split DX - 3	0.42	0.22	-	0.40	-	0.23	1.62	0.03	2.92
Large w/ Split DX - 10	0.50	0.27	-	0.48	-	0.28	1.97	0.04	3.55
Large w/ Split DX - 15	0.74	0.34	-	0.58	-	0.34	2.35	0.05	4.39
Large w/ Split DX - W6	1.13	0.46	-	0.69	-	0.43	2.78	0.03	5.52
Large w/ Chiller - 15	0.47	0.43	-	0.57	-	0.34	2.33	0.05	4.19
Large w/ Chiller - W6	0.70	0.63	-	0.69	-	0.43	2.78	0.03	5.27
Hangar - 15	1.71	1.32	-	0.25	-	0.07	3.49	0.04	6.88
Hospital - 9	6.24	1.72	0.68	11.81	0.61	0.33	9.40	-	30.80
Residential									
Detached - 5	5.09	0.44	0.21	3.78	0.86	0.38	0.81	-	11.57
Detached - 12	6.33	0.56	0.27	4.63	1.04	0.43	0.96	-	14.22
Detached - W4	4.53	0.40	0.20	3.29	0.73	0.31	0.68	-	10.14
Two Plex - 5	4.82	0.42	0.21	3.78	0.85	0.38	0.81	-	11.28
Two Plex - 12	6.00	0.52	0.28	4.63	1.03	0.43	0.96	-	13.85
Two Plex - W4	4.29	0.37	0.20	3.29	0.73	0.31	0.68	-	9.88
Two Plex - W5	12.11	1.20	0.60	11.63	2.70	1.37	2.43	-	32.04
Four Plex - 3	6.85	0.41	0.16	2.20	0.57	0.26	0.50	-	10.95
Four Plex - 12	5.51	0.54	0.28	4.63	1.03	0.43	0.96	-	13.37
Other									
Retail - Large - W5	9.00	8.74	1.16	5.29	5.74	1.53	29.09	-	60.54
Warehouse									
w/ No AC - 3	-	0.16	-	0.44	-	0.22	1.67	-	2.49
w/ Split DX - W6	2.41	0.53	-	0.75	-	0.43	2.78	-	6.90
Miscellaneous									
2	2.17	0.75	0.05	3.39	0.06	0.34	6.20	-	12.95
3	4.49	0.71	0.07	1.20	0.19	0.21	4.84	-	11.71
5	2.87	0.77	0.07	1.50	0.31	0.36	7.75	-	13.62
10	5.58	0.86	0.08	1.26	0.33	0.28	5.56	-	13.96
15	8.91	1.14	0.09	1.65	0.16	0.26	5.83	-	18.05

EDA Reconciled Total Electric Annual EUIs by Feeder

Table 4-4 summarizes the EDA reconciled annual total electric EUIs for all of the feeders, the DOE-2 simulated annual total electric EUI, and the EDA weighted reconciled annual total electric EUI for the prototypes identified in **Table 1-1**.

Some EUIs or load shapes, as noted on **Table 4-4** with a single dagger, appear higher than expected or unrealistic and hence these results were not used in the calculation of the EDA weighted EUIs in the final column. Also, in **Table 4-4** the EUIs with a double dagger identify prototypes that were only represented by a single feeder and had higher than expected EUIs, but were used as final results. The miscellaneous prototype EUIs were not merged into a single weighted value because the prototype was composed uniquely for each feeder.

The results for Feeder 2 show 2 prototypes with a single dagger, which are gymnasium (6.6% relative floor area) and old small administration with chiller (2.8%). In the case of the gymnasium, the load shapes are very doubtful within the shoulder hours of 5 - 9 and 17 - 23. The cooling load shape of the old small administration with chiller, illustrated a noticeably higher load during the shoulder hours than normal operating hours.

The space cooling EUI for the old small administration with split dx on Feeder 15 is unusually high (about 3 times higher than expected). For this reason it was omitted.

The EUIs for Feeder W5 are unreasonably high. Compare the two-plex residential prototype EUI of Feeder W5 with those of Feeders 5, 12, and W4, it is 2 1/2 to 3 times as high. The EUI of the large retail store for Feeder W5 is the only one available, but it is almost 3 times as high as the DOE-2 simulated EUI. We feel that there are actually more buildings connected to Feeder W5 that were indicated in the feeder to building data base discussed in Chapter 2.

The EUIs of Feeder W6 are substantially higher than those of other feeders, but the load shapes appear reasonable. The warehouse with split dx is the only prototype available and a comparison was not available.

Weighted EDA Reconciled Electric Enduse Annual EUIs

Table 4-5 summarizes the final weighted EDA reconciled electric end use annual EUIs. The prototypes from **Table 4-3** were combined under the methodology described in Chapter 3 to obtain the EUIs seen in this table. We feel confident in all prototypes listed in **Table 4-5** with the exception of the large retail store for reasons discussed above.

Simulated and EDA Reconciled Street Lighting Annual EUIs

Table 4-6 summarizes the simulated and EDA reconciled street lighting annual EUIs by feeder. The simulated (initial) EUI was derived according to the procedure described in Chapter 3. The street lighting was not estimated for Feeders 4 and 9.

EDA Validation

The total energy consumption in [GWh/yr] by prototype, for all the feeders analyzed, are displayed in the first 2 columns in **Table 4-7**. These values were obtained by combining EUIs and floor area for all usable EDA prototypes in **Table 4-4**, water pump data from feeder 4, and street lighting.

The EDA results for the 10 feeders analyzed were then extrapolated to the entire base. The energy consumption of the 10 feeders were scaled by the ratio of the total floor area of the base to the total floor area of the feeders for each prototype. Water pump data were not scaled. The extrapolated results by

Table 4-4. EDA Reconciled Total Electric Annual EUIs by Feeder [kWh/sqft/yr]

Prototype	DOE-2	2	3	5	9	10	12	15	W4	W5	W6	EDA Avg
Barrack												
Hammer Head	14.57	-	8.53	-	-	10.79	-	13.40	-	-	-	10.90
Rolling Pin	15.82	-	10.06	-	-	12.71	-	-	-	-	-	12.48
Modular	12.95	13.69	-	11.94	-	-	-	12.96	-	-	18.58†	12.76
Small	10.26	-	-	-	-	9.99	-	-	-	-	-	9.99
Dining Hall	28.18	-	16.39	25.66	-	20.35	-	25.75	-	-	-	21.72
Gymnasium	12.50	10.97†	-	-	-	-	-	9.95	-	-	-	9.95
Administration												
Large	24.23	19.57	-	21.32	-	-	-	-	-	-	-	20.06
Small - Old w/ Split DX	20.95	15.05	-	-	-	18.59	-	27.92†	-	-	-	17.63
Small - Old w/ Chiller	21.19	17.65†	12.16	-	-	15.47	-	19.56	-	-	-	15.75
Small - New w/ Split DX	18.19	13.04	-	-	-	15.27	-	-	-	-	-	14.75
Small - New w/ Chiller	19.86	16.21	-	-	-	-	-	-	-	-	26.59†	16.21
Vehicle Maintenance												
Small w/ No AC	5.13	-	2.69	-	-	3.29	-	-	-	-	-	3.03
Large w/ Split DX	5.23	-	2.92	-	-	3.55	-	4.39	-	-	5.52†	3.74
Large w/ Chiller	5.21	-	-	-	-	-	-	4.19	-	-	5.27†	4.19
Hangar	8.03	-	-	-	-	-	-	6.88	-	-	-	6.88
Hospital	43.06	-	-	-	30.80	-	-	-	-	-	-	30.80
Residential												
Detached	14.03	-	-	11.57	-	-	14.22	-	10.14	-	-	11.37
Two Plex	13.64	-	-	11.28	-	-	13.85	-	9.88	32.04†	-	10.76
Four Plex	13.15	-	10.95	-	-	-	13.37	-	-	-	-	11.67
Other												
Retail - Large	22.95	-	-	-	-	-	-	-	-	60.54	-	60.54‡
Warehouse w/ No AC	4.75	-	2.49	-	-	-	-	-	-	-	-	2.49
Warehouse w/ Split DX	5.59	-	-	-	-	-	-	-	-	-	6.90	6.90‡
Miscellaneous	-	12.95	11.71	13.62	-	13.96	-	18.05	-	-	-	§

‡ These EUIs appear to be out of range compared to similar EUIs estimated from analysis of other feeders, or the load shapes are unrealistic. In the column titled "EDA Avg", these "questionable" results are omitted in estimating the average EUIs and load shapes.

‡ The EUIs are higher than expected for this prototype, which is represented by only 1 feeder.

§ DOE-2 simulated and EDA weighted average EUIs for the miscellaneous prototype hold no value because it is defined uniquely for each feeder.

Table 4-5. Weighted EDA Reconciled Electric Enduse Annual EUIs [kWh/sqft/yr]

Prototype	Cool	Fan	Cook	Misc	Ref	Ex_Lit	In_Lit	Press	Total
Barrack									
Hammer Head	3.41	1.40	0.28	1.73	2.05	0.19	1.83	-	10.90
Rolling Pin	4.31	3.51	0.31	0.86	2.03	0.12	1.35	-	12.48
Modular	3.75	1.15	0.30	2.63	2.29	0.15	2.50	-	12.76
Small	5.10	1.36	0.16	0.99	1.16	0.19	1.03	-	9.99
Dining Hall	5.28	2.09	5.94	-	4.60	0.13	3.69	-	21.72
Gymnasium	2.32	0.90	-	0.60	-	0.19	5.85	0.09	9.95
Administration									
Large	2.85	3.18	-	9.05	-	0.12	4.87	-	20.06
Small - Old w/ Split DX	8.39	2.66	-	1.47	-	0.14	4.98	-	17.63
Small - Old w/ Chiller	4.98	4.65	-	1.37	-	0.12	4.61	-	15.75
Small - New w/ Split DX	6.30	1.93	-	1.45	-	0.13	4.92	-	14.75
Small - New w/ Chiller	4.35	4.02	-	1.74	-	0.18	5.92	-	16.21
Vehicle Maintenance									
Small w/ No AC	-	0.48	-	0.45	-	0.26	1.82	0.04	3.03
Large w/ Split DX	0.57	0.28	-	0.50	-	0.29	2.05	0.04	3.74
Large w/ Chiller	0.47	0.43	-	0.57	-	0.34	2.33	0.05	4.19
Hangar	1.71	1.32	-	0.25	-	0.07	3.49	0.04	6.88
Hospital	6.24	1.72	0.68	11.81	0.61	0.33	9.40	-	30.80
Residential									
Detached	5.03	0.44	0.21	3.71	0.83	0.37	0.78	-	11.37
Two Plex	4.65	0.40	0.21	3.59	0.80	0.35	0.75	-	10.76
Four Plex	6.45	0.44	0.19	2.92	0.70	0.31	0.64	-	11.67
Other									
Retail - Large	9.00	8.74	1.16	5.29	5.74	1.53	29.09	-	60.54
Warehouse									
w/ No AC	-	0.16	-	0.44	-	0.22	1.67	-	2.49
w/ Split DX	2.41	0.53	-	0.75	-	0.43	2.78	-	6.90

Table 4-6. Simulated and EDA Reconciled Annual Street Lighting EUIs [MWh/yr]

Feeder	Sim	EDA
2	1025	1369
3	1066	687
4	-	-
5	1066	1054
9	-	-
10	1066	878
12	533	652
15	1025	1006
W4	1066	900
W5	410	1439
W6	137	169

prototype are displayed in columns 3 and 4 in **Table 4-7**. Also, extrapolated results by end use are shown in column 1 of **Table 4-8**. The EDA predicted annual hourly electrical usage for the entire base is illustrated in the upper portion of **Figure 4-1**.

Texas utility annual hourly electrical usage data (see **Figure 2-1**) were used to check EDA results extrapolated to the entire base. The difference between the Texas utility annual hourly electrical usage and the EDA predicted annual hourly electrical usage is shown in the lower portion of **Figure 4-1**. In this plot, the larger fluctuations occur during shoulder hours, which are inherently less stable than normal operating hours. If the fluctuations in the lower portion of **Figure 4-1** are ignored, the EDA predicted usage is always less than the Texas utility data (the last 10 days of the year excluded). The comparison for the last 10 days of the year reveal that EDA overpredicts usage, this is due to nonstandard days being modeled as standard days. The Texas utility data should exceed the EDA predicted usage because Texas utility measures on the high side of the transformer, while PNL measured on the low side. Also, feeder line loss was not accounted for in EDA.

The EDA predicted total annual electrical usage is compared as a percentage to the total annual Texas utility data by prototype in column 5 of **Table 4-7**, and by end use in column 2 of **Table 4-8**. Clearly, the barrack, administration, and residential prototypes are the largest consumers of energy at 70%, and by end use, cooling, ventilation, miscellaneous, and indoor lighting consume almost 80%. The total energy consumption of the main and west substations serving Fort Hood predicted by EDA is 95.3% of the Texas utility data. This excess difference of 4.7% can be attributed to transformer loss, feeder line loss, and any error within the input data or methodology.

Table 4-7. EDA Predicted Annual Energy Consumption by Prototype

Prototype	EDA Application		Extrapolated to Fort Hood		
	Area [Sqft]	EDA [GWh/yr]	Area [Sqft]	EDA [GWh/yr]	Percent of Texas Utility
Barrack					
Hammer Head	1066798	11.6	1066798	11.6	3.3
Rolling Pin	776986	9.7	1810654	22.6	6.5
Modular	355353	4.5	1647994	21.0	6.0
Small	84960	0.8	403967	4.0	1.2
Dining Hall	218660	4.7	505877	11.0	3.1
Gymnasium	41960	0.4	223595	2.2	0.6
Administration					
Large	587817	11.7	674113	13.5	3.9
Small Old w/ Split DX	305103	5.3	1153551	20.3	5.8
Small Old w/ Chiller	945802	14.9	2029777	32.0	9.1
Small New w/ Split DX	119835	1.7	373706	5.5	1.6
Small New w/ Chiller	49320	0.8	356215	5.8	1.7
Vehicle Maintenance					
Small w/ No AC	457888	1.4	1034912	3.1	0.9
Large w/ Split DX	301899	1.1	1037480	3.9	1.1
Large w/ Chiller	58080	0.2	446072	1.9	0.5
Hangar	170010	1.2	743895	5.1	1.5
Hospital	504202	15.5	504202	15.5	4.4
Residential					
Detached	741594	8.4	1141815	13.0	3.7
Two Plex	3243286	34.9	4936284	53.1	15.2
Four Plex	686420	8.0	2490464	29.1	8.3
Other					
Retail Large	256116	15.5	256116	15.5	4.4
Warehouse					
w/ No AC	60974	0.2	1137313	2.8	0.8
w/ Split DX	56800	0.4	283407	2.0	0.6
Miscellaneous	470967	6.6	1245593†	17.5	5.0
Water Pump	-	3.2	-	3.2	0.9
Street Lights	-	8.2	-	18.1	5.2
EDA Total	11560830	170.9	25503800	333.4	95.3
Texas Utility	-	-	-	349.6	100.0

† Miscellaneous floor area includes non-building, utility, water pump, and fuel station.

Table 4-8. EDA Predicted Annual Energy Consumption by Enduse

Enduse	EDA [GWh/yr]	Percent of Texas Utility
Cooling	107.4	30.7
Fans	38.4	11.0
Cooking	6.8	1.9
Miscellaneous	61.0	17.4
Refrigeration	21.1	6.0
Exterior Lighting	6.4	1.8
Interior Lighting	70.7	20.2
Process	0.2	0.1
Street Lighting	18.1	5.2
Water Pump	3.2	0.9
EDA Total	333.4	95.3
Texas Utility	349.6	100.0

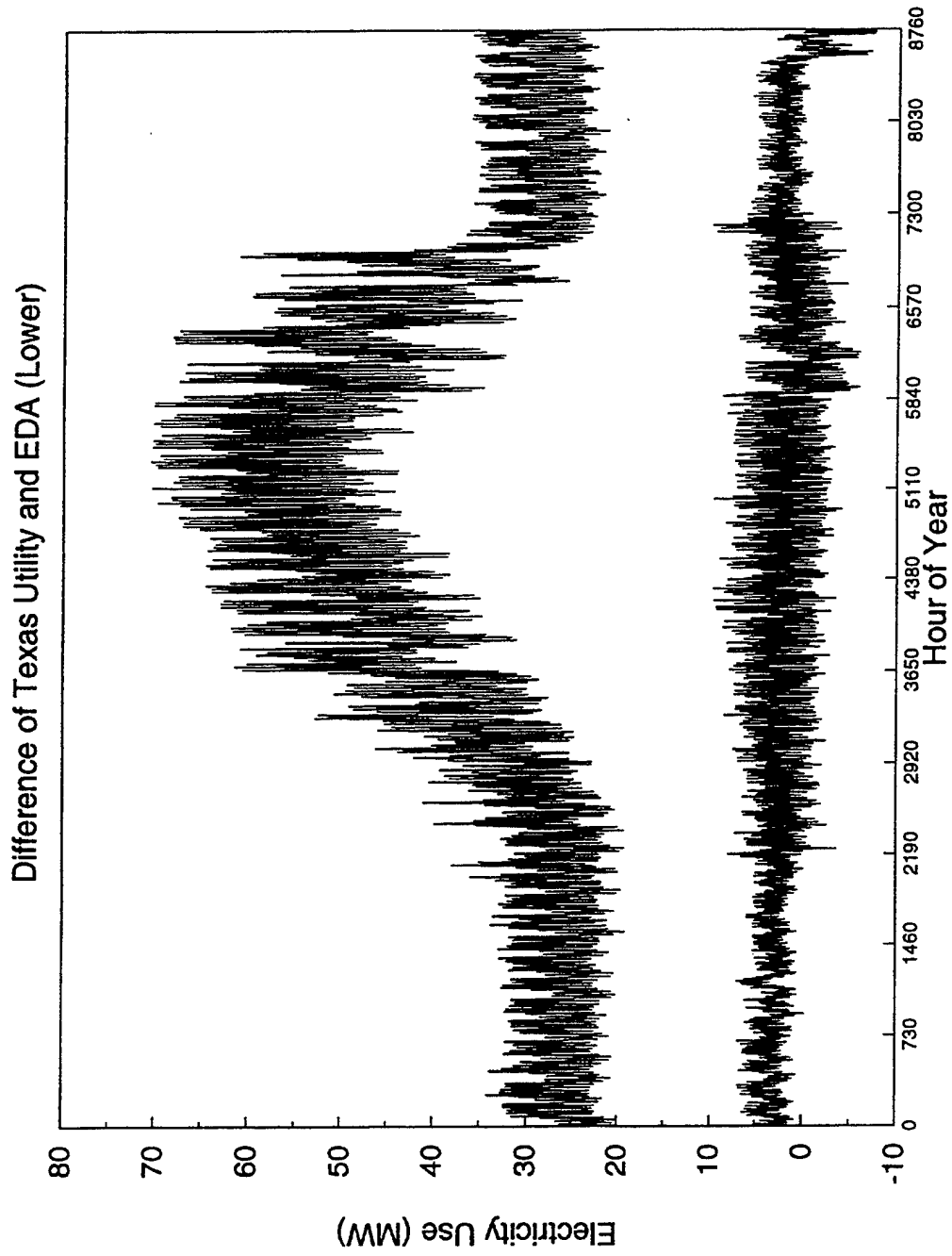


Figure 4-1. EDA Annual Hourly Electricity Use (Upper) Difference of Texas Utility and EDA (Lower)

Electronic Data

The results outlined below are available electronically in ascii text format.

For Each Prototype

- DOE-2 Prototype Input File
- DOE-2 Simulated Enduse Annual Hourly Loads
- DOE-2 Simulated Enduse Load Shapes - Winter - Standard Day
- DOE-2 Simulated Enduse Load Shapes - Winter - Nonstandard Day
- DOE-2 Simulated Enduse Load Shapes - Summer - Standard Day
- DOE-2 Simulated Enduse Load Shapes - Summer - Nonstandard Day

For Each Prototype and Feeder

- EDA Reconciled Enduse Annual Hourly Loads
- EDA Reconciled Enduse Load Shapes - Winter - Standard Day
- EDA Reconciled Enduse Load Shapes - Winter - Nonstandard Day
- EDA Reconciled Enduse Load Shapes - Summer - Standard Day
- EDA Reconciled Enduse Load Shapes - Summer - Nonstandard Day

For each Prototype

- Weighted EDA Reconciled Enduse Annual Hourly Loads
- Weighted EDA Reconciled Enduse Load Shapes - Winter - Standard Day
- Weighted EDA Reconciled Enduse Load Shapes - Winter - Nonstandard Day
- Weighted EDA Reconciled Enduse Load Shapes - Summer - Standard Day
- Weighted EDA Reconciled Enduse Load Shapes - Summer - Nonstandard Day

Chapter 5

Conclusion

The quality of the input data and methodology are both sources of uncertainty, which were examined and their limitations identified. Then, recommendations are discussed for improvements, which may add precision to the results of the next generation of this application. Finally, the next phase of work is outlined, which is the extrapolation of the results from Fort Hood to other DoD installations.

- Accuracy of the Results
- Recommendations
- Extrapolation of the Results to Other DoD Installations

Accuracy of the Results

The accuracy of the results were examined qualitatively to highlight areas of uncertainty. There was no attempt to quantify uncertainty, which sources from the input data and methodology.

The input data that demands the highest level of accuracy are the measured feeder hourly load, feeder-to-building assignment, IFS building inventory, and MEIP onsite survey.

The measured feeder hourly load data contained missing or questionable data for most of the feeders as discussed in detail in Chapter 2. Some of the feeders exhibited a difference in winter load during the 2 winter periods, January 1 through April 10 and October 23 through December 31. This difference may be related to feeder switching, which alters the set of buildings connected to a feeder. There were no available data documenting feeder switching.

The feeder-to-building assignment data base was questionable for several Feeders, 2, 14, 16, W5, and W6. This was discussed in detail in Chapter 2.

The IFS building inventory data base contained the building category code, which identifies the building's function. These category codes were used to group the buildings into prototypes, in addition to the floor area, year of construction, and HVAC system type.

The MEIP onsite survey data we used was not a final version and frequently contained conflicting data. For example, the text discussing a building might indicate that the building has 2 floors, but a summary table may indicate 3 floors. This level of confusion was evident for most of the buildings in the survey. Also, the survey lacked completeness. Some of the buildings were modeled as multiple zones with great detail, while some were described modestly as a single zone.

The schedules were primarily obtained from the MEIP survey. These schedules often included extended operating hours, and coupled with excessive electricity consumption produced over-estimated demands. This can be observed in **Table 4-4**, where the DOE-2 simulated EUI is usually higher than the EDA reconciled EUI for like prototypes. Also, schedules are inherently less certain during shoulder hours than non-shoulder hours.

The building floor area was reported from 2 sources, the IFS building inventory and the MEIP onsite survey. The IFS building inventory data base was the primary source since it contained floor area data for all 5122 buildings. However, the floor area data listed in the IFS data base did not match that in the MEIP survey.

The HVAC system type was found in 3 sources, the IFS building inventory, the MEIP onsite survey, and the chiller data base. The IFS building inventory data base was the source used to classify the buildings

into prototypes, since it identified systems either by ventilation only, packaged direct expansion, or centrifugal chiller. The MEIP survey was used to identify the prototype's system type. Again, these two data bases were not always in agreement concerning the system type. The chiller data base was not employed (except in the case of the hospital), since the information often was not in alignment as that reported in the other two data bases.

The mechanical equipment data base was compared with the MEIP motor survey for 7 buildings and resulted in frequent differences. These differences are discussed in Chapter 2. Because of this uncertainty the data were not used.

The uncertainties associated with the methodology are discussed below.

The temperature-dependent and temperature-independent components of the load are calculated from a statistical analysis of the measured feeder load data as discussed in Chapter 3. This method produces a difference between the calculated components and the actual load data. This difference is prorated by prototype and end use based on the relative floor area of the prototype to the floor area of the entire feeder. This difference was usually less than 10% of the hourly load.

The EDA application disaggregated hourly load based on DOE-2 simulated load shapes and the prototypes assigned to each feeder. Any error associated with these two operations would have an effect on the distribution.

The nonstandard day results show HVAC load shapes with greater load during the shoulder hours than normal operating hours. This may be the result of the input schedules in DOE-2 simulation, which results in overpredicting the HVAC load during shoulder hours and underpredicting during normal operation. This effect was observed a few times in standard day operation.

The feeder load was monitored at the substation, so naturally feeder line power loss results from the transmission. However, no data was available to identify the magnitude of the line power loss.

The EDA raw hourly results were scaled downward by the fraction of floor area covered by the prototypes served by each feeder. This scaling was weighted equally for all the prototypes of the feeder.

The smoothing operation which produced more realistic load shapes showed a negligible effect on the annual EUIs. The effect was less than 0.1% for most cases and never greater than 1%.

Recommendations

The problem of DOE-2 overpredicting energy consumption because of incorrect schedule information can be alleviated by short-term end use monitoring of carefully selected representative buildings. This could especially aid in more accurately modeling the shoulder hours. Another benefit may be to correct the "inverted" load shape effect, where the shoulder hours are greater in magnitude than normal operating hours.

The procedure of separating temperature-dependent and temperature-independent load components and distributing the difference from the measured load is a time consuming process. A quicker method may be to assume the summer temperature-independent component equals the winter average daily load, then the summer temperature-dependent hourly component would equal the difference between the measured hourly load and the winter average daily load with no error to distribute.

$$\text{Feeder_Load}_{\text{Sum,td}} = \text{Feeder_Load}_{\text{Sum,measured}} - \text{Feeder_Load}_{\text{Win,avg}}$$

[23]

The feeder to building assignment data needs to accurately reflect the actual buildings connected to the feeders.

Extrapolation of the Results to Other DoD Installations

The second phase of this project consists of extrapolating the results obtained from Fort Hood to other DoD installations. Here we outline 3 methods to accomplish this objective.

The first, called 'DOE-2 Scaling', is the least time consuming of the three methods. It uses hourly data from DOE-2 simulations and EDA reconciliations of Fort Hood prototypes, and weather data from each DoD installation. The hourly ratios of the HVAC end uses (electric space cooling, electric ventilation, and gas space heating) from the simulations, of the DoD installation to Fort Hood, are used to scale the hourly EDA results from Fort Hood. The non-HVAC end uses will not be modified from the Fort Hood result. This approach is modeled in equations [24 and 25], where the subscript 'i' identifies the number of prototypes in the installation and 'j' the number of end uses.

$$\text{HVAC_Load}_{\text{DoD},\text{hour,proto_ij}} = \left(\frac{\text{DOE2_HVAC_Load}_{\text{DoD},\text{hour,proto_ij}}}{\text{DOE2_HVAC_Load}_{\text{Fort_Hood},\text{hour,proto_ij}}} \right) \text{EDA_HVAC_Load}_{\text{Fort_Hood},\text{hour,proto_ij}} \quad [24]$$

$$\text{Non_HVAC_Load}_{\text{DoD},\text{hour,proto_ij}} = \text{EDA_Non_HVAC_Load}_{\text{Fort_Hood},\text{hour,proto_ij}} \quad [25]$$

The second, called the 'Simplified Approach', adds one step to the 'DOE-2 Scaling' method. The annual total EUI of all prototypes is constrained by the annual total EUI of the installation from utility data. This constraint is illustrated in equation [26].

$$\text{Utility_Billing_Data}_{\text{DoD},\text{annual}} = \sum_{i=1}^{M,N} (\text{HVAC_Load}_{\text{DoD},\text{annual,proto_ij}} + \text{Non_HVAC_Load}_{\text{DoD},\text{annual,proto_ij}}) \quad [26]$$

The third method requires a complete EDA analysis of the DoD installation, however the methodology differs from that used in this project. In this project, prototypes were grouped and reconciled by feeder, with DOE-2 simulations providing initial estimates of HVAC end uses. In Phase II, prototypes will be grouped and reconciled on the whole installation level, with DOE-2 simulations providing initial estimates of HVAC end uses, and Fort Hood EDA results providing initial estimates of non-HVAC end uses.

Bibliography

Documents Referenced in Report

Akbari, H., "Validation of an Algorithm to Disaggregate Whole-Building Hourly Electrical Load into End Uses," *Energy the International Journal*, 1995 (in Press).

Akbari, H., "End-use Energy Characterization and Conservation Potentials at DoD Facilities," Lawrence Berkeley Laboratory Detailed Workplan, Berkeley, CA, 1994.

Akbari, H., Eto, J. H., Konopacki, S., Afzal, A., Rainer, L., and Heinemeier, K., "Integrated Estimation of Commercial Sector End-Use Load Shapes and Energy Use Intensities in the PG&E Service Area," Lawrence Berkeley Laboratory Report LBL-34263, Berkeley, CA, 1993.

Akbari, H., Eto, J. H., Turiel, I., Heinemeier, K., Lebot, B., Nordman, B., and Rainer, L., "Integrated Estimation of Commercial Sector End-Use Load Shapes and Energy Use Intensities," Lawrence Berkeley Laboratory Report LBL-27512, Submitted to SCE and CEC, 1989.

Akbari, H., Rainer, L., and Eto, J. H., "Integrated Estimation of Commercial Sector End-use Load Shapes and Energy Use Intensities, Phase II," Lawrence Berkeley Laboratory Report LBL-30401, Submitted to CEC, 1991.

Building Energy Simulation Group (BESG), "Overview of the DOE-2 Building Energy Analysis Program, Version 2.1D," Lawrence Berkeley Laboratory Report LBL-19735, Rev.1, Berkeley, CA, 1990.

Other Relevant Documents

Akbari, H., Heinemeier, K., Flora, D., and Le Coniac, P., "Analysis of Commercial Whole-Building 15-Minute Electric Load Data," ASHRAE Transactions, 94(2), pp 855 - 871, 1988.

Akbari, H., Heinemeier, K., Le Coniac, P., and Flora, D., "An Algorithm to Disaggregate Commercial Whole-Building Electric Hourly Load into End Uses," Proceedings of ACEEE 1988 Summer Study on Energy Efficiency in Buildings, Vol 10, pp 13-26, Asilomar, CA, August,

Akbari, H., Rainer, L., Heinemeier, K., Huang, J., and Franconi, E., "Measured Commercial Load Shapes and Energy Use Intensities and Validation of the LBL End-use Disaggregation Algorithm," Lawrence Berkeley Laboratory Report LBL-32193, Submitted to SCE and CIEE, 1992.

Akbari, H., Turiel, I., Eto, J. H., Heinemeier, K., Lebot, B., and Rainer, L., "A Review of Existing Commercial Energy Use Intensity and Load-Shapes Studies," Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings, Volume 3, p. 7, Asilomar, CA, August 1990. also Lawrence Berkeley Laboratory Report LBL-29209, 1990.

Eto, J. H., Akbari, H., Pratt, R., and Braithwait, "End-Use Load Shape Data: Application, Estimation, and Collection," Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings, Volume 10, p.39, Asilomar, CA, 1990.

Eto, J. H., Turiel, I., Akbari, H., Lebot, B., and Heinemeier, K., "An Investigation of the Use of Prototypes for Commercial Sector EUI Analysis," Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings, Volume 10, p. 29, Asilomar, CA, 1990.

Appendix A

Feeder Data Analysis

The measured feeder hourly electricity use data and the results of analyses are presented in this appendix. The feeder annual hourly electricity use data may have been modified from the original data. If the original data were not modified, then the plot entitled "Modified Feeder Annual Hourly Electricity Use" is not included in the presentation.

Figure A-x(a). Original Annual Hourly Electricity Use

Figure A-x(b). Modified Annual Hourly Electricity Use

Figure A-x(c). Day-of-Week Average Load Shapes - Winter

Figure A-x(d). Day-of-Week Average Load Shapes - Summer

Figure A-x(e). Feeder Load vs. Outdoor Drybulb Temperature - Winter - Standard Day

Figure A-x(f). Feeder Load vs. Outdoor Drybulb Temperature Winter - Nonstandard Day

Figure A-x(g). Feeder Load vs. Outdoor Drybulb Temperature Summer - Standard Day

Figure A-x(h). Feeder Load vs. Outdoor Drybulb Temperature Summer - Nonstandard Day

Feeder 2

The feeder annual hourly load plot illustrates a wintertime load change between 1500 kW and 2100 kW and a summertime load change between 2000 kW and 2800 kW.

The scatter plot of feeder load versus drybulb temperature for summer standard days shows that the summertime load increases from approximately 2200 kW to 2800 kW, suggesting a daytime air-conditioning load of about 600 kW (about 21% of peak load).

Feeder 3

The original feeder annual hourly load was not modified.

The feeder annual hourly load plot illustrates a wintertime load change between 1000 kW and 1500 kW and a summertime load change between 2800 kW and 4000 kW.

The scatter plot of feeder load versus drybulb temperature for summer standard days shows that the summertime load increases from approximately 1200 kW to 4000 kW, suggesting a daytime air-conditioning load of about 2800 kW (about 70% of peak load).

Feeder 4

The original feeder annual hourly load was not modified.

The feeder annual hourly load plot illustrates a wintertime load change between 0 kW and 800 kW and a summertime load change between 0 kW and 1200 kW. The hourly load plot shows orderly load behavior, where the load takes a value of 0, 400, 800, or 1200 kW. This indicates water pump operation is either off or on, with 1 to 3 pumps online.

Feeder 5

The original feeder annual hourly load was not modified.

The feeder annual hourly load plot illustrates a wintertime load change between 1200 kW and 2300 kW and a summertime load change between 3000 kW and 6000 kW.

The scatter plot of feeder load versus drybulb temperature for summer standard days shows that the summertime load increases from approximately 2000 kW to 6000 kW, suggesting a daytime air-conditioning load of about 4000 kW (about 67% of peak load).

Feeder 9

The feeder annual hourly load plot illustrates a wintertime load change between 1500 kW and 1900 kW and a summertime load change between 1900 kW and 2300 kW.

The scatter plot of feeder load versus drybulb temperature for winter standard days shows that the wintertime load increases from approximately 1700 kW to 1900 kW, suggesting a daytime air-conditioning load of about 200 kW (about 11% of peak load).

The scatter plot of feeder load versus drybulb temperature for summer standard days shows that the summertime load increases from approximately 1900 kW to 2300 kW, suggesting a daytime air-conditioning load of about 400 kW (about 17% of peak load).

Feeder 10

The feeder annual hourly load plot illustrates a wintertime load change between 1900 kW and 2800 kW and a summertime load change between 4500 kW and 6300 kW.

The scatter plot of feeder load versus drybulb temperature for summer standard days shows that the summertime load increases from approximately 2700 kW to 6300 kW, suggesting a daytime air-conditioning load of about 3600 kW (about 56% of peak load).

Feeder 12

The original feeder annual hourly load was not modified.

The feeder annual hourly load plot illustrates a wintertime load change between 500 kW and 900 kW and a summertime load change between 1700 kW and 2800 kW.

The scatter plot of feeder load versus drybulb temperature for summer standard days shows that the summertime load increases from approximately 800 kW to 2800 kW, suggesting a daytime air-conditioning load of about 2000 kW (about 71% of peak load).

Feeder 15

The feeder annual hourly load plot illustrates a wintertime load change between 1800 kW and 2500 kW and a summertime load change between 3500 kW and 4700 kW.

The scatter plot of feeder load versus drybulb temperature for summer standard days shows that the summertime load increases from approximately 2000 kW to 4700 kW, suggesting a daytime air-conditioning load of about 2700 kW (about 57% of peak load).

Feeder W4

The original feeder annual hourly load was not modified.

The feeder annual hourly load plot illustrates a wintertime load change between 1100 kW and 2200 kW and a summertime load change between 3500 kW and 6500 kW.

The scatter plot of feeder load versus drybulb temperature for summer standard days shows that the summertime load increases from approximately 2000 kW to 6500 kW, suggesting a daytime air-conditioning load of about 4500 kW (about 70% of peak load).

Feeder W5

The original feeder annual hourly load was not modified.

The feeder annual hourly load plot illustrates a wintertime load change between 2000 kW and 2900 kW and a summertime load change between 3200 kW and 4700 kW.

The scatter plot of feeder load versus drybulb temperature for summer standard days shows that the summertime load increases from approximately 2900 kW to 4700 kW, suggesting a daytime air-conditioning load of about 1800 kW (about 38% of peak load).

Feeder W6

The original feeder annual hourly load was not modified.

The feeder annual hourly load plot illustrates a wintertime load change between 300 kW and 700 kW and a summertime load change between 500 kW and 900 kW.

The scatter plot of feeder load versus drybulb temperature for summer standard days shows that the summertime load increases from approximately 600 kW to 900 kW, suggesting a daytime air-conditioning load of about 300 kW (about 33% of peak load).

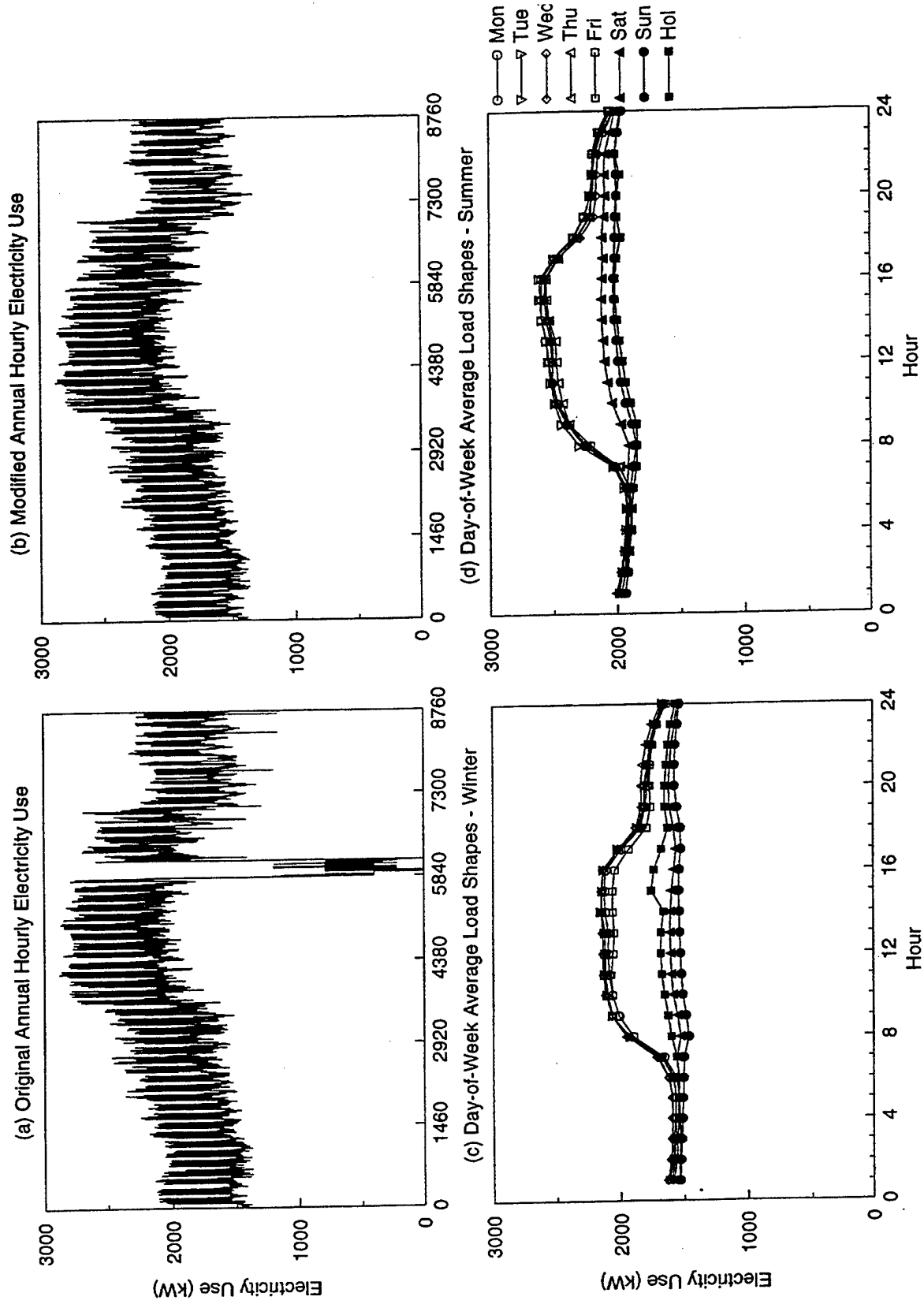


Figure A-1. Feeder 2 Data

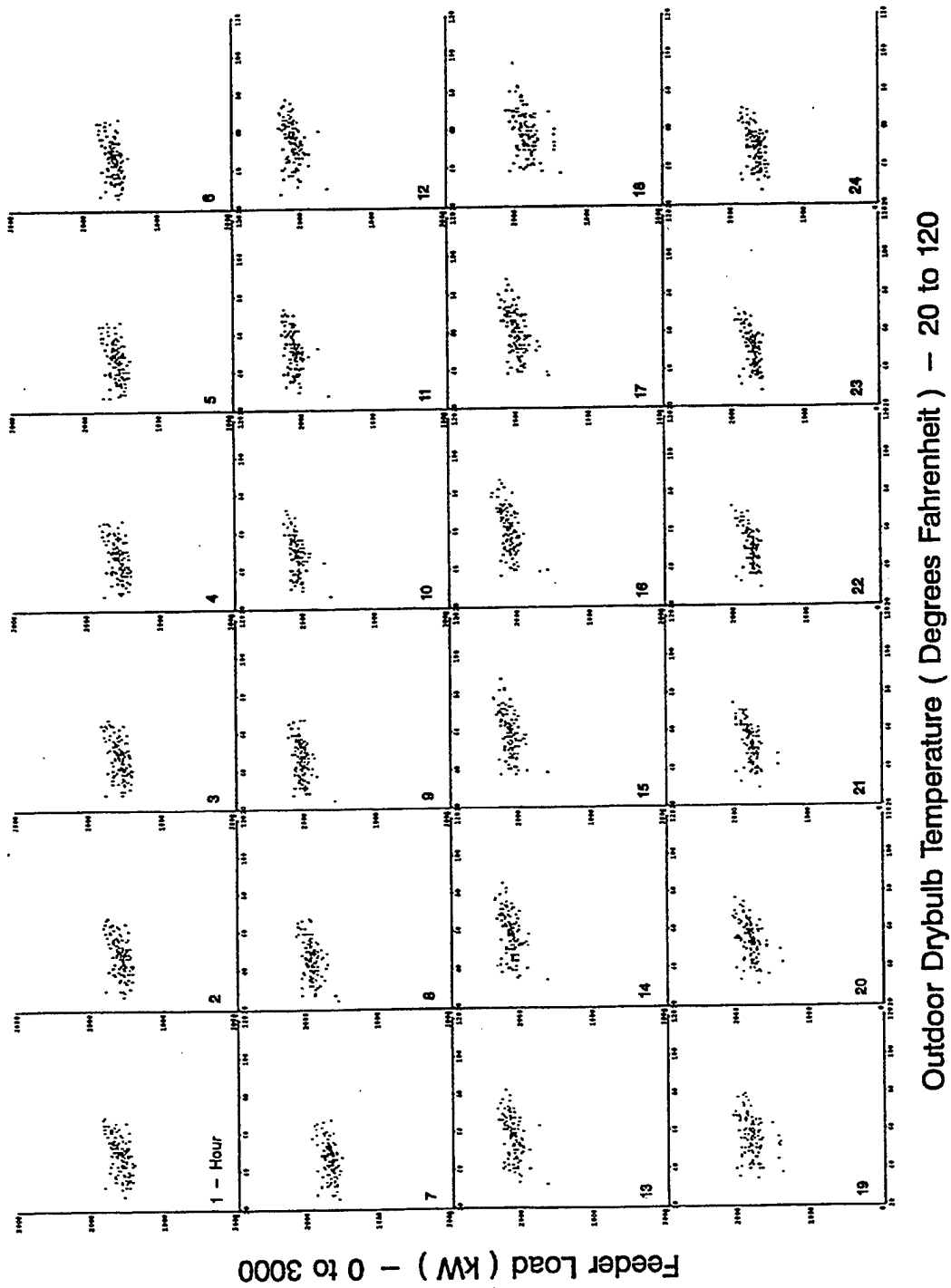


Figure A-2. Scatterplots of Feeder 2 Hourly Load vs. Drybulb Temperature for Standard Winter Days

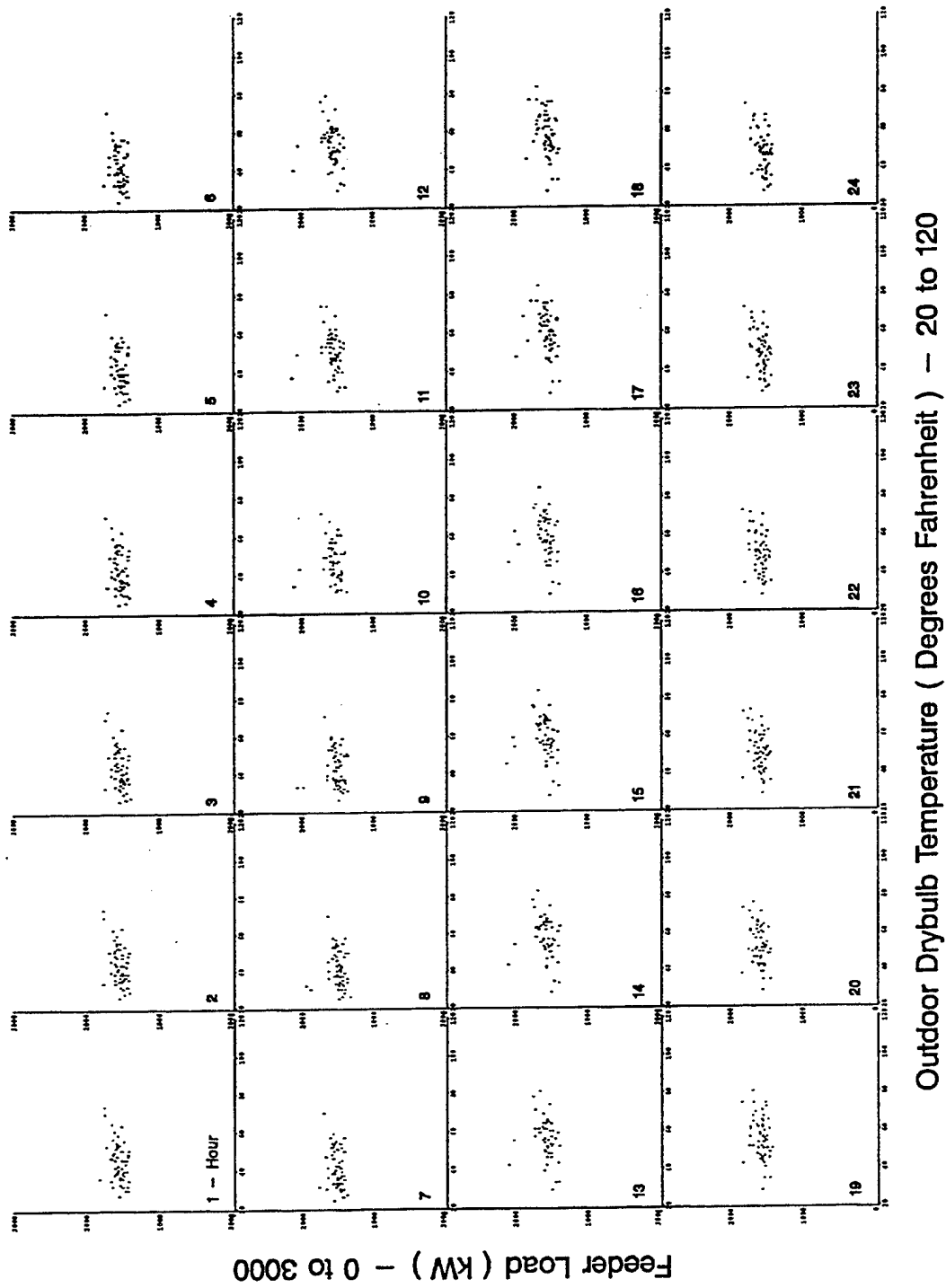


Figure A-3. Scatterplots of Feeder 2 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days

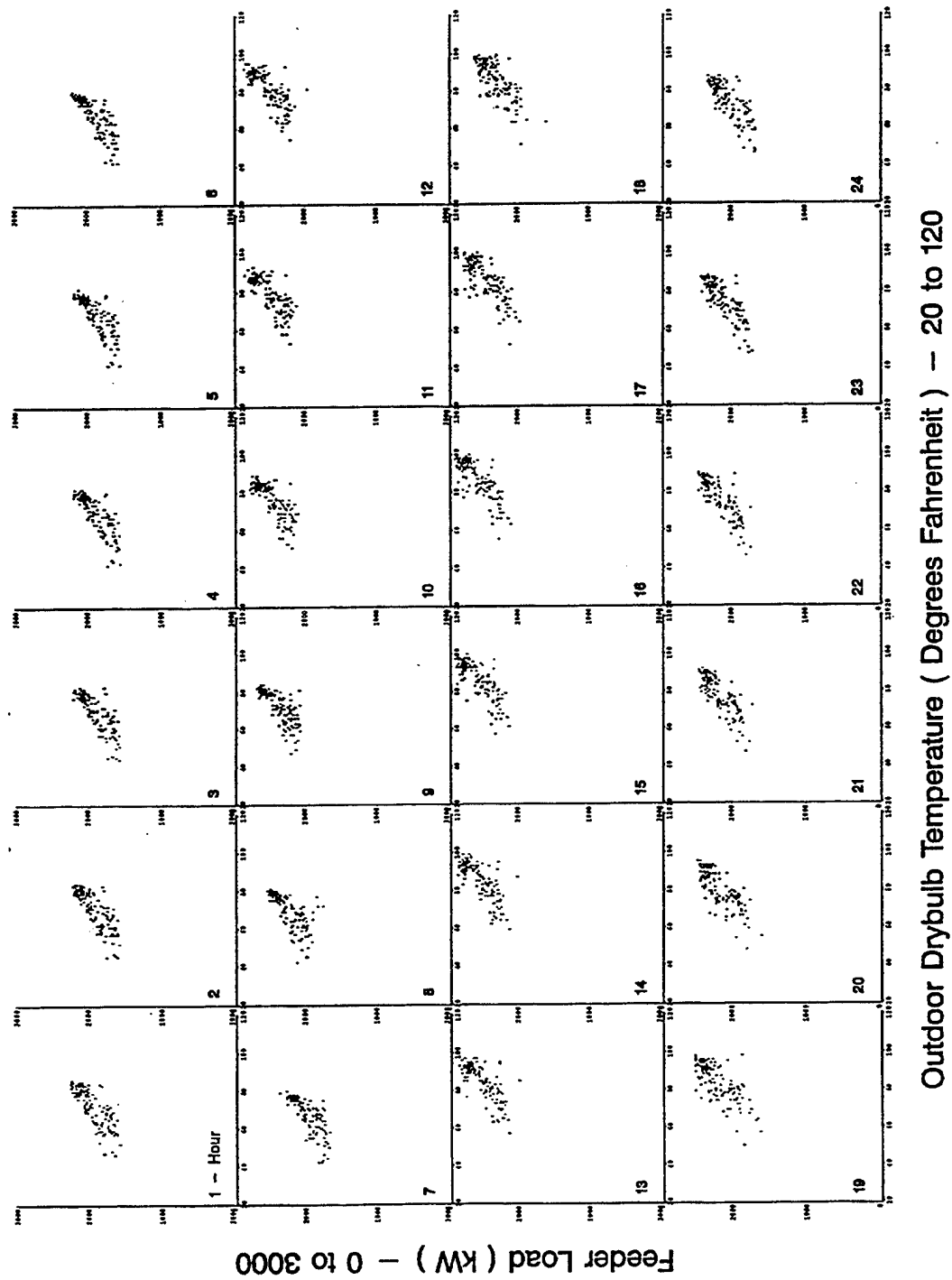


Figure A-4. Scatterplots of Feeder 2 Hourly Load vs. Drybulb Temperature for Standard Summer Days

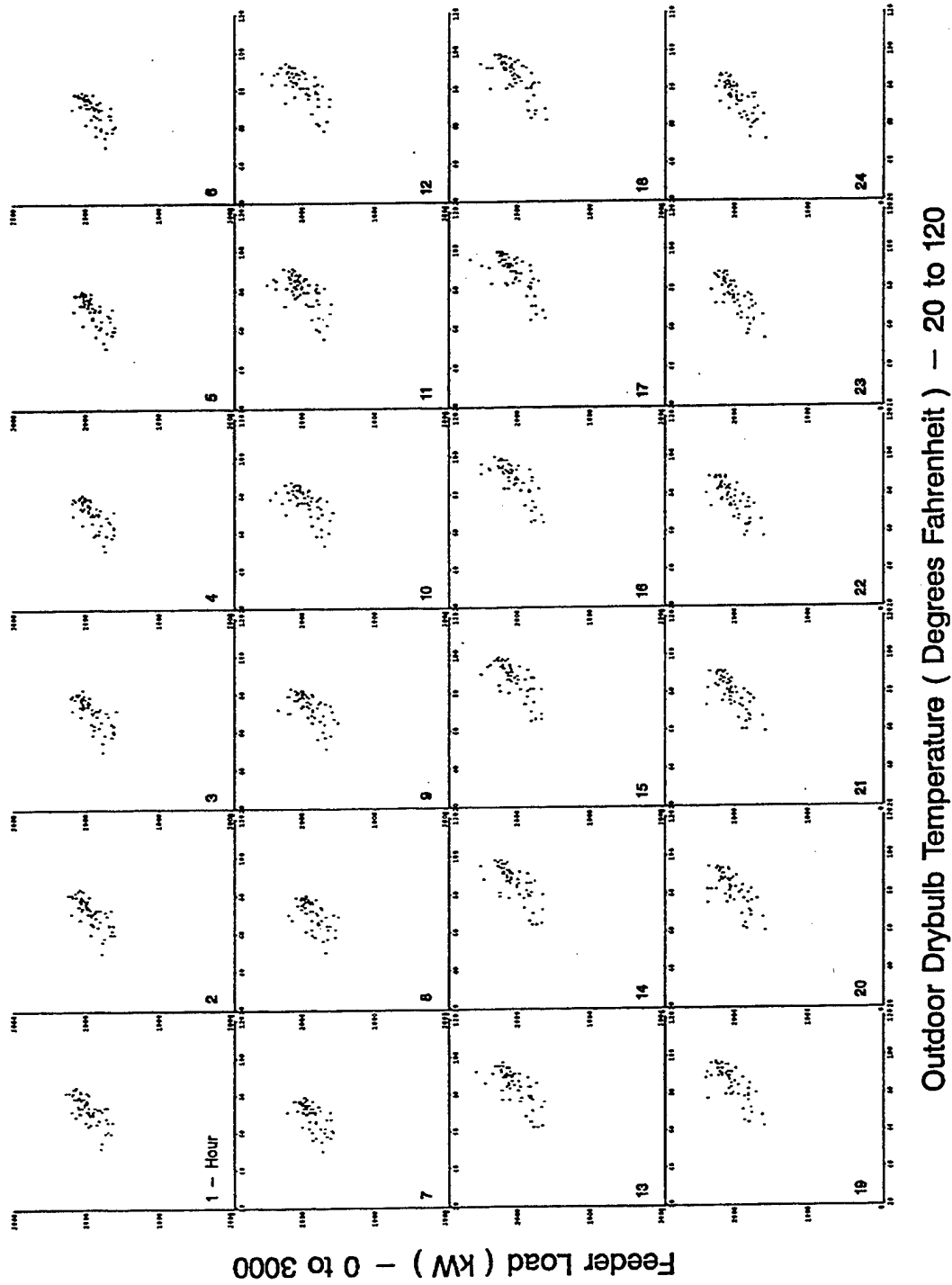


Figure A-5. Scatterplots of Feeder 2 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days

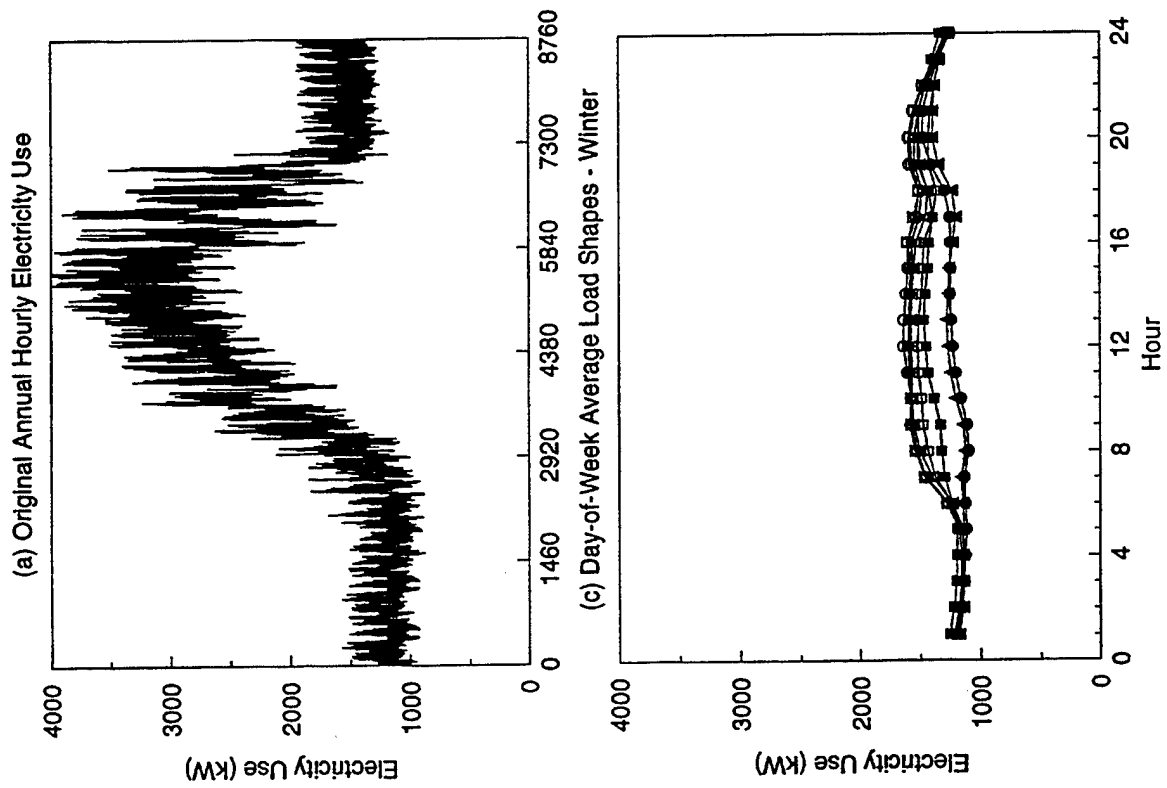


Figure A-6. Feeder 3 Data

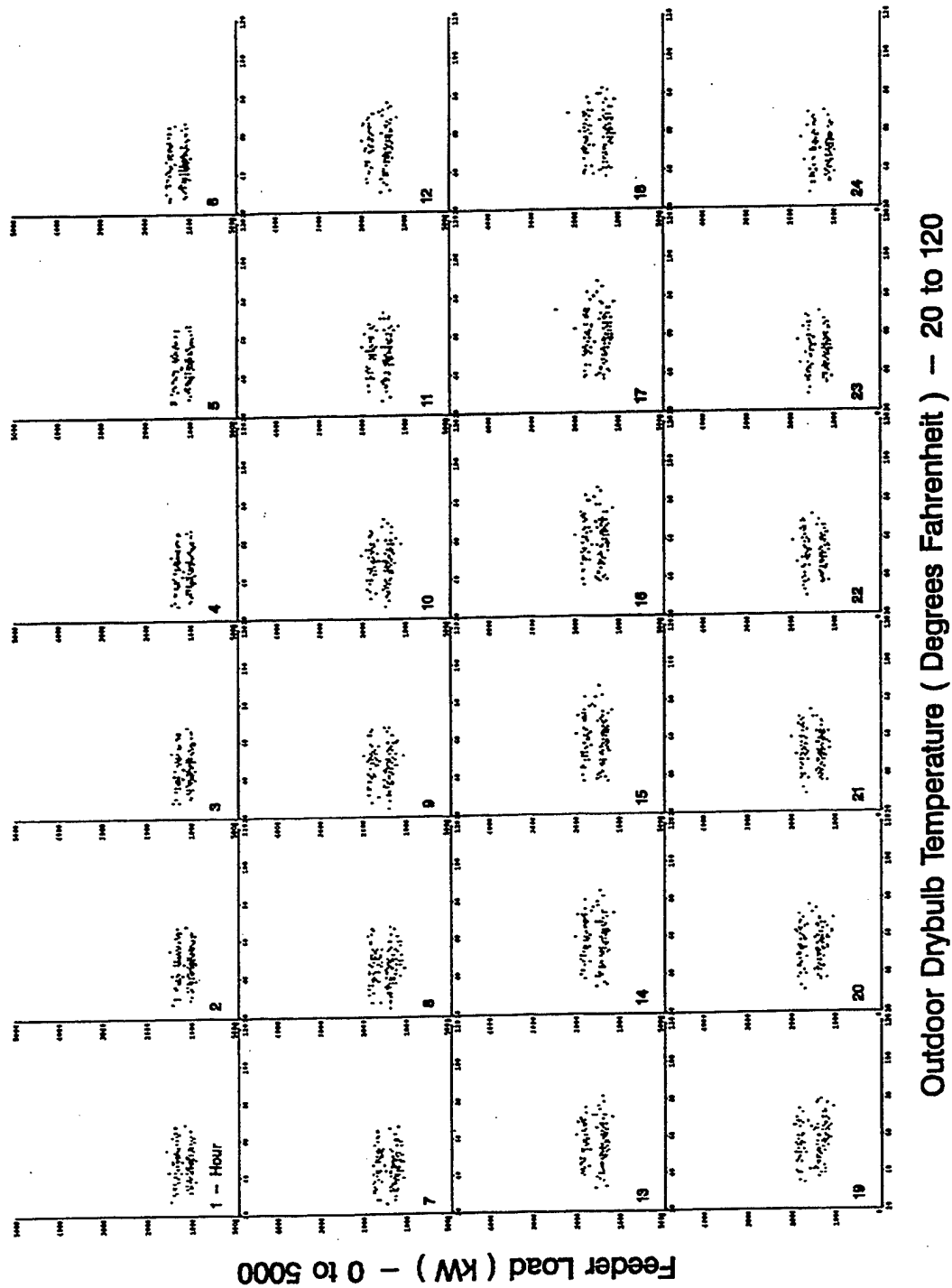


Figure A-7. Scatterplots of Feeder 3 Hourly Load vs. Drybulb Temperature for Standard Winter Days

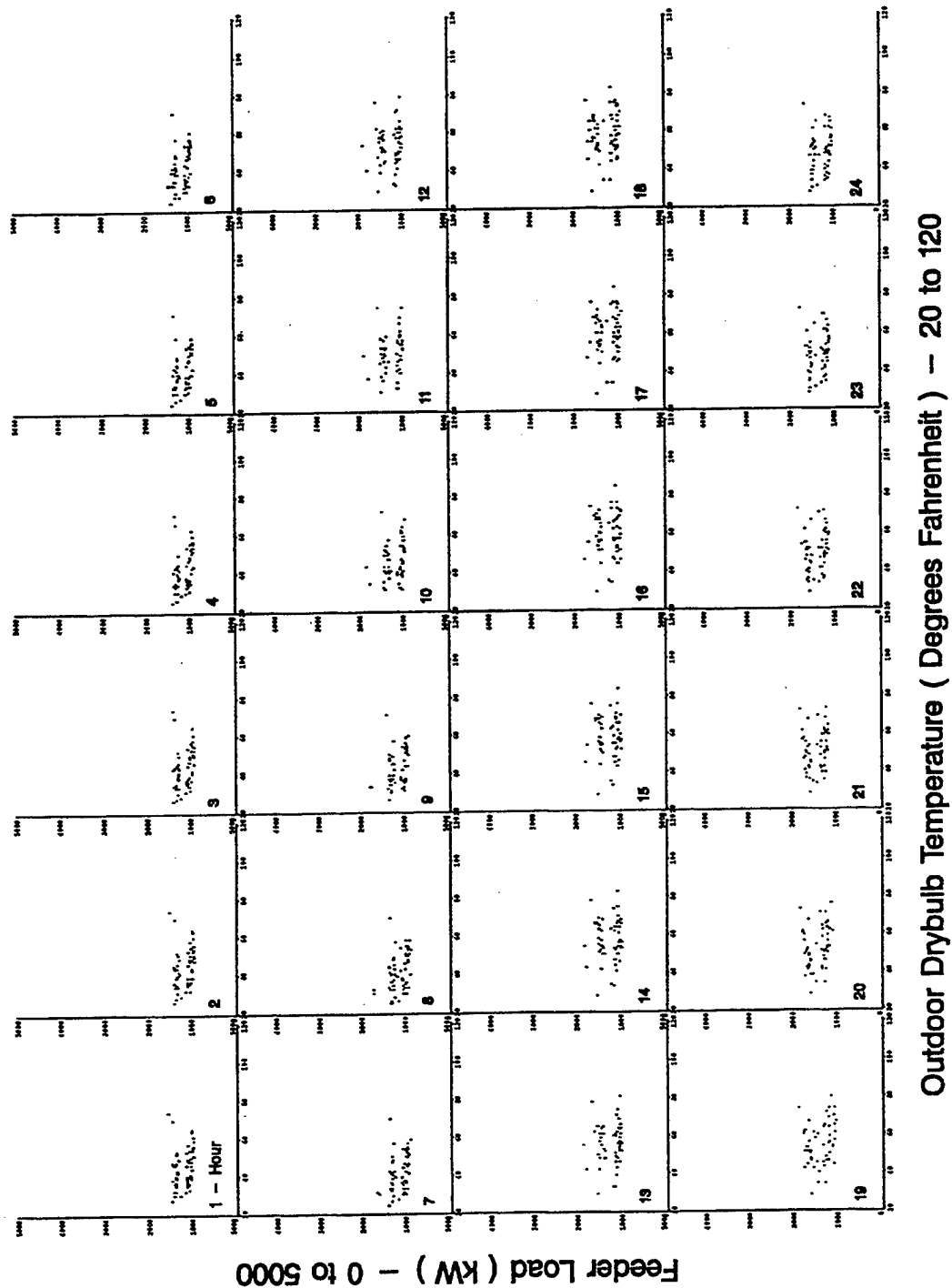


Figure A-8. Scatterplots of Feeder 3 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days

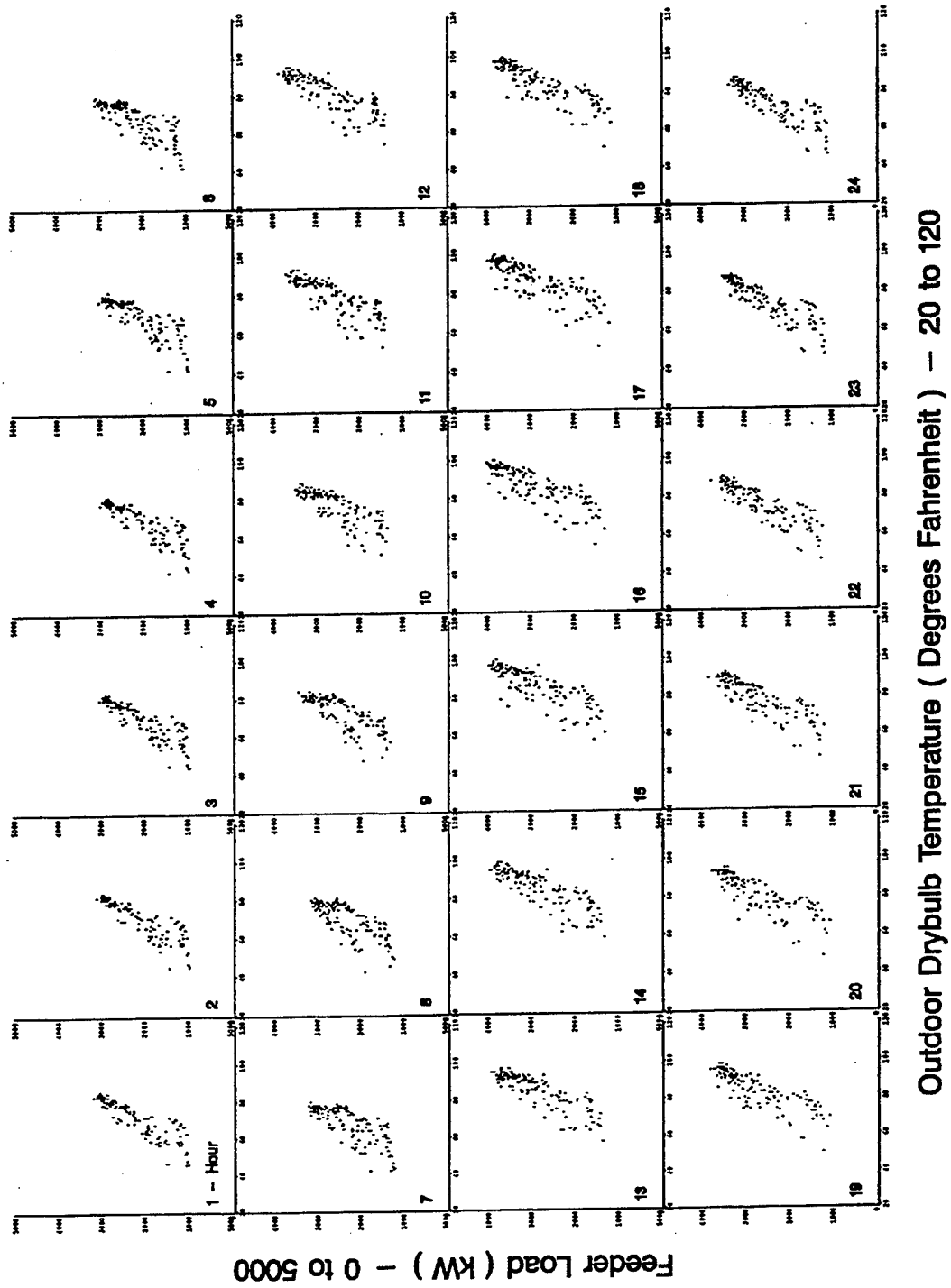


Figure A-9. Scatterplots of Feeder 3 Hourly Load vs. Drybulb Temperature for Standard Summer Days

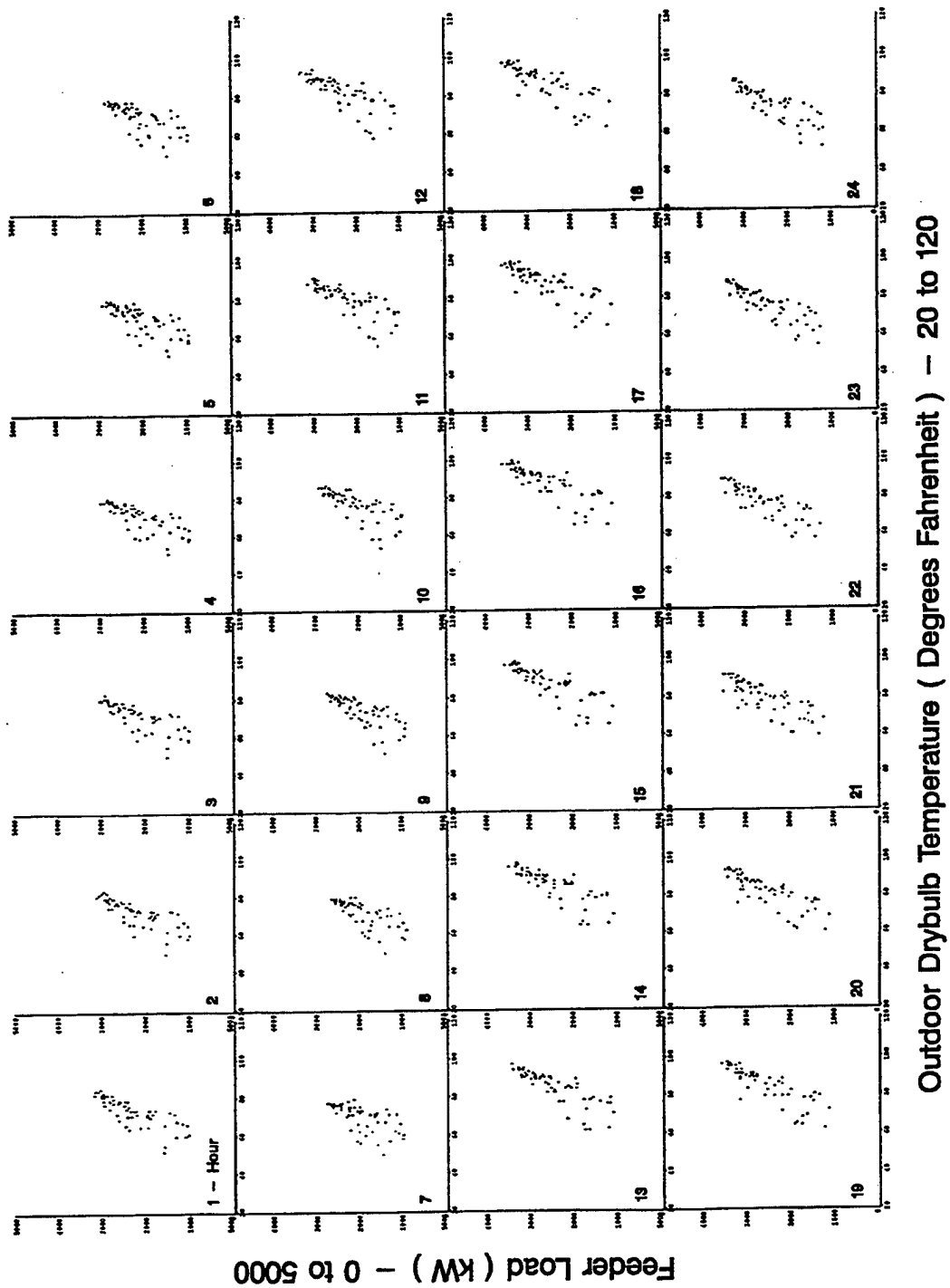


Figure A-10. Scatterplots of Feeder 3 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days

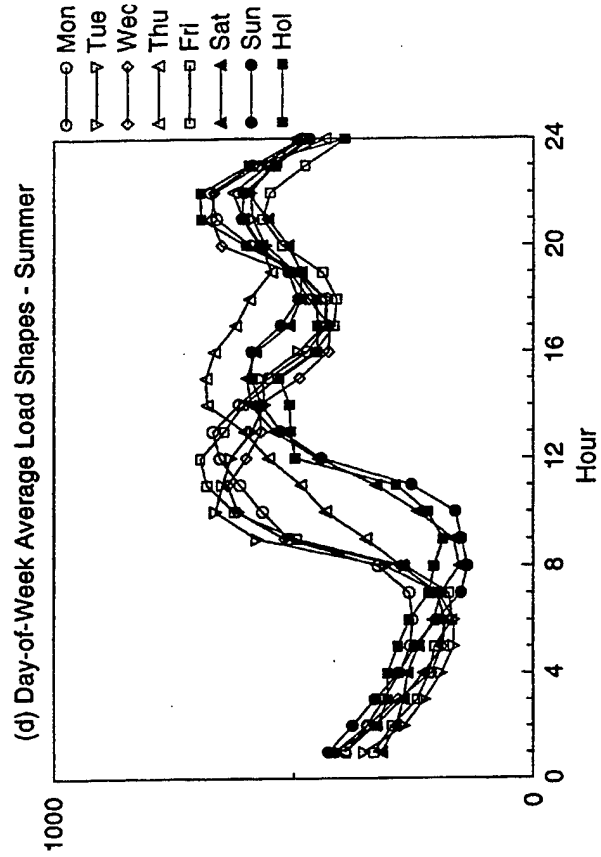
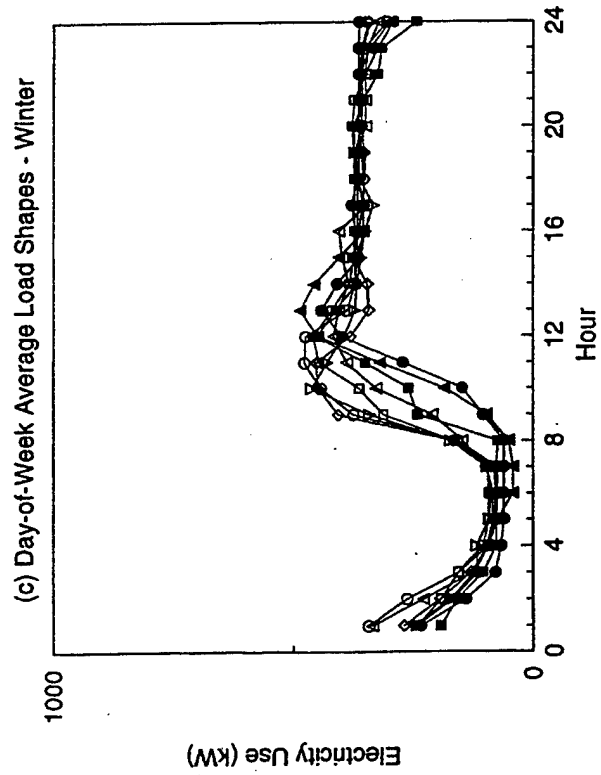
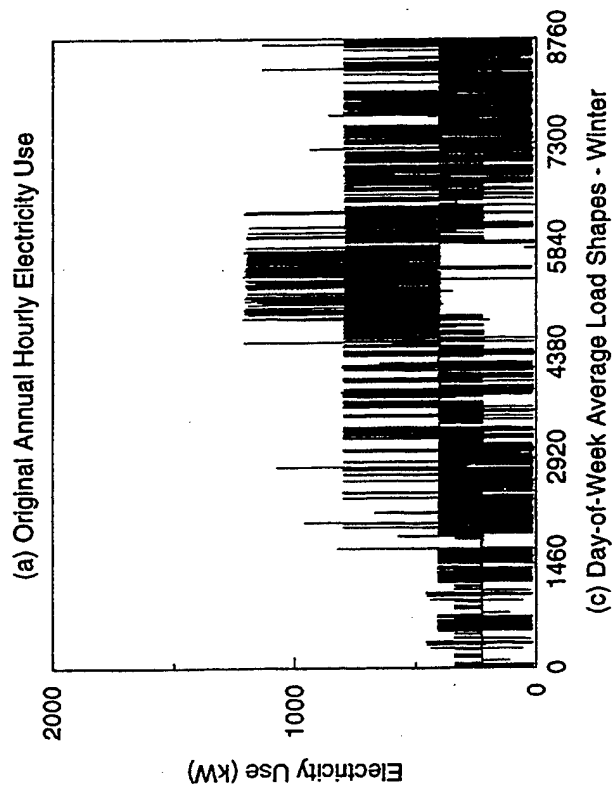


Figure A-11. Feeder 4 Data

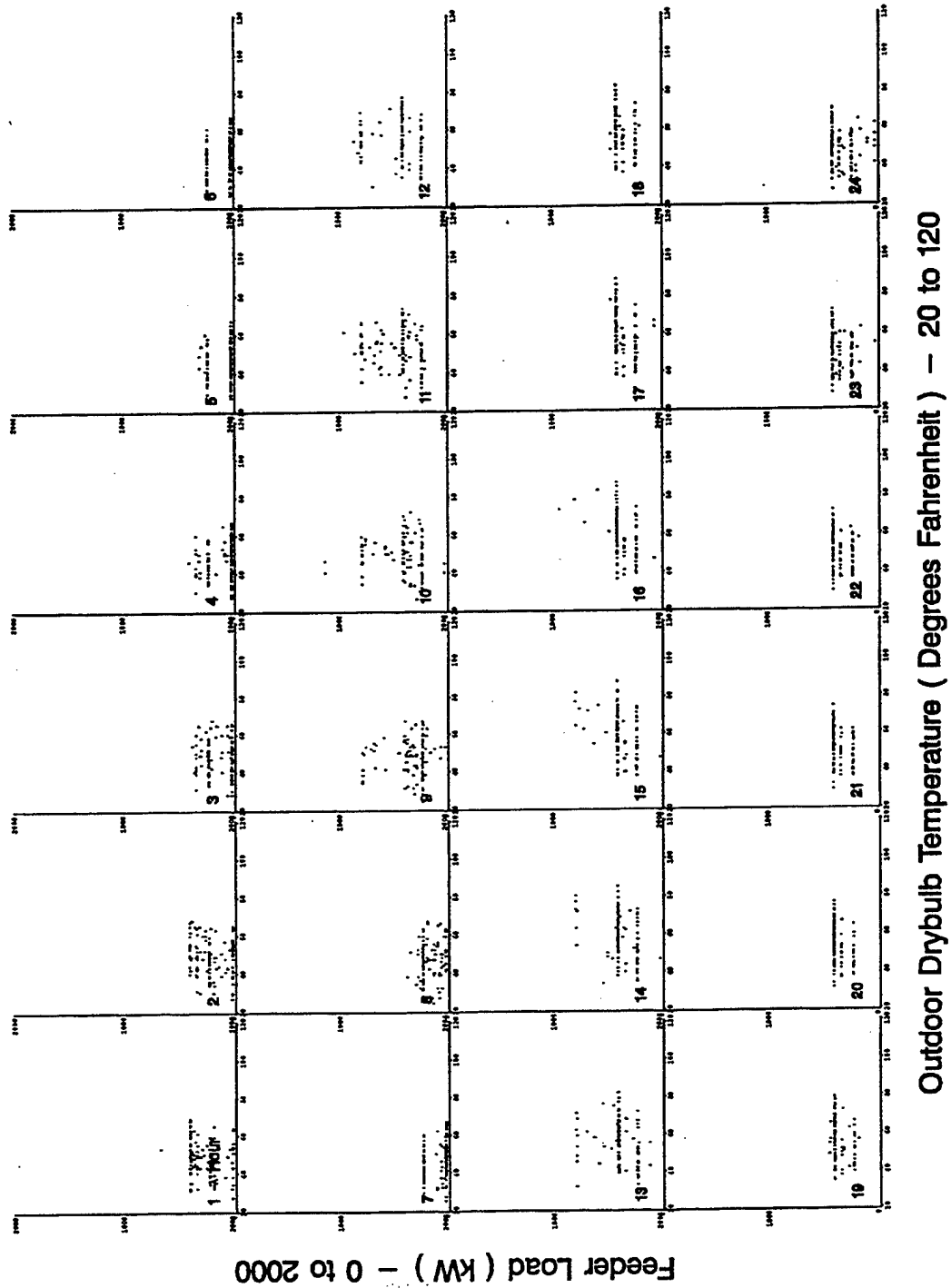


Figure A-12. Scatterplots of Feeder 4 Hourly Load vs. Drybulb Temperature for Standard Winter Days

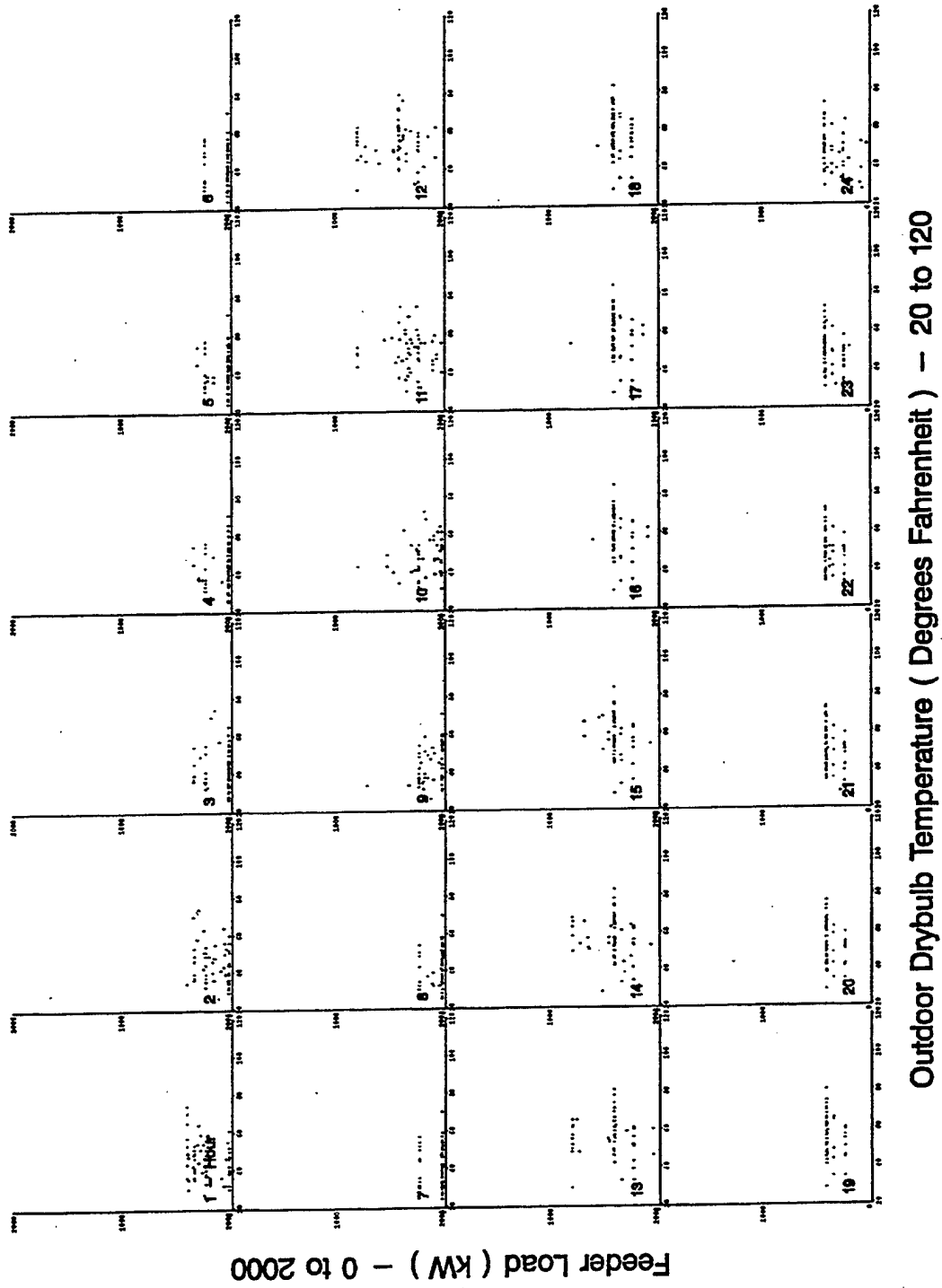


Figure A-13. Scatterplots of Feeder 4 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days

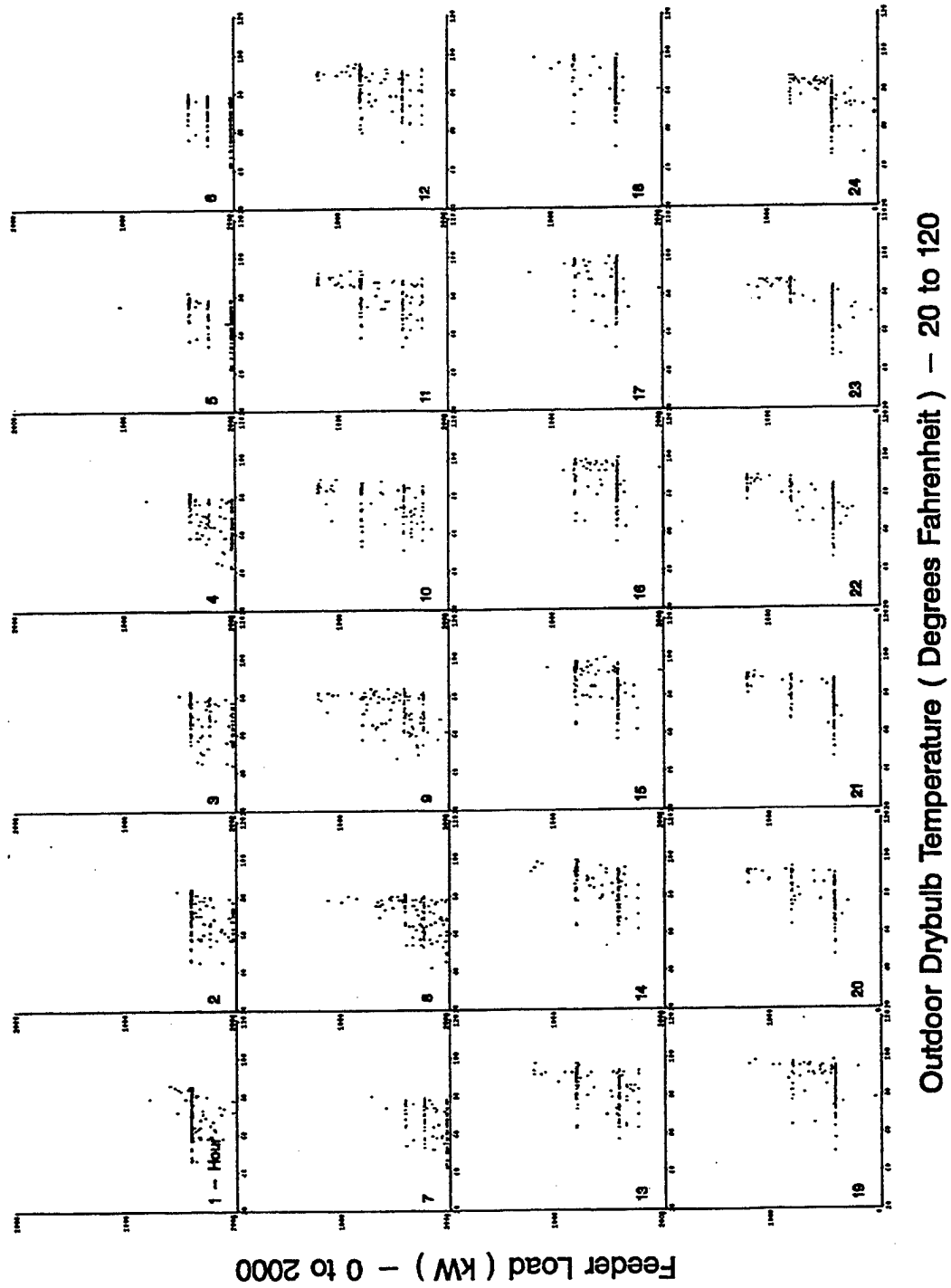


Figure A-14. Scatterplots of Feeder 4 Hourly Load vs. Drybulb Temperature for Standard Summer Days

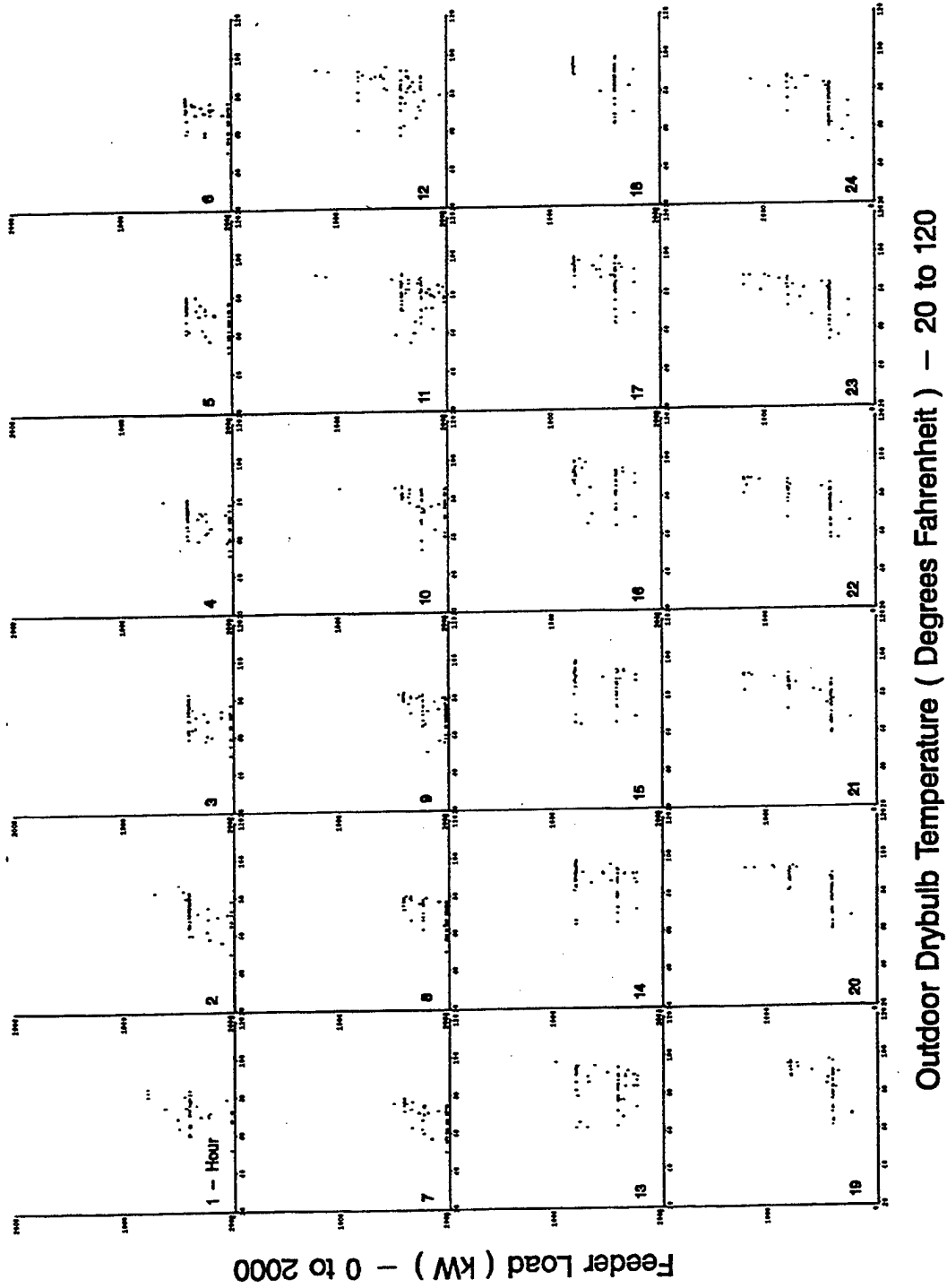


Figure A-15. Scatterplots of Feeder 4 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days

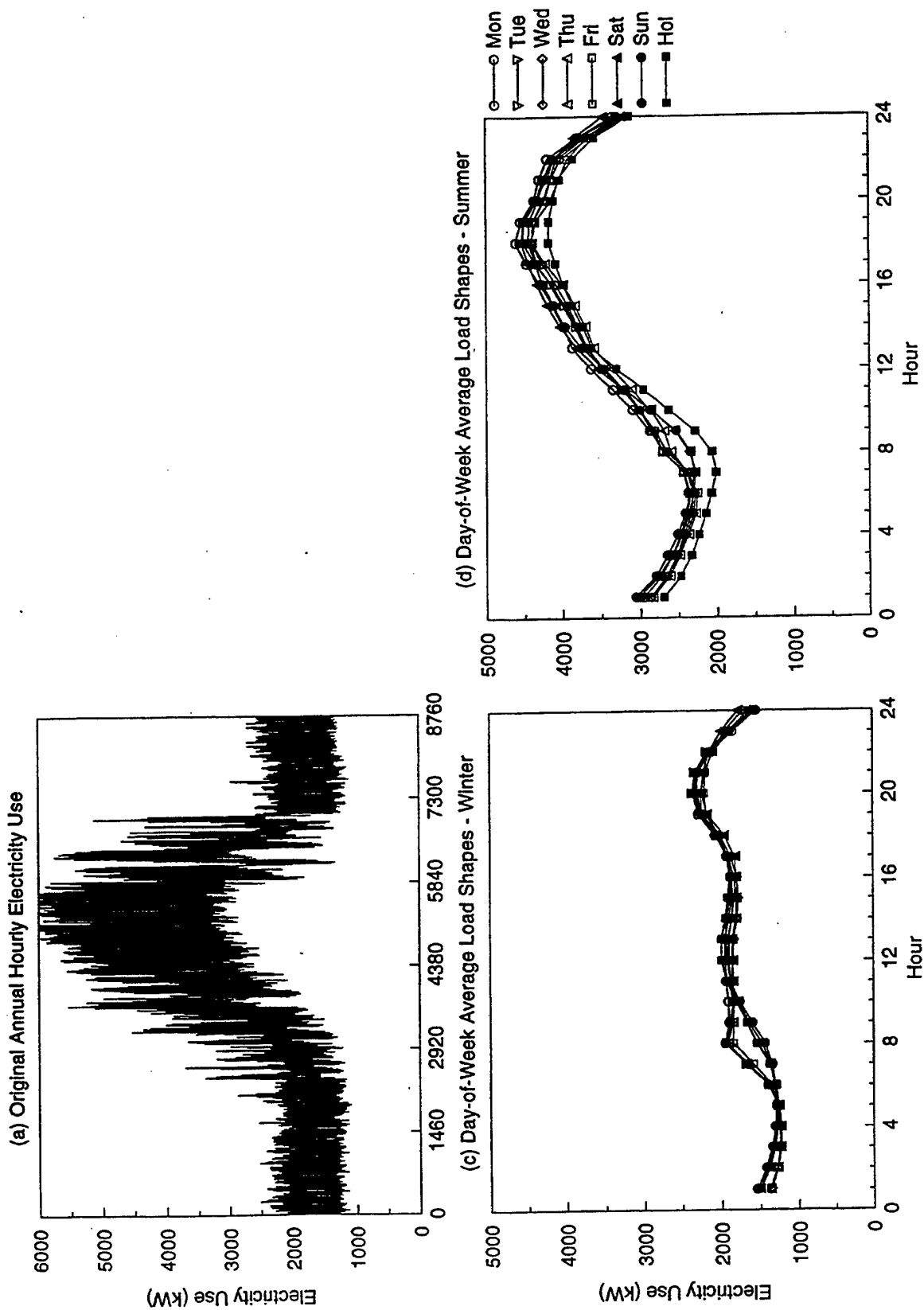


Figure A-16. Feeder 5 Data

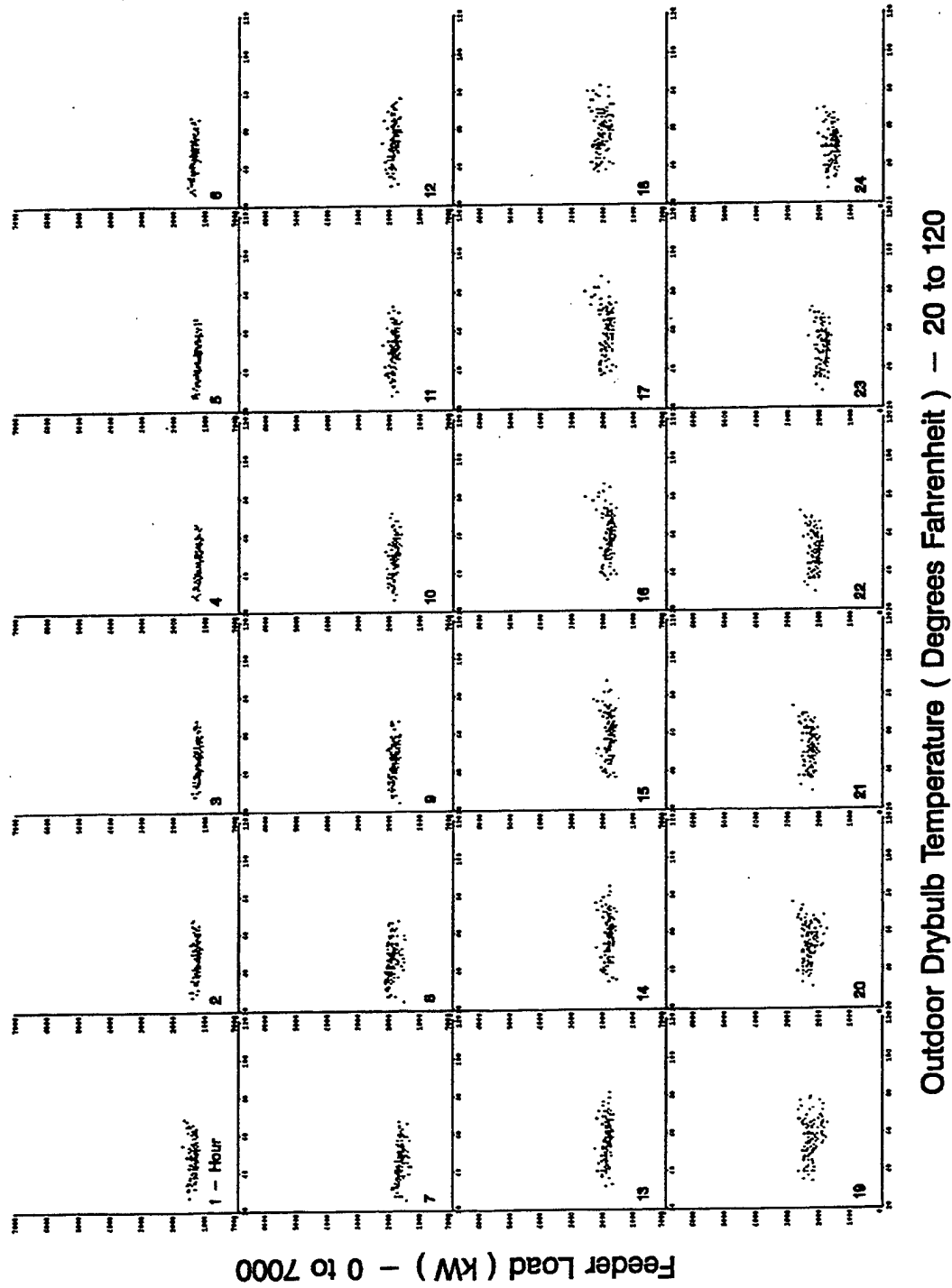


Figure A-17. Scatterplots of Feeder 5 Hourly Load vs. Drybulb Temperature for Standard Winter Days

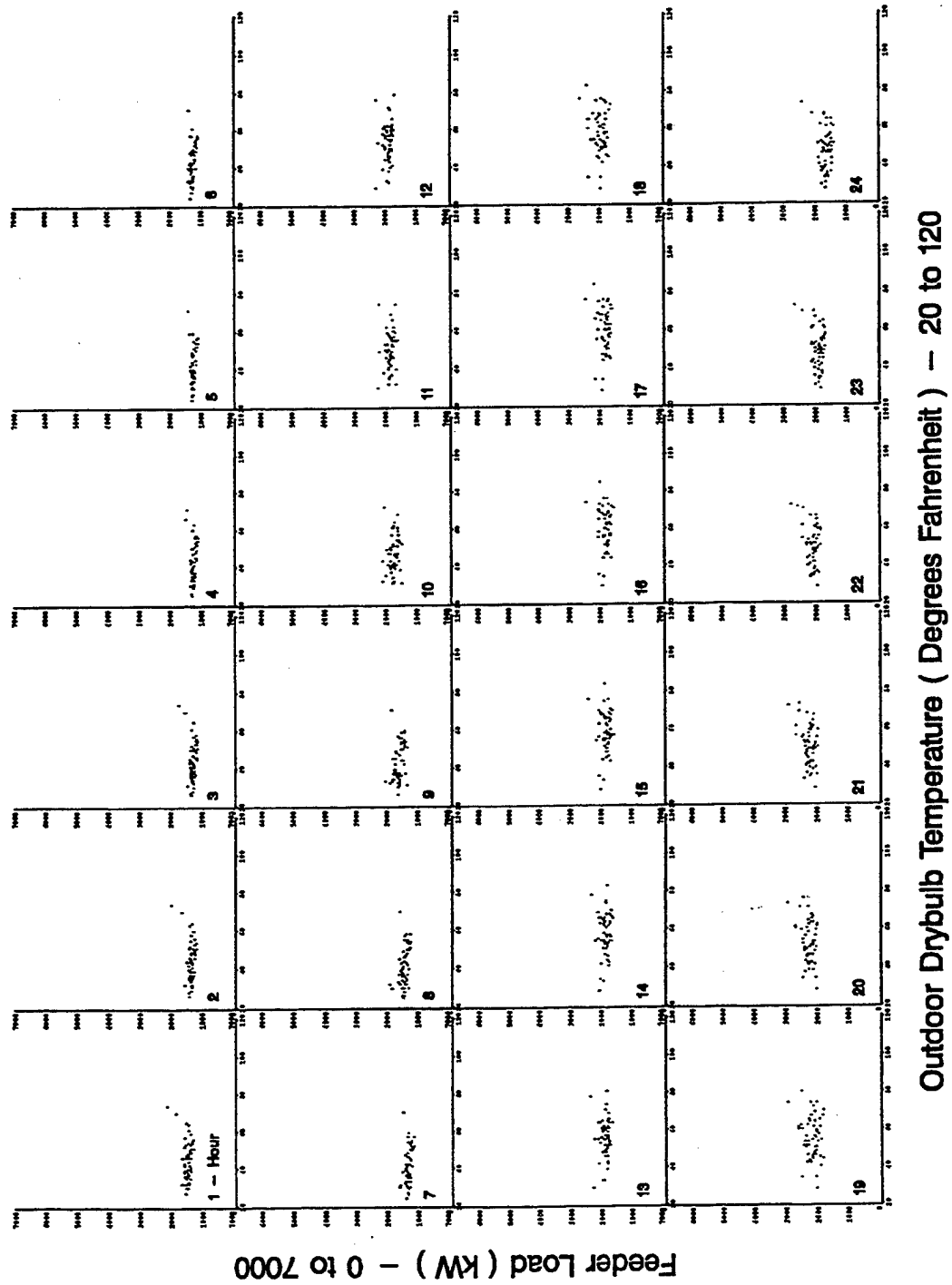


Figure A-18. Scatterplots of Feeder 5 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days

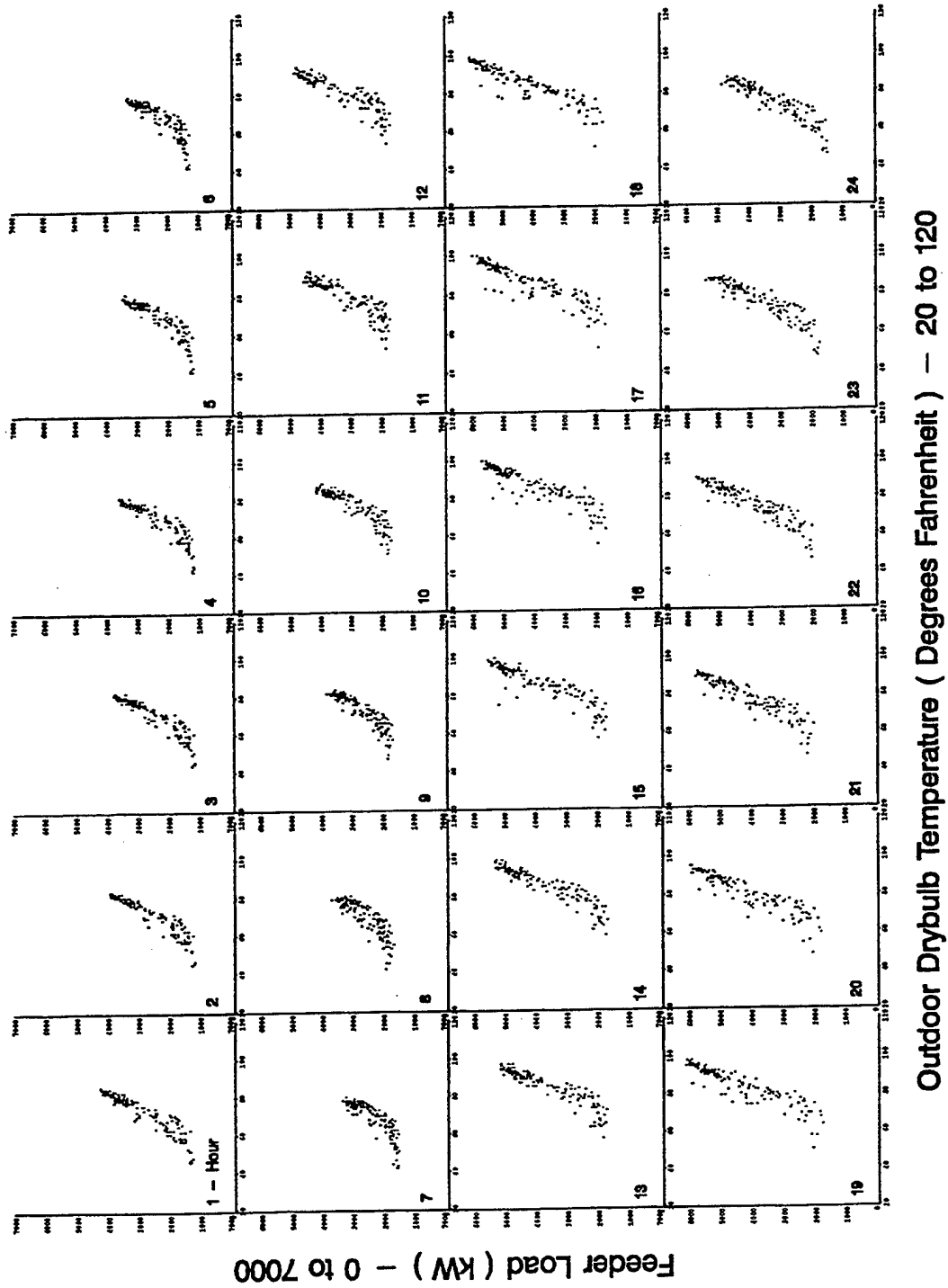


Figure A-19. Scatterplots of Feeder 5 Hourly Load vs. Drybulb Temperature for Standard Summer Days

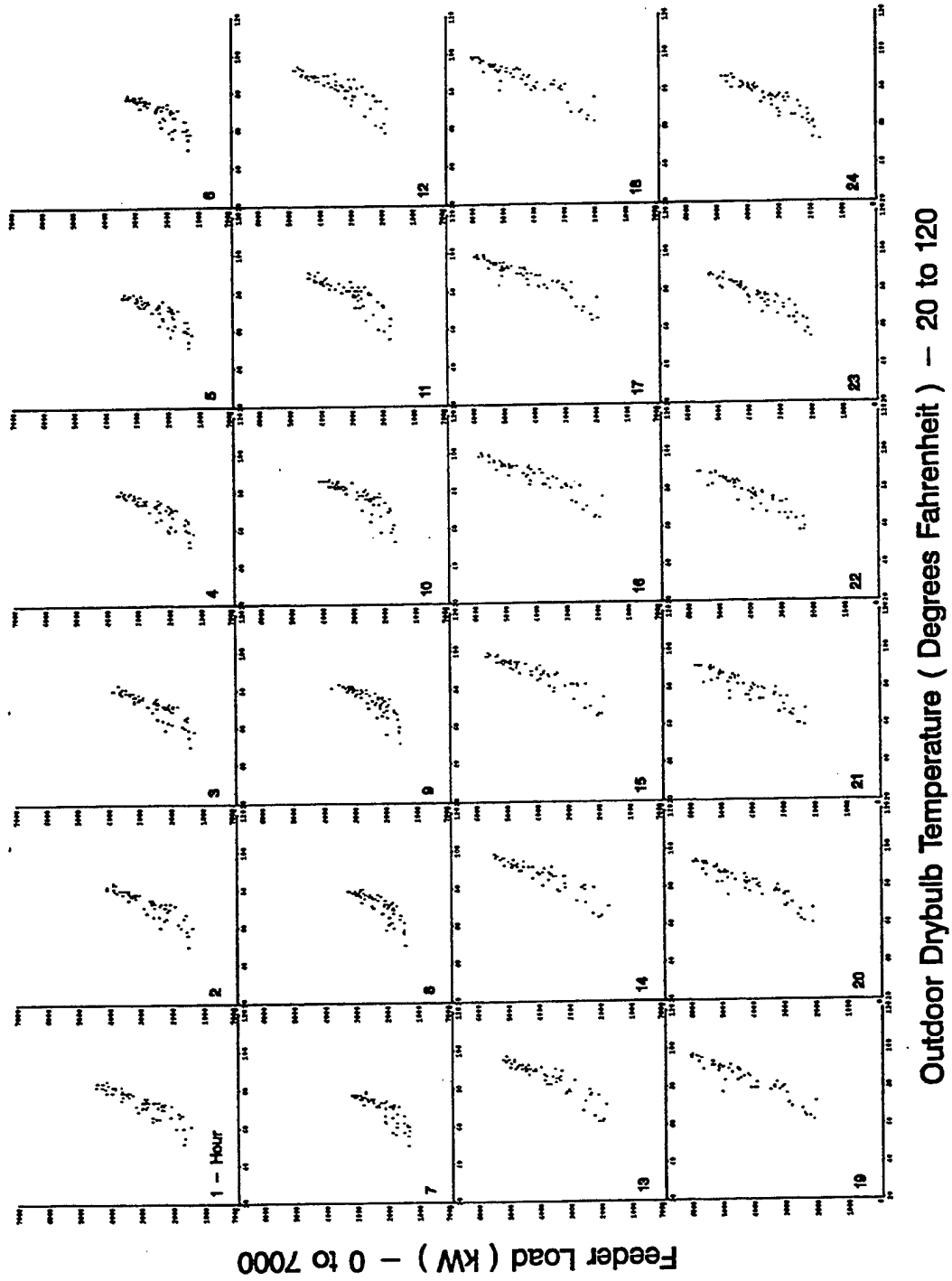


Figure A-20. Scatterplots of Feeder 5 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days

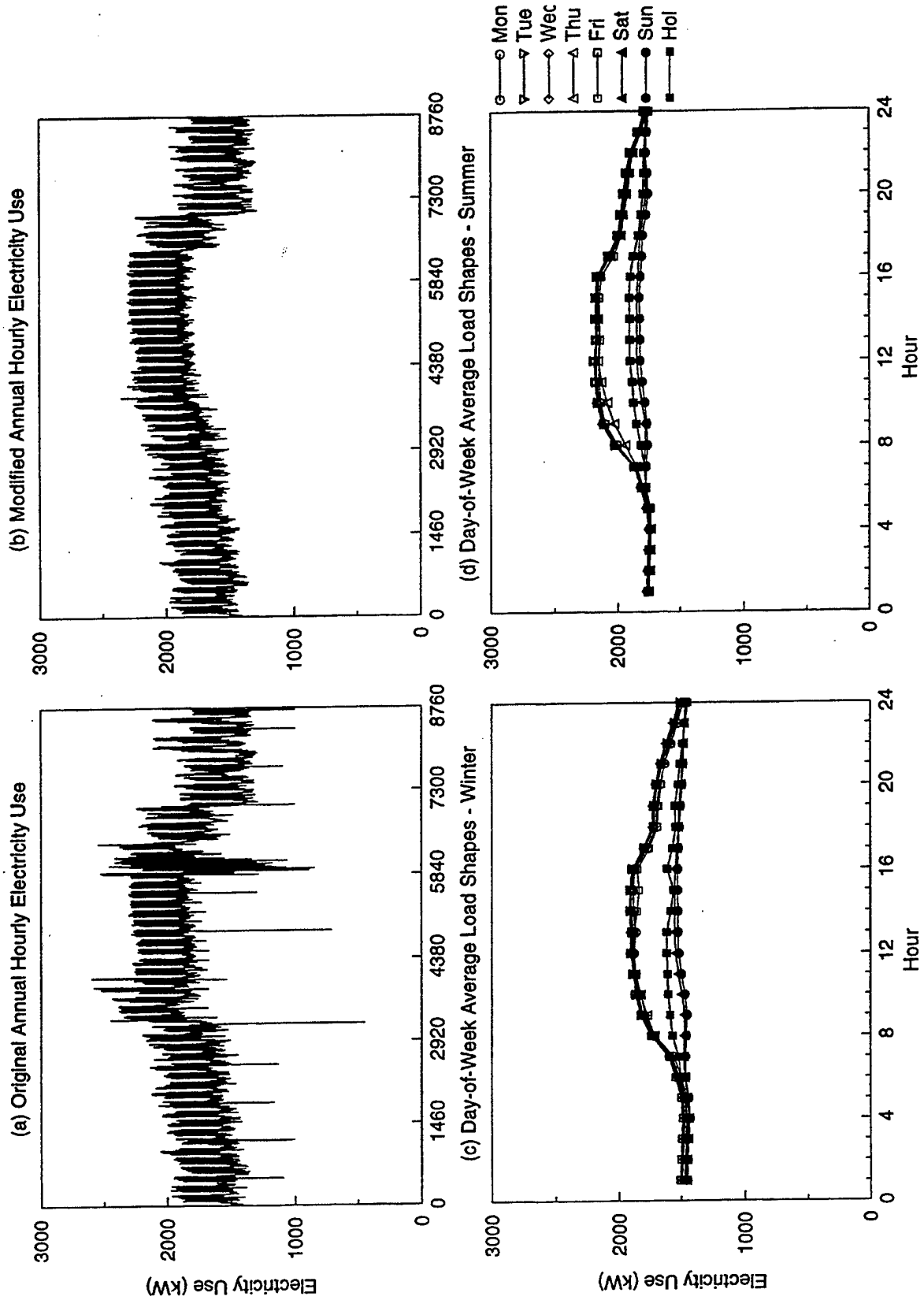


Figure A-21. Feeder 9 Data

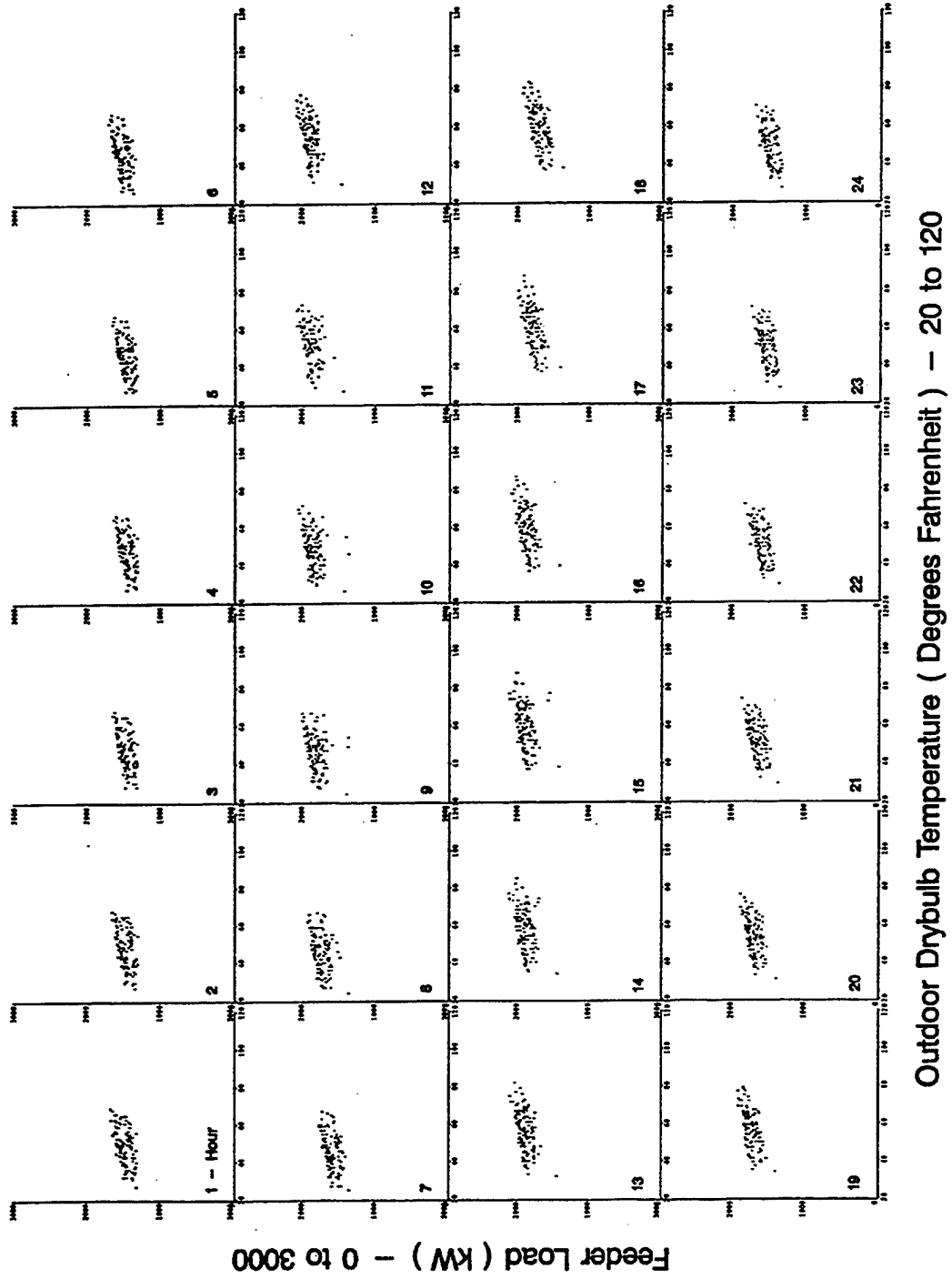


Figure A-22. Scatterplots of Feeder 9 Hourly Load vs. Drybulb Temperature for Standard Winter Days

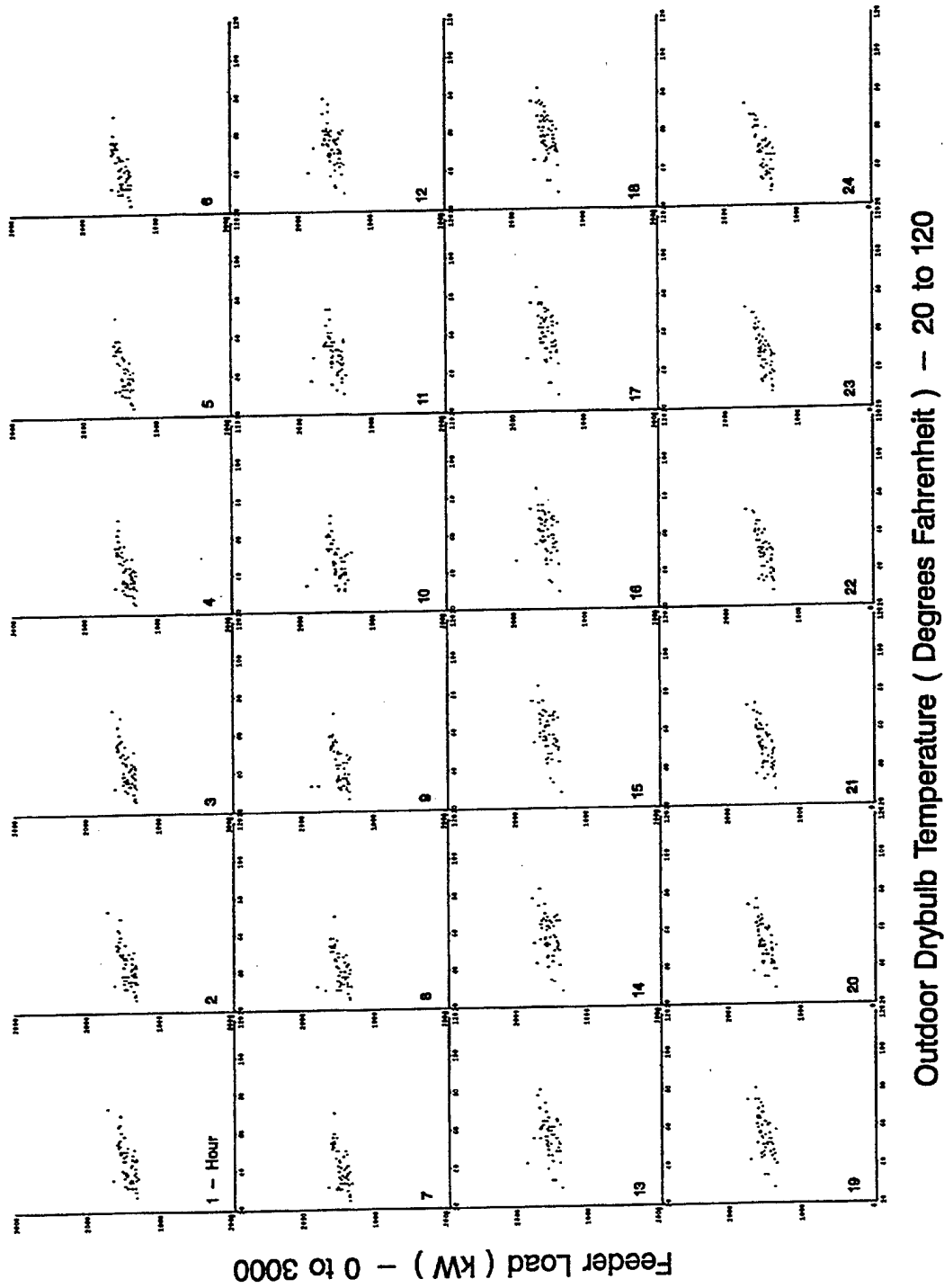


Figure A-23. Scatterplots of Feeder 9 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days

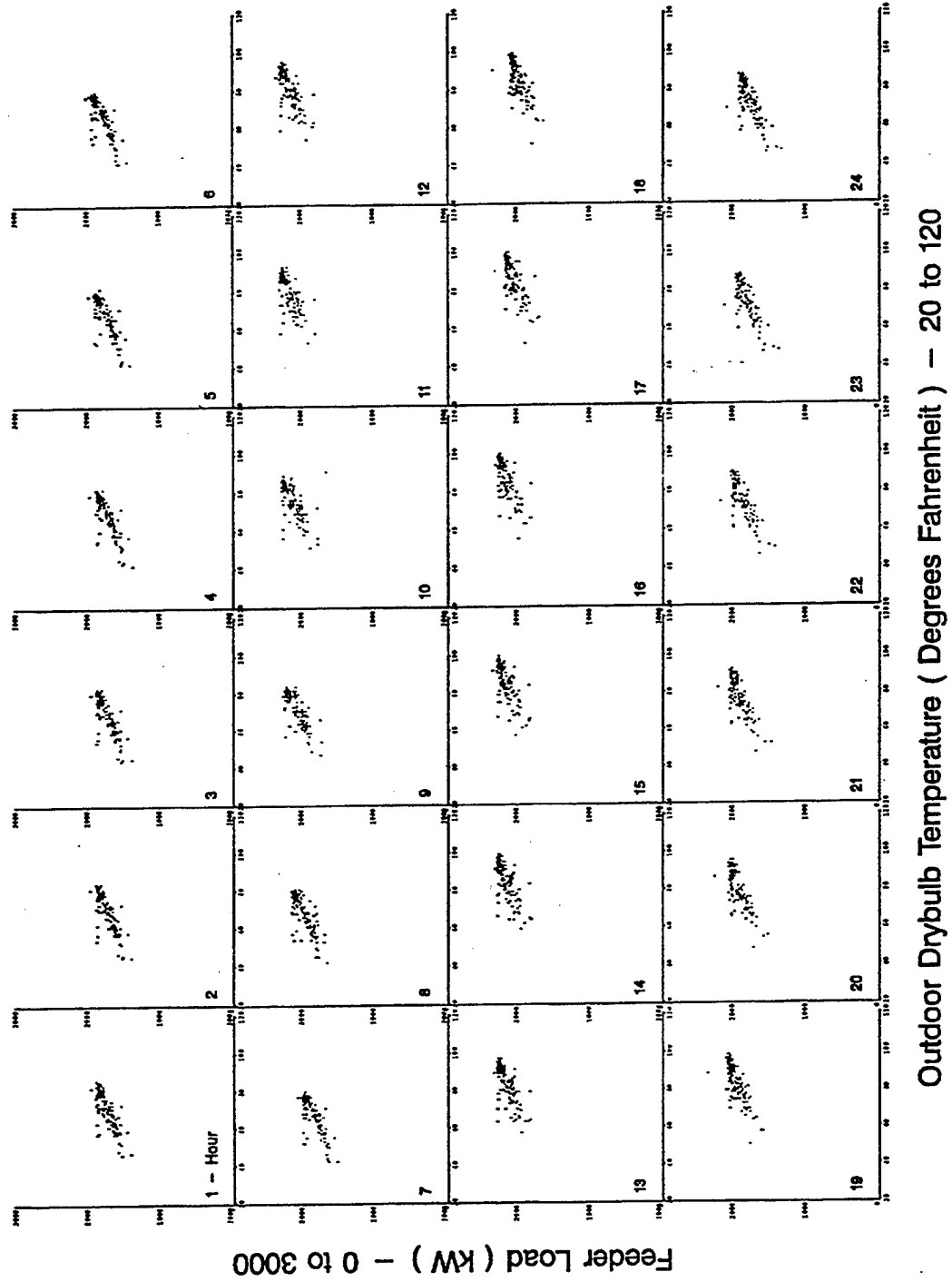


Figure A-24. Scatterplots of Feeder 9 Hourly Load vs. Drybulb Temperature for Standard Summer Days

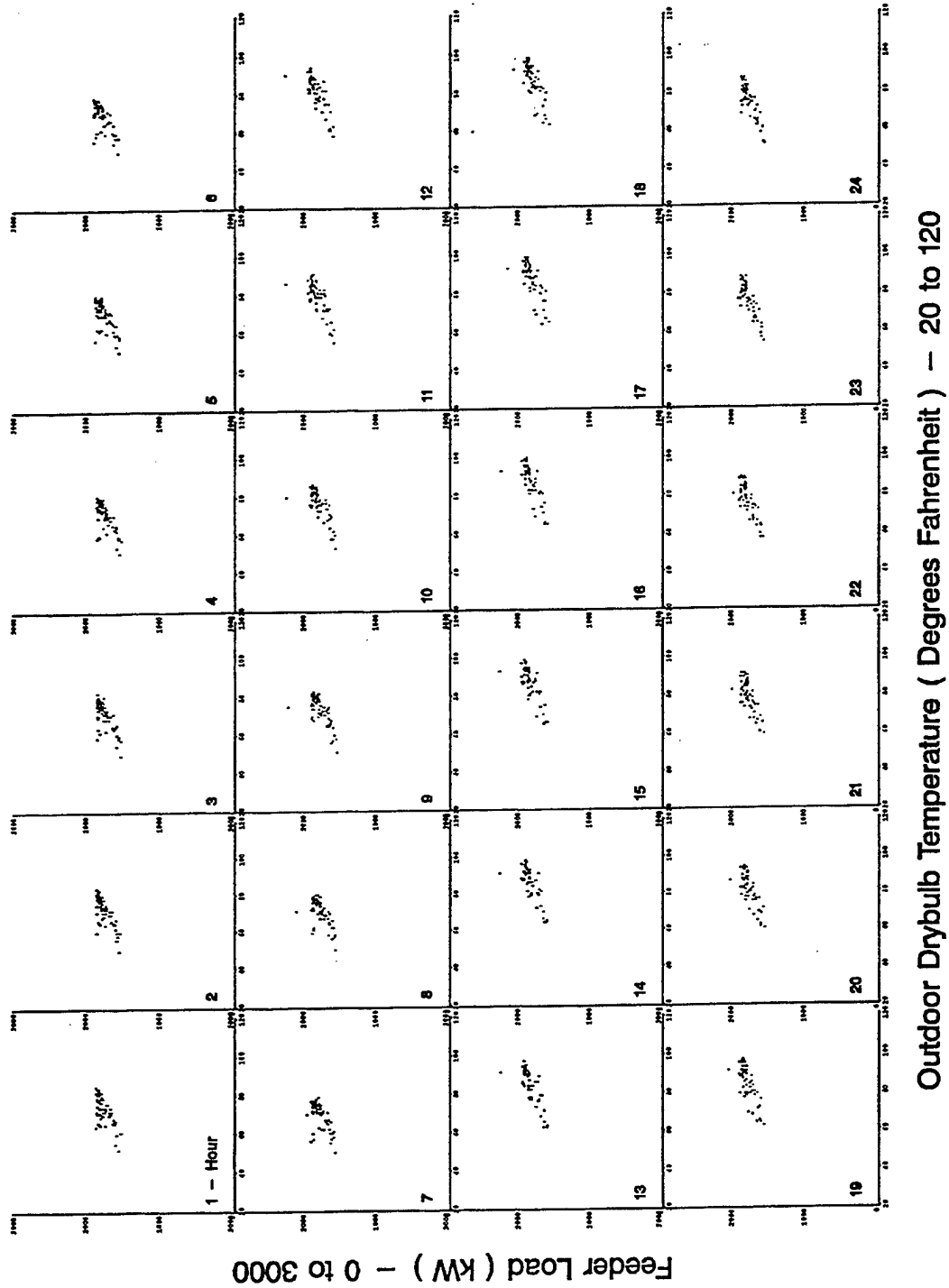


Figure A-25. Scatterplots of Feeder 9 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days

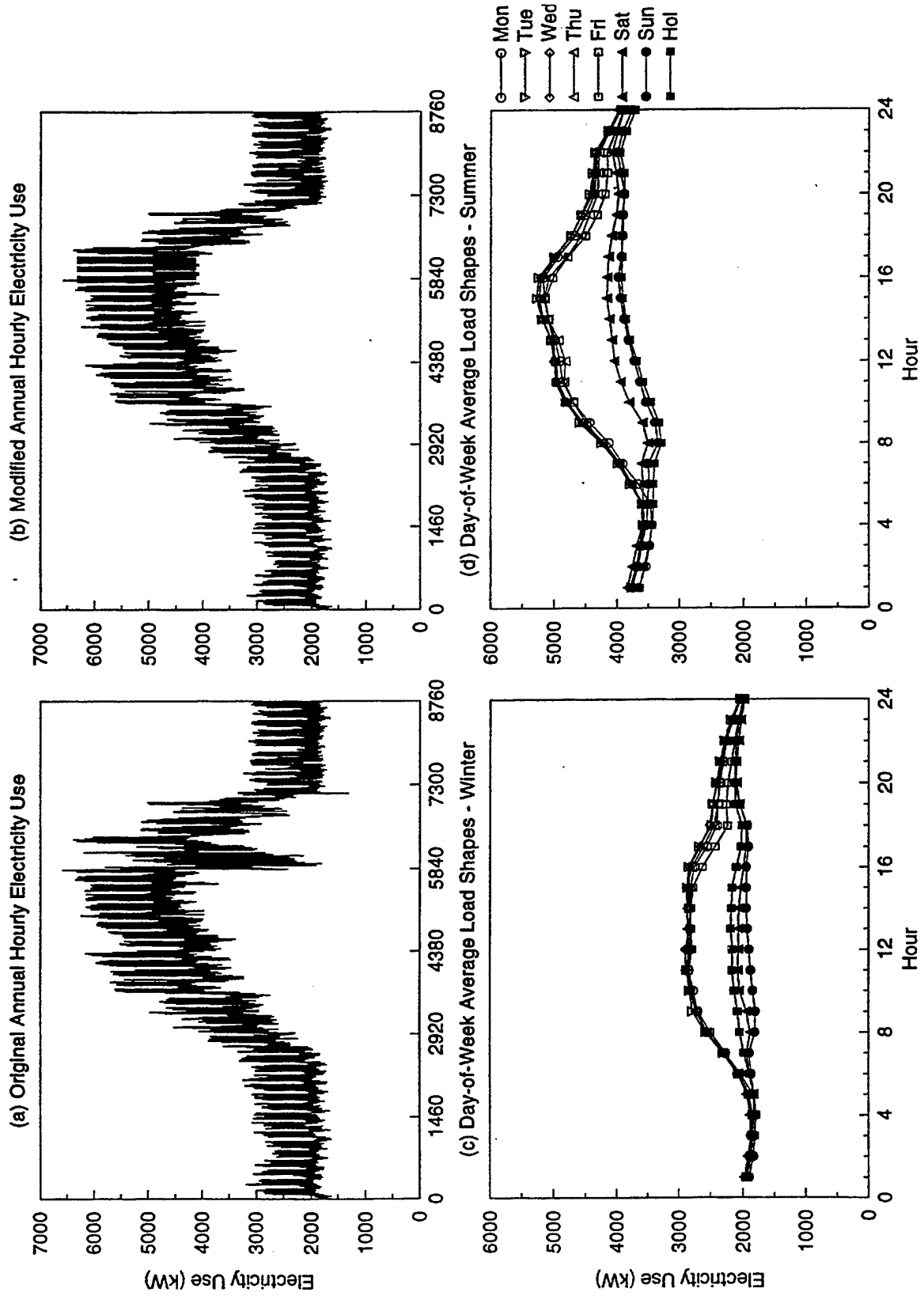


Figure A-26. Feeder 10 Data

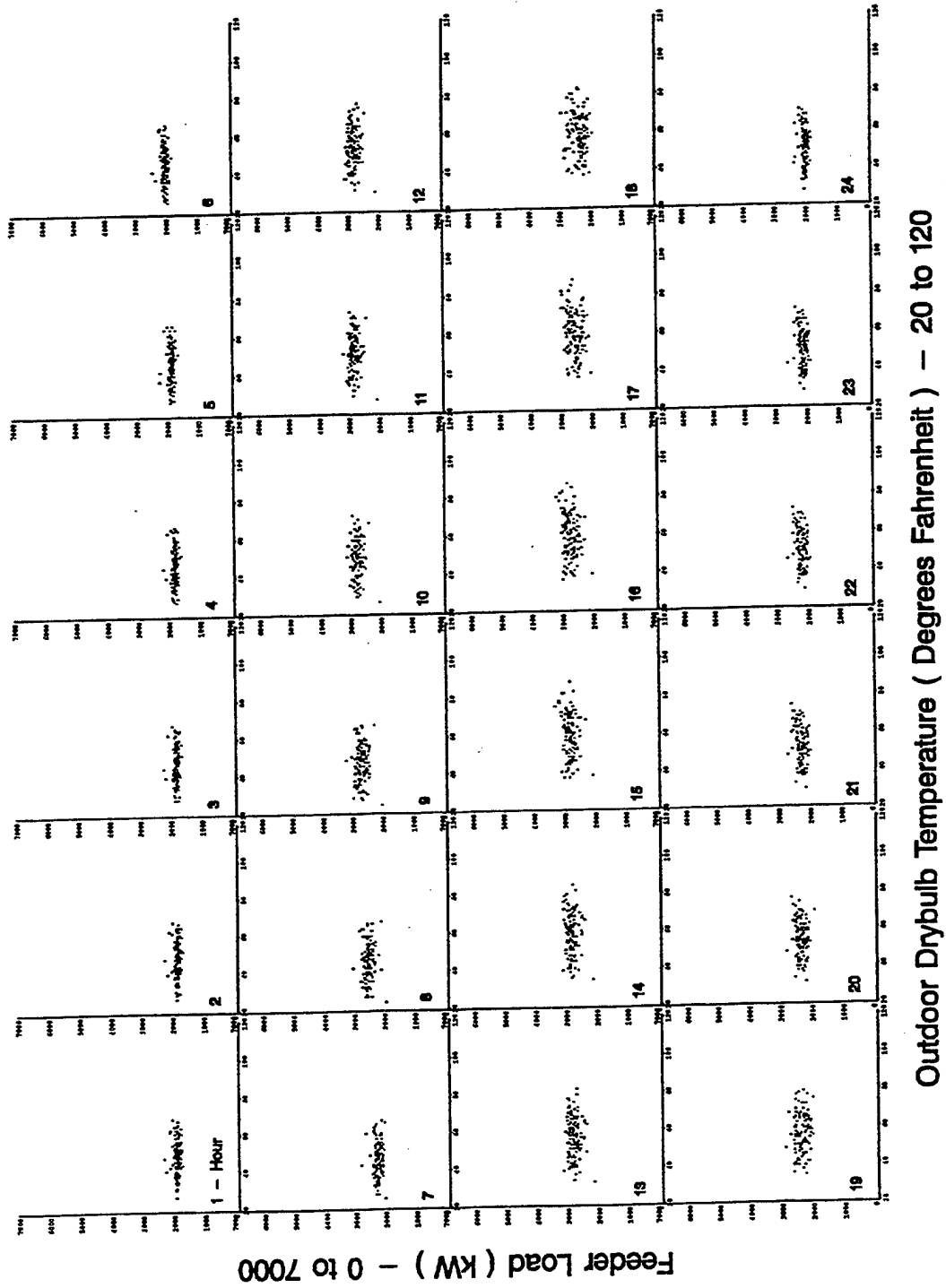


Figure A-27. Scatterplots of Feeder 10 Hourly Load vs. Drybulb Temperature for Standard Winter Days

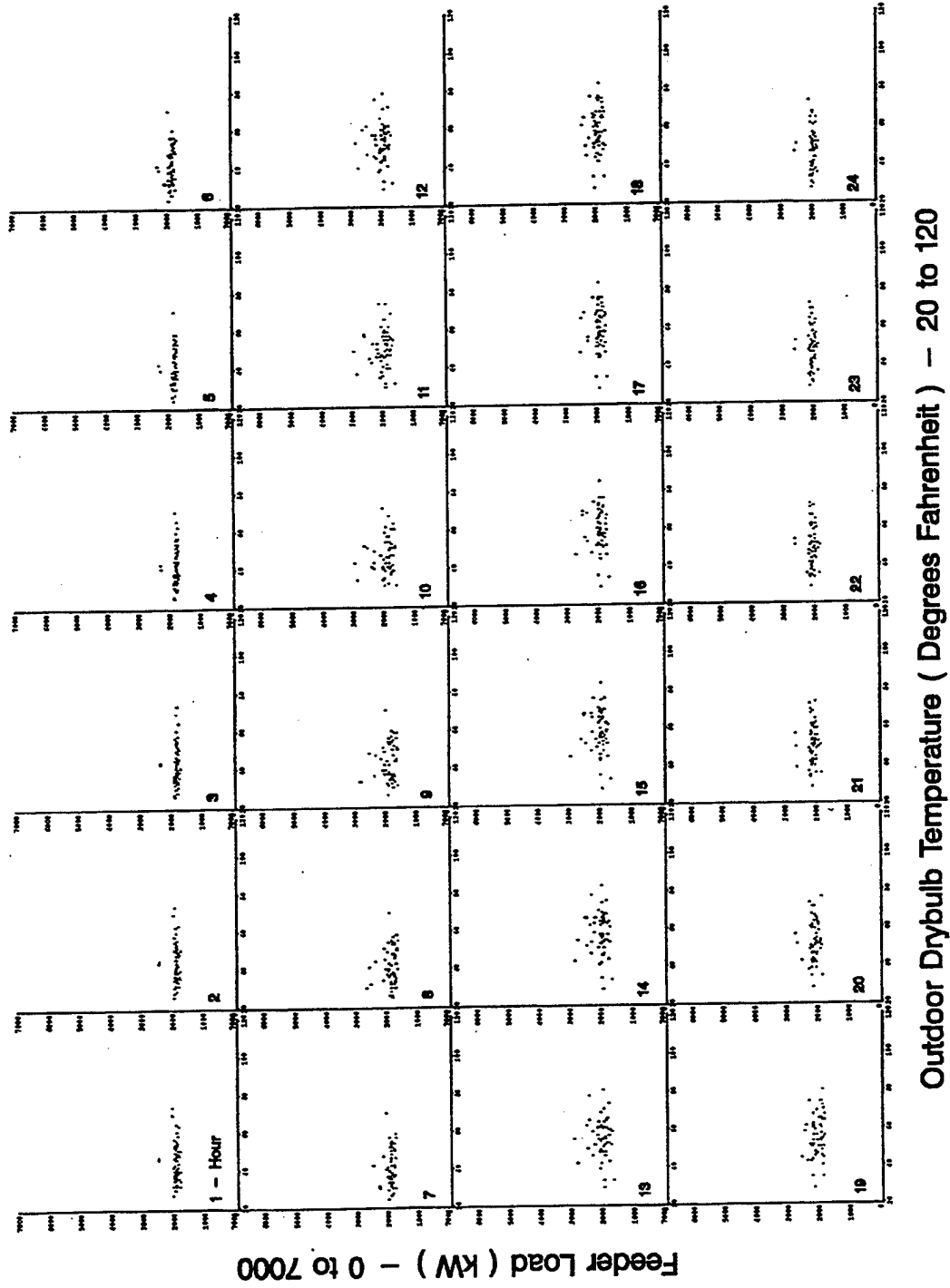


Figure A-28. Scatterplots of Feeder 10 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days

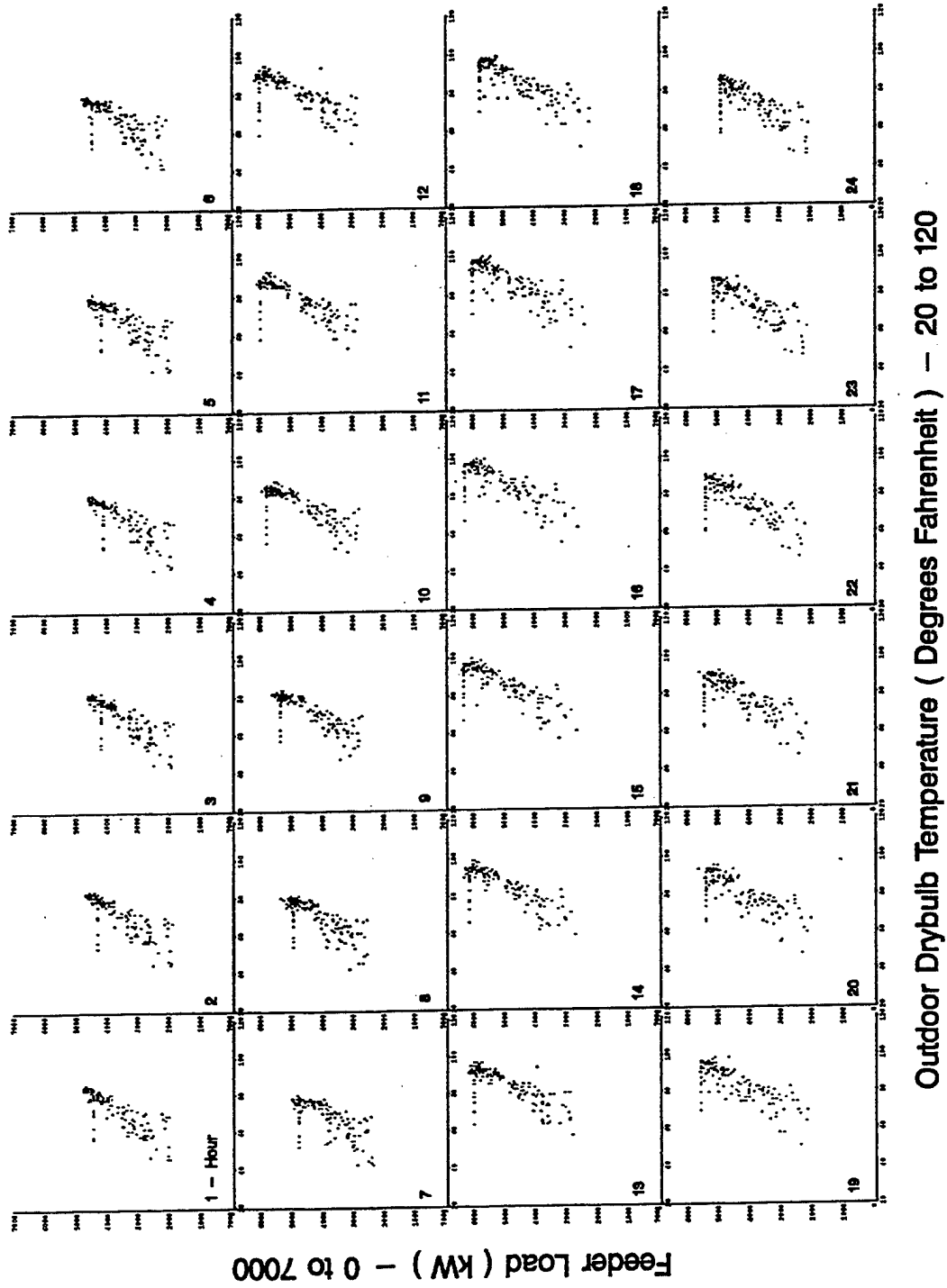


Figure A-29. Scatterplots of Feeder 10 Hourly Load vs. Drybulb Temperature for Standard Summer Days

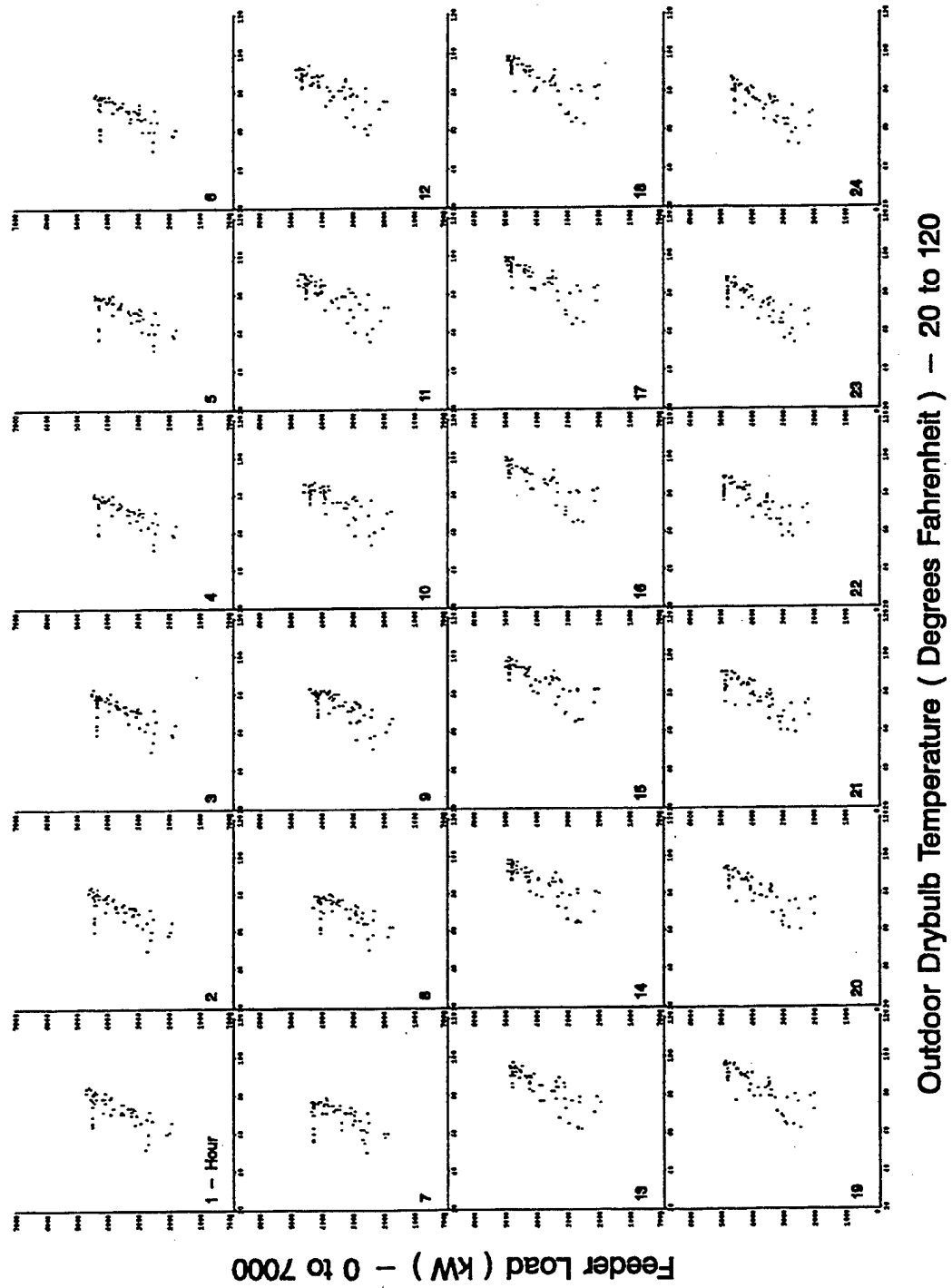


Figure A-30. Scatterplots of Feeder 10 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days

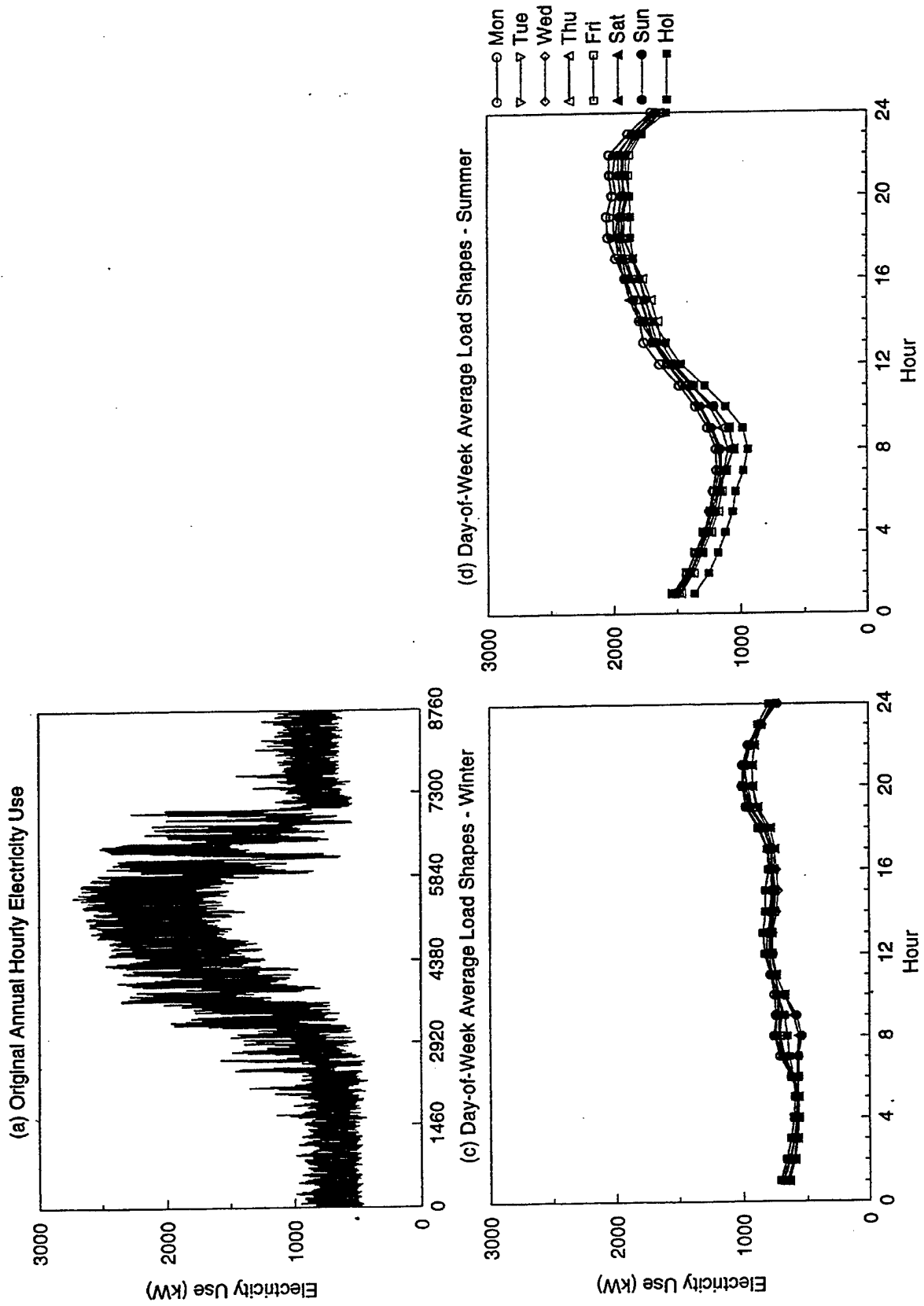


Figure A-31. Feeder 12 Data

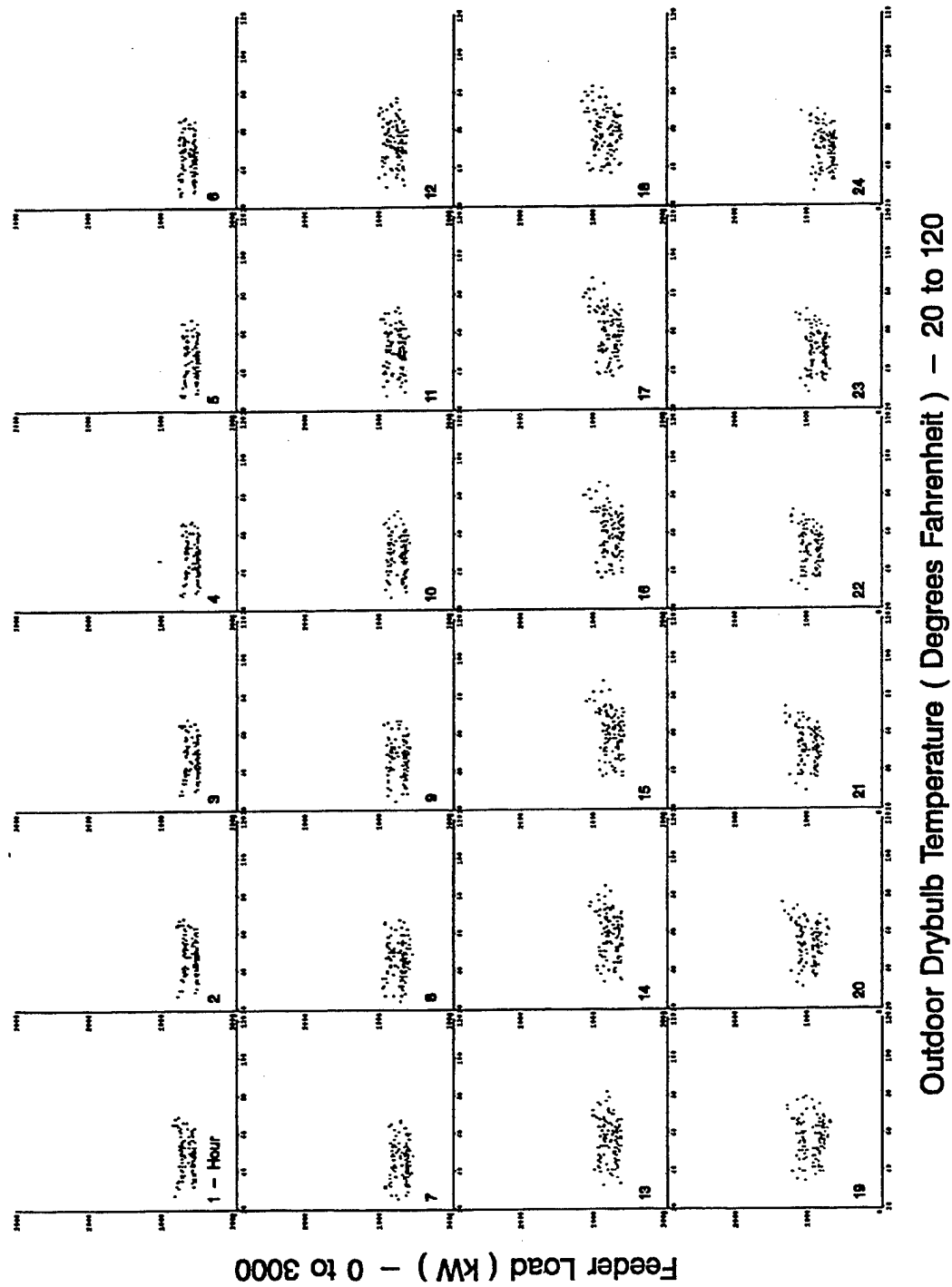


Figure A-32. Scatterplots of Feeder 12 Hourly Load vs. Drybulb Temperature for Standard Winter Days

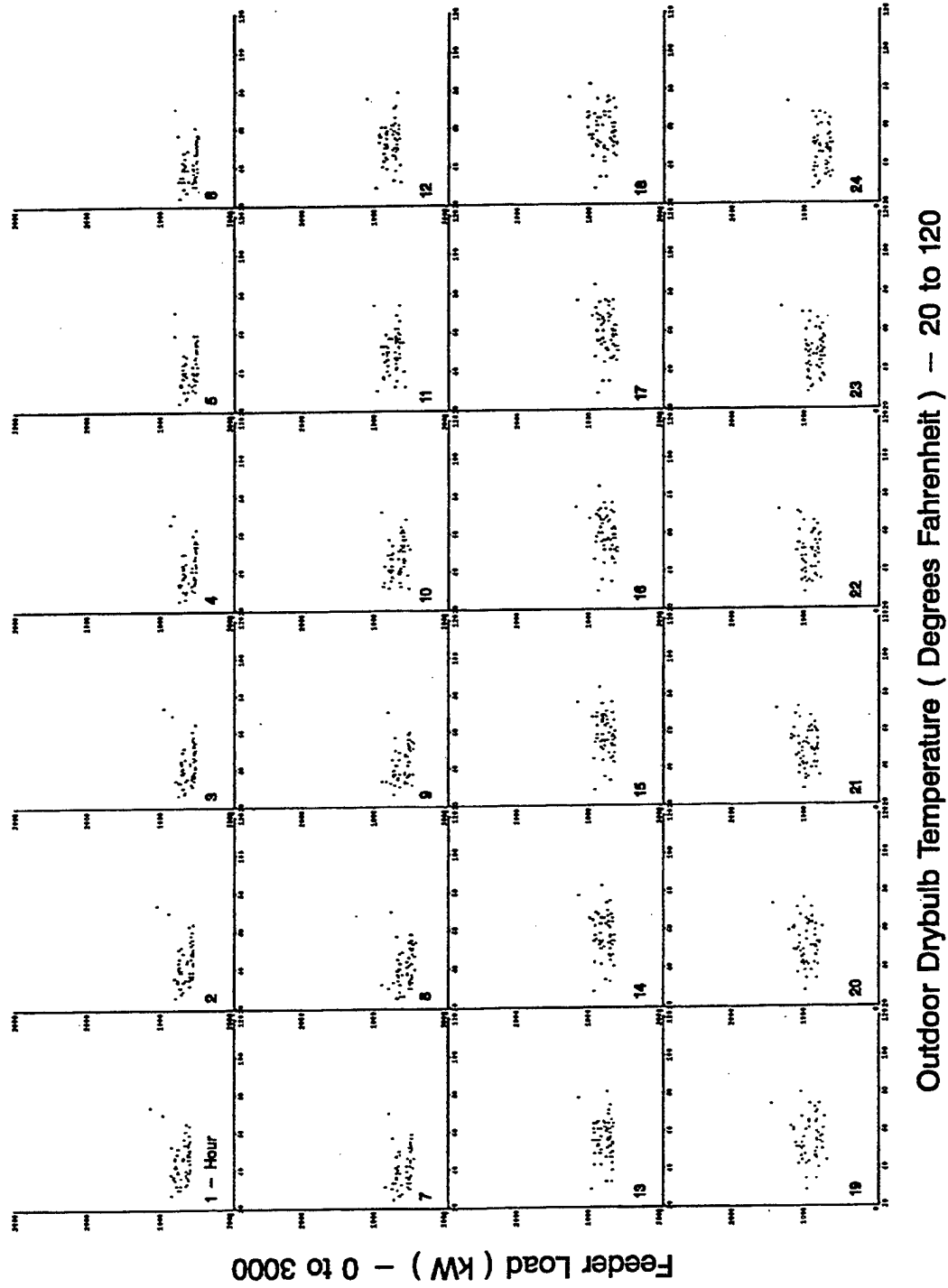


Figure A-33. Scatterplots of Feeder 12 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days

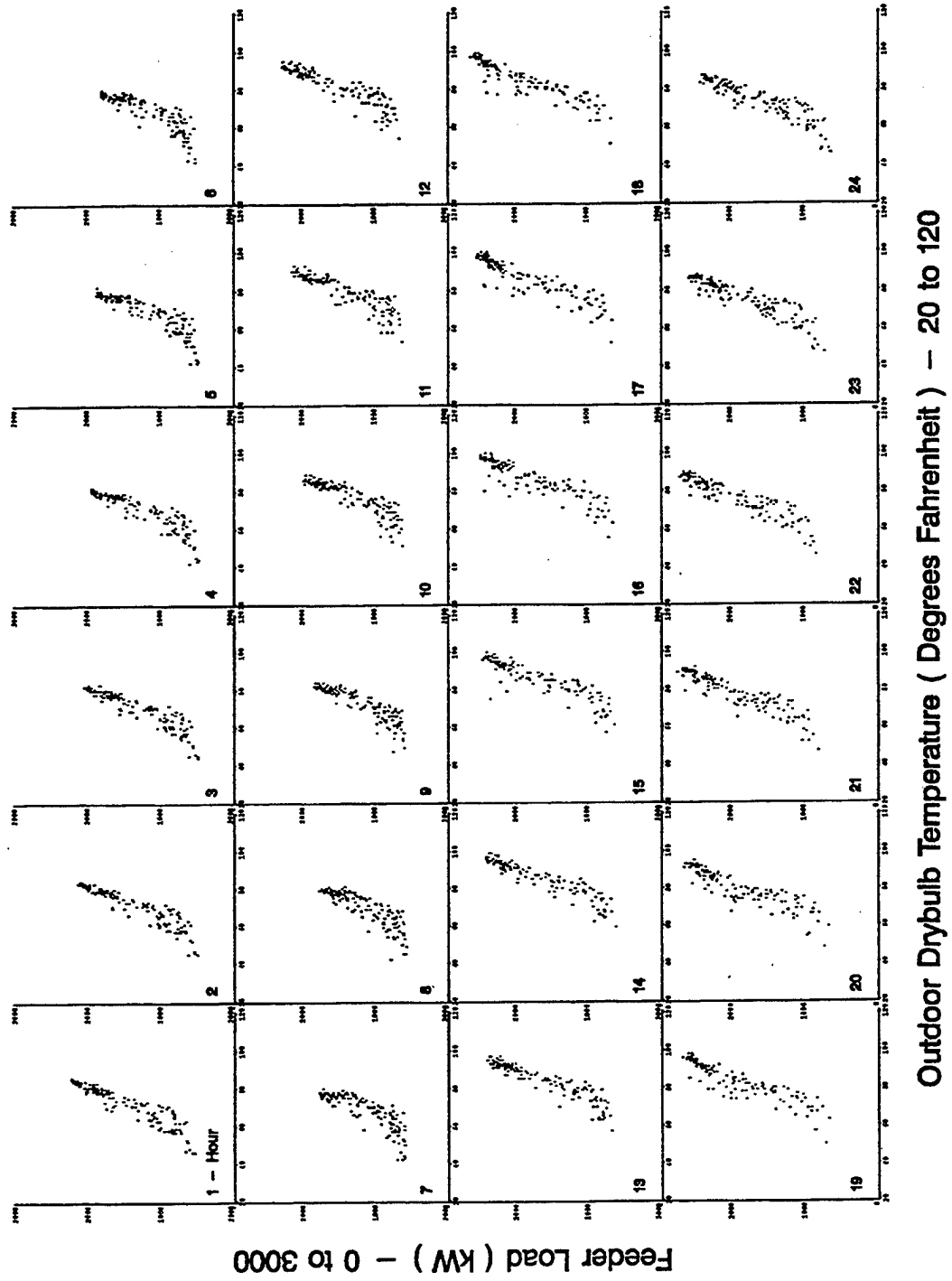


Figure A-34. Scatterplots of Feeder 12 Hourly Load vs. Drybulb Temperature for Standard Summer Days

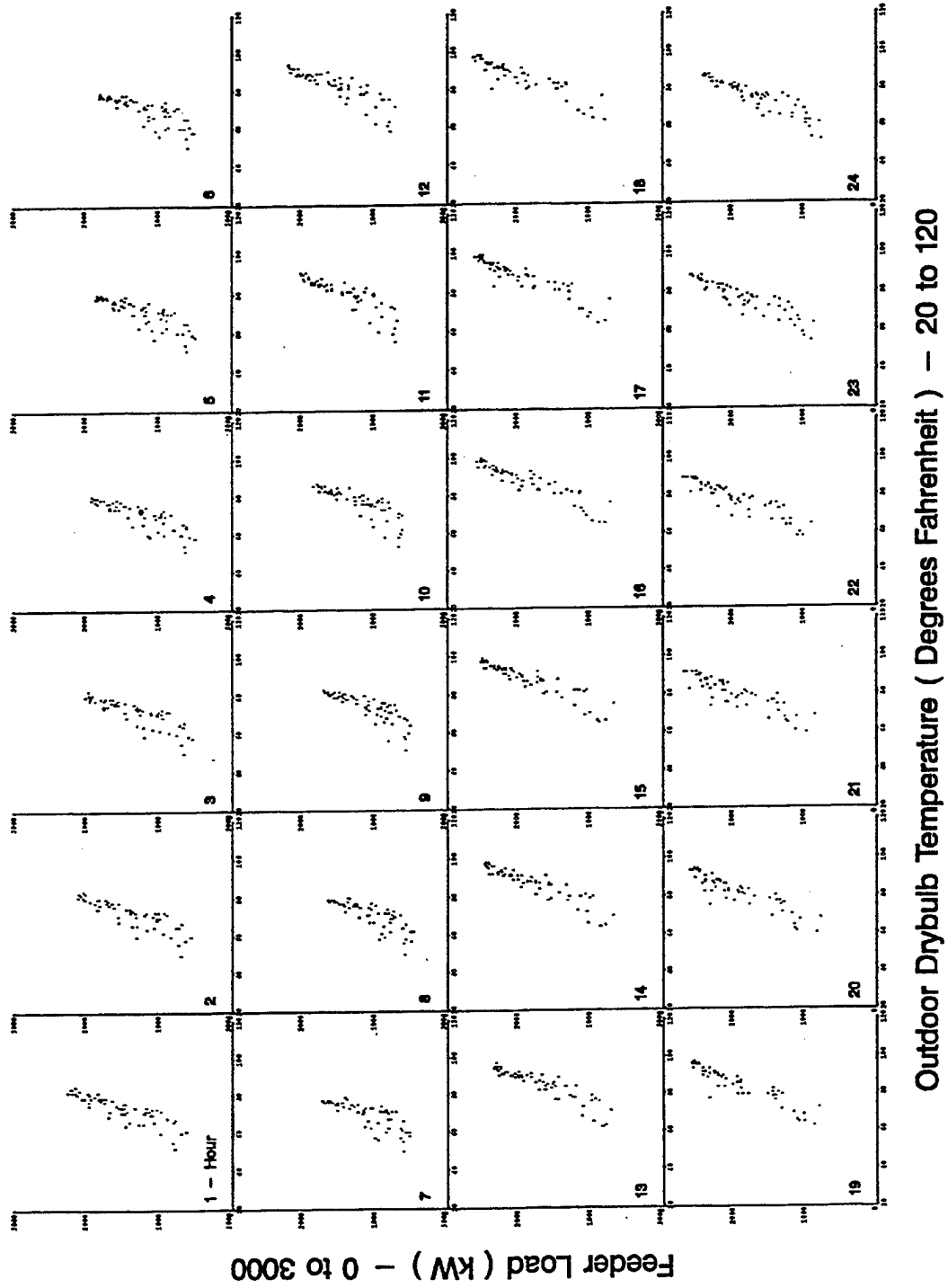


Figure A-35. Scatterplots of Feeder 12 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days

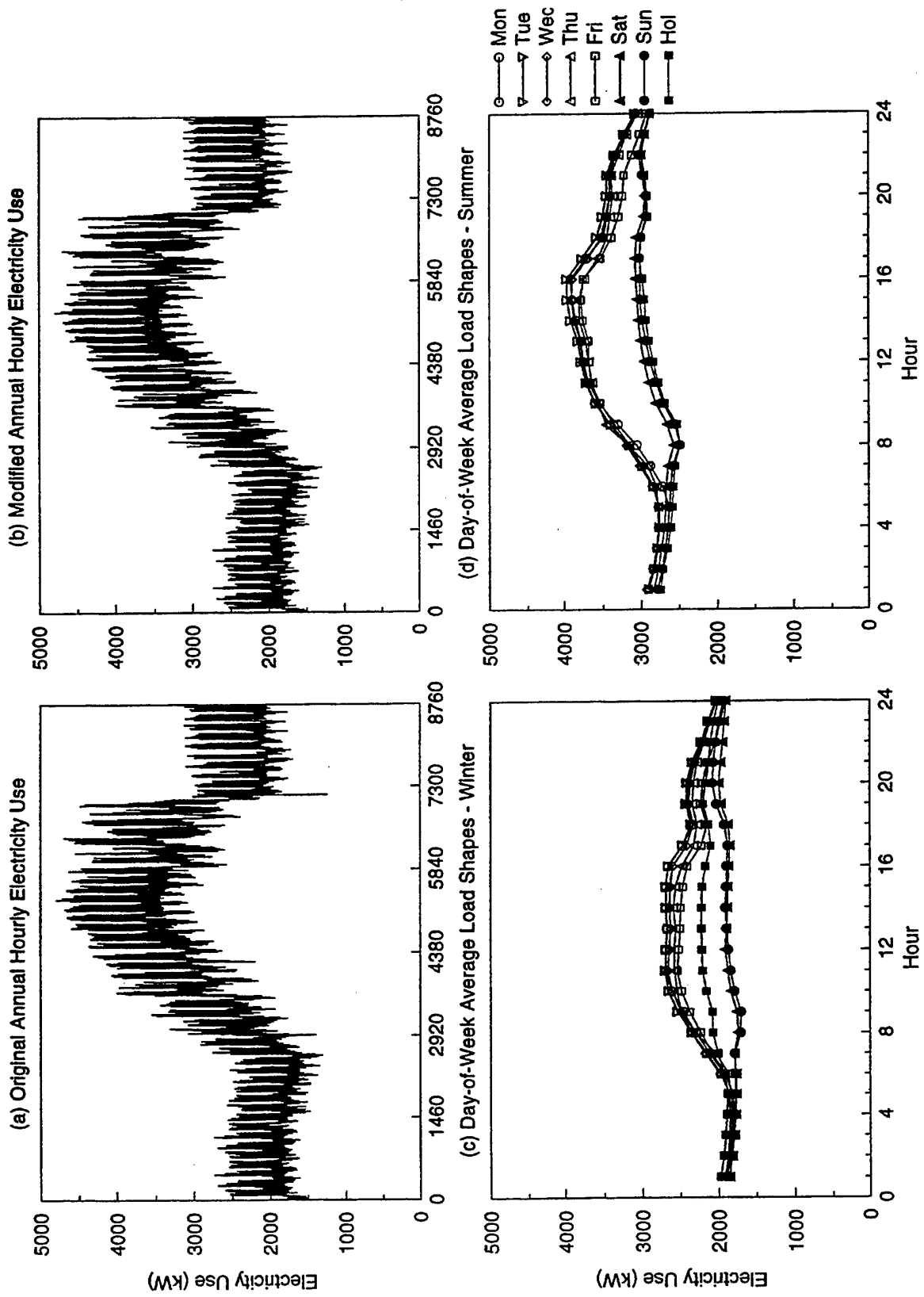


Figure A-36. Feeder 15 Data

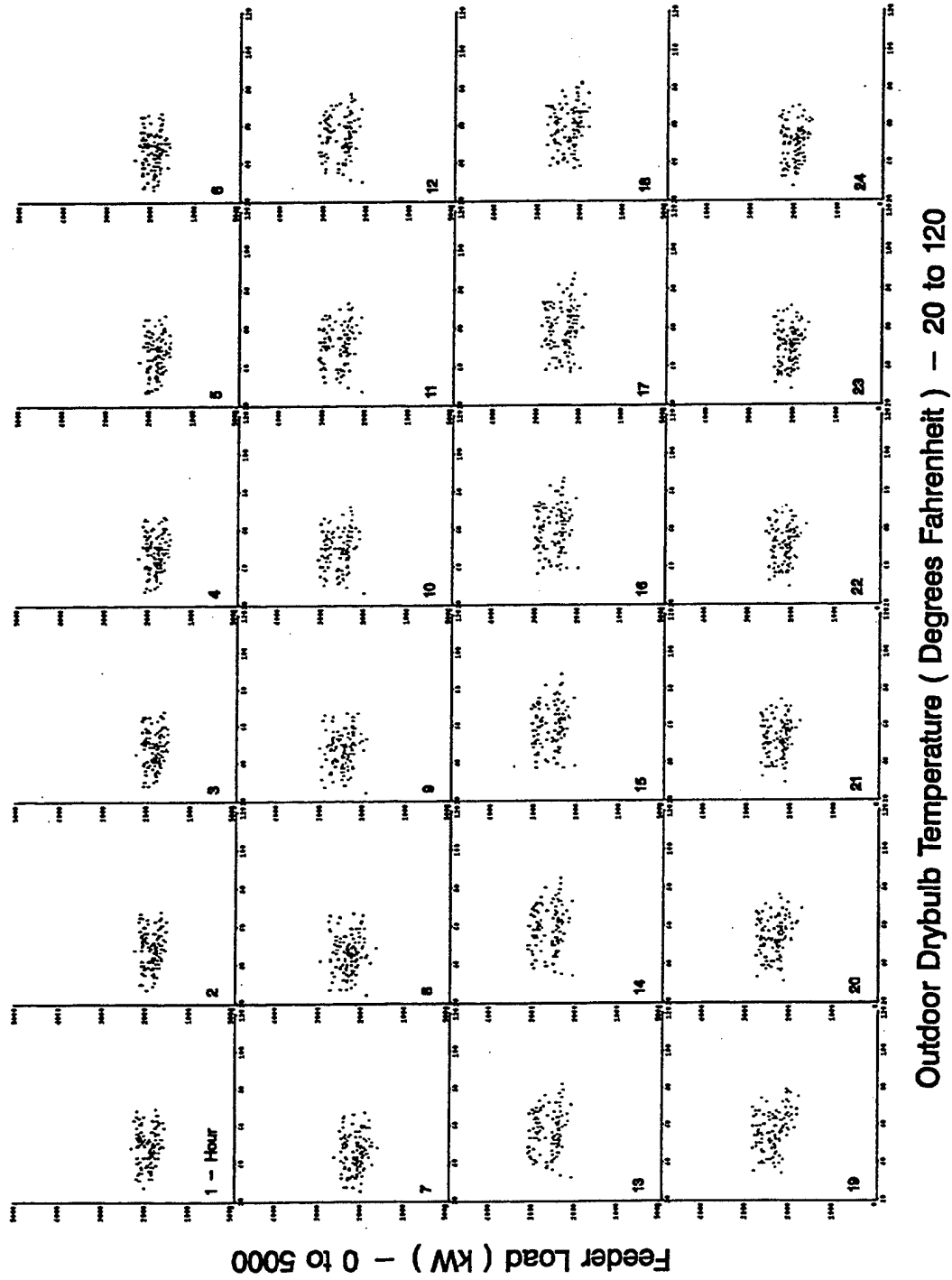


Figure A-37. Scatterplots of Feeder 15 Hourly Load vs. Drybulb Temperature for Standard Winter Days

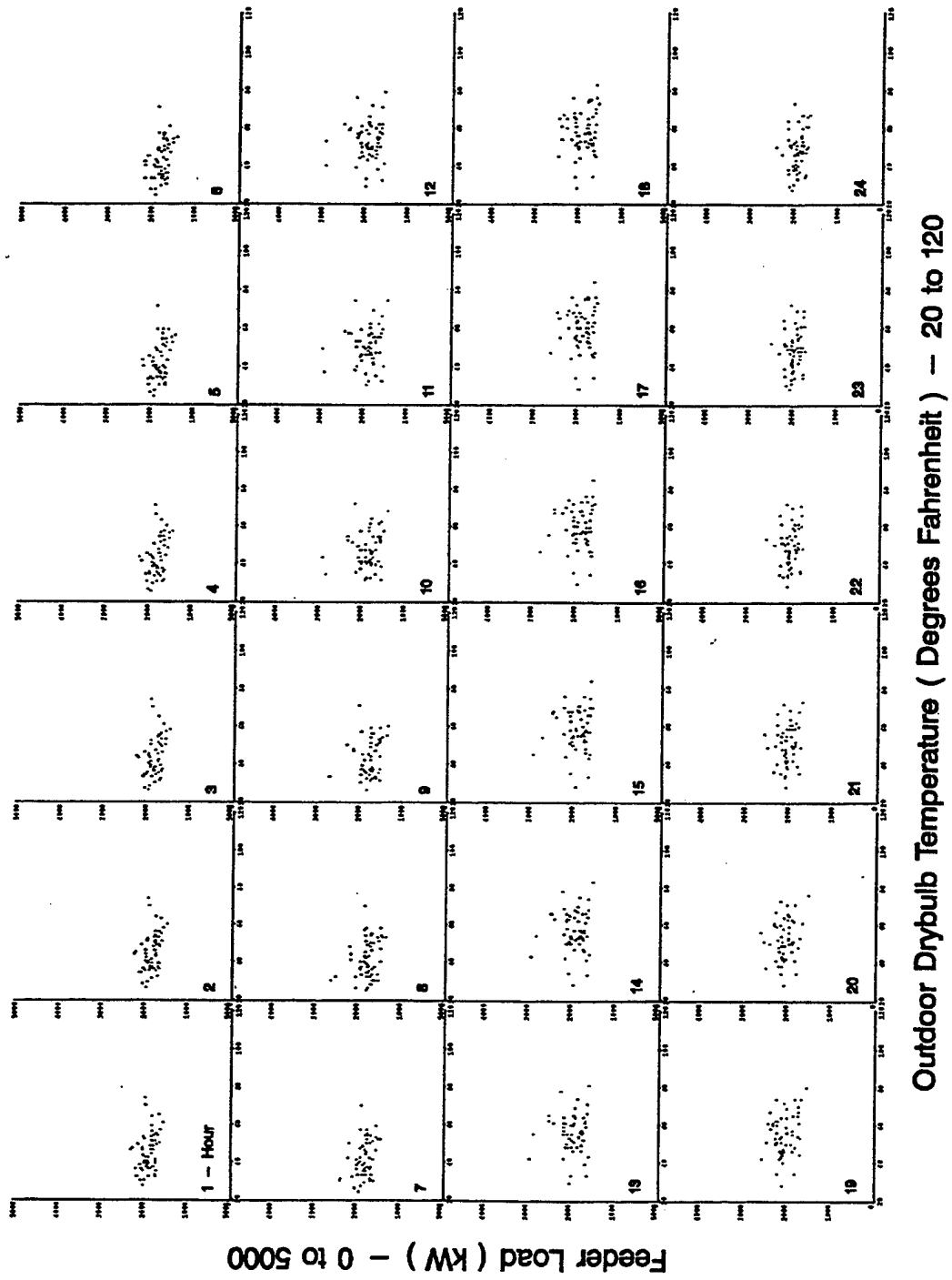


Figure A-38. Scatterplots of Feeder 15 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days

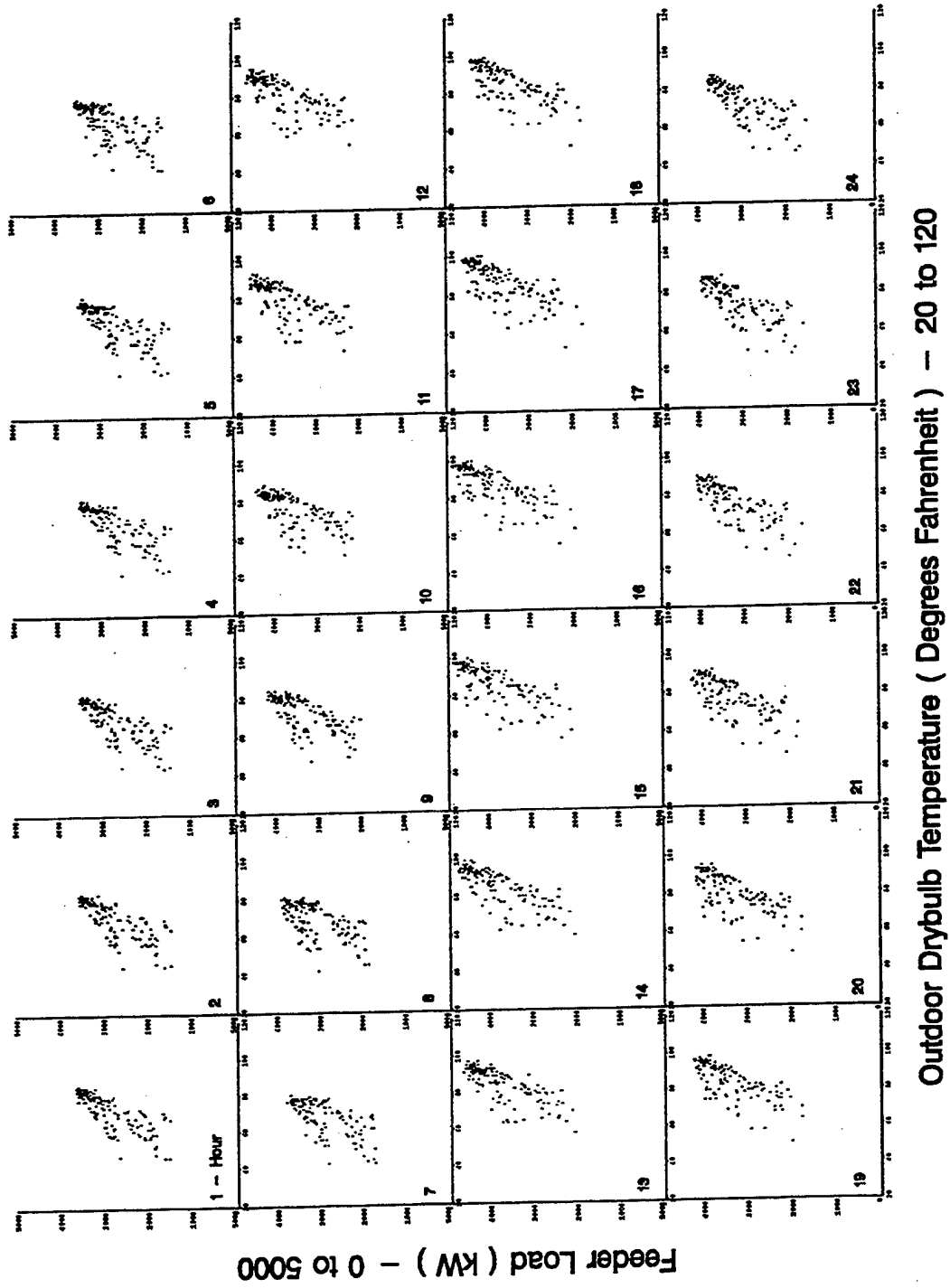


Figure A-39. Scatterplots of Feeder 15 Hourly Load vs. Drybulb Temperature for Standard Summer Days

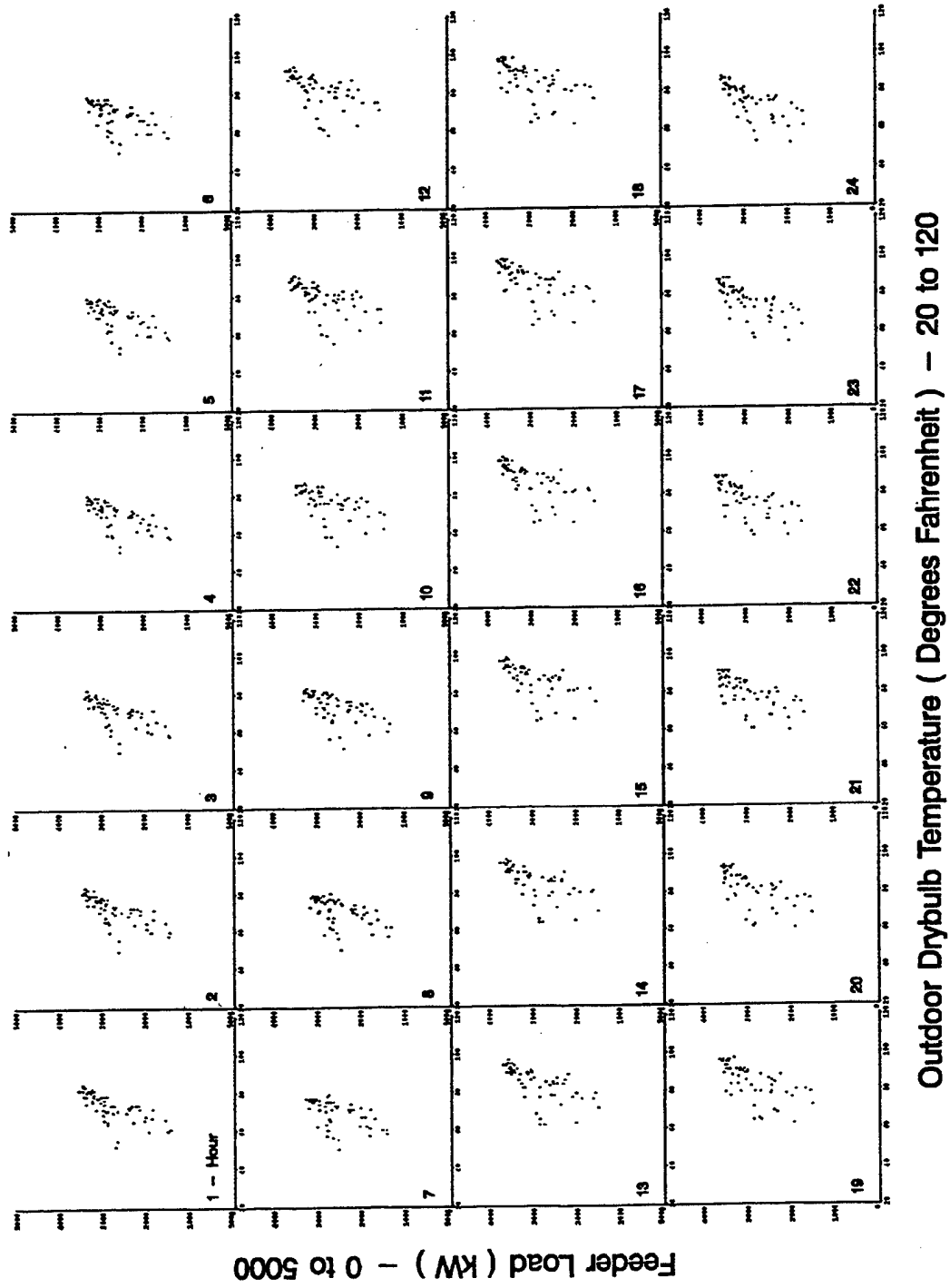


Figure A-40. Scatterplots of Feeder 15 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days

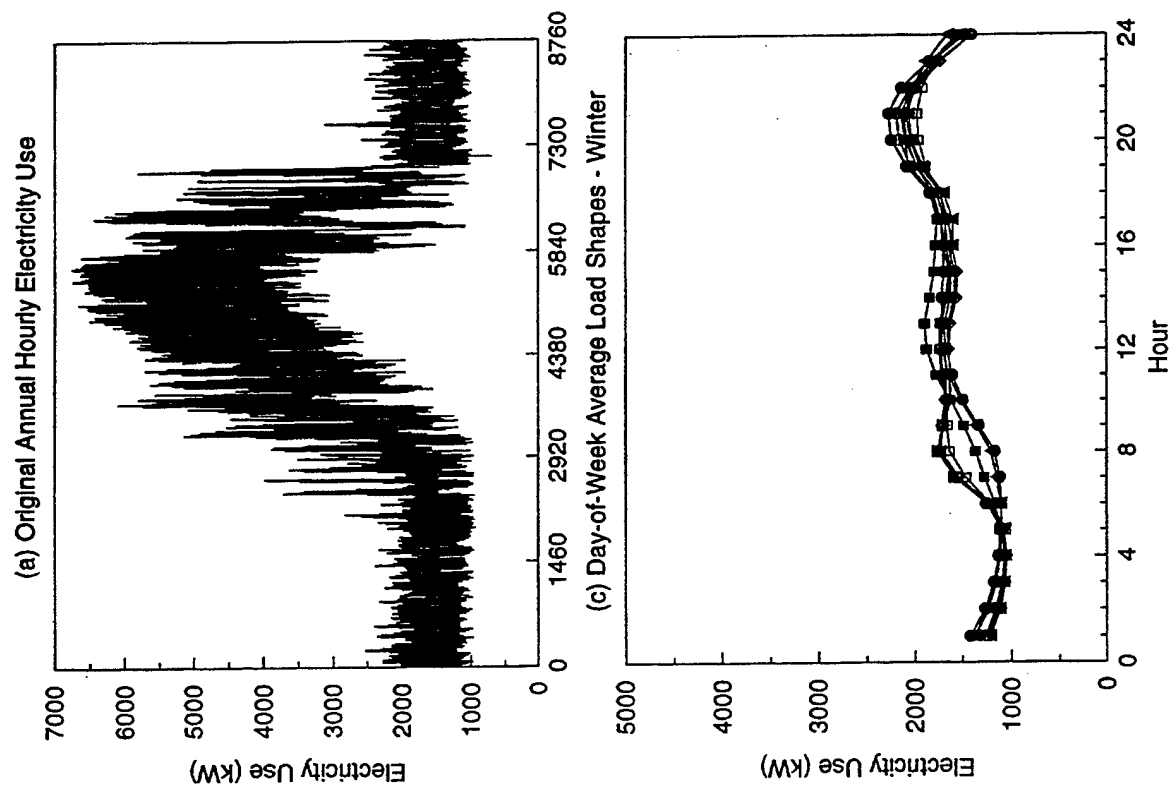


Figure A-41. Feeder W4 Data

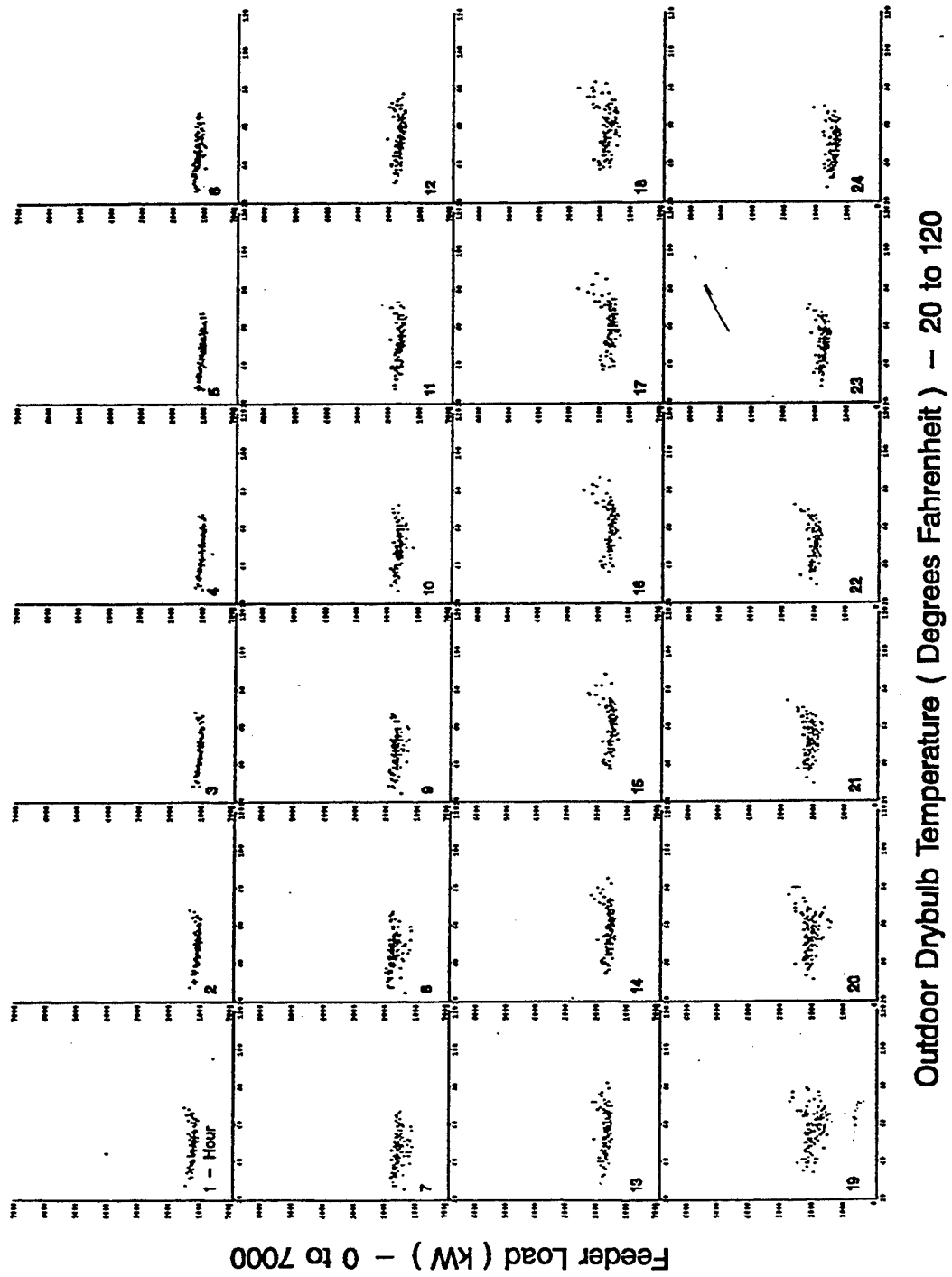


Figure A-42. Scatterplots of Feeder W4 Hourly Load vs. Drybulb Temperature for Standard Winter Days

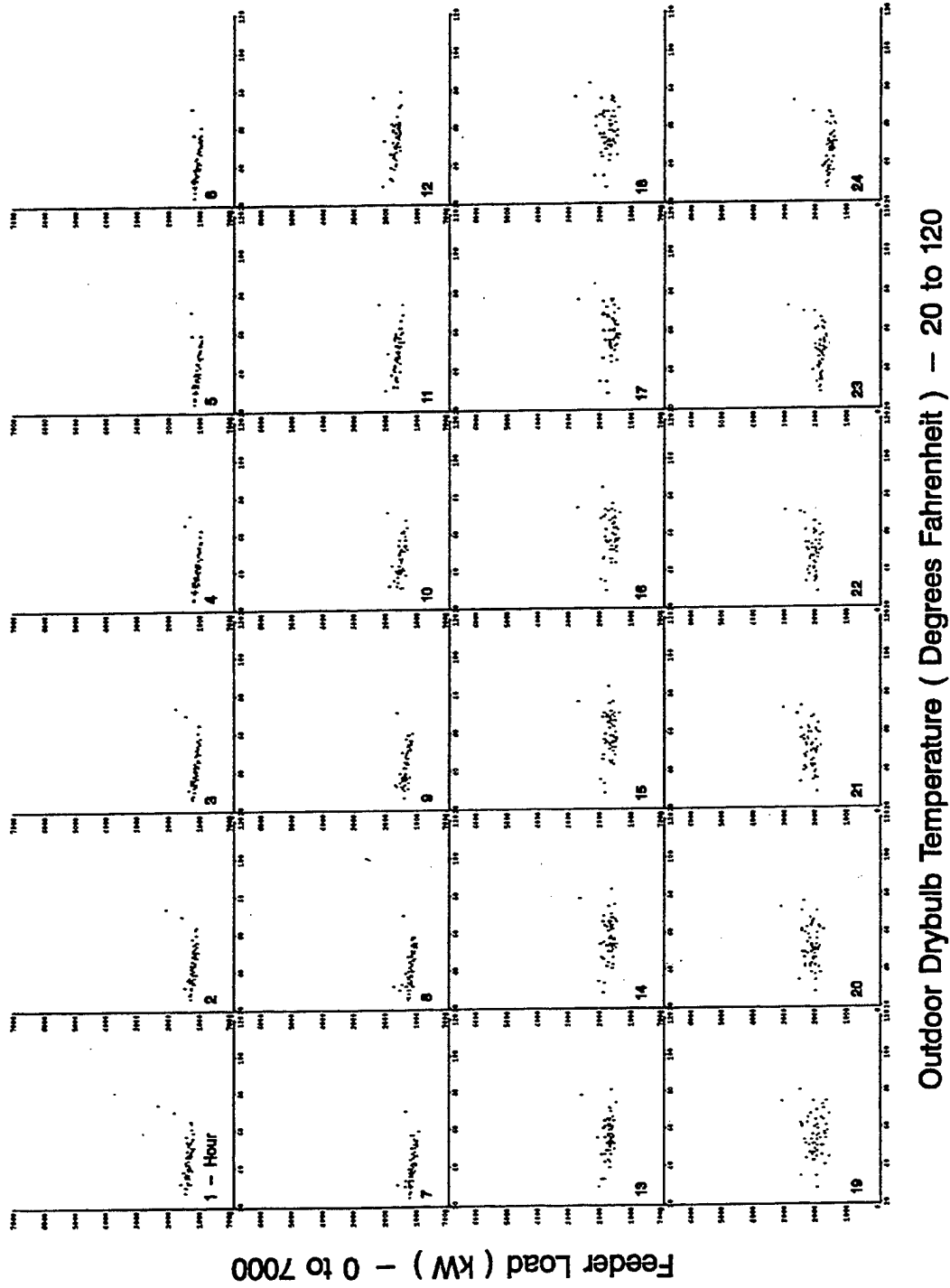


Figure A-43. Scatterplots of Feeder W4 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days

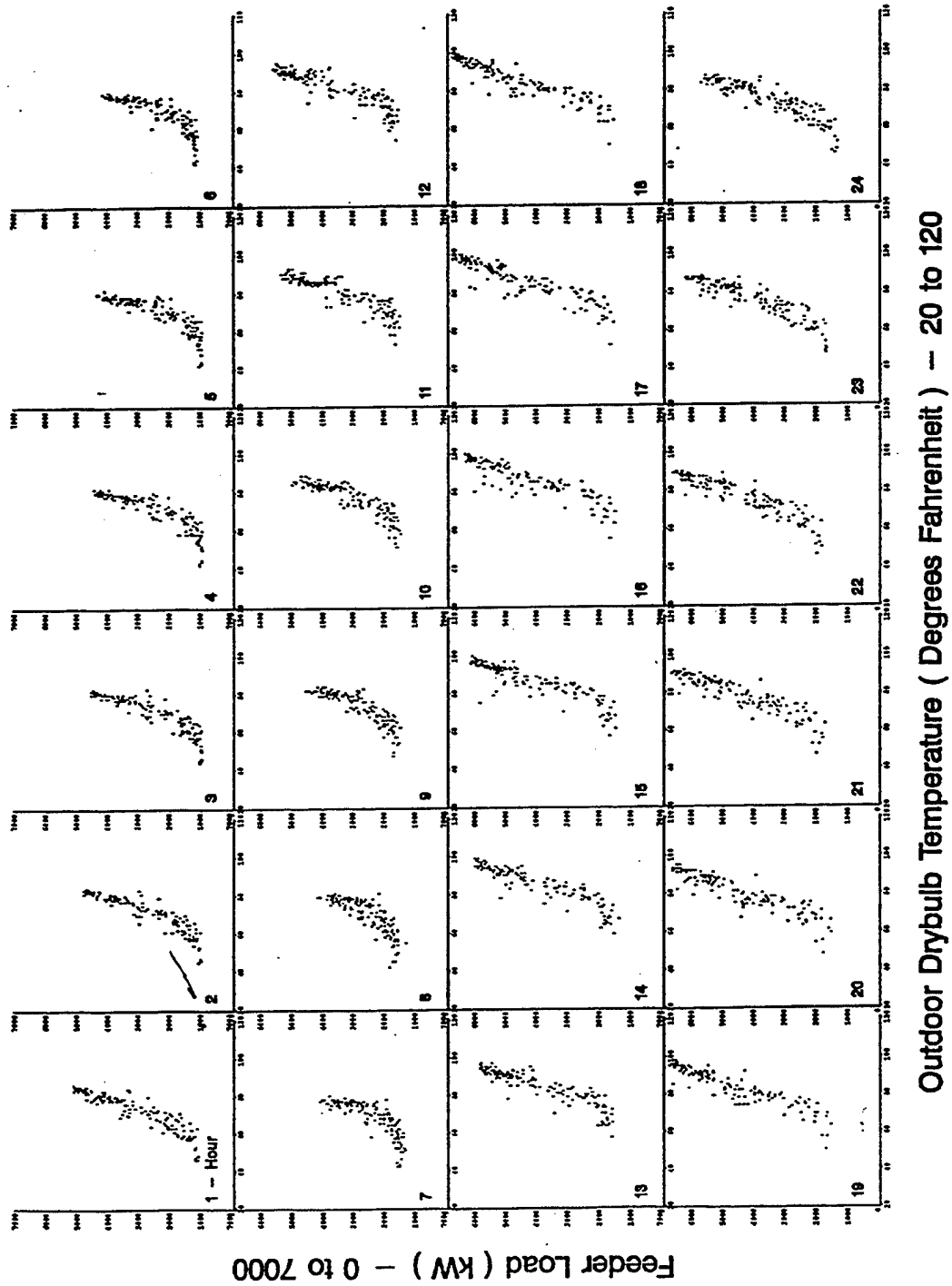


Figure A-44. Scatterplots of Feeder W4 Hourly Load vs. Drybulb Temperature for Standard Summer Days

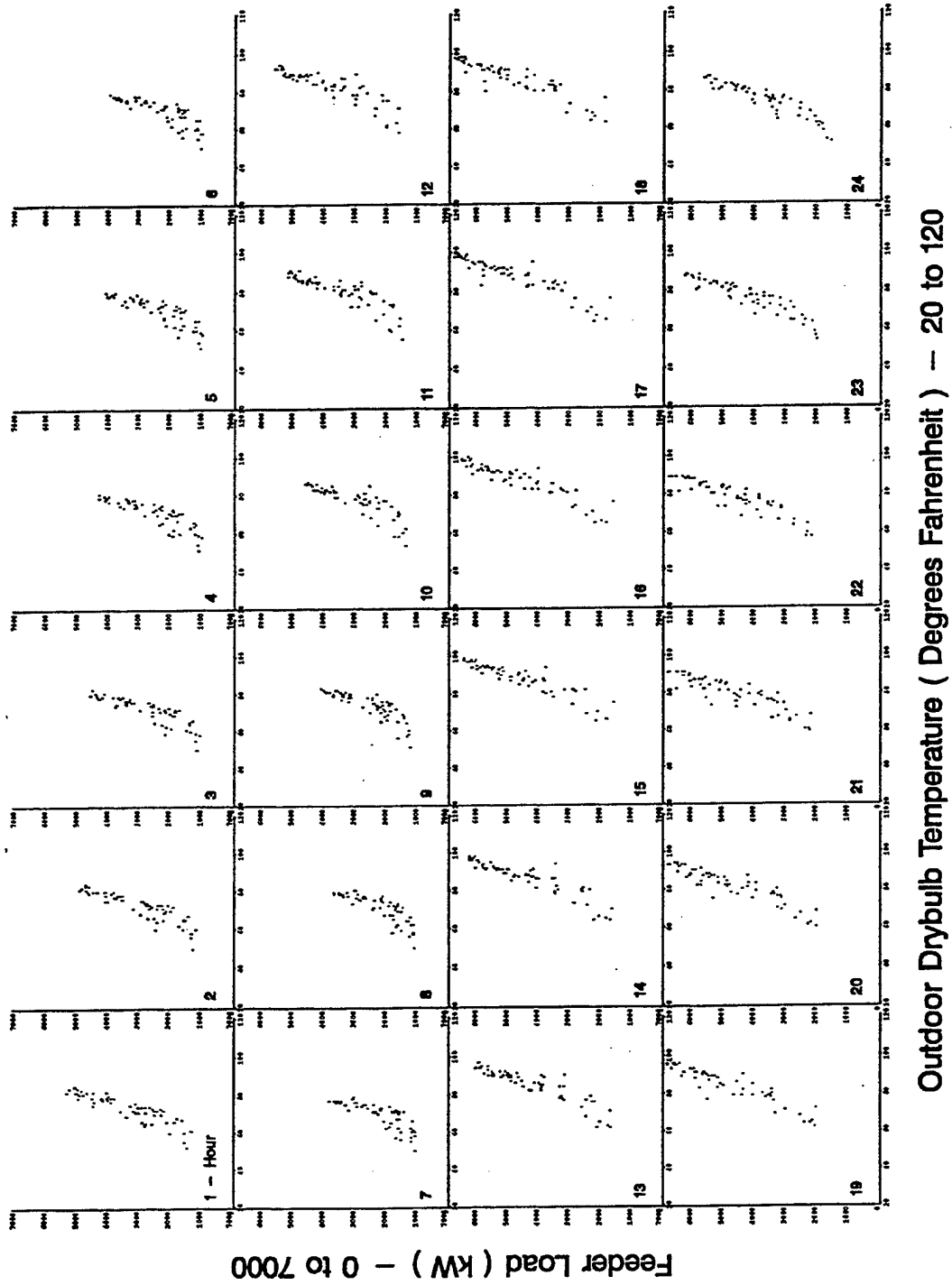


Figure A-45. Scatterplots of Feeder W4 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days

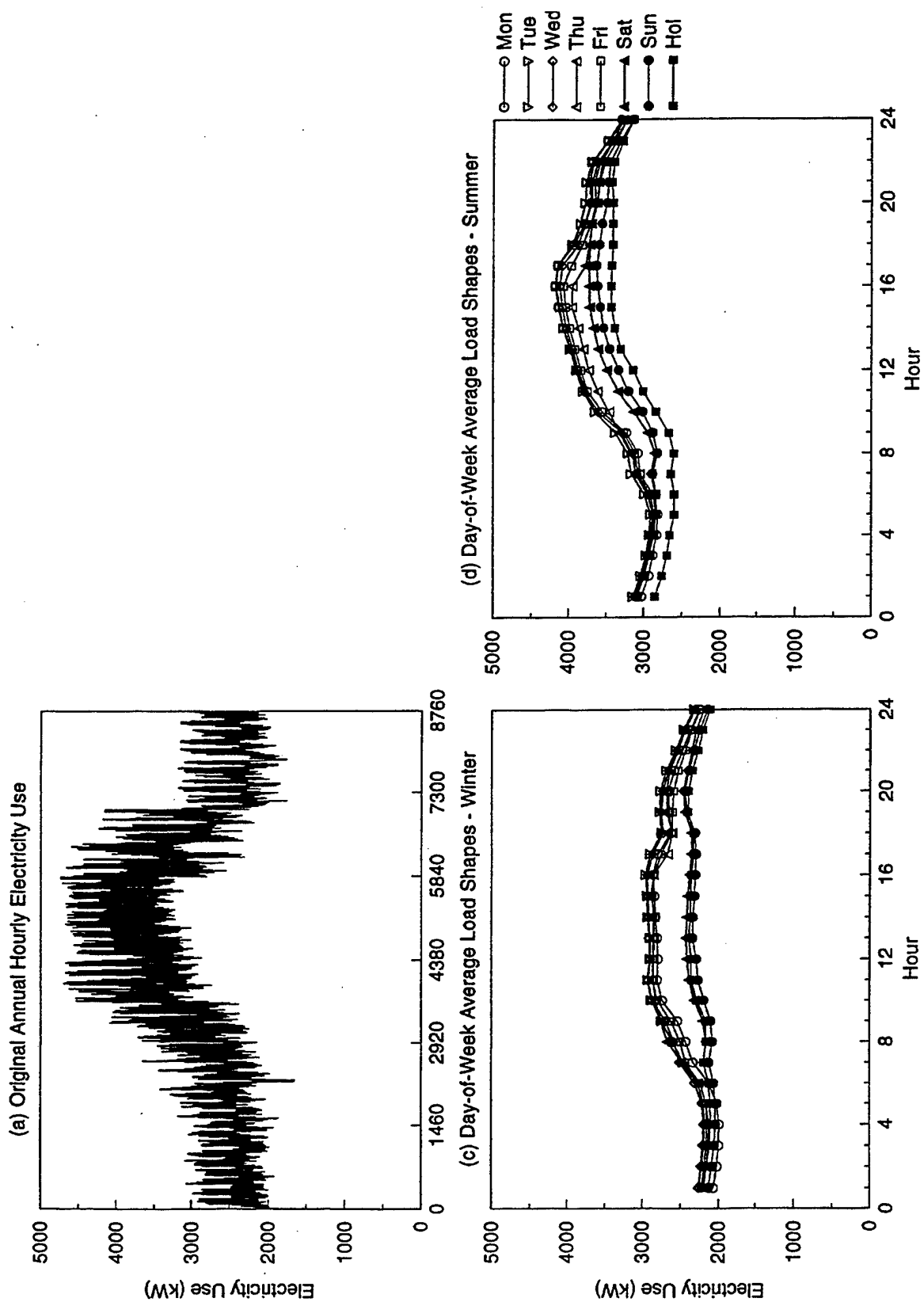


Figure A-46. Feeder W5 Data

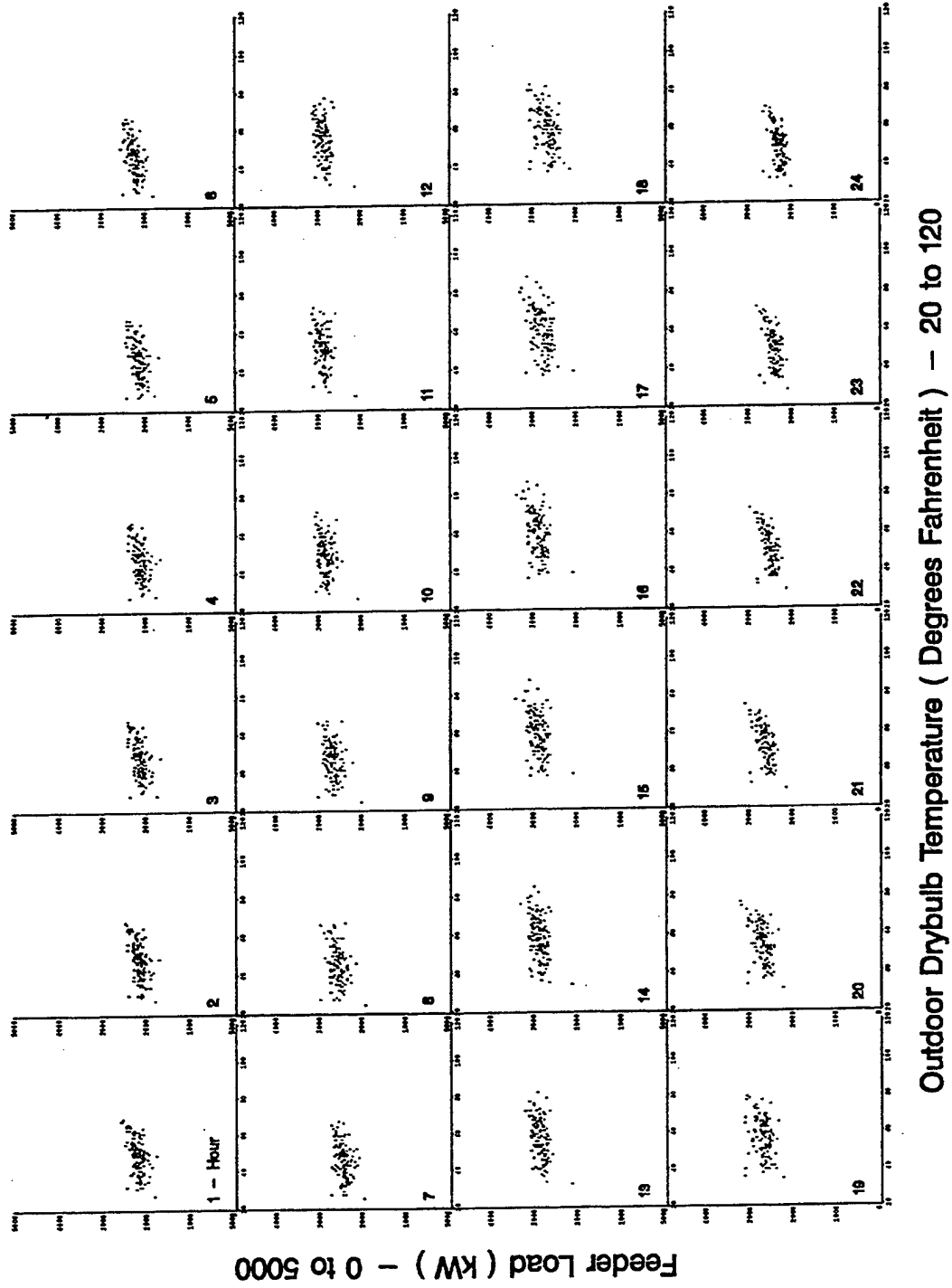


Figure A-47. Scatterplots of Feeder W5 Hourly Load vs. Drybulb Temperature for Standard Winter Days

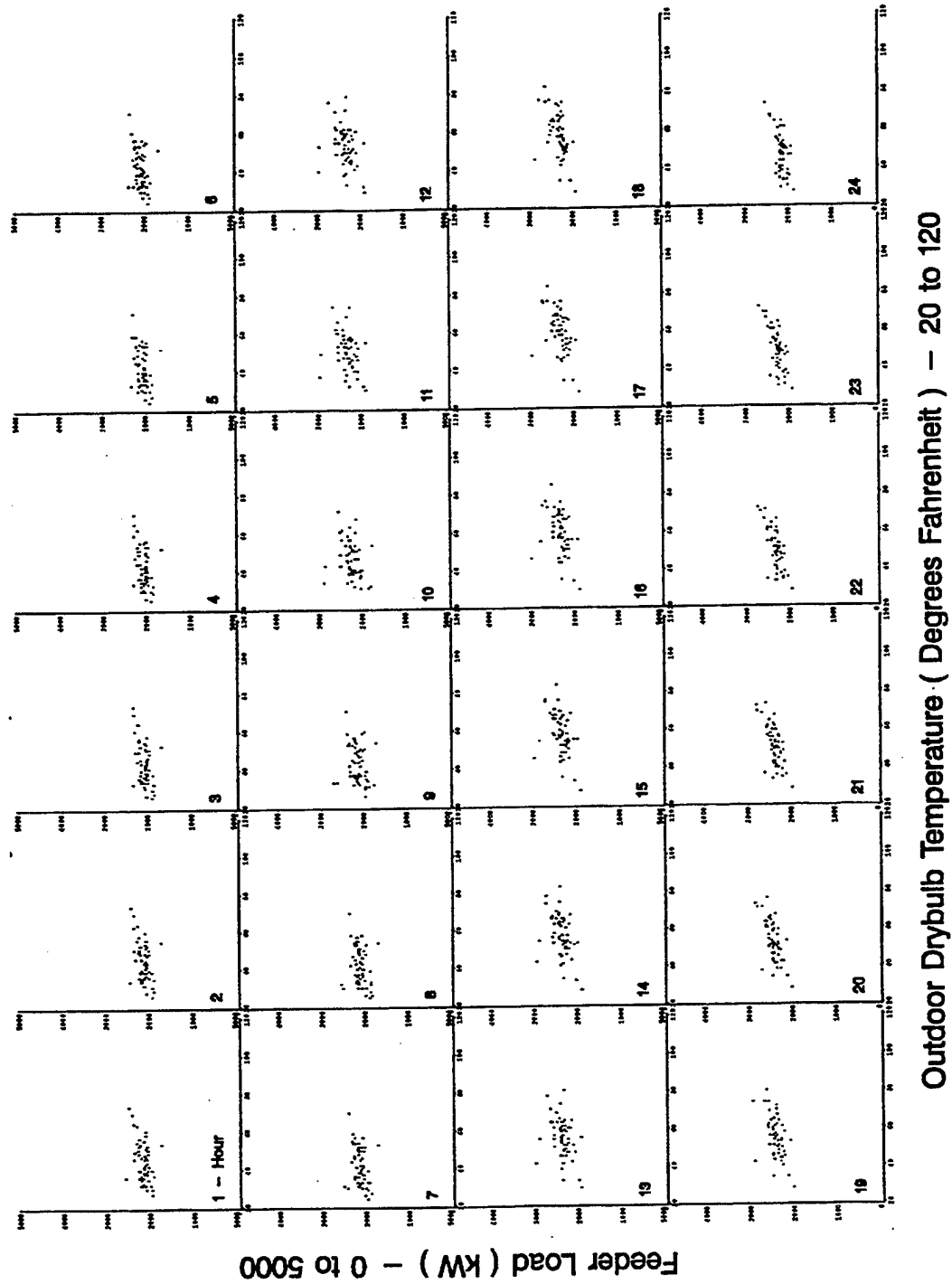


Figure A-48. Scatterplots of Feeder W5 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days

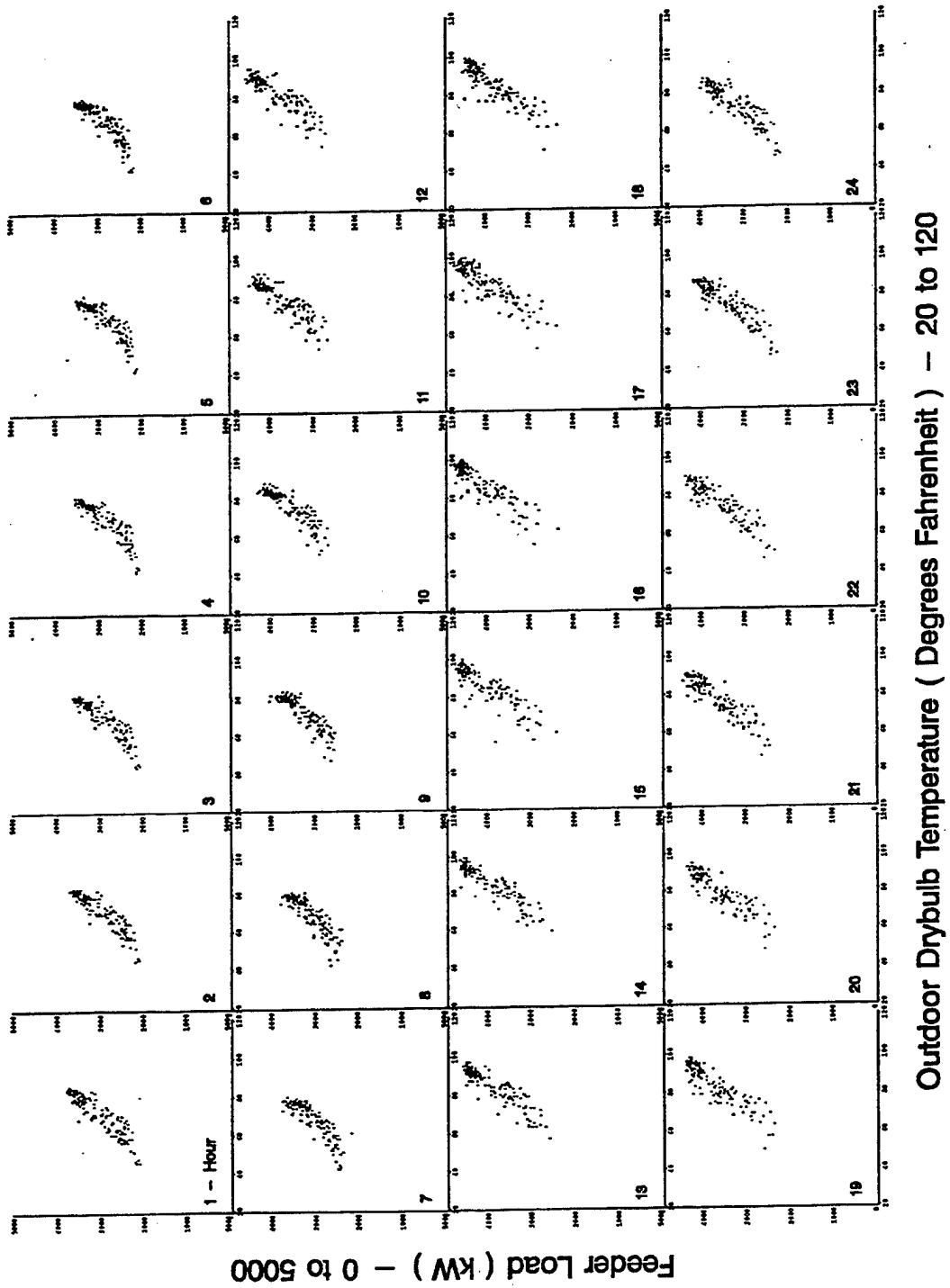


Figure A-49. Scatterplots of Feeder W5 Hourly Load vs. Drybulb Temperature for Standard Summer Days

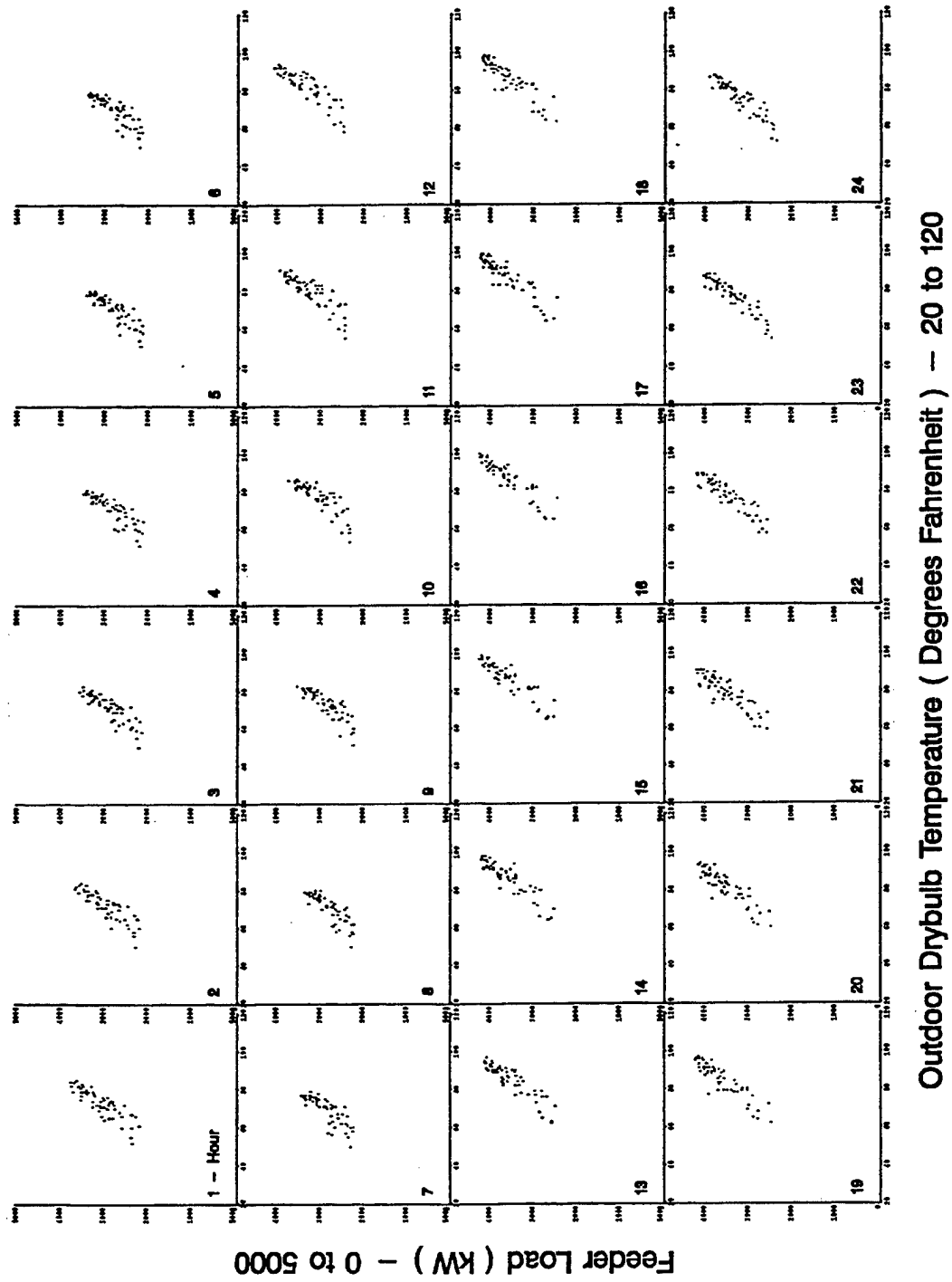


Figure A-50. Scatterplots of Feeder W5 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days

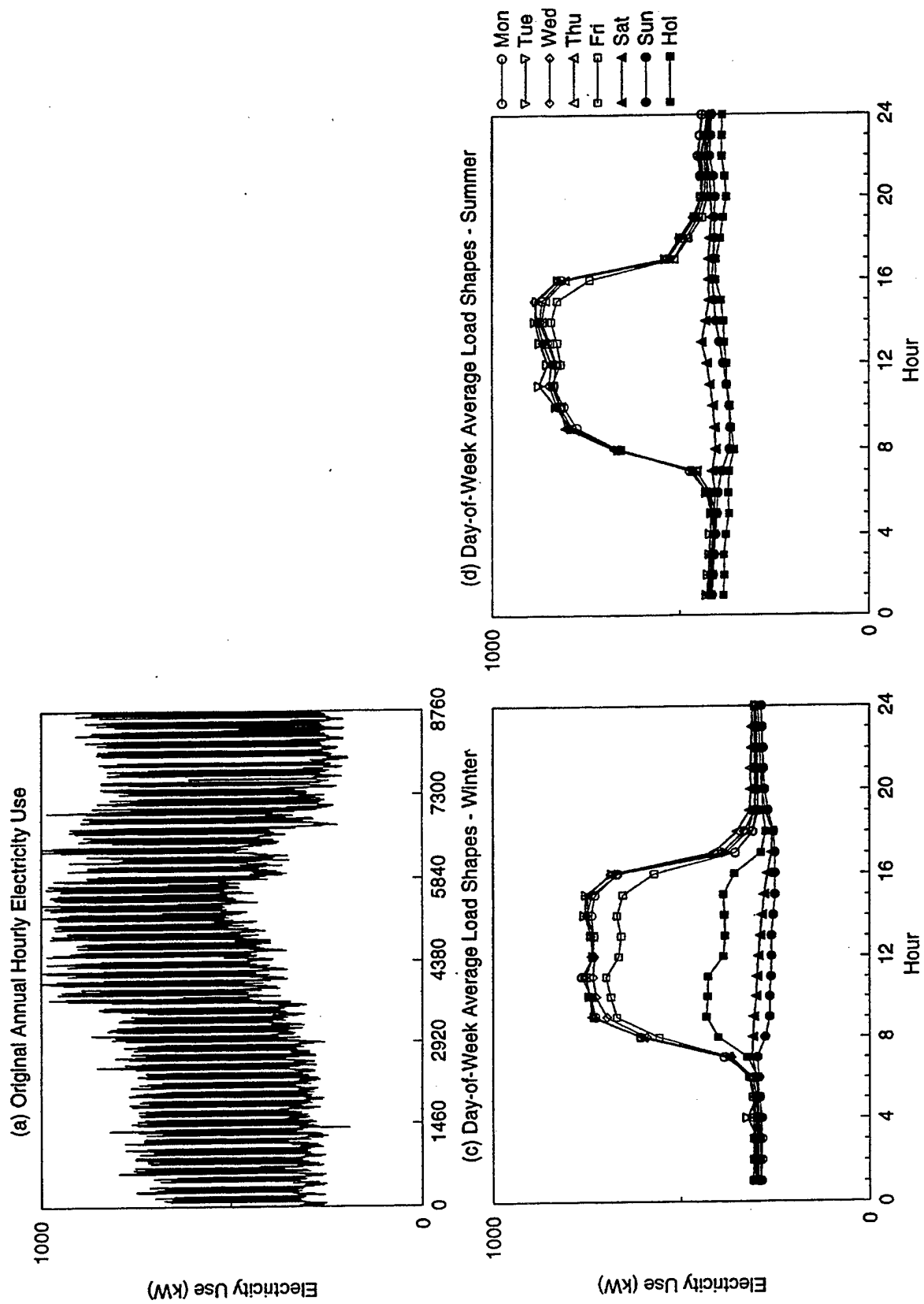


Figure A-51. Feeder W6 Data

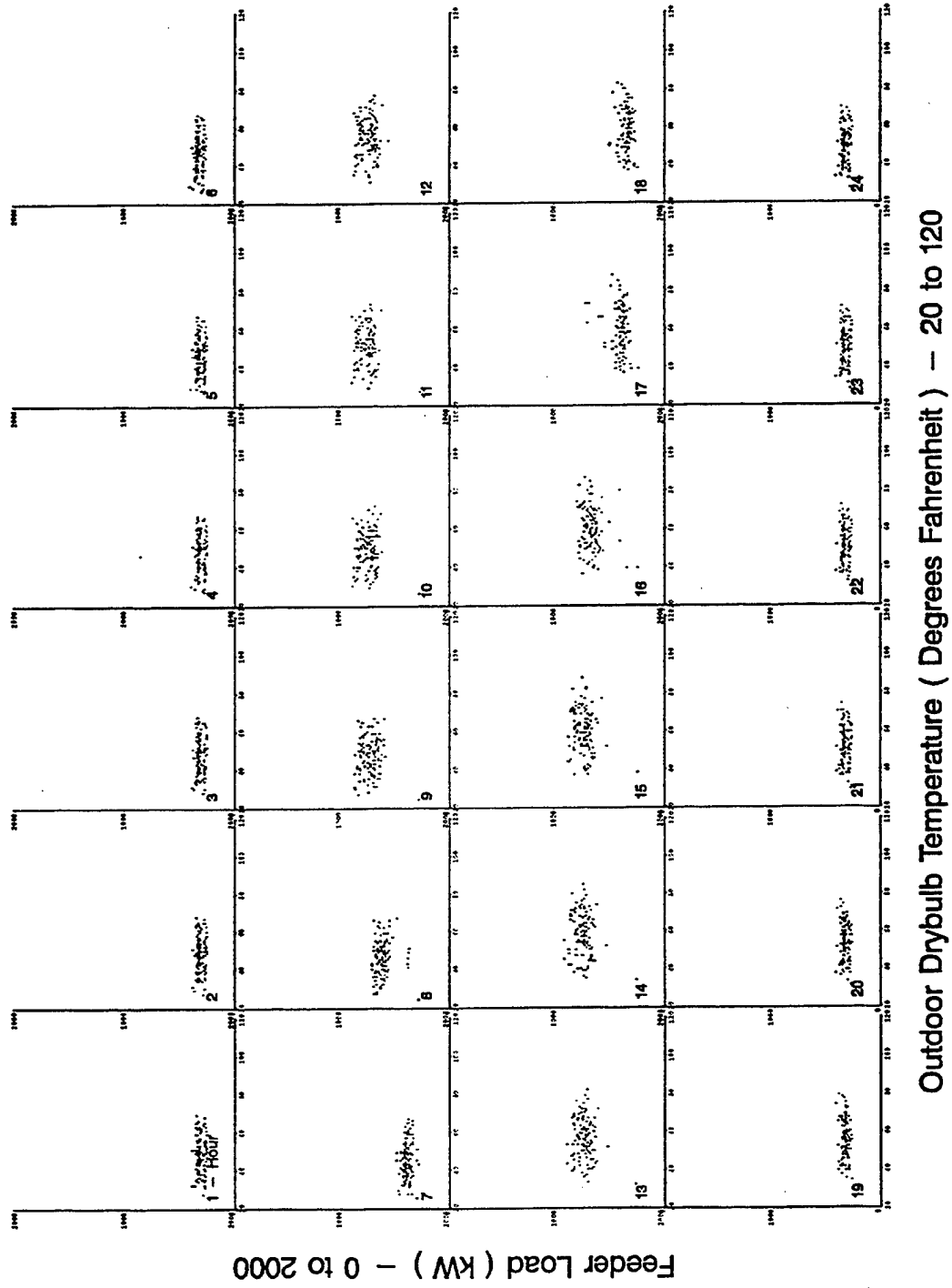


Figure A-52. Scatterplots of Feeder W6 Hourly Load vs. Drybulb Temperature for Standard Winter Days

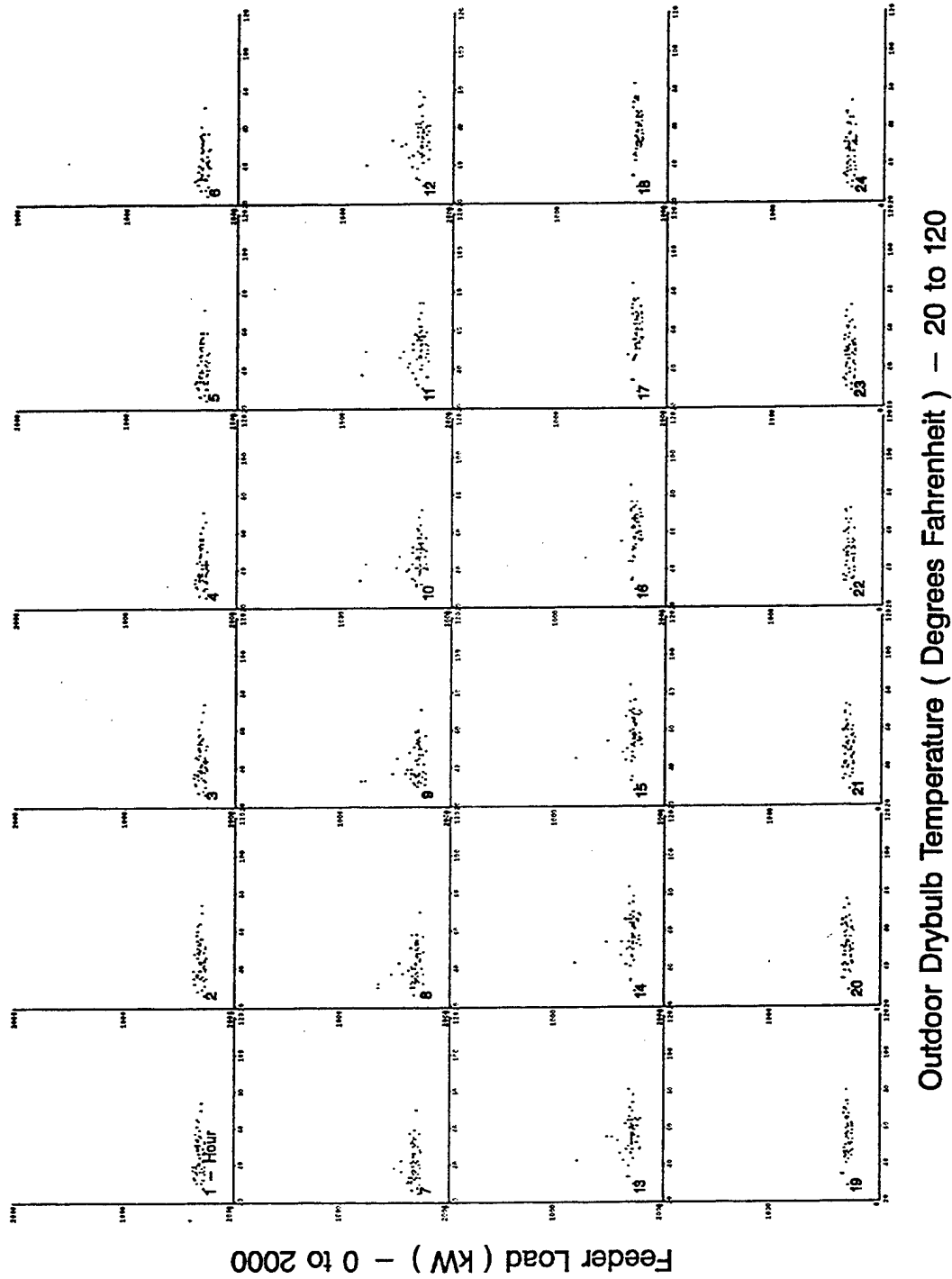


Figure A-53. Scatterplots of Feeder W6 Hourly Load vs. Drybulb Temperature for non-Standard Winter Days

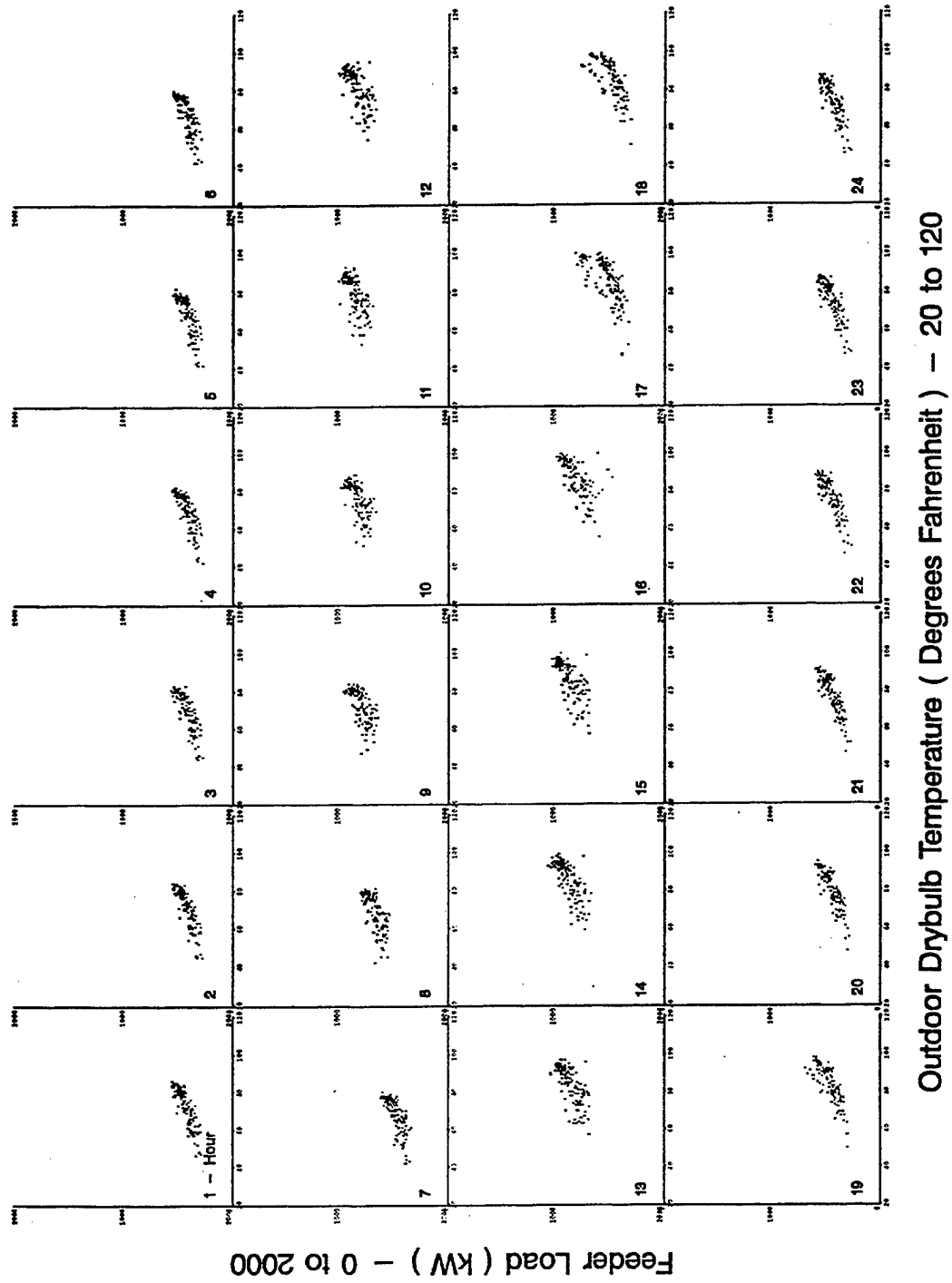


Figure A-54. Scatterplots of Feeder W6 Hourly Load vs. Drybulb Temperature for Standard Summer Days

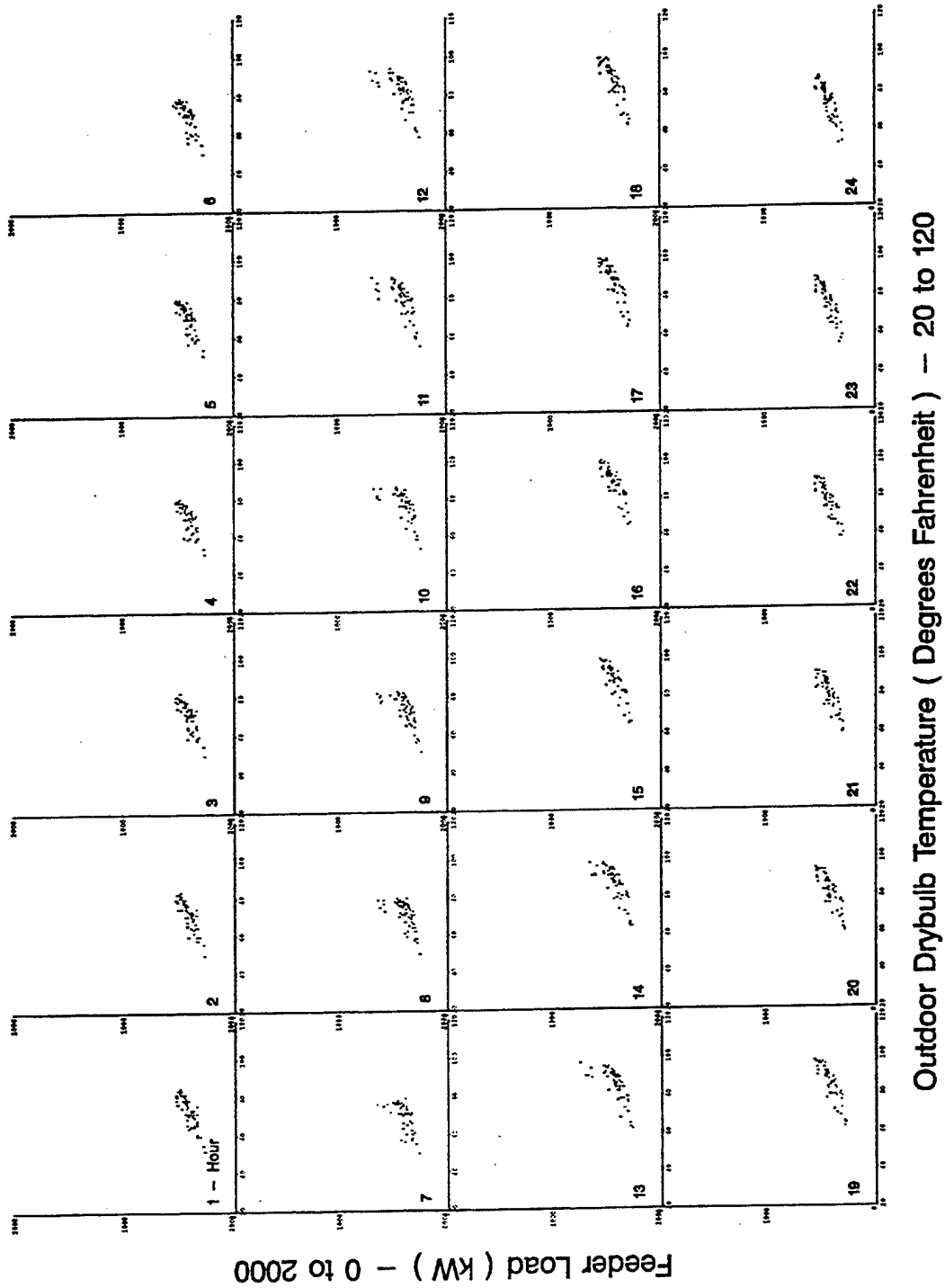


Figure A-55. Scatterplots of Feeder W6 Hourly Load vs. Drybulb Temperature for non-Standard Summer Days

Appendix B

Prototype Characteristic Tables and DOE-2 Simulated Loadshapes

Prototype characteristic tables and DOE-2 simulated loadshapes are presented in this appendix in the order specified in **Table 1-1**.

Tables B-1 to B-30. Prototype Characteristic Tables

Figures B-1 to B-30. DOE-2 Simulated End-use Load Shapes

Table B-1(a). Hammerhead Barrack - Prototype Characteristics

Construction	
Floor Area (ft ²)	33337
Number of Floors	3
Floor Materials	4" Light Weight Concrete Carpet w/ Pad
Roof Materials	3/8" Built-up Roofing 3" Rigid Insulation 4" Light Weight Concrete Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	1" Exterior Insulation Board 1/2" Sheathing 6" Batt Insulation R-19 Metal Studs 5/8" Gypsum Board
Window Characteristics	
Number of Panes	2
Shading Coefficient	0.57
Window/Wall Ratio	0.30
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.05
HVAC System	
Economizer	Inactive
Cooling	
Type	Herm Cent Chiller / Cooling Tower
Setpoint (°F)	76
Availability	Apr 11 - Oct 22
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	72
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	1 - 9 and 17 - 24
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	1 - 24
Intensity	80% of Standard Days

Table B-1(b). Hammerhead Barrack - Prototype Zonal Characteristics

	Barracks	Office	Total
Floor Area (% total)	58	42	100
Occupancy	112	75	-
Outside Air / Person (CFM)	10	10	-
Cooking (W/ft ²)	0.33	-	0.19
Interior Lights (W/ft ²)	1.1	1.1	0.68
Miscellaneous (W/ft ²)	1.1	0.4	0.65
Refrigeration (W/ft ²)	0.58	-	0.34
System Type	TPFC	VAVS	-
Fan Type	Constant Volume	Variable Volume	-

Table B-2(a). Rolling Pin Barrack - Prototype Characteristics

Construction	
Floor Area (ft ²)	64666
Number of Floors	3
Floor Materials	4" Light Weight Concrete Carpet w/ Pad
Roof Materials	3/8" Built-up Roofing 3" Rigid Insulation Steel Deck Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	4" Face Brick Air Layer 8" Concrete Masonary Unit, Medium, Hollow
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.57
Window/Wall Ratio	0.30
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.03
HVAC System	
Economizer	Inactive
Cooling	
Type	Herm Cent Chiller / Cooling Tower
Setpoint (°F)	76
Availability	Apr 11 - Oct 22
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	74
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	1 - 9 and 17 - 24
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	1 - 24

Table B-2(b). Rolling Pin Barrack - Prototype Zonal Characteristics

	Barracks	Office	Total
Floor Area (% total)	67	33	100
Occupancy	544	35	-
Outside Air / Person (CFM)	10	10	-
Cooking (W/ft ²)	0.33	-	0.22
Interior Lights (W/ft ²)	0.81	0.81	0.57
Miscellaneous (W/ft ²)	0.40	0.40	0.28
Refrigeration (W/ft ²)	0.63	-	0.42
System Type	VAVS	VAVS	-
Fan Type	Variable Volume	Variable Volume	-

Table B-3(a). Modular Barrack - Prototype Characteristics

Construction	
Floor Area (ft ²)	33633
Number of Floors	3
Floor Materials	4" Light Weight Concrete Carpet w/ Pad
Roof Materials	3/8" Built-up Roofing 2" Rigid Insulation 6" Light Weight Concrete Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	4" Face Brick Air Layer 6" Concrete Masonary Unit w/ Perlite
Window Characteristics	
Number of Panes	2
Shading Coefficient	0.57
Window/Wall Ratio	0.20
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.03
HVAC System	
Economizer	Inactive
Fan Type	Constant Volume
Cooling	
Type	Herm Cent Chiller / Cooling Tower
Setpoint (°F)	76
Availability	Apr 11 - Oct 22
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	74
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	1 - 9 and 17 - 24
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	1 - 24
Intensity	80% of Standard Days

Table B-3(b). Modular Barrack - Prototype Zonal Characteristics

	Barracks	Lobby	Total
Floor Area (% total)	80	20	100
Occupancy	200	2	-
Outside Air / Person (CFM)	10	10	-
Cooking (W/ft ²)	0.20	-	0.16
Interior Lights (W/ft ²)	0.80	0.80	0.80
Miscellaneous (W/ft ²)	1.07	-	0.86
Refrigeration (W/ft ²)	0.36	-	0.29
System Type	TPFC	TPFC	-

Table B-4. Small Barrack - Prototype Characteristics

Construction	
Floor Area (ft ²)	4867
Number of Floors	1
Floor Materials	Carpet w/ Pad
Roof Materials	Asphalt Shingle
	1" Plywood
	R-19 Insulation
	1" Plywood
	Air Layer
	1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	4" Face Brick
	Air Layer
	6" Concrete Masonary Unit, Heavy, Filled w/ Perlite
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.57
Window/Wall Ratio	0.30
Non-HVAC Loads	
Occupancy	8
Outside Air / Person (CFM)	10
Cooking (W/ft ²)	0.10
Exterior Lights (W/ft ²)	0.05
Interior Lights (W/ft ²)	0.60
Miscellaneous (W/ft ²)	0.40
Refrigeration (W/ft ²)	0.20
HVAC System	
Economizer	Inactive
System Type	PVAVS
Fan Type	Variable Volume
Cooling	
Type	Direct Expansion / Air Cooled
Setpoint (°F)	76
Availability	Apr 11 - Oct 22
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	74
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	1 - 9 and 17 - 24
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	1 - 24

Table B-5(a). Dining Hall Prototype Characteristics

Construction	
Floor Area (ft ²)	4361
Number of Floors	1
Floor Material	4" Light Weight Concrete
Roof Materials	3/8" Built-up Roofing 3 1/2" Rigid Insulation Steel Deck Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	4" Face Brick Air Layer 8" Concrete Masonary Unit
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.57
Window/Wall Ratio	0.20
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.03
HVAC System	
Economizer	Inactive
Fan Type	Constant Volume
Cooling	
Type	Herm Cent Chiller / Cooling Tower
Setpoint (°F)	76
Availability	Apr 11 - Oct 22
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	68/72
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	4 - 20
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	6 - 19

Table B-5(b). Dining Hall Prototype Zonal Characteristics

	Kitchen	Dining	Total
Floor Area (% total)	50	50	100
Occupancy	15	150	-
Outside Air / Person (CFM)	10	10	-
Cooking (W/ft ²)	3.30	-	1.65
Interior Lights (W/ft ²)	0.94	0.94	0.94
Refrigeration (W/ft ²)	1.40	-	0.70
System Type	TPFC	TPFC	-

Table B-6(a). Gymnasium Prototype Characteristics

Construction	
Floor Area (ft ²)	58333
Number of Floors	1
Floor Material	1" Hardwood
Roof Materials	3/8" Built-up Roofing 3 1/2" Rigid Insulation Steel Deck
Slab Material	6" Heavy Weight Concrete
Wall Materials	4" Face Brick Air Layer 8" Medium, Hollow Concrete Masonary Unit
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.88
Window/Wall Ratio	0.10
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.04
HVAC System	
Economizer	Inactive
Cooling	
Type	Direct Expansion / Air Cooled
Setpoint (°F)	76
Availability	Apr 11 - Oct 22
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	72
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	6 - 22
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	8 - 19

Table B-6(b). Gymnasium Prototype Zonal Characteristics

	Office/Locker/Handball	Natatorium	Basketball Court	Total
Floor Area (% total)	30	20	50	100
Occupancy	30	15	40	85
Outside Air / Person (CFM)	10	10	10	10
Interior Lights (W/ft ²)	0.41	0.20	0.94	1.55
Miscellaneous (W/ft ²)	0.08	0.12	0.07	0.13
Pumps (W/ft ²)	-	0.004	-	0.0007
System Type	PVAVS	UH	UH	-
Fan Type	Variable Volume	Constant Volume	Constant Volume	-

Table B-7. Large Administration Prototype Characteristics

Construction	
Floor Area (ft ²)	168528
Number of Floors	3
Floor Materials	4" Light Weight Concrete Carpet w/ Pad
Roof Materials	3/8" Built-up Roofing 2 1/2" Roof Insulation Metal Deck Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	Face Brick 6" Metal Studs 3 1/2" R-11 Insulation Air Layer 5/8" Gypsum
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.55
Window/Wall Ratio	0.40
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.02
Interior Lights (W/ft ²)	1.32
Miscellaneous (W/ft ²)	2.45
Occupancy	380
Outside Air / Person (CFM)	10
HVAC System	
Economizer	Active
System Type	VAVS
Fan Type	Variable Volume
Cooling	
Type	Herm Cent Chiller / Cooling Tower
Setpoint (°F)	76
Availability	Apr 11 - Oct 22
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	70
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	8 - 17
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	8 - 17

Table B-8. Small Administration - Old w/ Split DX Prototype Characteristics

Construction	
Floor Area (ft ²)	5015
Number of Floors	1
Floor Materials	4" Light Weight Concrete Carpet w/ Pad
Roof Materials	3/8" Built-up Roofing 2 1/2" Roof Insulation Metal Deck Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	4" Face Brick Air Layer 8" Medium Weight Concrete Masonary Unit
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.62
Window/Wall Ratio	0.4
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.03
Interior Lights (W/ft ²)	2.50
Miscellaneous (W/ft ²)	0.73
Occupancy (ft ² /person)	148
Outside Air / Person (CFM)	10
HVAC System	
Economizer	Inactive
System Type	PVAVS
Fan Type	Variable Volume
Cooling	
Type	Direct Expansion / Air Cooled
Setpoint (°F)	76
Availability	Apr 11 - Oct 23
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	72
Availability	Apr 11 - Oct 23
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	6 - 18
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	Unoccupied

Table B-9. Small Administration - Old w/ Chiller Prototype Characteristics

Construction	
Floor Area (ft ²)	6403
Number of Floors	1
Floor Materials	4" Light Weight Concrete Carpet w/ Pad
Roof Materials	3/8" Built-up Roofing 2 1/2" Roof Insulation Metal Deck Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	4" Face Brick Air Layer 8" Medium Weight Concrete Masonary Unit
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.62
Window/Wall Ratio	0.4
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.03
Interior Lights (W/ft ²)	2.50
Miscellaneous (W/ft ²)	0.73
Occupancy (ft ² /person)	148
Outside Air / Person (CFM)	10
HVAC System	
Economizer	Inactive
System Type	VAVS
Fan Type	Variable Volume
Cooling	
Type	Herm Cent Chiller / Cooling Tower
Setpoint (°F)	76
Availability	Apr 11 - Oct 23
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	72
Availability	Apr 11 - Oct 23
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	6 - 18
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	Unoccupied

Table B-10. Small Administration - New w/ Split DX Prototype Characteristics

Construction	
Floor Area (ft ²)	6334
Number of Floors	1
Floor Materials	4" Light Weight Concrete Carpet w/ Pad
Roof Materials	3/8" Built-up Roofing 3" Roof Insulation Metal Deck Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	4" Face Brick 3" Rigid Insulation 8" Medium Weight Concrete Masonary Unit
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.30
Window/Wall Ratio	0.4
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.03
Interior Lights (W/ft ²)	2.50
Miscellaneous (W/ft ²)	0.73
Occupancy (ft ² /person)	148
Outside Air / Person (CFM)	10
HVAC System	
Economizer	Active
System Type	PVAVS
Fan Type	Variable Volume
Cooling	
Type	Direct Expansion / Air Cooled
Setpoint (°F)	76
Availability	Apr 11 - Oct 23
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	72
Availability	Apr 11 - Oct 23
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	6 - 18
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	Unoccupied

Table B-11. Small Administration - New w/ Chiller Prototype Characteristics

Construction	
Floor Area (ft ²)	4398
Number of Floors	1
Floor Materials	4" Light Weight Concrete Carpet w/ Pad
Roof Materials	3/8" Built-up Roofing 3" Roof Insulation Metal Deck Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	4" Face Brick 3" Rigid Insulation 8" Medium Weight Concrete Masonary Unit
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.30
Window/Wall Ratio	0.4
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.03
Interior Lights (W/ft ²)	2.50
Miscellaneous (W/ft ²)	0.73
Occupancy (ft ² /person)	148
Outside Air / Person (CFM)	10
HVAC System	
Economizer	Active
System Type	VAVS
Fan Type	Variable Volume
Cooling	
Type	Herm Cent Chiller / Cooling Tower
Setpoint (°F)	76
Availability	Apr 11 - Oct 23
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	72
Availability	Apr 11 - Oct 23
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	6 - 18
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	Unoccupied

Table B-12(a). Vehicle Maintenance - Small w/ No AC - Prototype Characteristics

Construction	
Floor Area (ft ²)	4747
Number of Floors	1
Roof Materials	Corrugated Metal 3 1/2" Batt Insulation Steel Frame
Slab Material	6" Heavy Weight Concrete
Wall Materials	Corrugated Metal 3 1/2" Batt Insulation 12" Heavy, Hollow Concrete Masonary Block
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.74
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.08
HVAC System	
Economizer	Inactive
System Type	Constant Volume Unit Heater
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F) (Office)	70
Setpoint (°F) (Bay)	65
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	9 - 16
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	Unoccupied

Table B-12(b). Vehicle Maintenance - Small w/ No AC - Prototype Zonal Characteristics

	Bay	Office	Total
Floor Area (% total)	90	10	100
Occupancy	20	10	30
Outside Air / Person (CFM)	-	10	-
Interior Lights (W/ft ²)	1.12	1.63	1.17
Miscellaneous (W/ft ²)	0.07	0.60	0.12
Process Load (W/ft ²)	0.006	-	0.005

Table B-13(a). Vehicle Maintenance - Large w/ Split DX - Prototype Characteristics

Construction	
Floor Area (ft ²)	25937
Number of Floors	1
Roof Materials	Corrugated Metal 3 1/2" Batt Insulation Steel Frame
Slab Material	6" Heavy Weight Concrete
Wall Materials	Corrugated Metal 3 1/2" Batt Insulation 12" Heavy, Hollow Concrete Masonary Block
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.74
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.08
HVAC System (Office)	
Economizer	Inactive
System Type	PVAVS
Fan Type	Variable Volume
Cooling	
Type	Direct Expansion / Air Cooled
Setpoint (°F)	76
Availability	Apr 11 - Oct 22
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	70
Availability	Oct 23 - Apr 10
HVAC System (Bay)	
Type	Constant Volume Unit Heater
Economizer	Inactive
Setpoint (°F)	65
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	9 - 16
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	Unoccupied

Table B-13(b). Vehicle Maintenance - Large w/ Split DX - Prototype Zonal Characteristics

	Bay	Office	Total
Floor Area (% total)	90	10	100
Occupancy	20	10	30
Outside Air / Person (CFM)	-	10	-
Interior Lights (W/ft ²)	1.12	1.63	1.17
Miscellaneous (W/ft ²)	0.07	0.60	0.12
Process Load (W/ft ²)	0.006	-	0.005

Table B-14(a). Vehicle Maintenance - Large w/ Chiller - Prototype Characteristics

Construction	
Floor Area (ft ²)	44607
Number of Floors	1
Roof Materials	Corrugated Metal 3 1/2" Batt Insulation Steel Frame
Slab Material	6" Heavy Weight Concrete
Wall Materials	Corrugated Metal 3 1/2" Batt Insulation 12" Heavy, Hollow Concrete Masonary Block
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.74
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.08
HVAC System (Office)	
Economizer	Inactive
System Type	VAVS
Fan Type	Variable Volume
Cooling	
Type	Herm Cent Chiller / Cooling Tower
Setpoint (°F)	76
Availability	Apr 11 - Oct 22
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	70
Availability	Oct 23 - Apr 10
HVAC System (Bay)	
Type	Constant Volume Unit Heater
Economizer	Inactive
Setpoint (°F)	65
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	9 - 16
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	Unoccupied

Table B-14(b). Vehicle Maintenance - Large w/ Chiller - Prototype Zonal Characteristics

	Bay	Office	Total
Floor Area (% total)	90	10	100
Occupancy	20	10	30
Outside Air / Person (CFM)	-	10	-
Interior Lights (W/ft ²)	1.12	1.63	1.17
Miscellaneous (W/ft ²)	0.07	0.60	0.12
Process Load (W/ft ²)	0.006	-	0.005

Table B-15(a). Hangar Prototype Characteristics

Construction	
Floor Area (ft ²)	41328
Number of Floors	2
Roof Materials	Built-up Roofing 6" Rigid Insulation Metal Deck
Slab Material	6" Heavy Weight Concrete
Wall Materials	Corrugated Metal 3 1/2" Batt Insulation Steel Frame
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.98
Window/Wall Ratio	0.20
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.01
HVAC System (Office)	
Economizer	Inactive
Cooling	
Type	Herm Cent Chiller / Cooling Tower
Setpoint (°F)	76
Availability	Apr 11 - Oct 22
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	72
Availability	Oct 23 - Apr 10
HVAC System (Bay)	
Economizer	Inactive
Type	Constant Volume Unit Heater
Setpoint (°F)	65
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	9 - 16
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	Unoccupied

Table B-15(b). Hangar Prototype Zonal Characteristics

	Bay	1st Floor Office	2nd Floor Office	Total
Floor Area (% total)	46	27	27	100
Occupancy	30	30	30	90
Outside Air / Person (CFM)	-	10	10	-
Interior Lights (W/ft ²)	2.25	1.20	1.20	1.68
Miscellaneous (W/ft ²)	0.10	0.10	0.10	0.10
Process Load (W/ft ²)	0.01	-	-	0.005
System Type	UH	TPFC	VAVS	-
Fan Type	Constant Volume	Constant Volume	Variable Volume	-

Table B-16(a). Hospital Prototype Characteristics

Construction	
Floor Area (ft ²)	504202
Number of Floors	6
Floor Materials	4" Light Weight Concrete Carpet w/ Pad
Roof Materials	3/8" Built-up Roofing 6" Light Weight Concrete 2" Rigid Insulation Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	12" Concrete Block Filled 3 1/2" R-11 Insulation Air Layer 5/8" Gypsum
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.90
Window/Wall Ratio	0.40
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.1
Refrigeration (W/ft ²)	0.1
HVAC System	
Economizer	Inactive
Fan System	Variable Volume
Cooling	
Type	Herm Cent Chiller / Cooling Tower
Capacity (Tons)	417 (3)
Setpoint (°F)	73
Availability	Jan 1 - Dec 31
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	73
Availability	Jan 1 - Dec 31
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	1 - 24
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	1 - 24

Table B-16(b). Hospital Prototype Zonal Characteristics

	Clinic	Core	Perimeter	Kitchen	Hallway	Total
Floor Area (% total)	25	35	15	5	20	100
Occupancy (ft ² /person)	289	289	150	321	578	-
Outside Air (ACH)	-	-	-	1.8	-	-
Outside Air / Person (CFM)	15	15	15	-	15	-
Interior Lights (W/ft ²)	2.1	1.6	1.6	2.1	0.8	1.6
Miscellaneous (W/ft ²)	4.0	1.3	1.3	9.0	-	2.1
Cooking (W/ft ²)	-	-	-	4.0	-	0.2
System Type	DD	VAV	FPFC	SZRH	VAV	

Table B-17. Detached Residential Prototype Characteristics

Construction	
Floor Area (ft ²)	1334
Number of Floors	1
Floor Materials	3/4" Hardwood Carpet
Roof Materials	3/8" Built-up Roofing 6" R-19 Insulation 1" Plywood Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	3/4" Hard Board 8" Brick 5/8" Gypsum 6" R-19 Insulation 5/8" Gypsum
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.80
Window/Wall Ratio	0.20
Non-HVAC Peak Loads	
Cooking (W/ft ²)	0.10
Exterior Lights (W/ft ²)	0.09
Interior Lights (W/ft ²)	0.19
Miscellaneous (W/ft ²)	0.72
Occupancy	4
Refrigeration (W/ft ²)	0.10
HVAC System	
Economizer	Inactive
Fan Type	Constant Volume
Cooling	
Type	Direct Expansion / Air Cooled
Capacity (Tons)	2.75
COP	2.05
Setpoint (°F)	72
Availability	Apr 11 - Oct 22
Heating	
Type	Forced Air Gas Furnace
Setpoint (°F)	70
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	6 - 24
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	6 - 24

Table B-18. Two-Plex Residential Prototype Characteristics

Construction	
Floor Area (ft ²)	2938
Number of Floors	1
Floor Materials	3/4" Hardwood Carpet
Roof Materials	3/8" Built-up Roofing 6" R-19 Insulation 1" Plywood Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	3/4" Hard Board 8" Brick 5/8" Gypsum 6" R-19 Insulation 5/8" Gypsum
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.80
Window/Wall Ratio	0.20
Non-HVAC Peak Loads	
Cooking (W/ft ²)	0.10
Exterior Lights (W/ft ²)	0.09
Interior Lights (W/ft ²)	0.19
Miscellaneous (W/ft ²)	0.72
Occupancy	4
Refrigeration (W/ft ²)	0.10
HVAC System	
Economizer	Inactive
Fan Type	Constant Volume
Cooling	
Type	Direct Expansion / Air Cooled
Capacity (Tons)	2.75
COP	2.05
Setpoint (°F)	72
Availability	Apr 11 - Oct 22
Heating	
Type	Forced Air Gas Furnace
Setpoint (°F)	70
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	6 - 24
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	6 - 24

Table B-19. Four-Plex Residential Prototype Characteristics

Construction	
Floor Area (ft ²)	6772
Number of Floors	1
Floor Materials	3/4" Hardwood Carpet
Roof Materials	3/8" Built-up Roofing 6" R-19 Insulation 1" Plywood Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	3/4" Hard Board 8" Brick 5/8" Gypsum 6" R-19 Insulation 5/8" Gypsum
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.80
Window/Wall Ratio	0.20
Non-HVAC Peak Loads	
Cooking (W/ft ²)	0.10
Exterior Lights (W/ft ²)	0.09
Interior Lights (W/ft ²)	0.19
Miscellaneous (W/ft ²)	0.72
Occupancy	4
Refrigeration (W/ft ²)	0.10
HVAC System	
Economizer	Inactive
Fan Type	Constant Volume
Cooling	
Type	Direct Expansion / Air Cooled
Capacity (Tons)	2.75
COP	2.05
Setpoint (°F)	72
Availability	Apr 11 - Oct 22
Heating	
Type	Forced Air Gas Furnace
Setpoint (°F)	70
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	6 - 24
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	6 - 24

Table B-20. Large Retail Prototype Characteristics

Construction	
Floor Area (ft ²)	128058
Number of Floors	1
Roof Materials	3/8" Built-up Roofing Concrete Deck 2" Roof Insulation Air Layer 1/2" Acoustical Tile
Floor Materials	3/4" Hardwood Carpet
Slab Material	6" Heavy Weight Concrete
Wall Materials	8" Light Weight Concrete Masonary Unit 3 1/2" R-11 Insulation Air Layer 5/8" Gypsum Board
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.62
Window/Wall Ratio	0.24
Non-HVAC Loads	
Cooking (W/ft ²)	0.10
Exterior Lights (W/ft ²)	0.10
Interior Lights (W/ft ²)	1.70
Miscellaneous (W/ft ²)	0.31
Occupancy (ft ² /person)	337
Outside Air / Person (CFM)	10
Refrigeration (W/ft ²)	0.22
HVAC System	
Economizer	Active
System Type	VAVS
Fan Type	Variable Volume
Cooling	
Type	Herm Cent Chiller / Cooling Tower
Setpoint (°F)	75
Availability	Apr 11 - Oct 22
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	71
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	6 - 23
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	6 - 23

Table B-21(a). Warehouse w/ No AC - Prototype Characteristics

Construction	
Floor Area (ft ²)	2689
Number of Floors	1
Roof Materials	Builtup Roofing 2 1/2" Rigid Insulation Steel Frame
Slab Material	6" Heavy Weight Concrete
Wall Materials	4" Face Brick 1/2" Air Space 8" Medium Perlite Filled Concrete Masonary Block
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.74
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.08
HVAC System (Office)	
Economizer	Inactive
System Type	PVAVS
Fan Type	Variable Volume
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	70
Availability	Oct 23 - Apr 10
HVAC System (Bay)	
Heating	
Type	Constant Volume Unit Heater
Economizer	Inactive
Setpoint (°F)	65
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	9 - 16
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	Unoccupied

Table B-21(b). Warehouse w/ No AC - Prototype Zonal Characteristics

	Bay	Office	Total
Floor Area (% total)	90	10	100
Occupancy	10	5	15
Outside Air / Person (CFM)	-	10	-
Interior Lights (W/ft ²)	1.12	1.63	1.17
Miscellaneous (W/ft ²)	0.10	0.60	0.15

Table B-22(a). Warehouse w/ Split DX - Prototype Characteristics

Construction	
Floor Area (ft ²)	10122
Number of Floors	1
Roof Materials	Builtup Roofing 2 1/2" Rigid Insulation Steel Frame
Slab Material	6" Heavy Weight Concrete
Wall Materials	4" Face Brick 1/2" Air Space 8" Medium Perlite Filled Concrete Masonary Block
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.74
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.08
HVAC System (Office)	
Economizer	Inactive
System Type	PVAVS
Fan Type	Variable Volume
Cooling	
Type	Direct Expansion / Air Cooled
Setpoint (°F)	76
Availability	Apr 11 - Oct 22
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	70
Availability	Oct 23 - Apr 10
HVAC System (Bay)	
Type	Constant Volume Unit Heater
Economizer	Inactive
Setpoint (°F)	65
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	9 - 16
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	Unoccupied

Table B-22(b). Warehouse w/ Split DX - Prototype Zonal Characteristics

	Bay	Office	Total
Floor Area (% total)	90	10	100
Occupancy	10	5	15
Outside Air / Person (CFM)	-	10	-
Interior Lights (W/ft ²)	1.12	1.63	1.17
Miscellaneous (W/ft ²)	0.10	0.60	0.15

Table B-23. Bowling Alley Prototype Characteristics

Construction	
Floor Area (ft ²)	27772
Number of Floors	1
Roof Materials	3/8" Built-up Roofing Steel Deck 3" Roof Insulation Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	8" Medium Weight Hollow Concrete Masonary Unit 3/4" Poly-Expand Insulation Air Layer 5/8" Gypsum Board
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.60
Window/Wall Ratio	0.10
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.05
Interior Lights (W/ft ²)	1.00
Miscellaneous (W/ft ²)	1.50
Occupancy (ft ² /person)	333
Outside Air / Person (CFM)	10
HVAC System	
Economizer	Active
System Type	VAVS
Fan Type	Variable Volume
Cooling	
Type	Herm Cent Chiller / Cooling Tower
Setpoint (°F)	78
Availability	Apr 11 - Oct 22
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	72
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	10 - 22
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	10 - 22

Table B-24. Church Prototype Characteristics

Construction	
Floor Area (ft ²)	7090
Number of Floors	1
Roof Materials	3/8" Built-up Roofing Steel Deck 3" Roof Insulation Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	8" Medium Weight Hollow Concrete Masonary Unit 3/4" Poly-Expand Insulation Air Layer 5/8" Gypsum Board
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.60
Window/Wall Ratio	0.10
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.05
Interior Lights (W/ft ²)	1.20
Miscellaneous (W/ft ²)	0.20
Occupancy (ft ² /person)	333
Outside Air / Person (CFM)	10
HVAC System	
Economizer	Active
System Type	VAVS
Fan Type	Variable Volume
Cooling	
Type	Herm Cent Chiller / Cooling Tower
Setpoint (°F)	78
Availability	Apr 11 - Oct 22
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	72
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	7 - 21
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	7 - 21

Table B-25. Library Prototype Characteristics

Construction	
Floor Area (ft ²)	8273
Number of Floors	1
Roof Materials	3/8" Built-up Roofing Steel Deck 3" Roof Insulation Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	8" Medium Weight Hollow Concrete Masonary Unit 3/4" Poly-Expand Insulation Air Layer 5/8" Gypsum Board
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.60
Window/Wall Ratio	0.10
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.05
Interior Lights (W/ft ²)	1.70
Miscellaneous (W/ft ²)	0.50
Occupancy (ft ² /person)	333
Outside Air / Person (CFM)	10
HVAC System	
Economizer	Active
System Type	VAVS
Fan Type	Variable Volume
Cooling	
Type	Herm Cent Chiller / Cooling Tower
Setpoint (°F)	78
Availability	Apr 11 - Oct 22
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	72
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	5 - 24
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	9 - 24

Table B-26(a). Grocery Store Prototype Characteristics

Construction	
Floor Area (ft ²)	4432
Number of Floors	1
Floor Materials	Linoleum Tile
Roof Materials	3/8" Built-up Roofing R-11 Insulation 6" Light Weight Concrete Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	8" Concrete Masonary Unit w/ Perlite R-6 Insulation 5/8" Gypsum Board
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.81
Window/Wall Ratio	0.07
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.22
Refrigeration (W/ft ²)	5.5
HVAC System	
Economizer	Active
System Type	PSZ
Fan Type	Constant Volume
Cooling	
Type	Direct Expansion / Air Cooled
Setpoint (°F)	75
Availability	Jan 1 - Dec 31
Heating	
Type	Forced Air Gas Furnace
Setpoint (°F)	70
Availability	Jan 1 - Dec 31
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	6 - 24
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	10 - 20

Table B-26(b). Grocery Store Prototype Zonal Characteristics

	Office	Storage	Bakery	Deli	Sale	Total
Floor Area (% total)	3	20	12	5	60	100
Occupancy (ft ² /person)	130	880	220	220	325	-
Outside Air / Person (CFM)	15	15	-	15	15	-
Outside Air (ACH)	-	-	5.6	-	-	-
Cooking (W/ft ²)	-	-	5.0	-	-	0.6
Interior Lights (W/ft ²)	1.7	1.0	1.7	1.7	1.7	1.6
Miscellaneous (W/ft ²)	0.5	0.4	7.5	3.8	0.4	0.6

Table B-27(a). Fastfood Restaurant Prototype Characteristics

Construction	
Floor Area (ft ²)	1650
Number of Floors	1
Floor Materials	Linoleum Tile
Roof Materials	3/8" Built-up Roofing 1" Plywood R-12 Insulation Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	8" Concrete Masonary Unit w/ Perlite R-9 Insulation 5/8" Gypsum Board
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.79
Window/Wall Ratio	0.09
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.92
Refrigeration (W/ft ²)	4.8
HVAC System	
Economizer	Active
System Type	PSZ
Fan Type	Constant Volume
Cooling	
Type	Direct Expansion / Air Cooled
Setpoint (°F)	73
Availability	Jan 1 - Dec 31
Heating	
Type	Forced Air Gas Furnace
Setpoint (°F)	65
Availability	Jan 1 - Dec 31
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	5 - 24
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	5 - 24

Table B-27(b). Fastfood Restaurant Prototype Zonal Characteristics

	Dining	Kitchen	Total
Floor Area (% total)	50	50	100
Occupancy (ft ² /person)	34	114	-
Outside Air / Person (CFM)	15	-	-
Outside Air (ACH)	-	7.3	-
Cooking (W/ft ²)	-	10.4	5.2
Interior Lights (W/ft ²)	1.7	2.5	2.1
Miscellaneous (W/ft ²)	-	7.2	3.6

Table B-28(a). Sitdown Restaurant Prototype Characteristics

Construction	
Floor Area (ft ²)	2994
Number of Floors	1
Floor Materials	Linoleum Tile
Roof Materials	3/8" Built-up Roofing 1" Plywood R-8 Insulation Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	4" Face Brick R-6 Insulation 5/8" Gypsum Board
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.78
Window/Wall Ratio	0.08
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.36
Refrigeration (W/ft ²)	2.9
HVAC System	
Economizer	Active
System Type	PSZ
Fan Type	Constant Volume
Cooling	
Type	Direct Expansion / Air Cooled
Setpoint (°F)	74
Availability	Jan 1 - Dec 31
Heating	
Type	Forced Air Gas Furnace
Setpoint (°F)	72
Availability	Jan 1 - Dec 31
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	5 - 24
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	5 - 24

Table B-28(h). Sitdown Restaurant Prototype Zonal Characteristics

	Dining	Kitchen	Total
Floor Area (% total)	70	30	100
Occupancy (ft ² /person)	-	-	67
Outside Air / Person (CFM)	15	-	-
Outside Air (ACH)	-	6.6	-
Cooking (W/ft ²)	-	15.0	4.5
Interior Lights (W/ft ²)	1.2	1.5	1.3
Miscellaneous (W/ft ²)	0.1	7.5	2.3

Table B-29. Small Retail Prototype Characteristics

Construction	
Floor Area (ft ²)	10146
Number of Floors	1
Roof Materials	3/8" Built-up Roofing Steel Deck 3" Roof Insulation Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	8" Medium Weight Hollow Concrete Masonary Unit 3/4" Poly-Expand Insulation Air Layer 5/8" Gypsum Board
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.60
Window/Wall Ratio	0.10
Non-HVAC Loads	
Cooking (W/ft ²)	0.01
Exterior Lights (W/ft ²)	0.10
Interior Lights (W/ft ²)	2.00
Miscellaneous (W/ft ²)	0.40
Occupancy (ft ² /person)	159
Outside Air / Person (CFM)	10
Refrigeration (W/ft ²)	0.06
HVAC System	
Economizer	Active
System Type	PVAVS
Fan Type	Variable Volume
Cooling	
Type	Direct Expansion / Air Cooled
Setpoint (°F)	76
Availability	Apr 11 - Oct 22
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	72
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	9 - 18
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	9 - 18

Table B-30. Youth Center Prototype Characteristics

Construction	
Floor Area (ft ²)	4363
Number of Floors	1
Roof Materials	3/8" Built-up Roofing Steel Deck 3" Roof Insulation Air Layer 1/2" Acoustical Tile
Slab Material	6" Heavy Weight Concrete
Wall Materials	8" Medium Weight Hollow Concrete Masonary Unit 3/4" Poly-Expand Insulation Air Layer 5/8" Gypsum Board
Window Characteristics	
Number of Panes	1
Shading Coefficient	0.60
Window/Wall Ratio	0.10
Non-HVAC Loads	
Exterior Lights (W/ft ²)	0.05
Interior Lights (W/ft ²)	1.70
Miscellaneous (W/ft ²)	0.50
Occupancy (ft ² /person)	333
Outside Air / Person (CFM)	10
HVAC System	
Economizer	Active
System Type	VAVS
Fan Type	Variable Volume
Cooling	
Type	Herm Cent Chiller / Cooling Tower
Setpoint (°F)	78
Availability	Apr 11 - Oct 22
Heating	
Type	Hot Water Boiler / Natural Gas
Setpoint (°F)	72
Availability	Oct 23 - Apr 10
Loads / System Schedule	
Standard Days	Monday - Friday
On Hours	7 - 18
Nonstandard Days	Saturday, Sunday, Holiday
On Hours	9 - 16

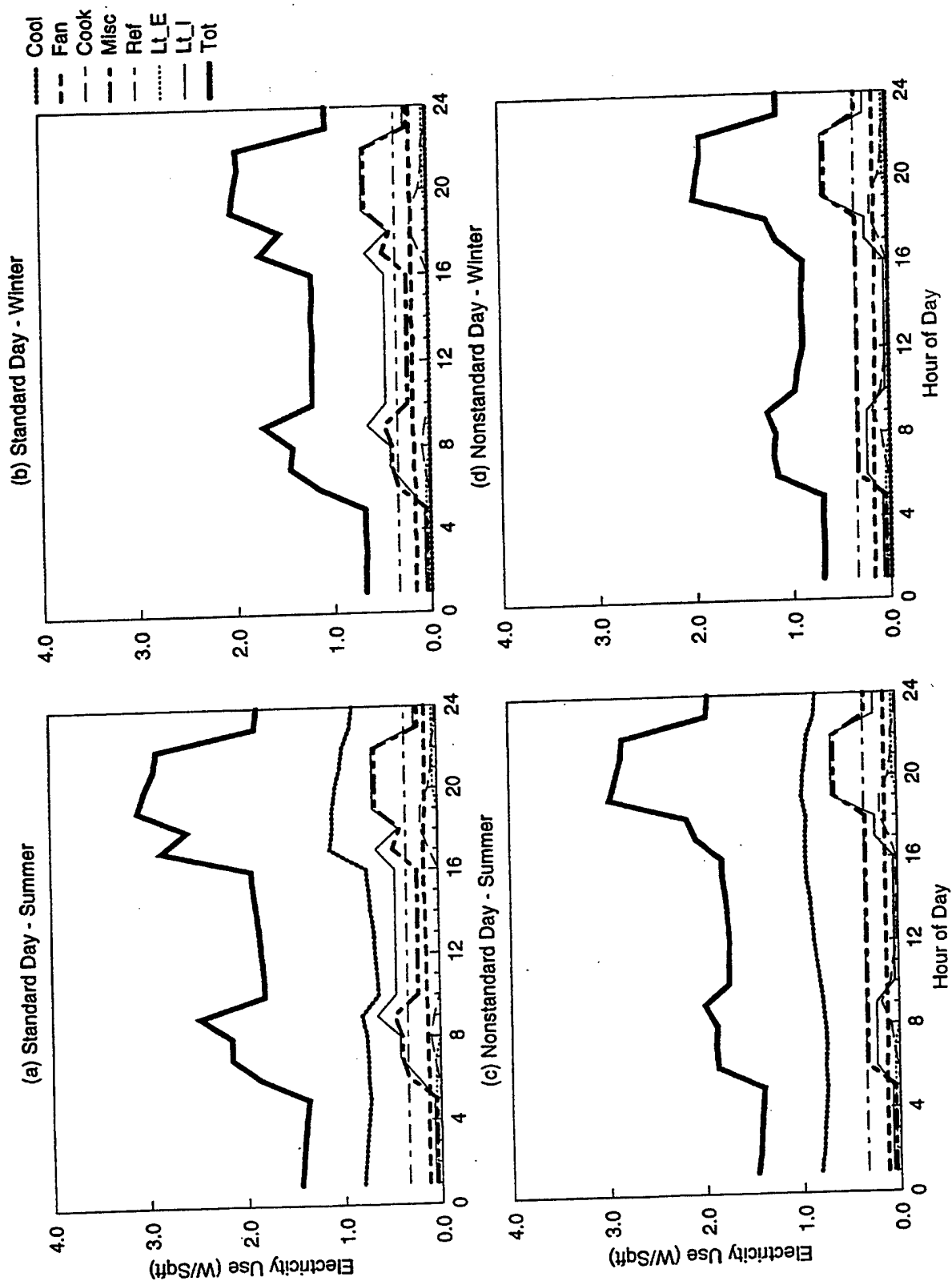


Figure B-1. DOE-2 Simulated End-use Load Shapes for Hammerhead Barrack

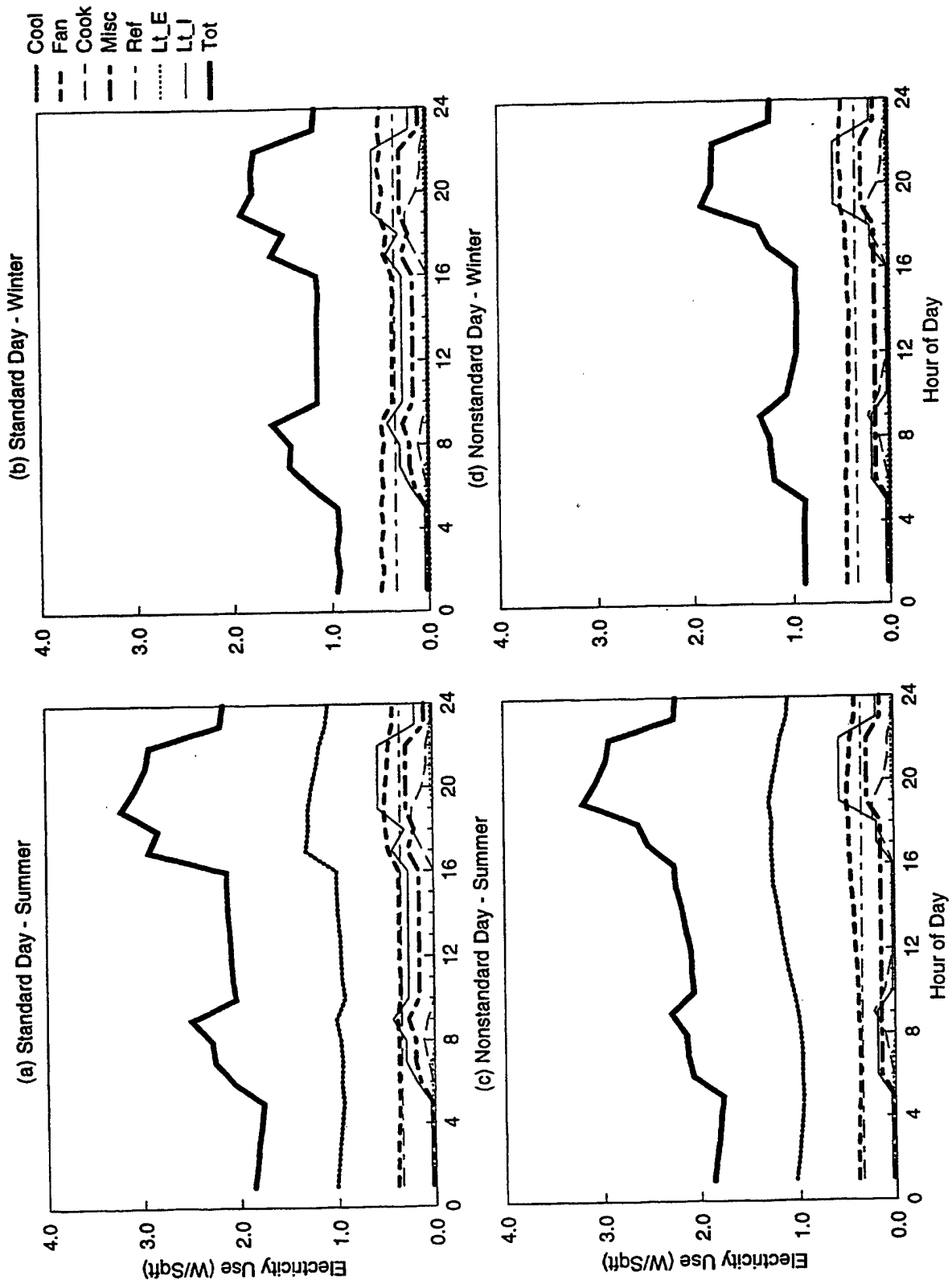


Figure B-2. DOE-2 Simulated End-use Load Shapes for Rolling Pin Barrack

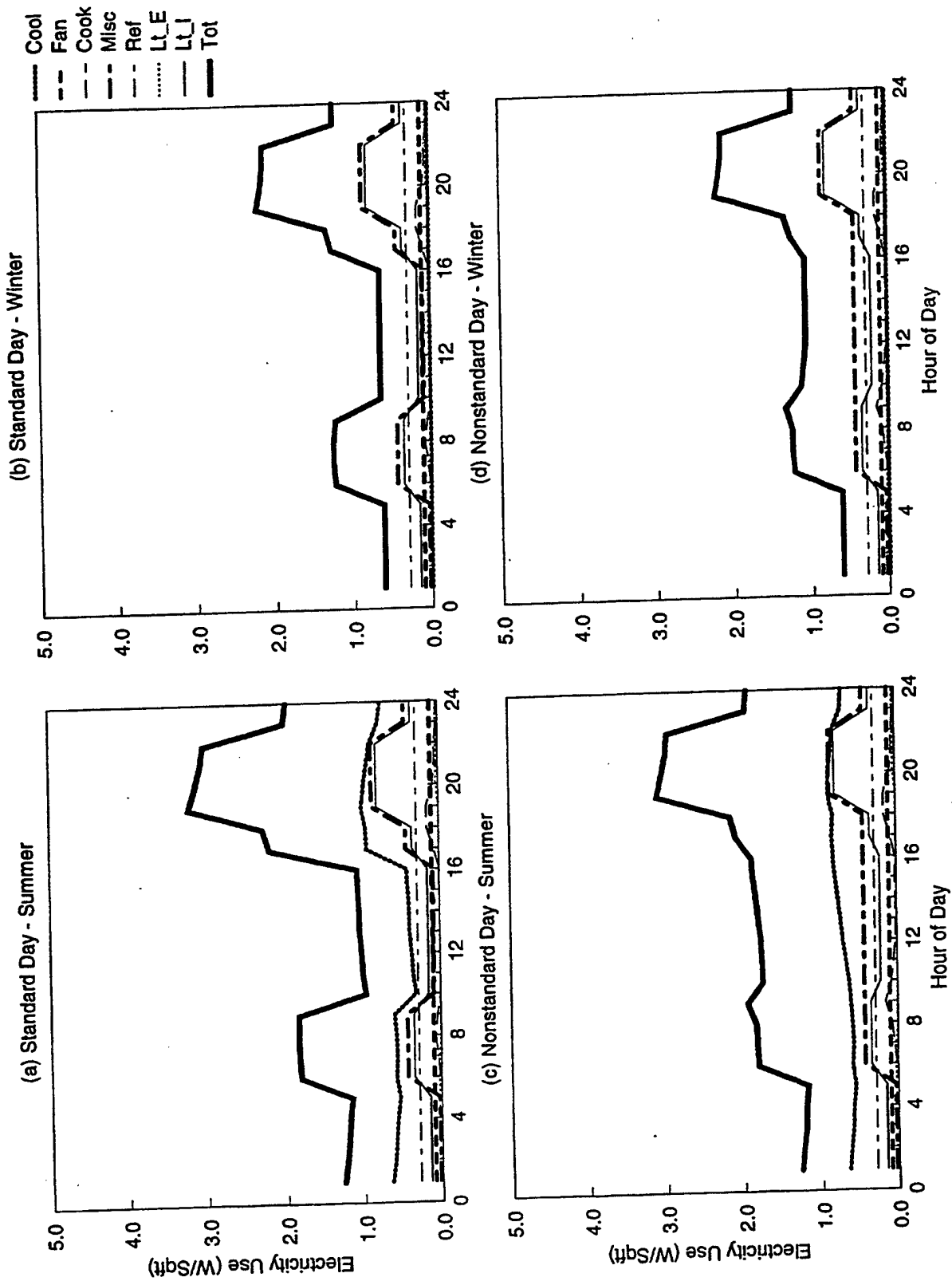


Figure B-3. DOE-2 Simulated End-use Load Shapes for Modular Barrack

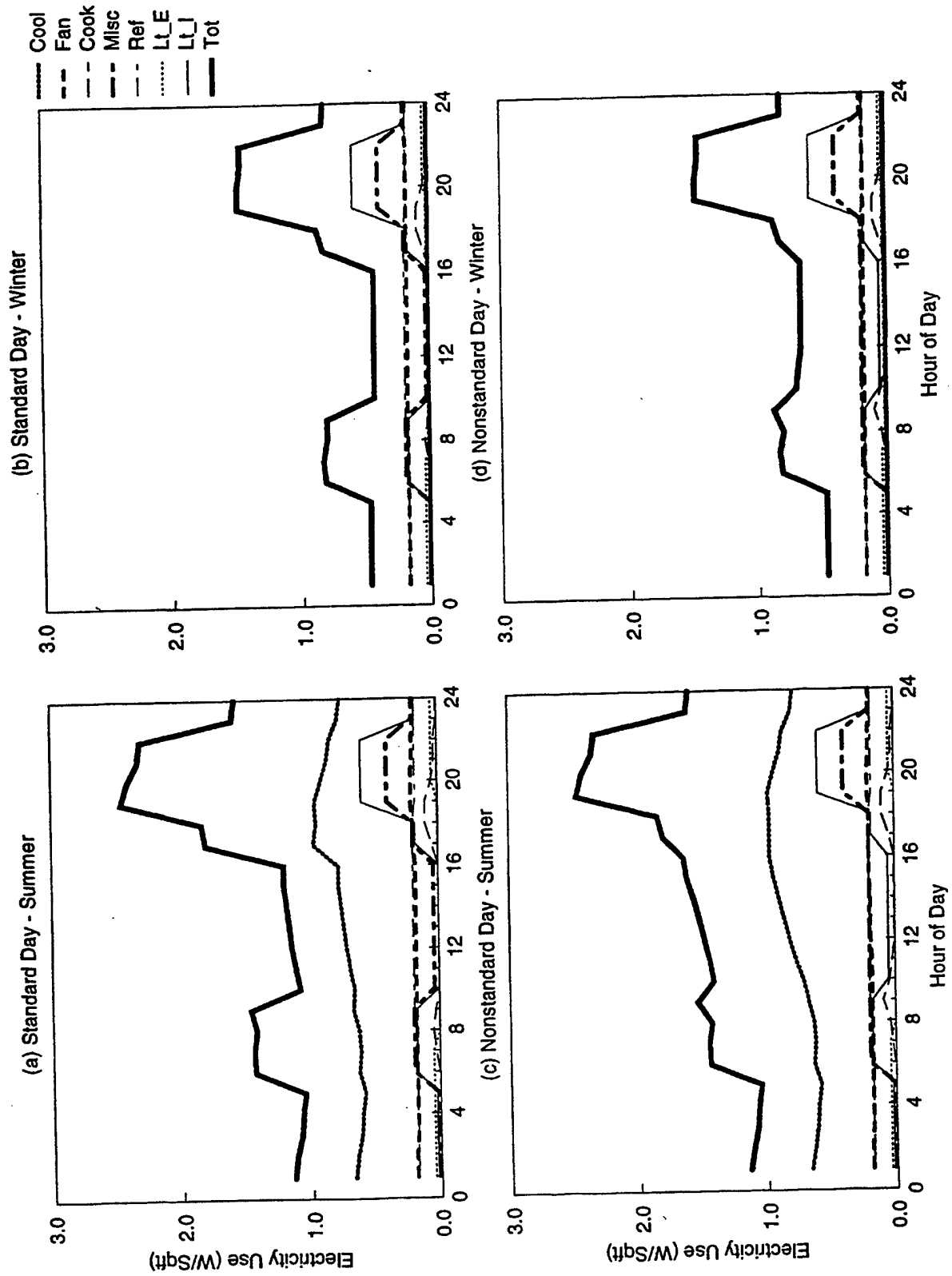


Figure B-4. DOE-2 Simulated End-use Load Shapes for Small Barrack

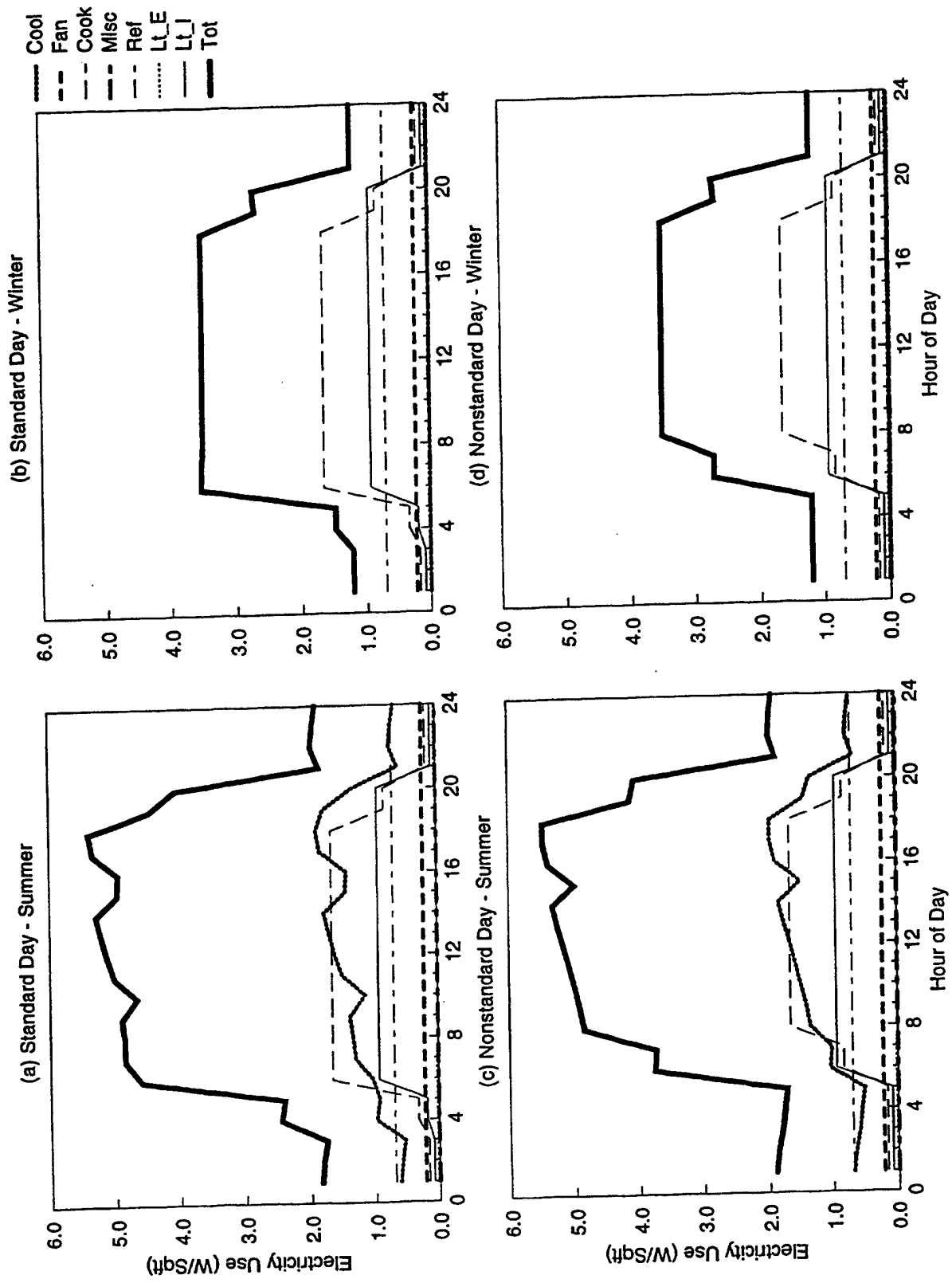


Figure B-5. DOE-2 Simulated End-use Load Shapes for Dining Hall

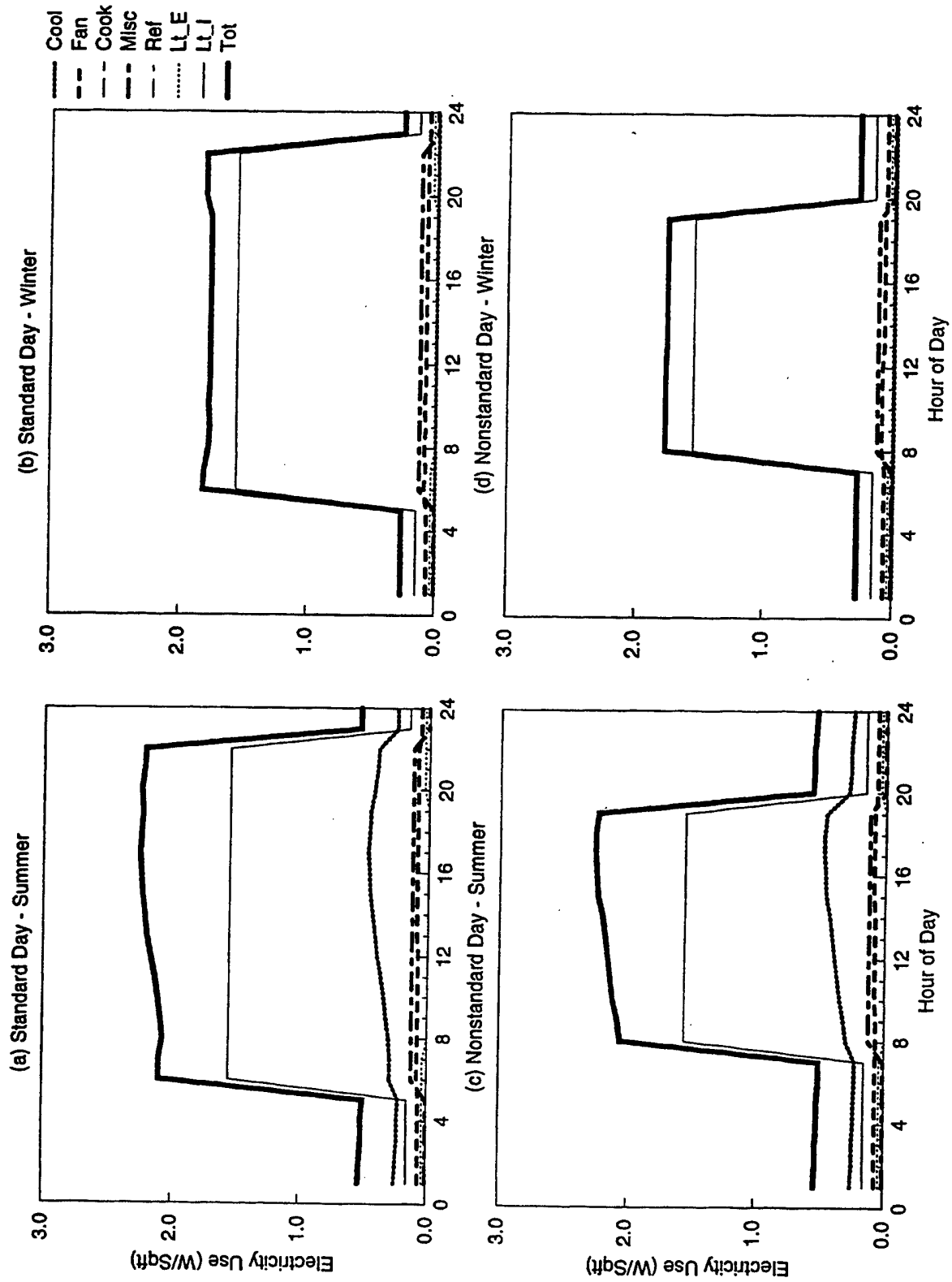


Figure B-6. DOE-2 Simulated End-use Load Shapes for Gymnasium

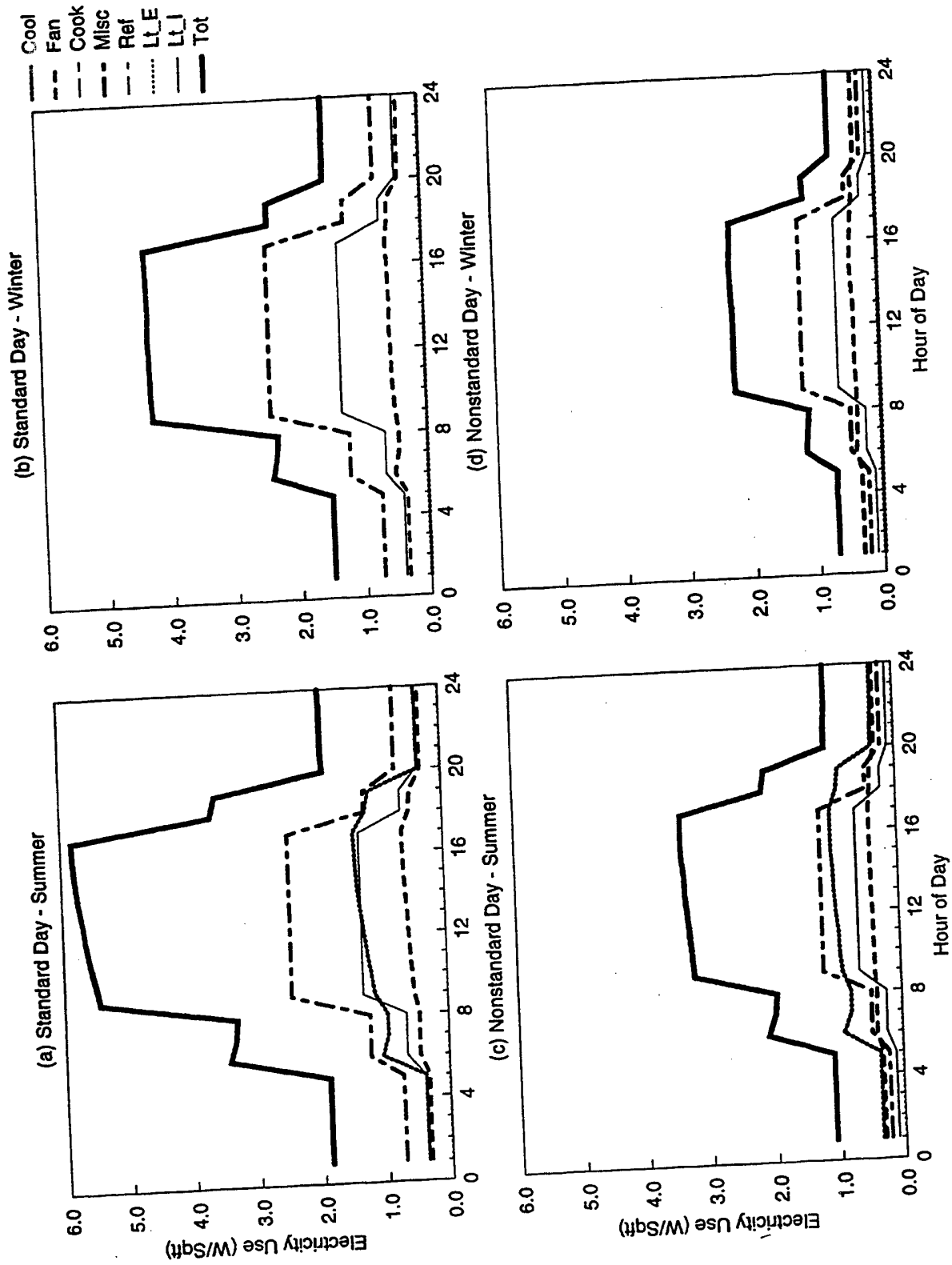


Figure B-7. DOE-2 Simulated End-use Load Shapes for Large Administration

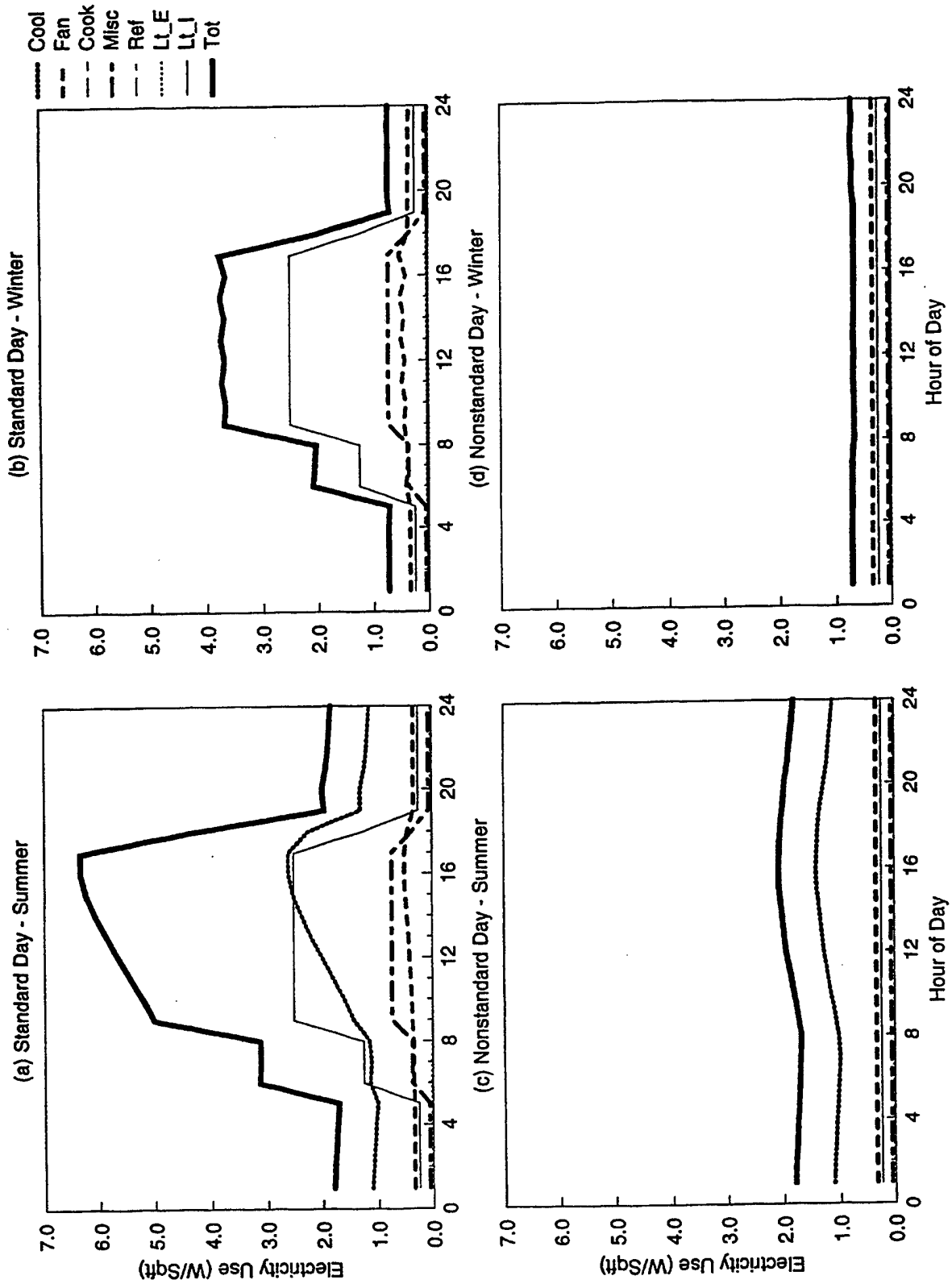


Figure B-8. DOE-2 Simulated End-use Load Shapes for Small Administration (Old w/ Split DX)

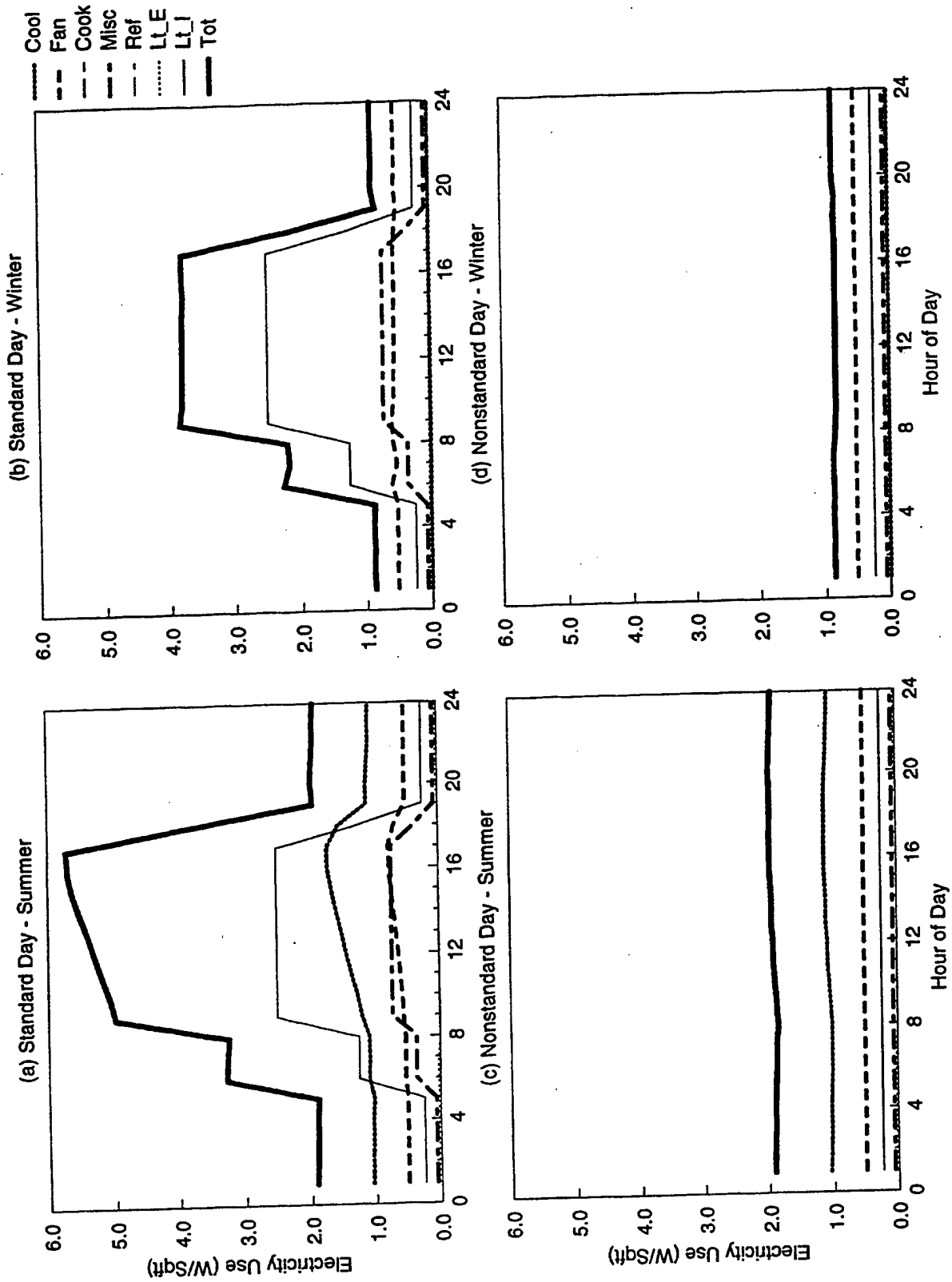


Figure B-9. DOE-2 Simulated End-use Load Shapes for Small Administration (Old w/ Chiller)

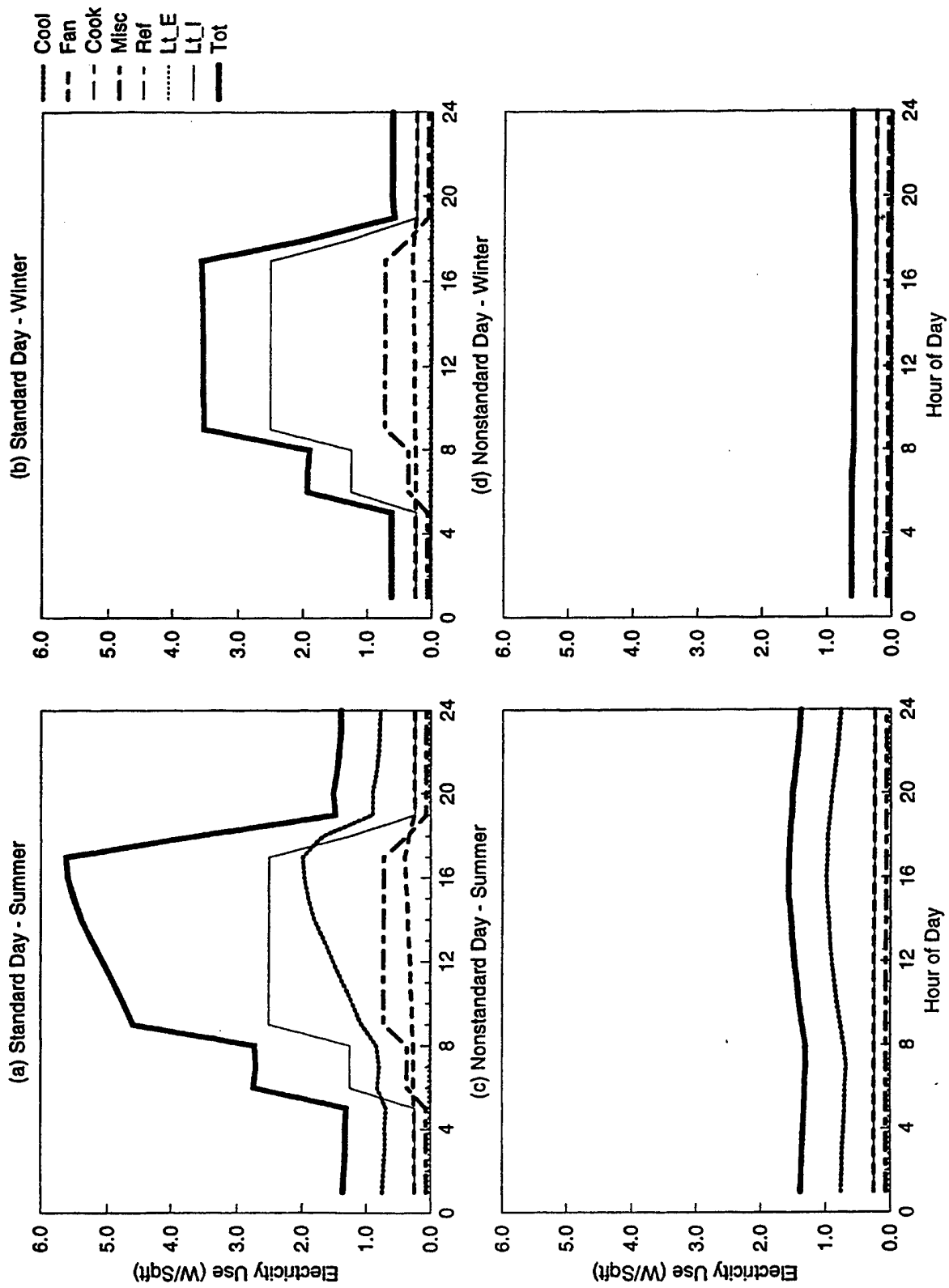


Figure B-10. DOE-2 Simulated End-use Load Shapes for Small Administration (New w/ Split DX)

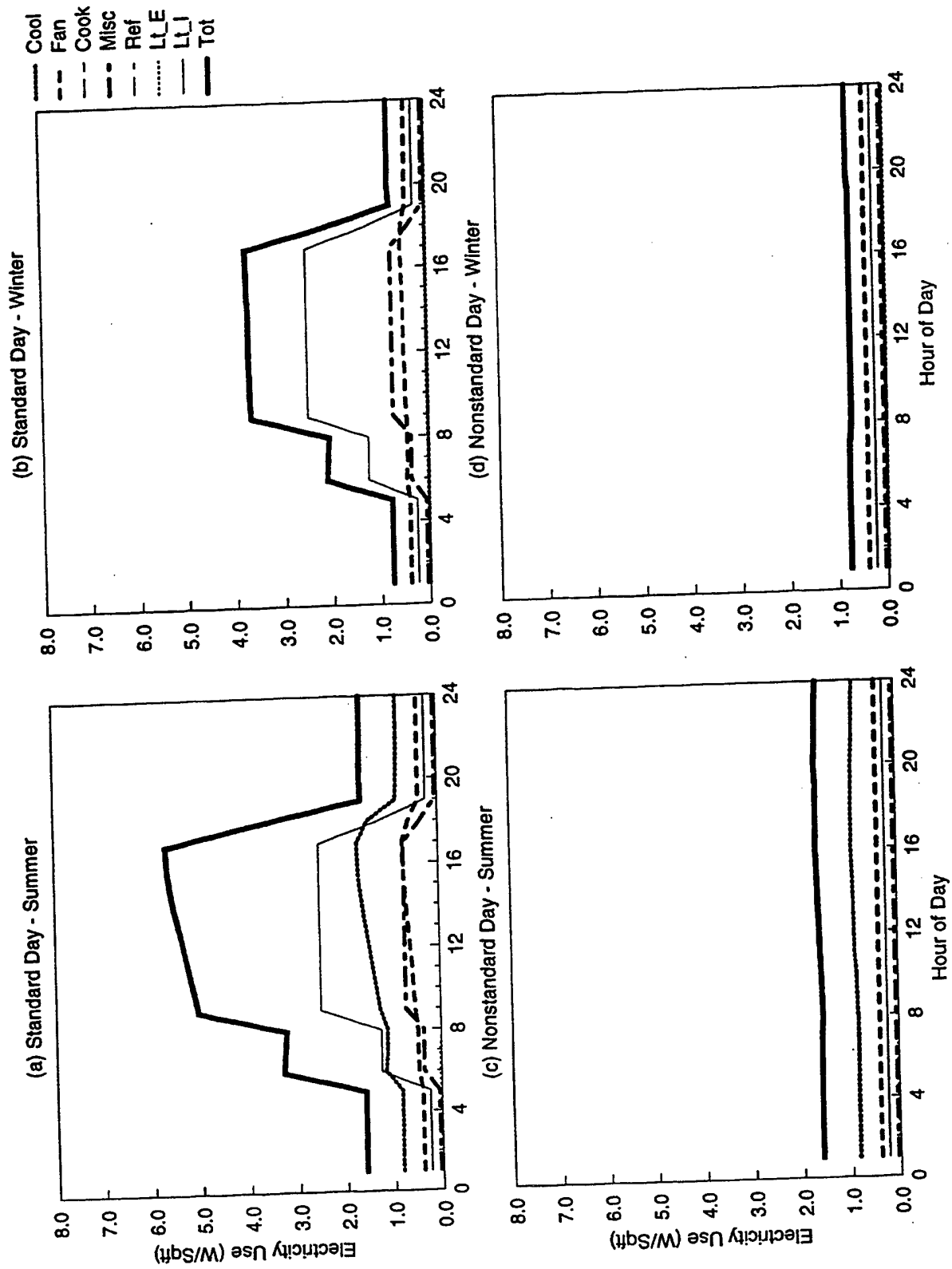


Figure B-11. DOE-2 Simulated End-use Load Shapes for Small Administration (New w/ Chiller)

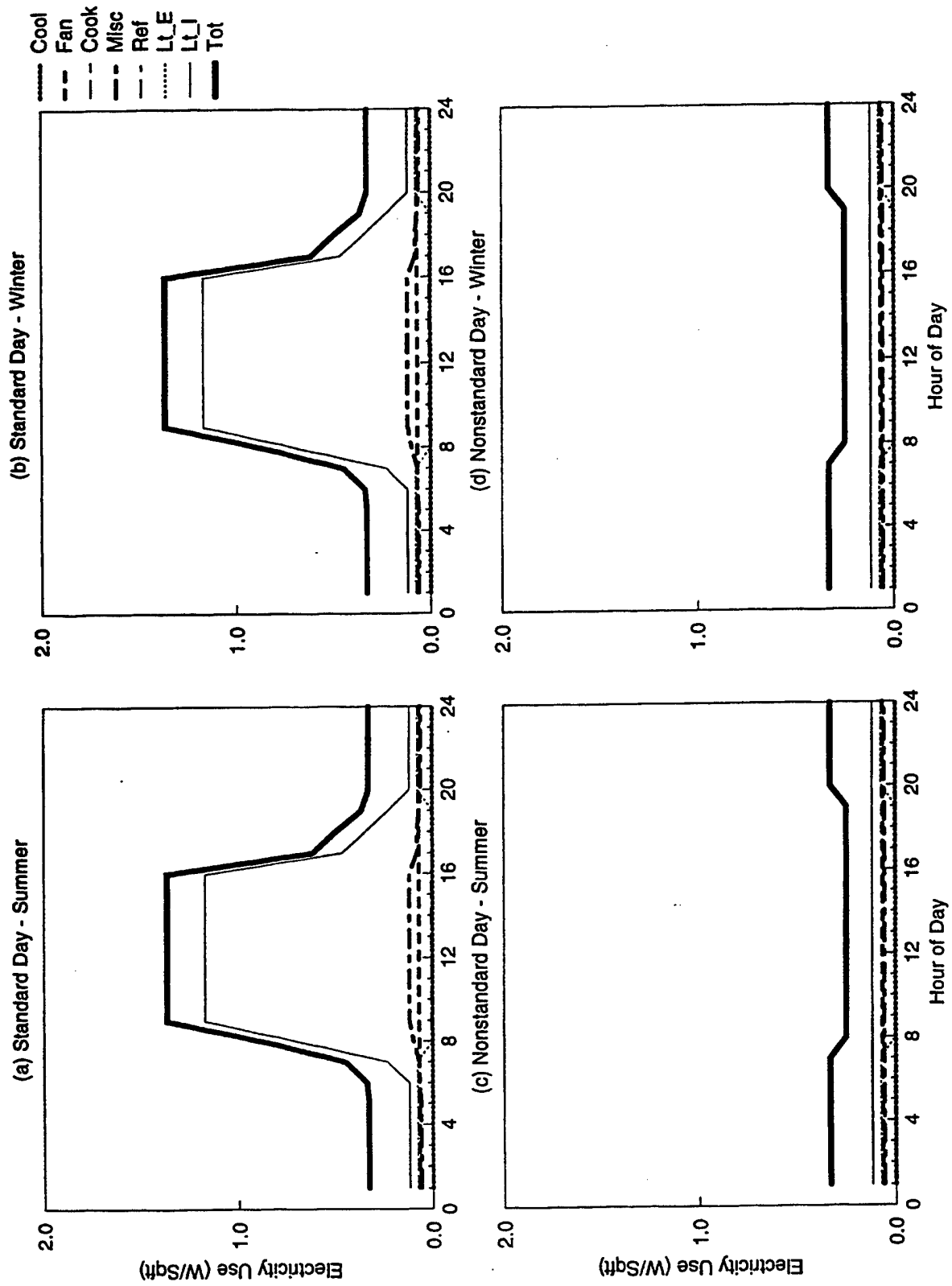


Figure B-12. DOE-2 Simulated End-use Load Shapes for Small Vehicle Maintenance (No AC)

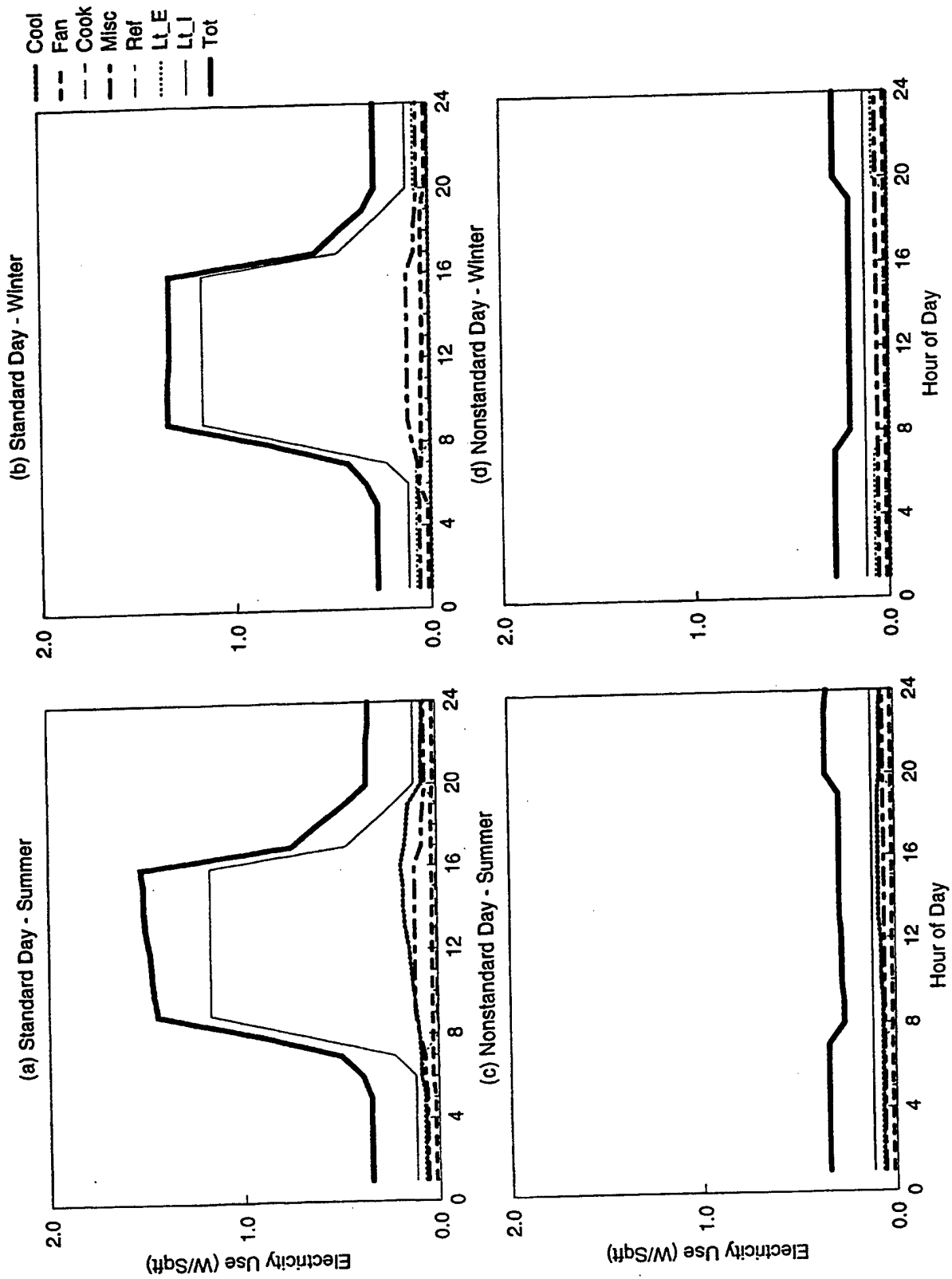


Figure B-13. DOE-2 Simulated End-use Load Shapes for Large Vehicle Maintenance (Split DX)

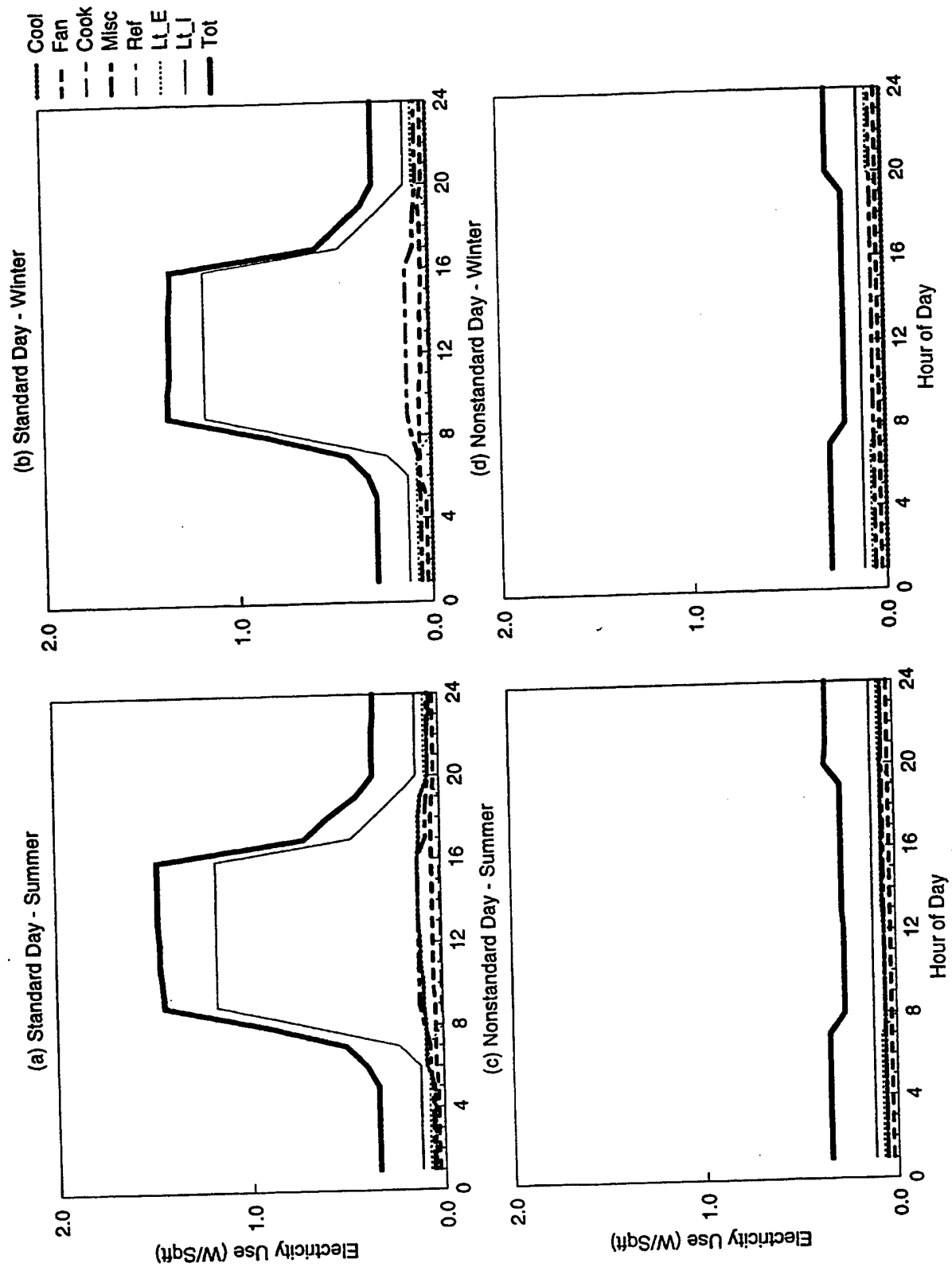


Figure B-14. DOE-2 Simulated End-use Load Shapes for Large Vehicle Maintenance (Chiller)

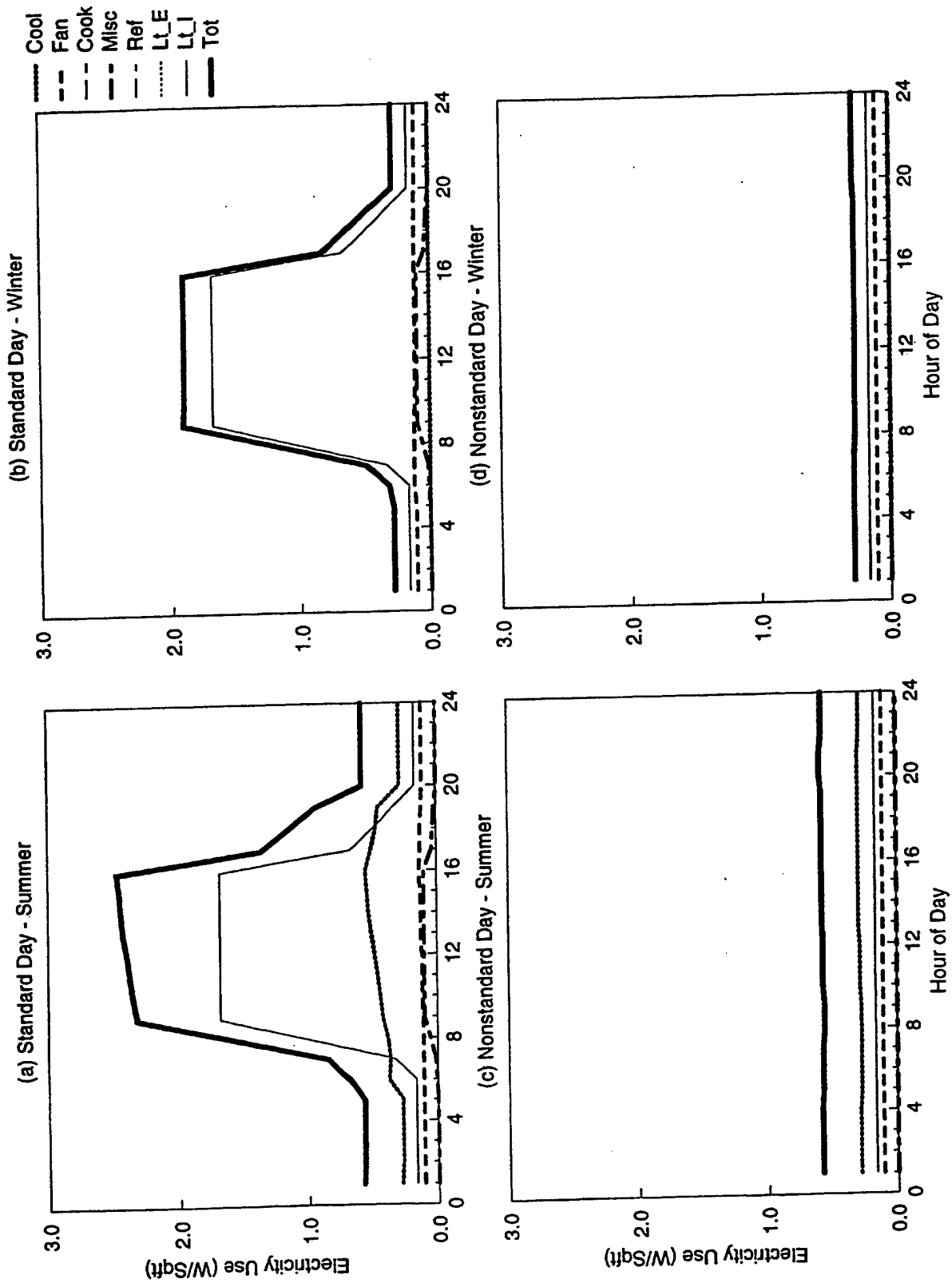


Figure B-15. DOE-2 Simulated End-use Load Shapes for Hangar

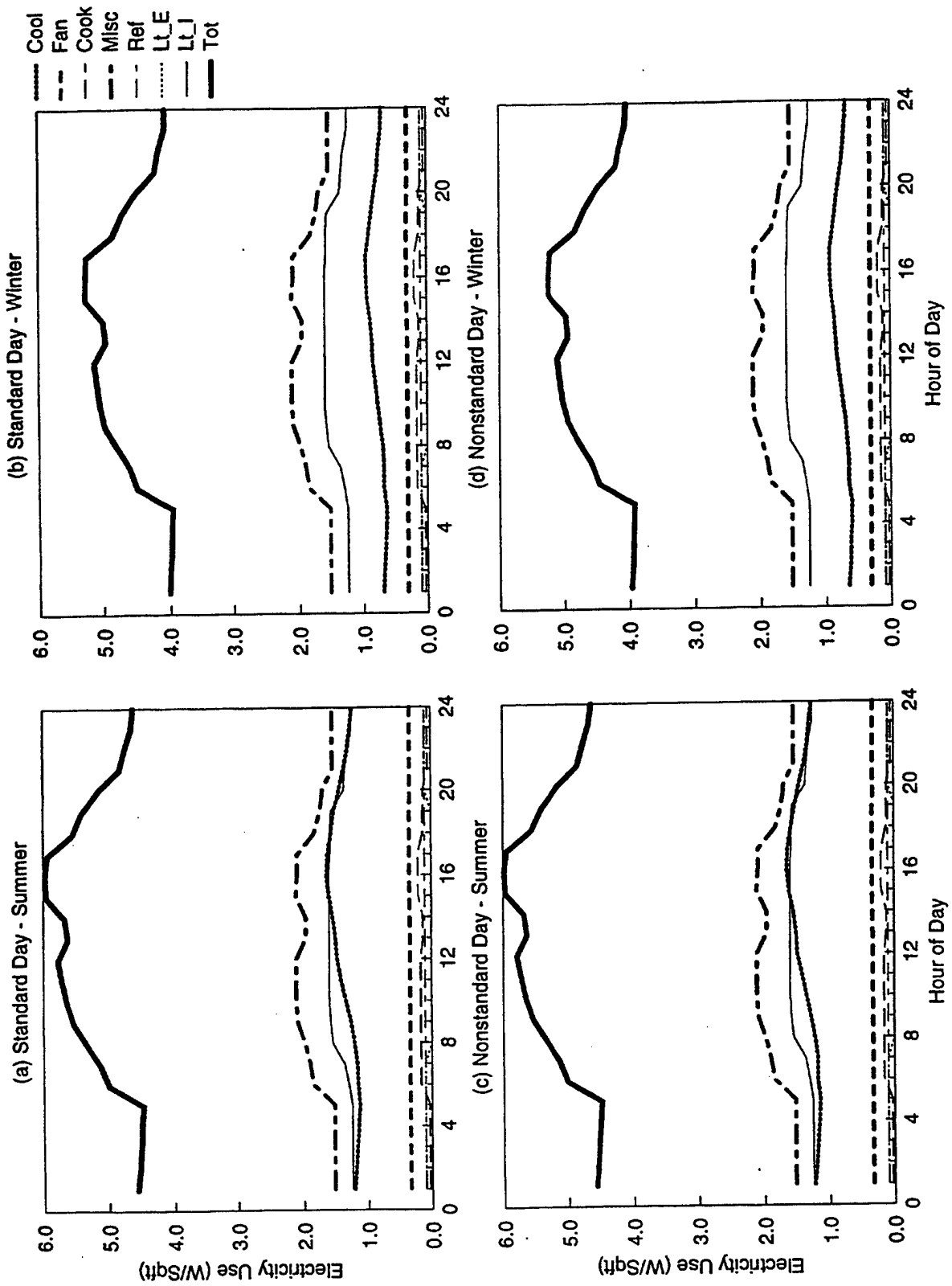


Figure B-16. DOE-2 Simulated End-use Load Shapes for Hospital

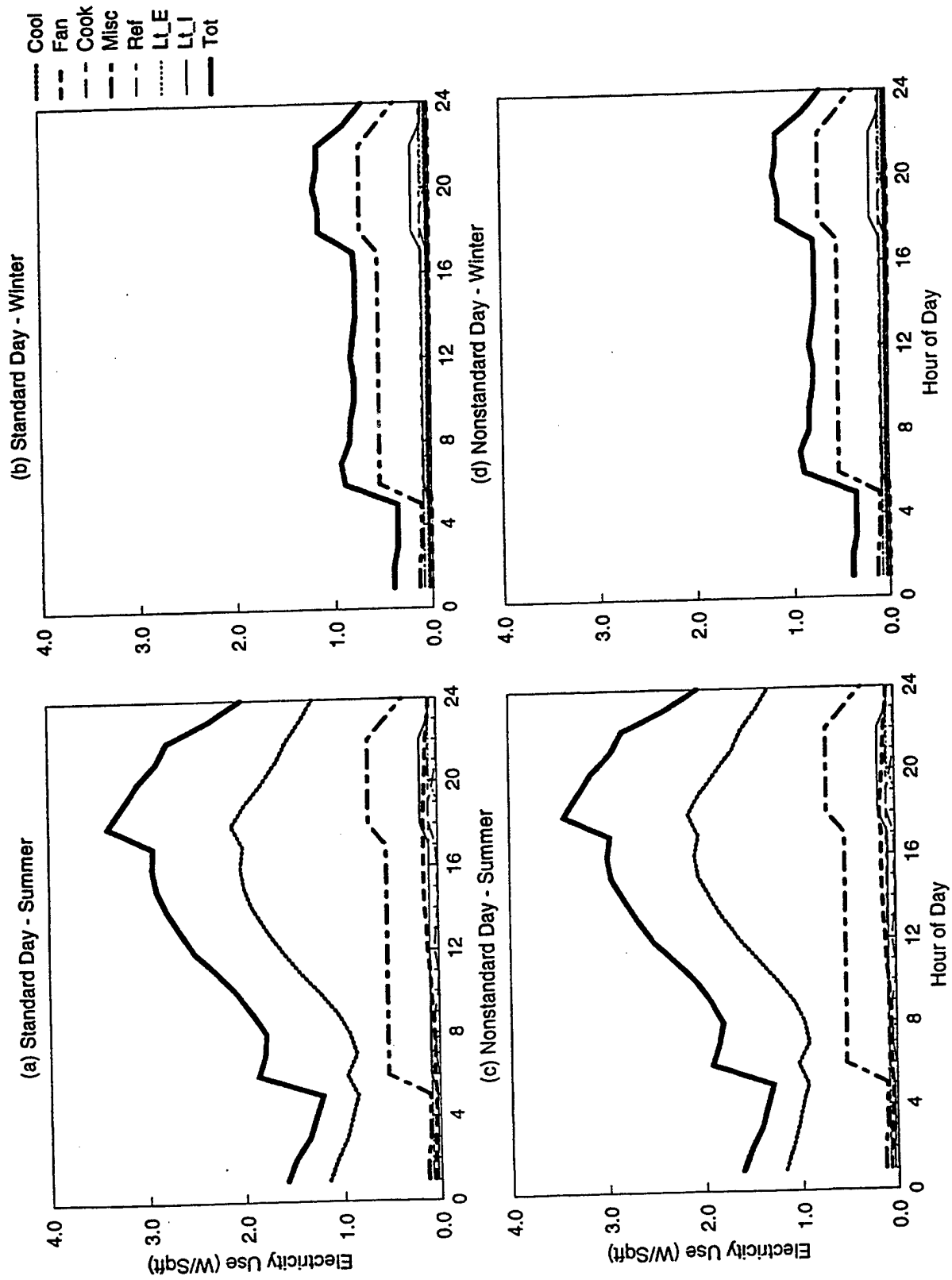


Figure B-17. DOE-2 Simulated End-use Load Shapes for Detached Residential

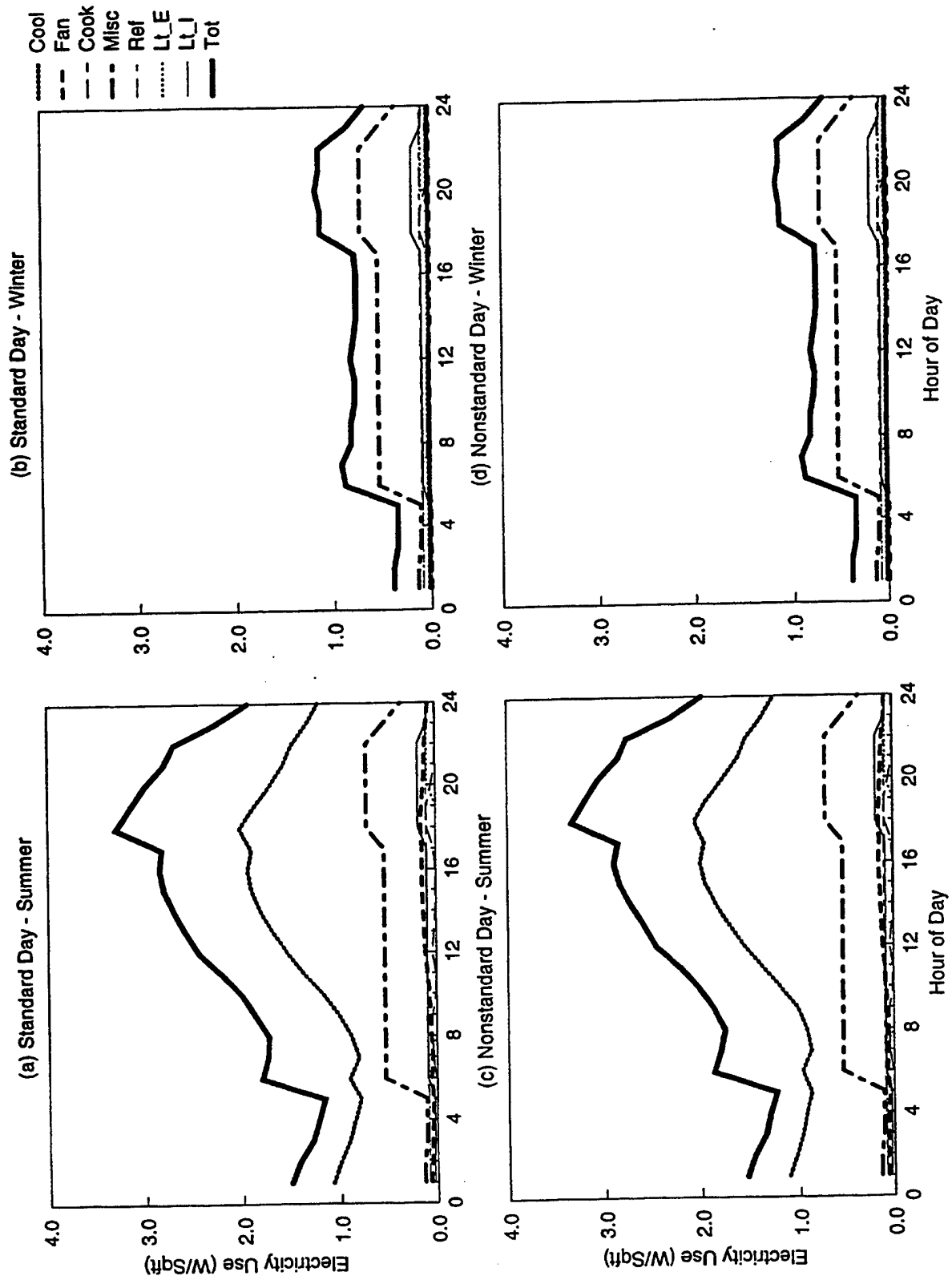


Figure B-18. DOE-2 Simulated End-use Load Shapes for Two-Plex Residential

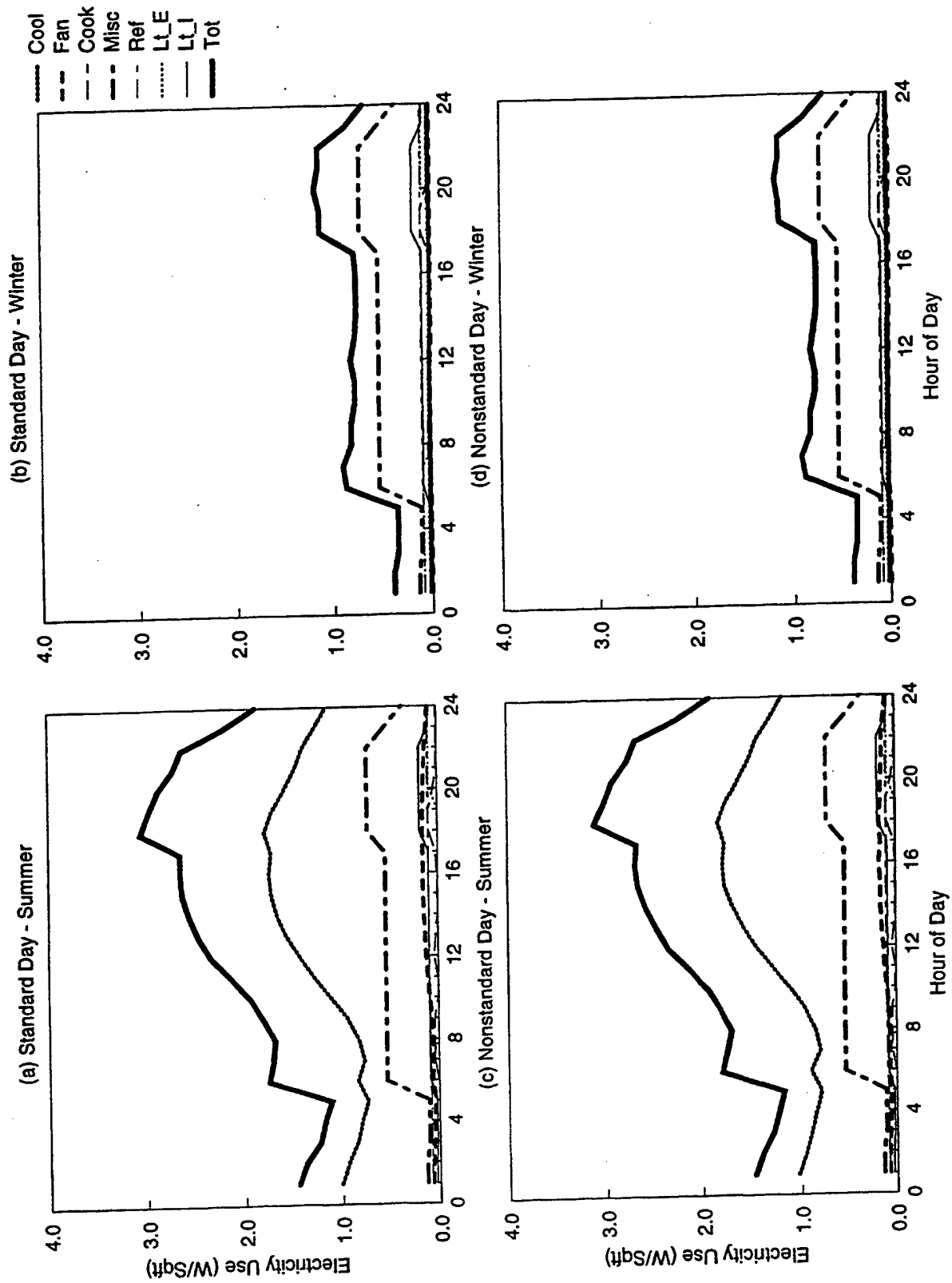


Figure B-19. DOE-2 Simulated End-use Load Shapes for Four-Plex Residential

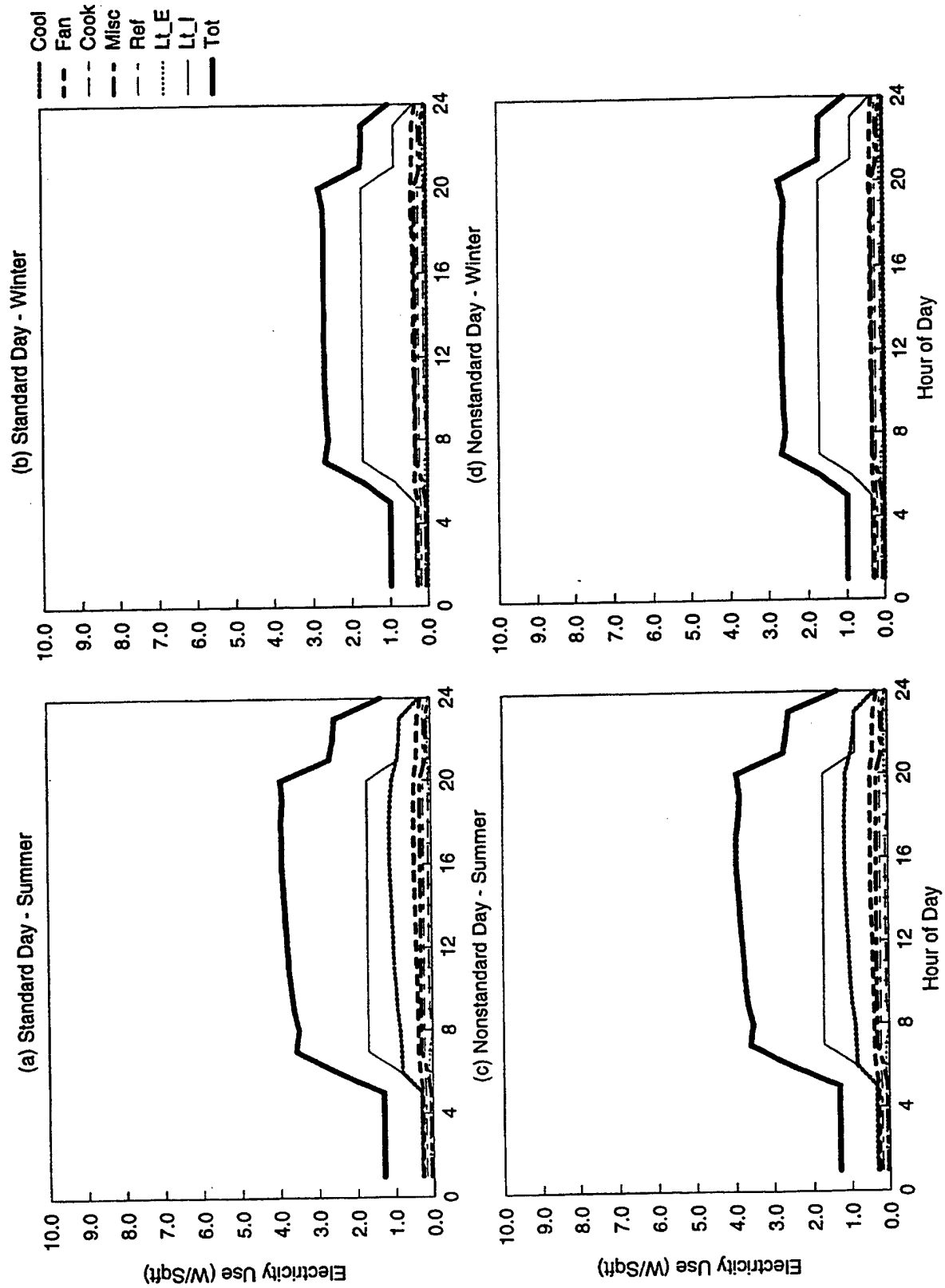


Figure B-20. DOE-2 Simulated End-use Load Shapes for Large Retail

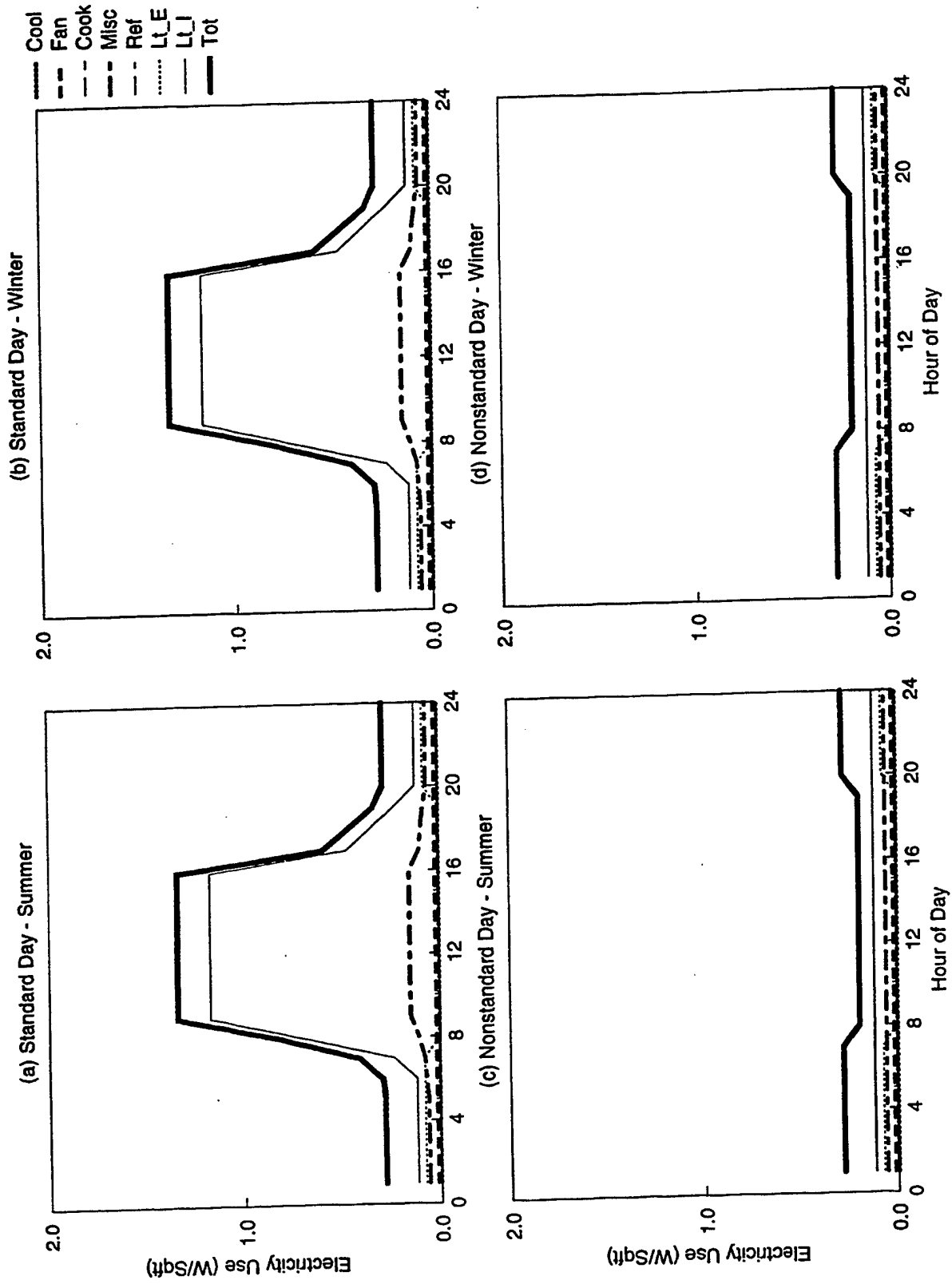


Figure B-21. DOE-2 Simulated End-use Load Shapes for Warehouse (No AC)

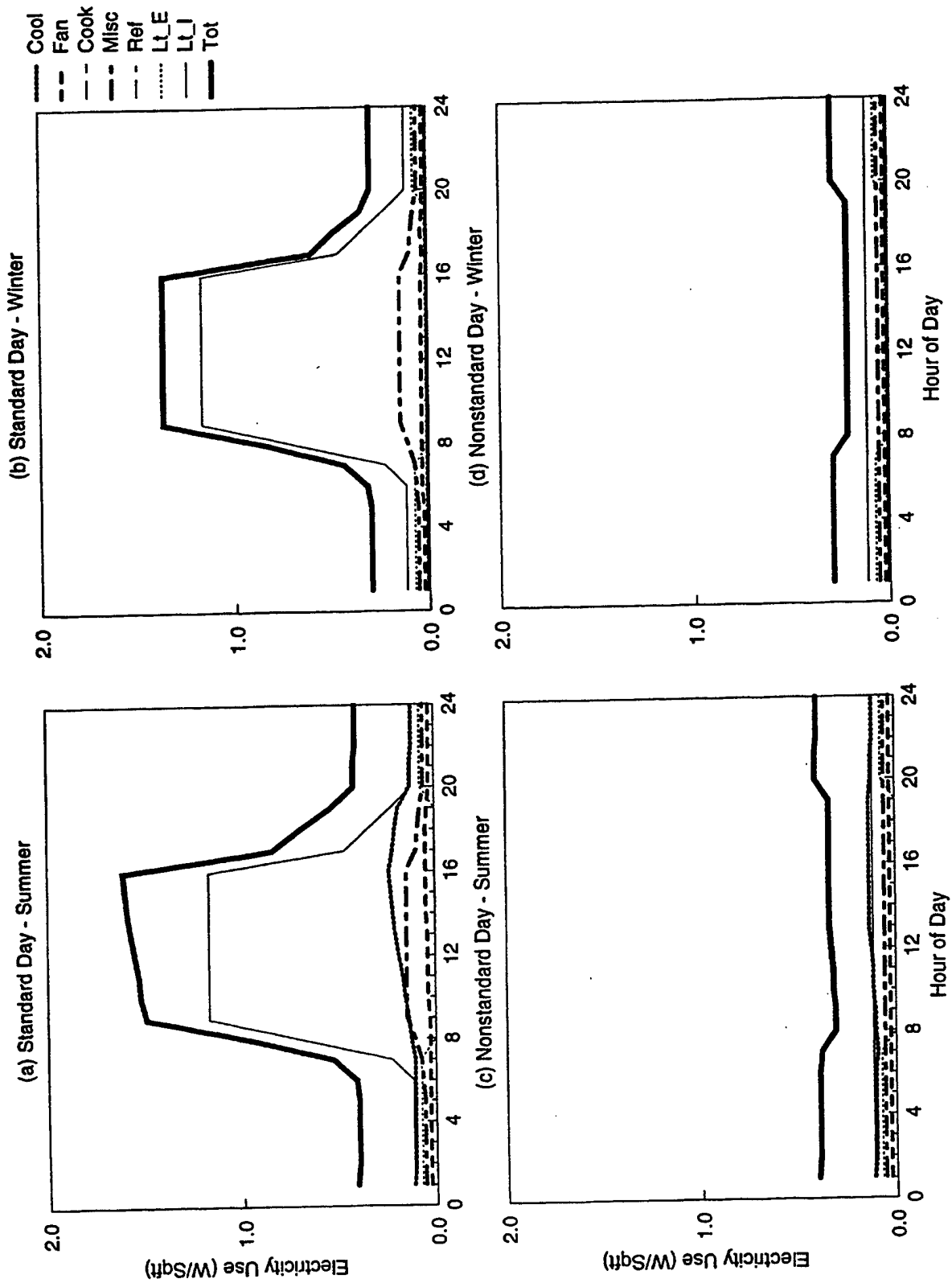


Figure B-22. DOE-2 Simulated End-use Load Shapes for Warehouse (Split DX)

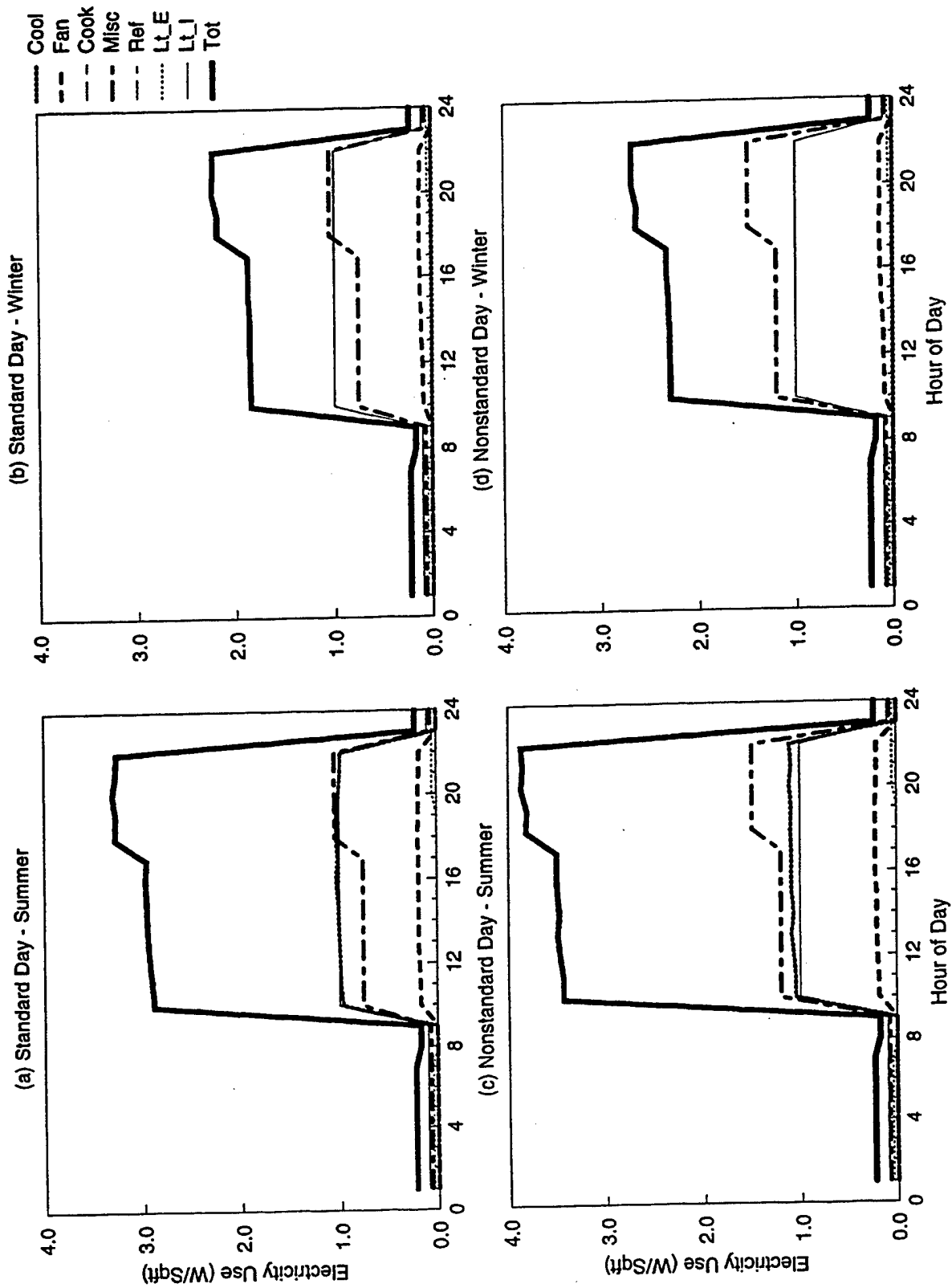


Figure B-23. DOE-2 Simulated End-use Load Shapes for Bowling Center

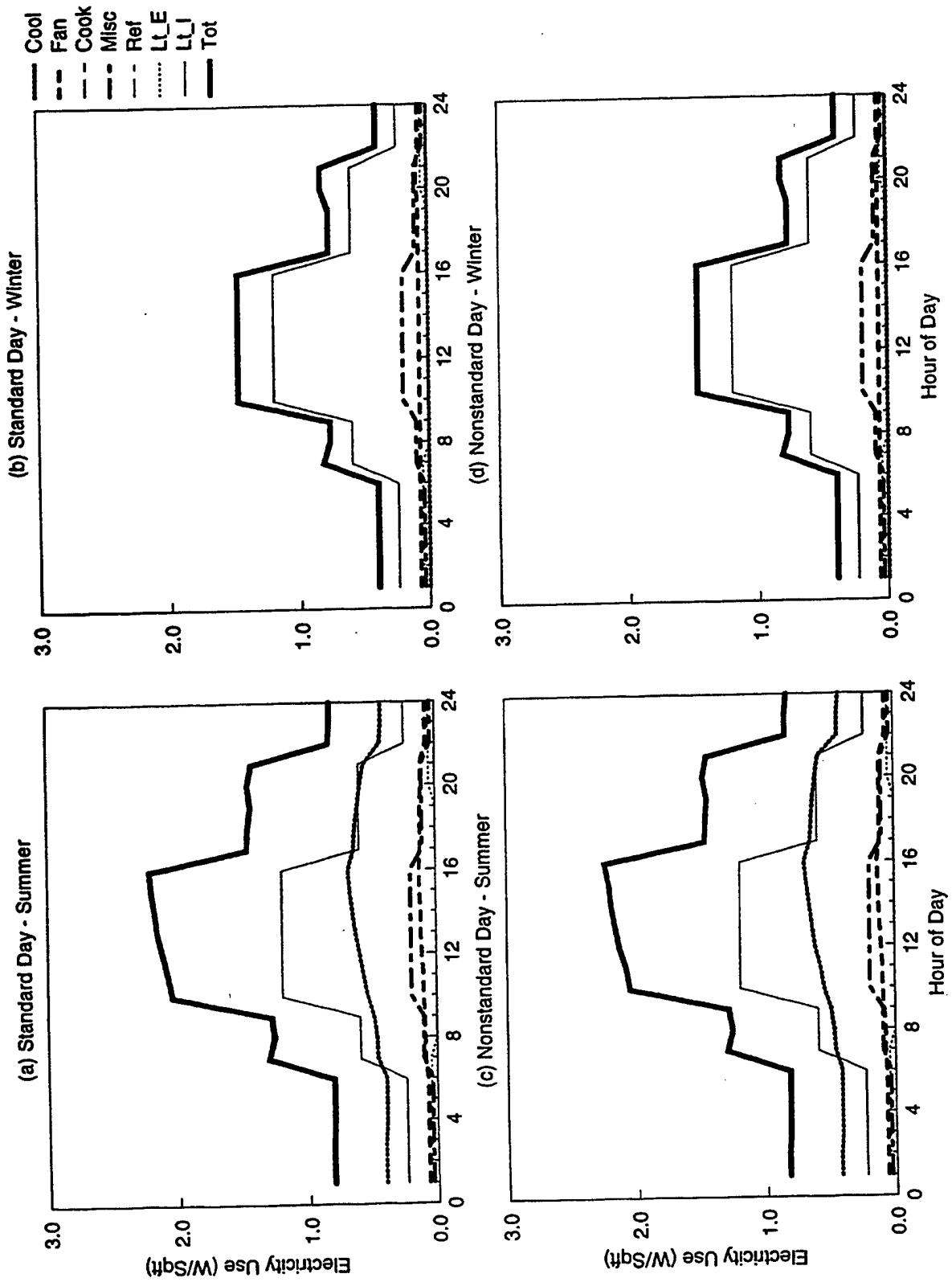


Figure B-24. DOE-2 Simulated End-use Load Shapes for Church

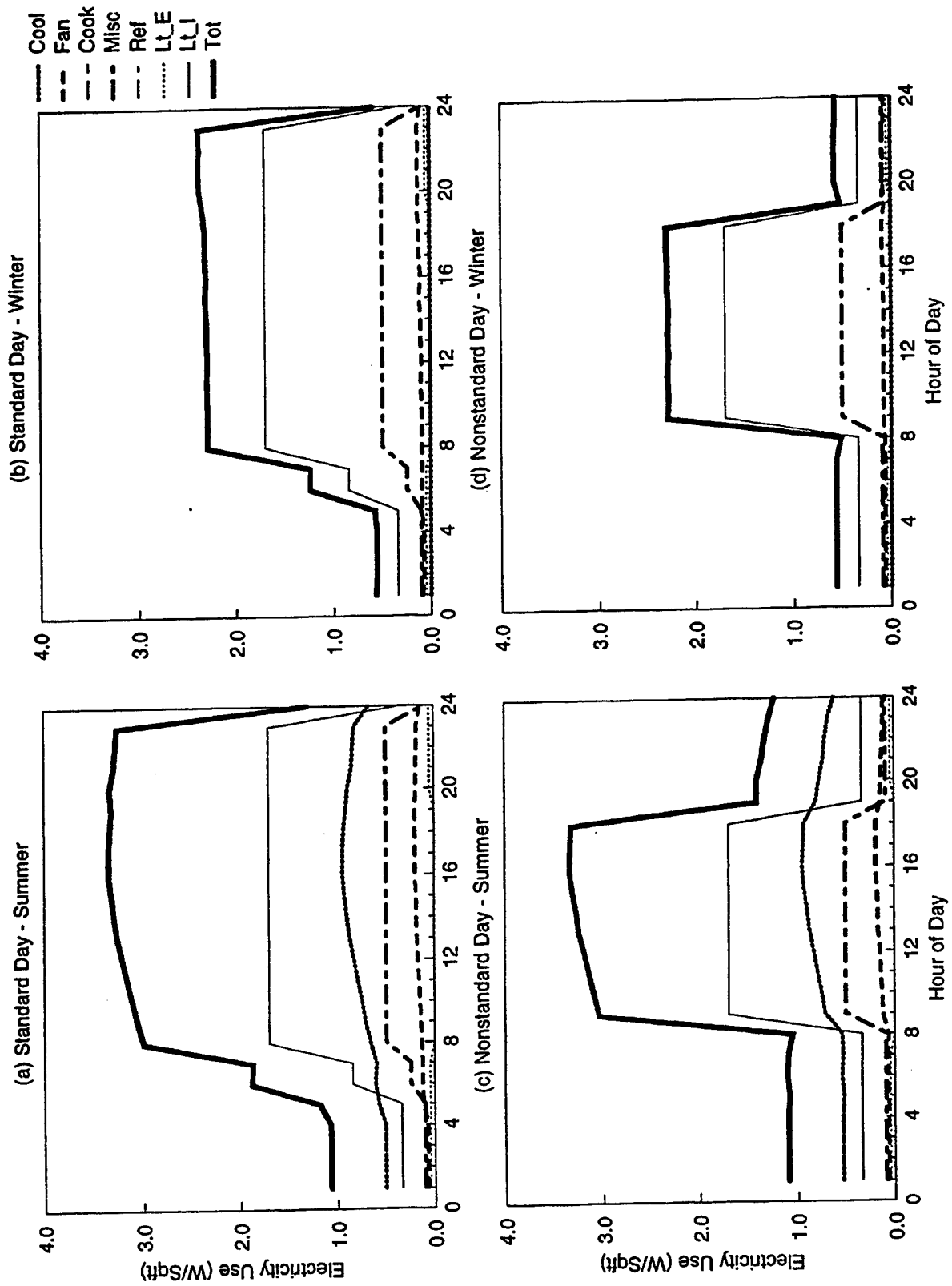


Figure B-25. DOE-2 Simulated End-use Load Shapes for Grocery Store

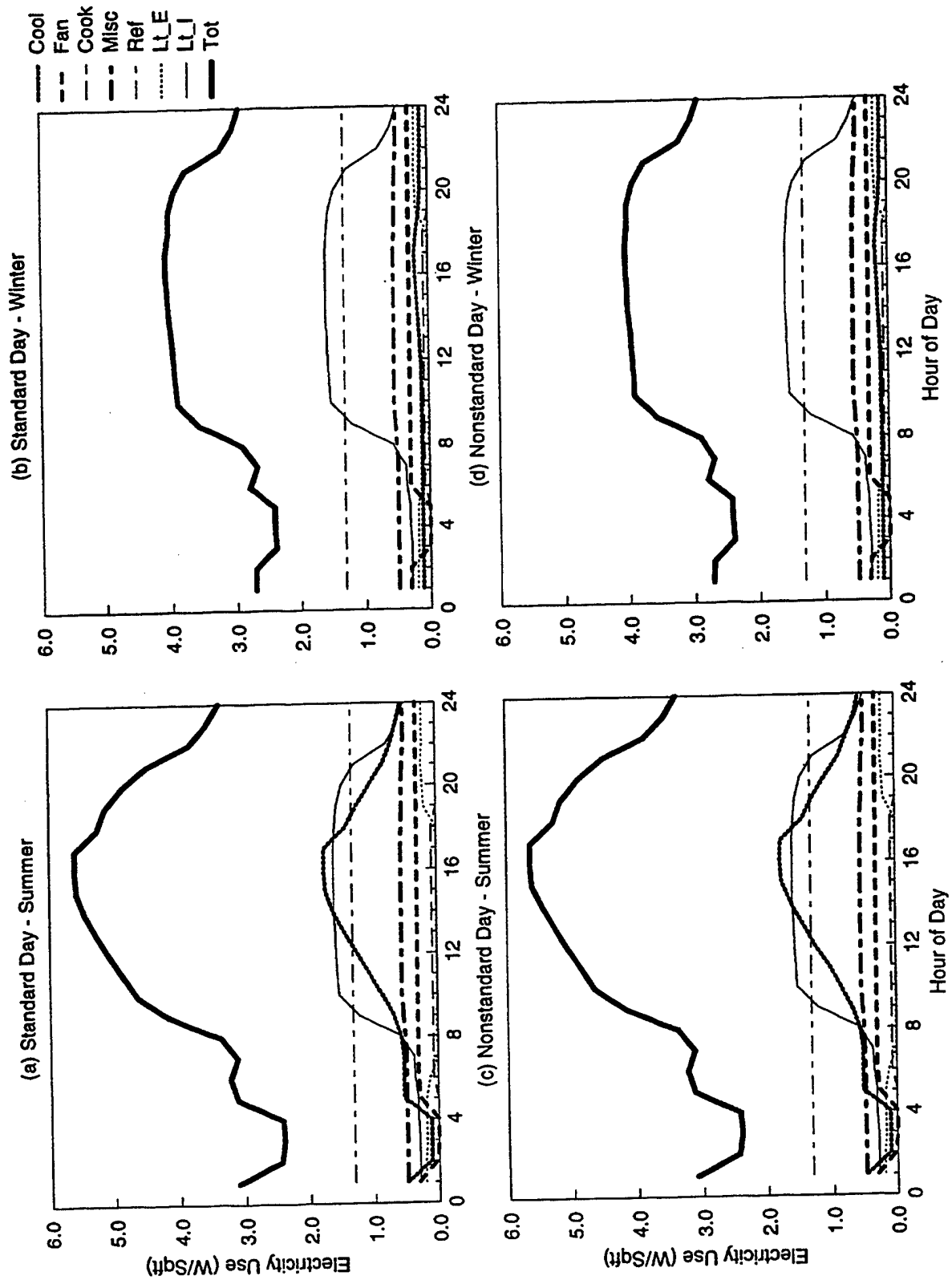


Figure B-26. DOE-2 Simulated End-use Load Shapes for Library

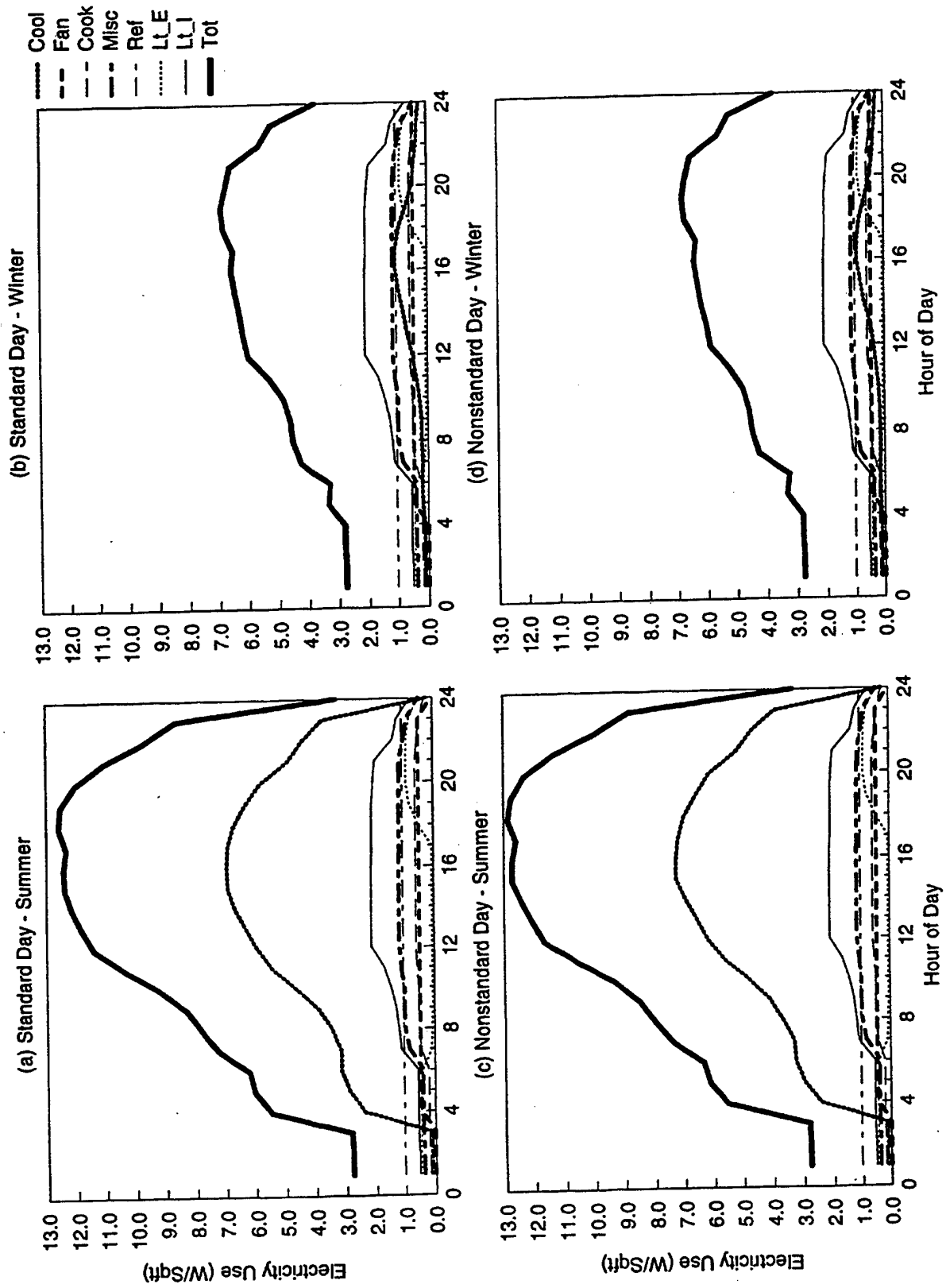


Figure B-27. DOE-2 Simulated End-use Load Shapes for Fastfood Restaurant

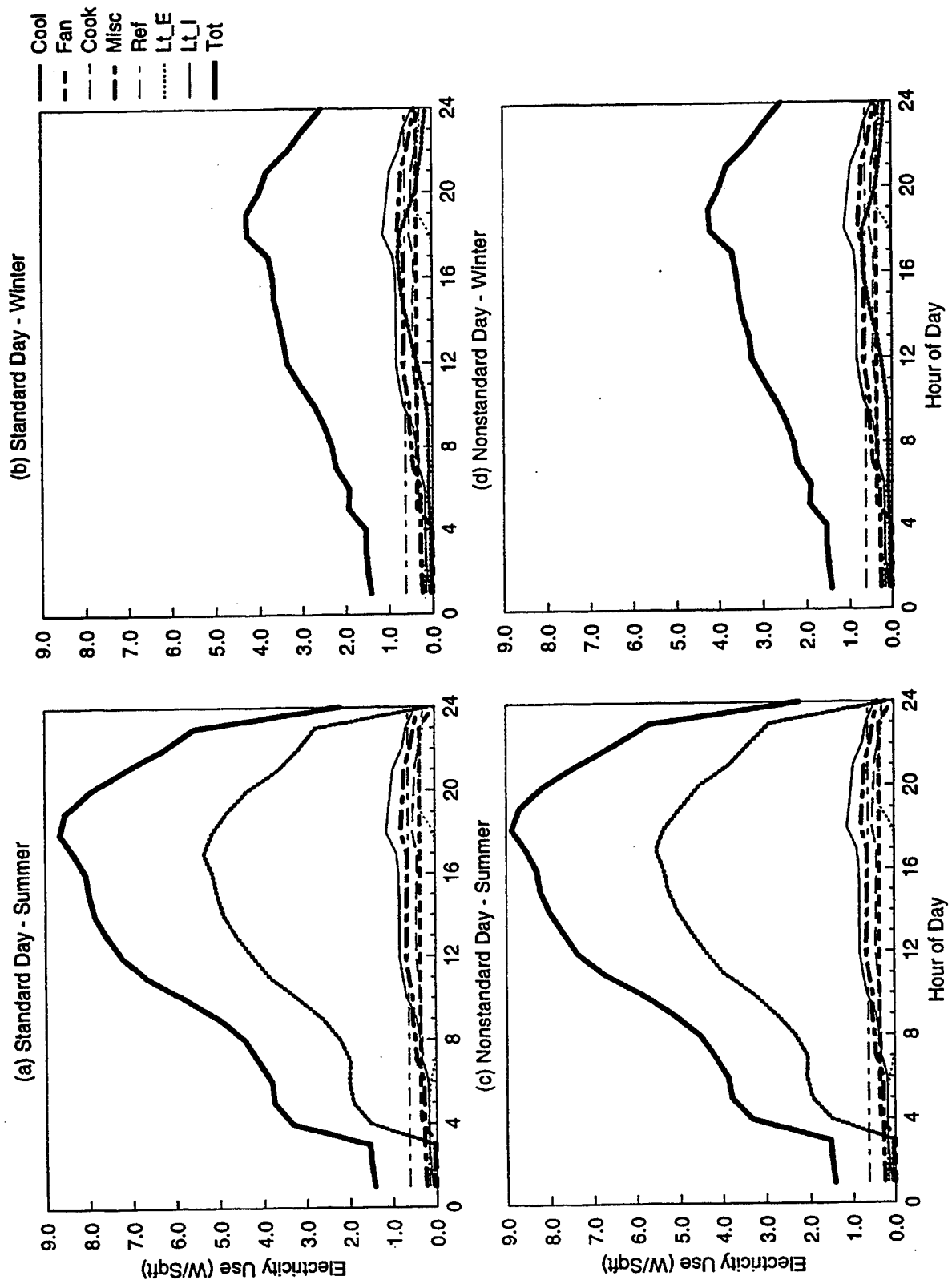


Figure B-28. DOE-2 Simulated End-use Load Shapes for Sitdown Restaurant

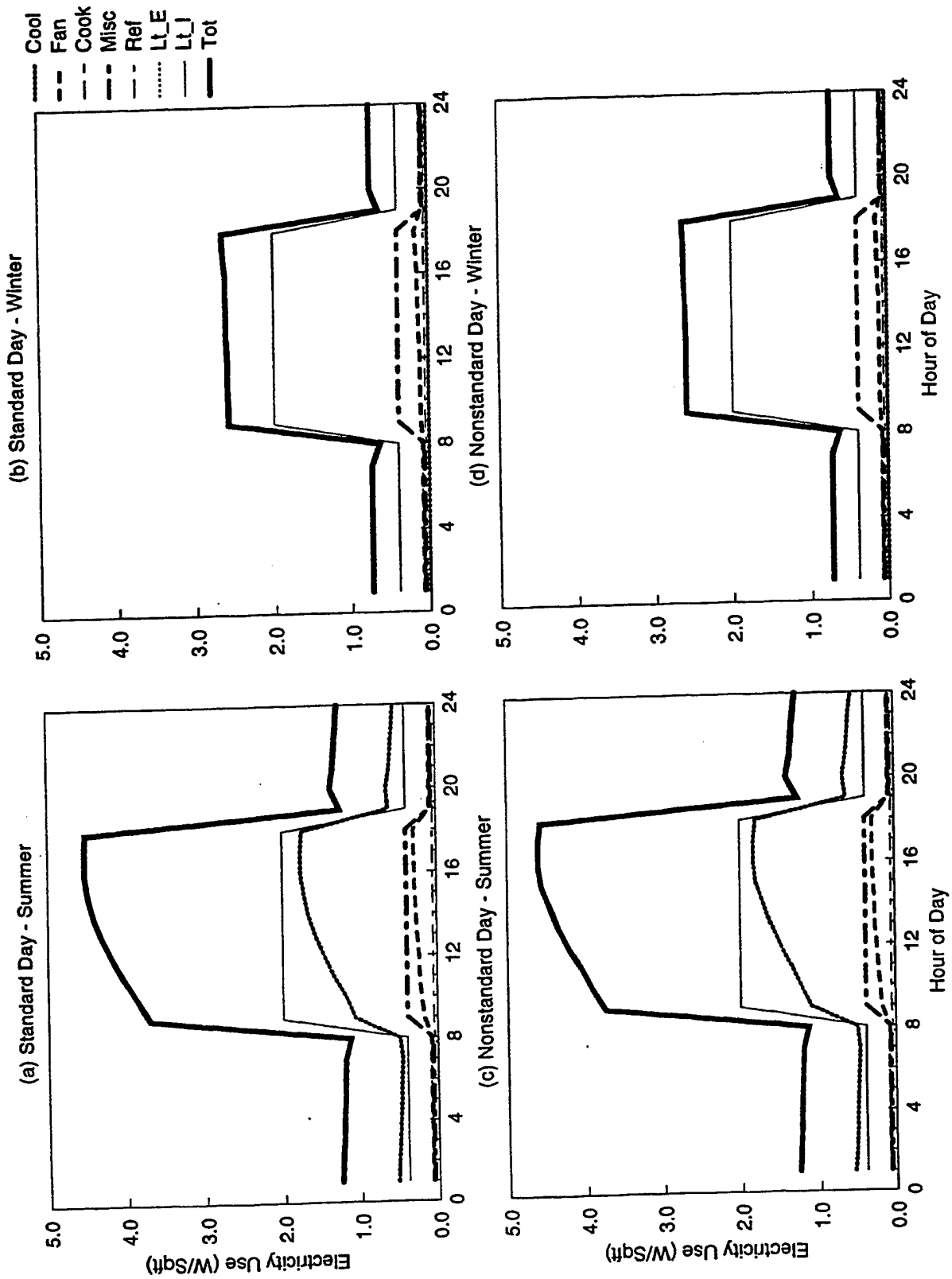


Figure B-29. DOE-2 Simulated End-use Load Shapes for Small Retail

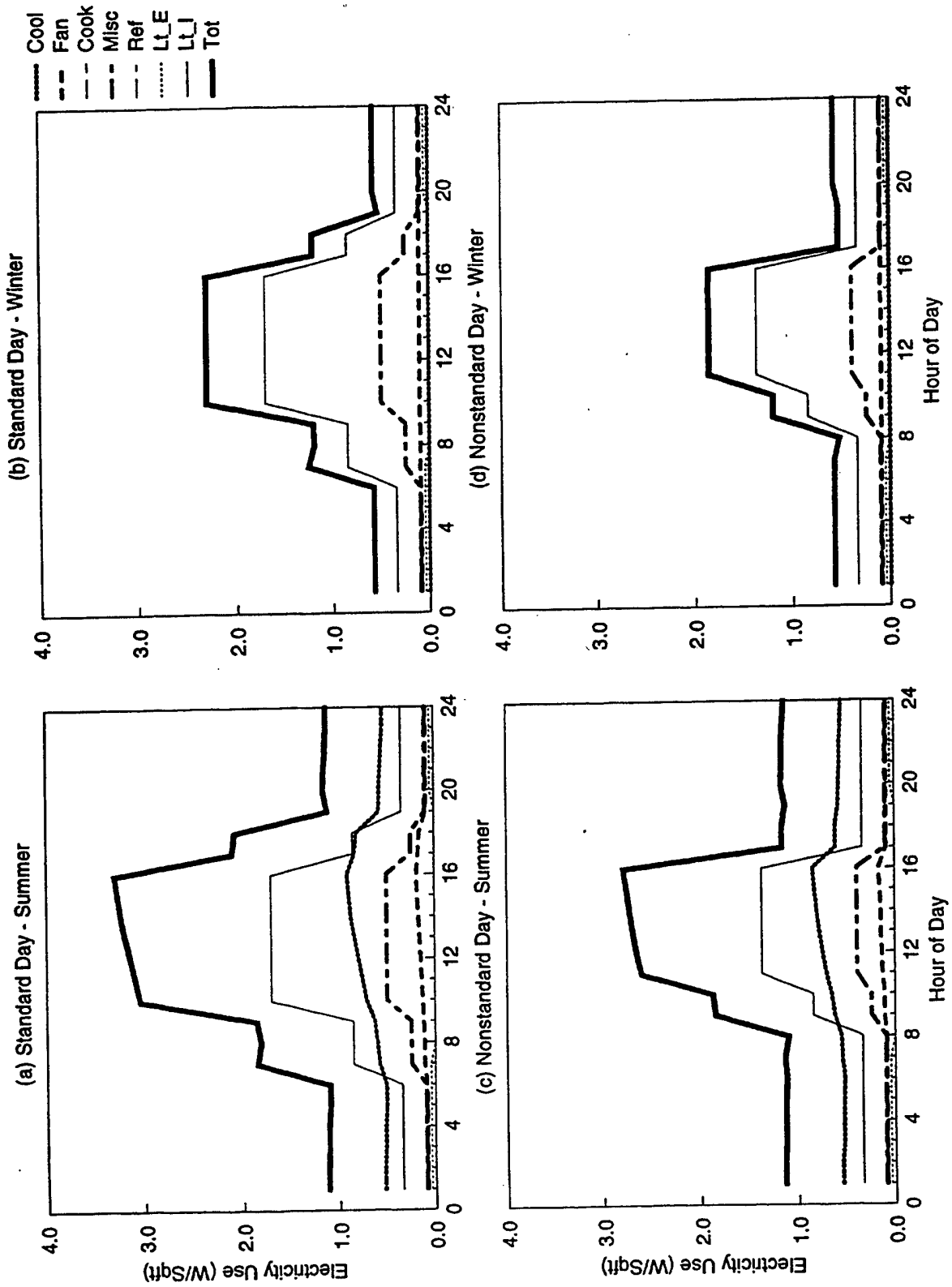


Figure B-30. DOE-2 Simulated End-use Load Shapes for Youth Center

Appendix C

EDA Reconciled Load Shapes by Prototype

EDA reconciled load shapes are presented by prototype in the order presented in **Table C-1** in this appendix. These load shapes were produced after scaling and smoothing the raw EDA hourly load. If smoothing was necessary, the end-uses and hourly intervals are denoted in **Table C-1**.

Figures C-1 to 3, 5-6, 8-11, 13-17, 19-22, 24-26, 28-31, 33-34, 36-39, 41-44, 46-52, 54-57, 59-60, 62-69.
EDA Reconciled End-use Load Shapes

The EDA prototypes combined by floor area into weighted EDA prototypes are presented immediately after the EDA load shapes mentioned above. See **Table 4-4** for those EDA prototypes combined into weighted EDA prototypes.

Figures C-4, 7, 12, 18, 23, 27, 32, 35, 40, 45, 53, 58, 61.
Weighted EDA Reconciled End-use Load Shapes - Winter - Standard Day

Table C-1. EDA Hourly Load Smoothing Summary

Prototype	Cool	Fan	Cook	Misc	Ref	Ex_Lit	In_Lit	Press
Barrack								
Hammer Head - 3	17-21	-	-	17-21	-	-	17-21	-
Hammer Head - 10	17-21	-	-	17-21	-	-	17-21	-
Hammer Head - 15	17-21	-	-	17-21	-	-	17-21	-
Rolling Pin - 3	17-20	-	-	-	-	-	17-20	-
Rolling Pin - 10	17-20	-	-	-	-	-	17-20	-
Modular - 2	5-8,19-21	5-8	-	-	5-8	-	-	-
Modular - 5	5-8,17-19	5-8	-	-	5-8	-	-	-
Modular - 15	5-8,18-21	5-8	-	-	5-8	-	-	-
Modular - W6†	-	-	-	-	-	-	-	-
Small - 10	15-19	15-19	-	-	-	-	-	-
Dining Hall - 3	4-8,18-22	4-8,18-22	-	-	4-8	-	-	-
Dining Hall - 5	4-8,18-22	4-8,18-22	-	-	4-8	-	-	-
Dining Hall - 10	4-8,18-22	4-8,18-22	-	-	4-8	-	-	-
Dining Hall - 15	4-8,18-22	4-8,18-22	-	-	4-8	-	-	-
Gymnasium - 2†	-	-	-	-	-	-	-	-
Gymnasium - 15	5-9,17-23	-	-	-	-	-	5-9,17-23	-
Administration								
Large - 2	17-20	17-20	-	17-20	-	-	17-20	-
Large - 5	17-20	17-20	-	17-20	-	-	17-20	-
Small - Old w/ Split DX - 2	5-10,17-21	5-10	-	-	-	-	-	-
Small - Old w/ Split DX - 10	-	-	-	-	-	-	-	-
Small - Old w/ Split DX - 15†	-	-	-	-	-	-	-	-
Small - Old w/ Chiller - 2†	-	-	-	-	-	-	-	-
Small - Old w/ Chiller - 3	5-10	-	-	-	-	-	-	-
Small - Old w/ Chiller - 10	5-10	-	-	-	-	-	-	-
Small - Old w/ Chiller - 15	5-10	-	-	-	-	-	-	-
Small - New w/ Split DX - 2	5-10,18-21	5-10,18-21	-	-	-	-	-	-
Small - New w/ Split DX - 10	-	-	-	-	-	-	-	-
Small - New w/ Chiller - 2	5-10,16-20	5-10,16-20	-	-	-	-	-	-
Small - New w/ Chiller - W6†	-	-	-	-	-	-	-	-
Vehicle Maintenance								
Small w/ No AC - 3	-	-	-	5-7	-	-	5-7	-
Small w/ No AC - 10	-	-	-	5-7	-	-	5-7	-
Large w/ Split DX - 3	5-7,18-20	5-7	-	5-7	-	-	5-7	-
Large w/ Split DX - 10	5-7,18-20	5-7	-	5-7	-	-	5-7	-
Large w/ Split DX - 15	5-7,18-20	5-7	-	5-7	-	-	5-7	-
Large w/ Split DX - W6†	-	-	-	-	-	-	-	-
Large w/ Chiller - 15	5-7,17-20	-	-	-	-	-	5-7,17-20	-
Large w/ Chiller - W6†	-	-	-	-	-	-	-	-
Hangar - 15	5-8,17-20	5-8	-	-	-	-	5-8	-
Hospital - 9	-	-	-	-	-	-	-	-
Residential								
Detached - 5	6-10	-	-	6-10	-	-	-	-
Detached - 12	-	-	-	18-21	-	-	18-21	-
Detached - W4	-	-	-	-	-	-	-	-
Two Plex - 5	6-10	-	-	6-10	-	-	-	-
Two Plex - 12	-	-	-	18-21	-	-	18-21	-
Two Plex - W4	-	-	-	-	-	-	-	-
Two Plex - W5†	-	-	-	-	-	-	-	-
Four Plex - 3	16-19	-	-	-	-	-	-	-
Four Plex - 12	-	-	-	18-21	-	-	18-21	-
Other								
Retail - Large - W5	-	-	-	-	-	-	-	-
Warehouse								
w/ No AC - 3	-	-	-	5-8	-	5-8	5-8	-
w/ Split DX - W6	-	-	-	-	-	-	-	-
Miscellaneous	-	-	-	-	-	-	-	-

† These feeders produced "questionable" EUIs or loadshapes and were not smoothed, see Chapter 4 for explanation.

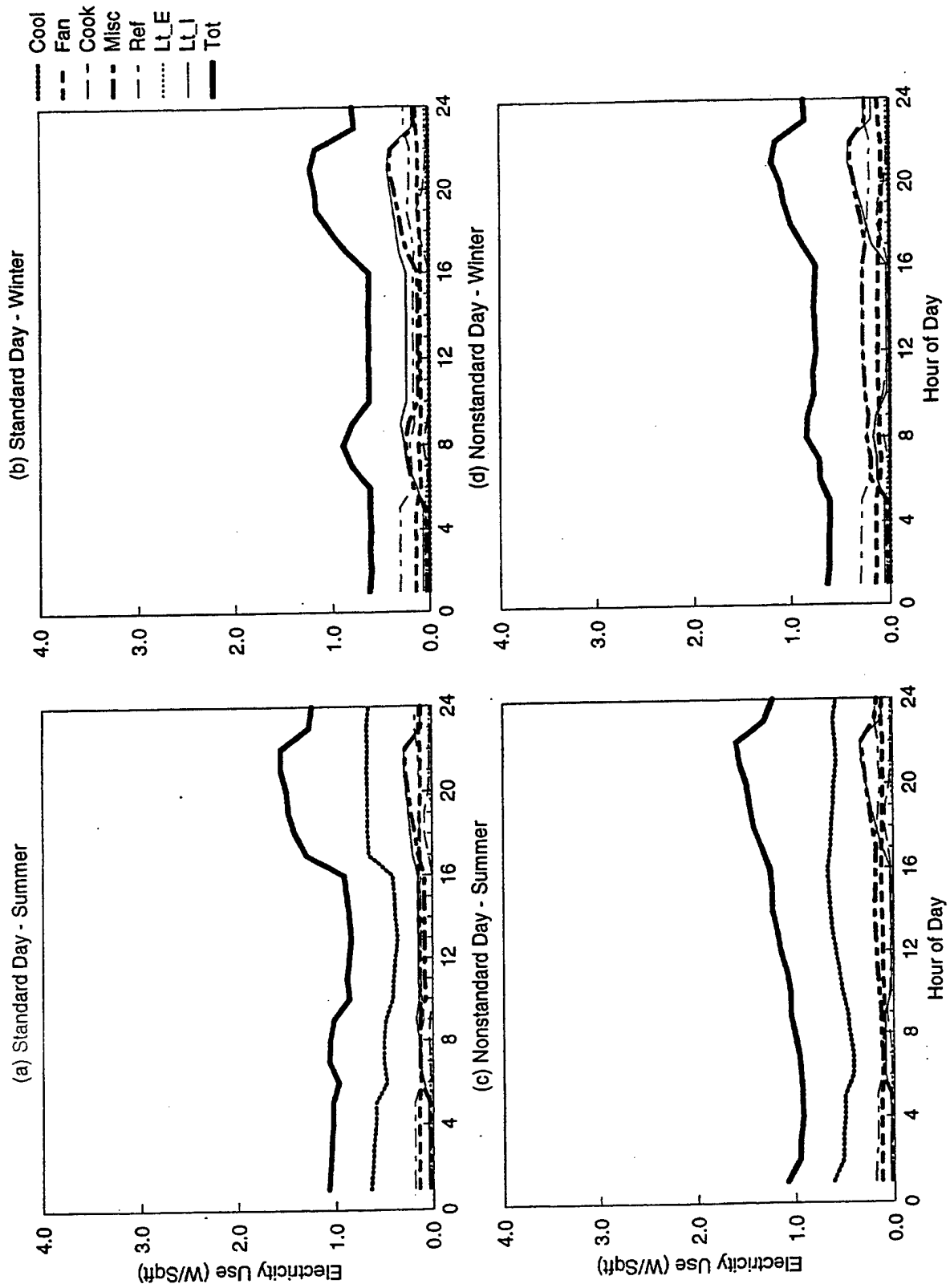


Figure C-1. EDA Reconciled End-use Load Shapes for Hammerhead Barrack (Feeder 3)

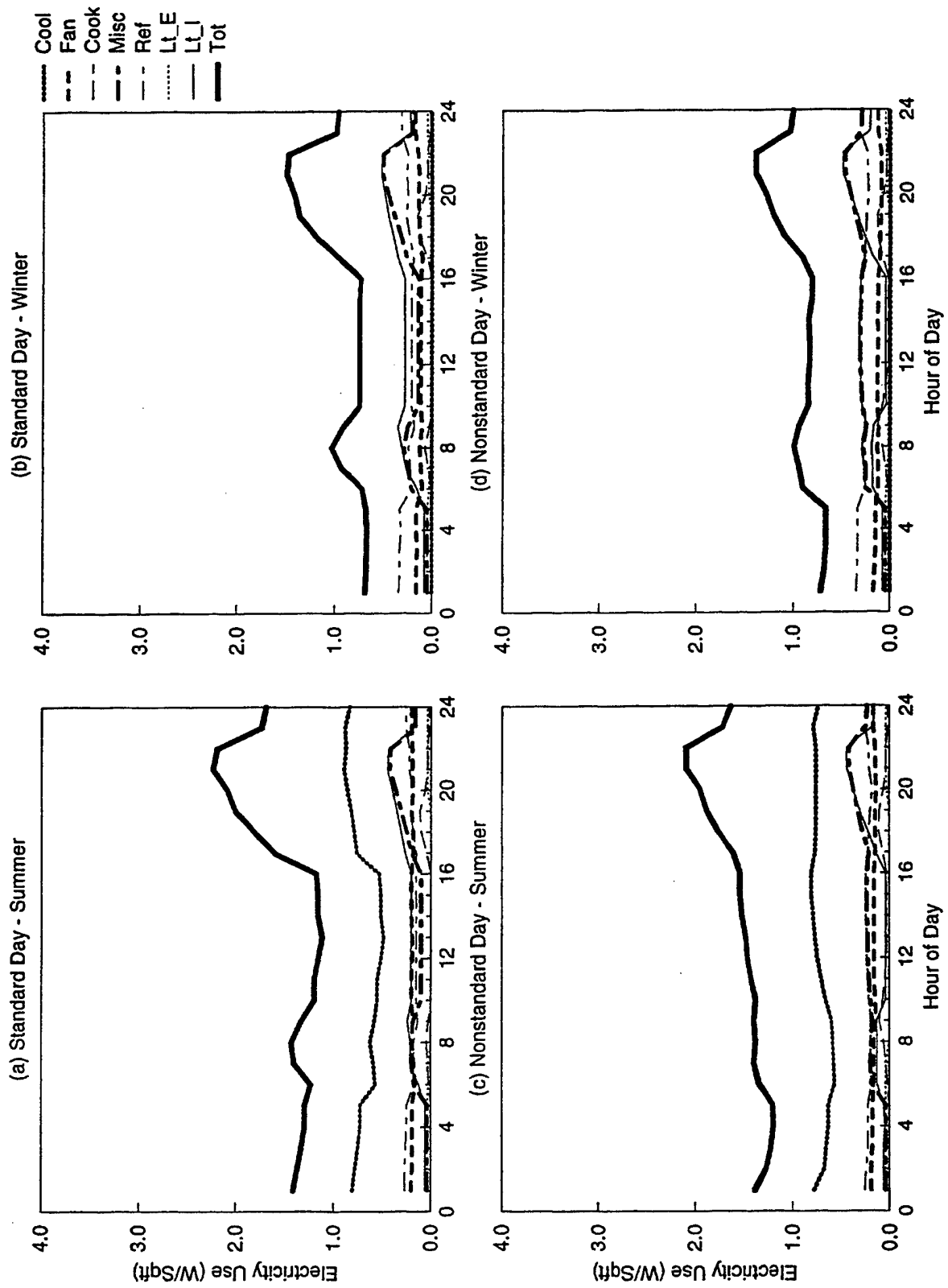


Figure C-2. EDA Reconciled End-use Load Shapes for Hammerhead Barrack (Feeder 10)

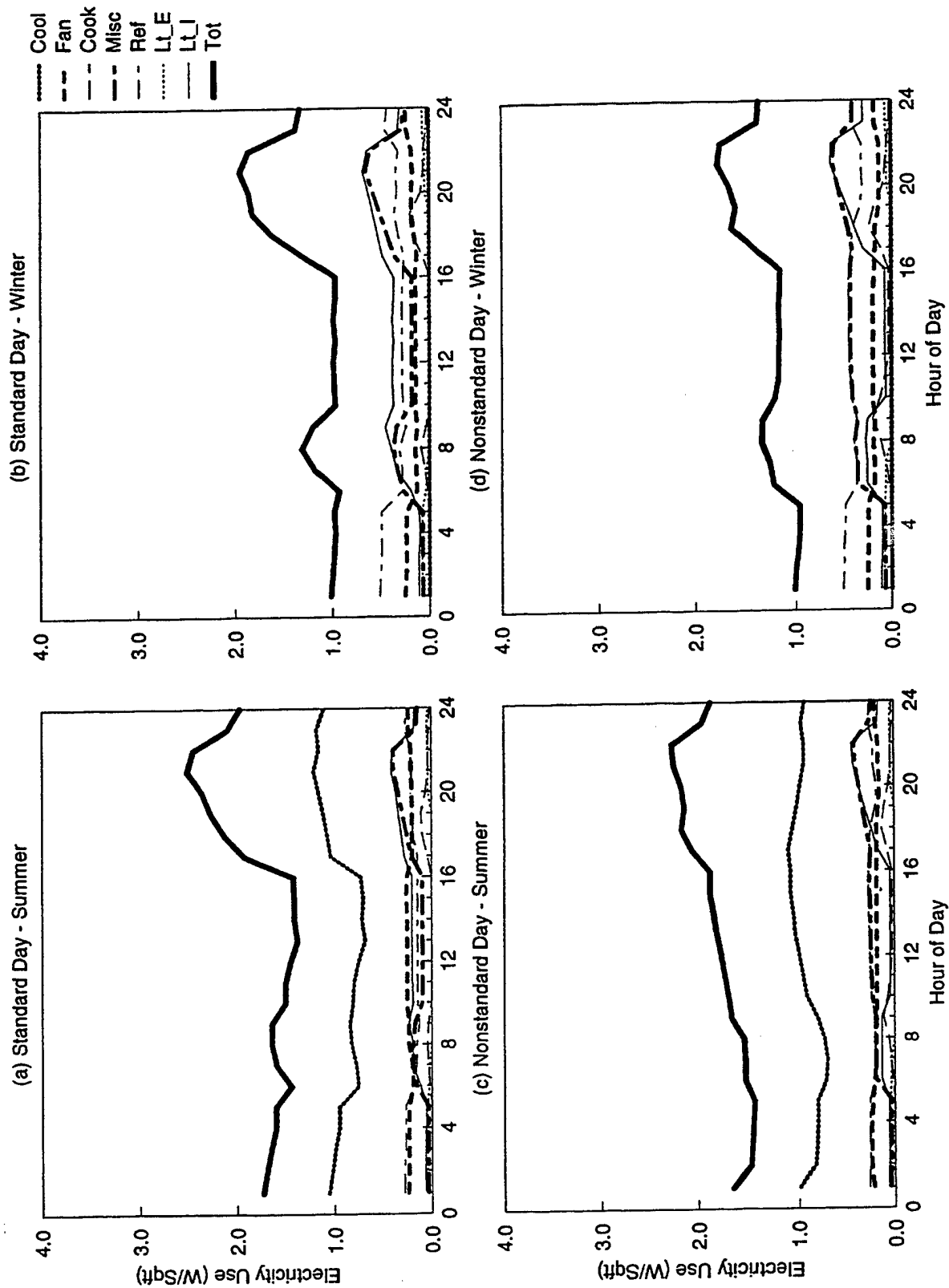


Figure C-3. EDA Reconciled End-use Load Shapes for Hammerhead Barrack (Feeder 15)

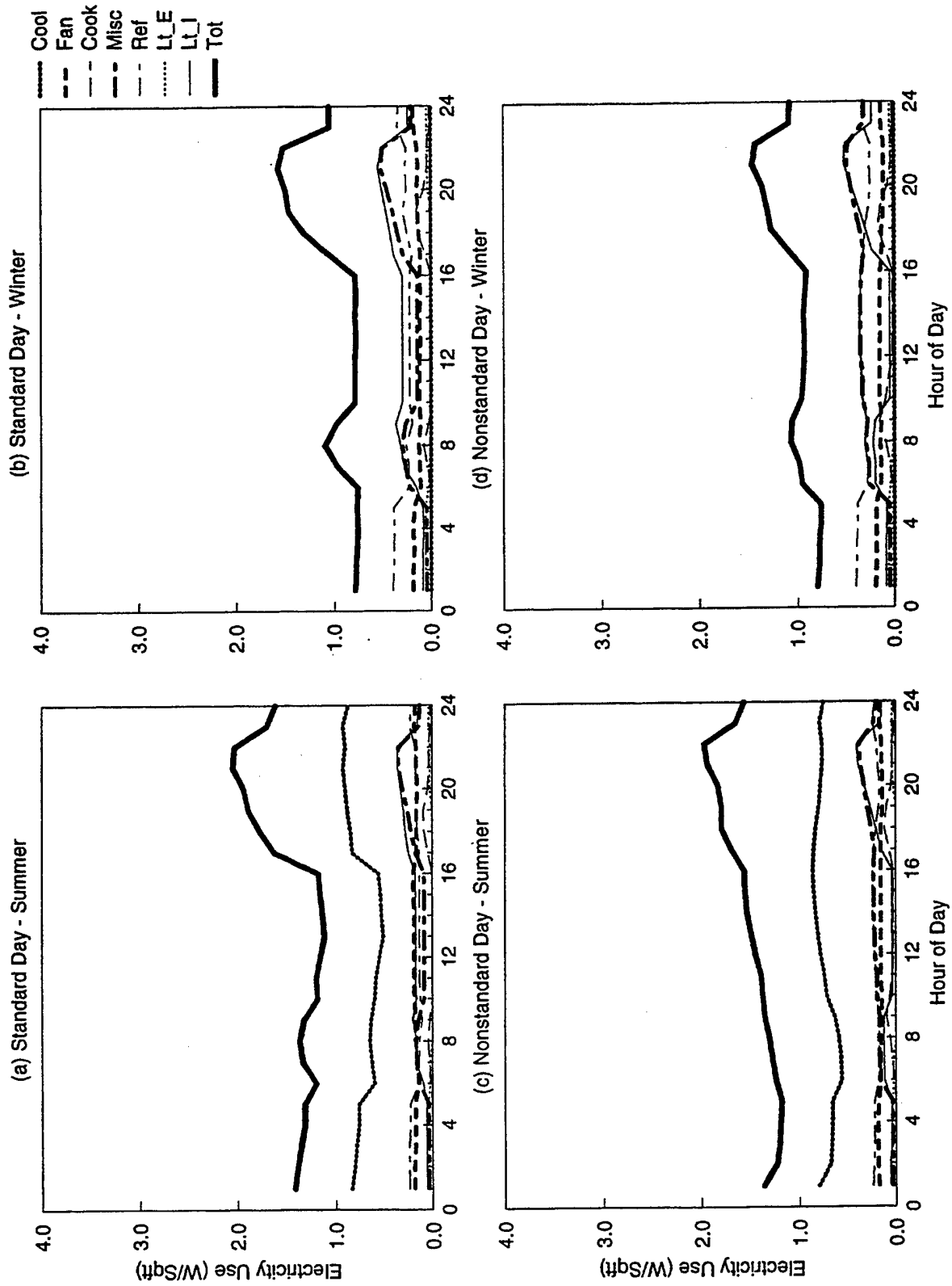


Figure C-4. EDA Reconciled End-use Load Shapes for Hammerhead Barrack (Weighted 3,10,15)

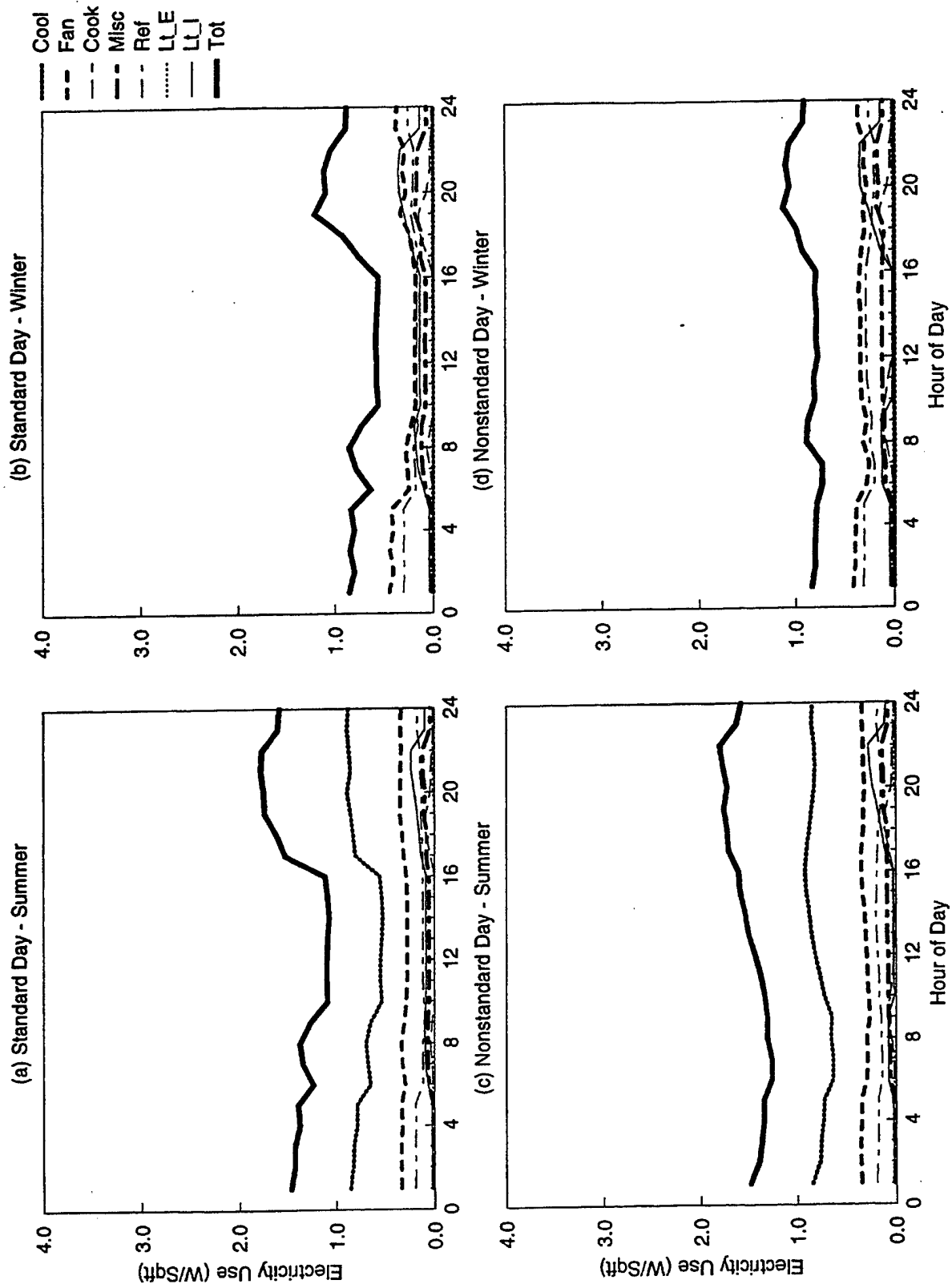


Figure C-5. EDA Reconciled End-use Load Shapes for Rolling Pin Barrack (Feeder 3)

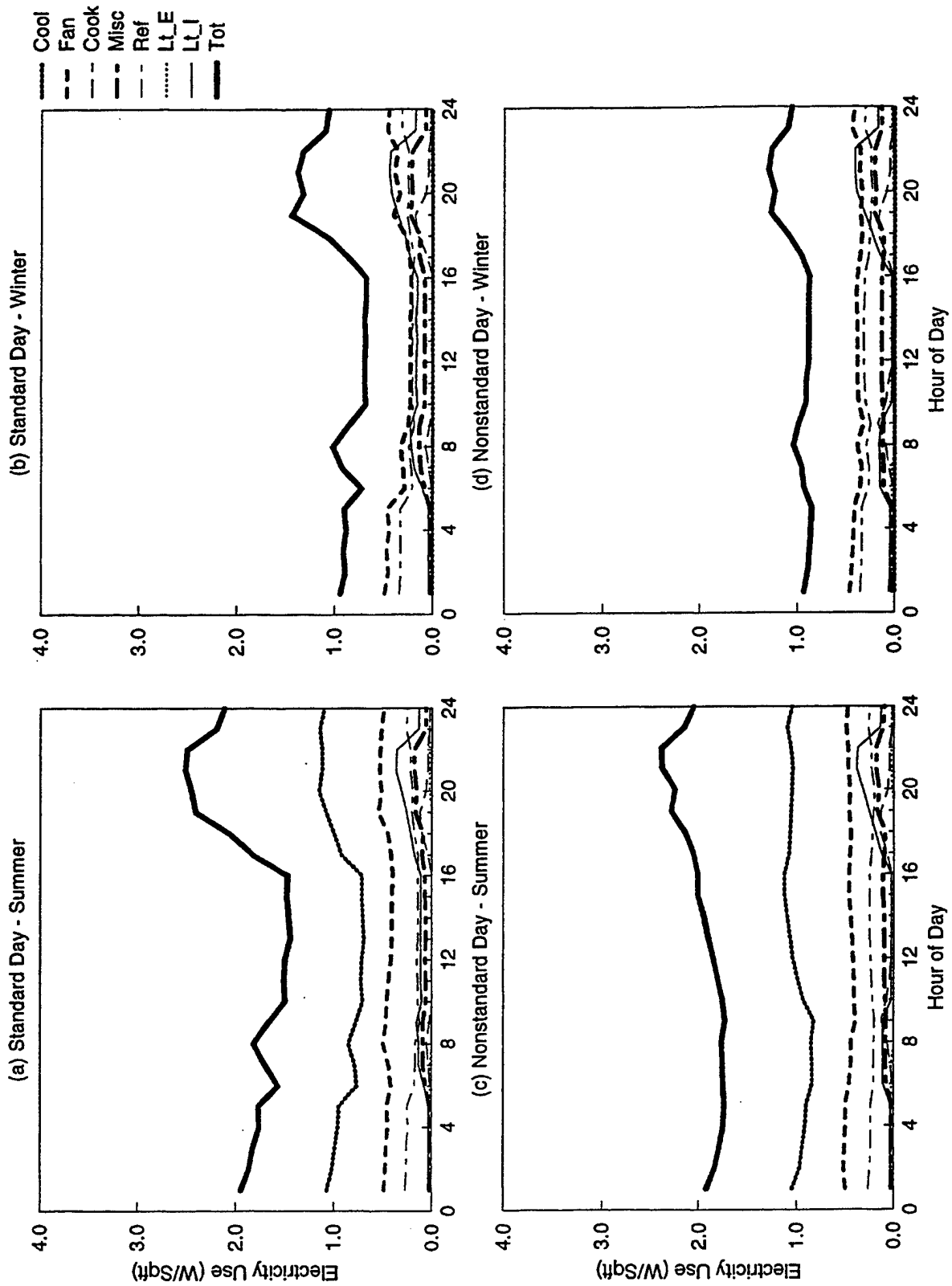


Figure C-6. EDA Reconciled End-use Load Shapes for Rolling Pin Barrack (Feeder 10)

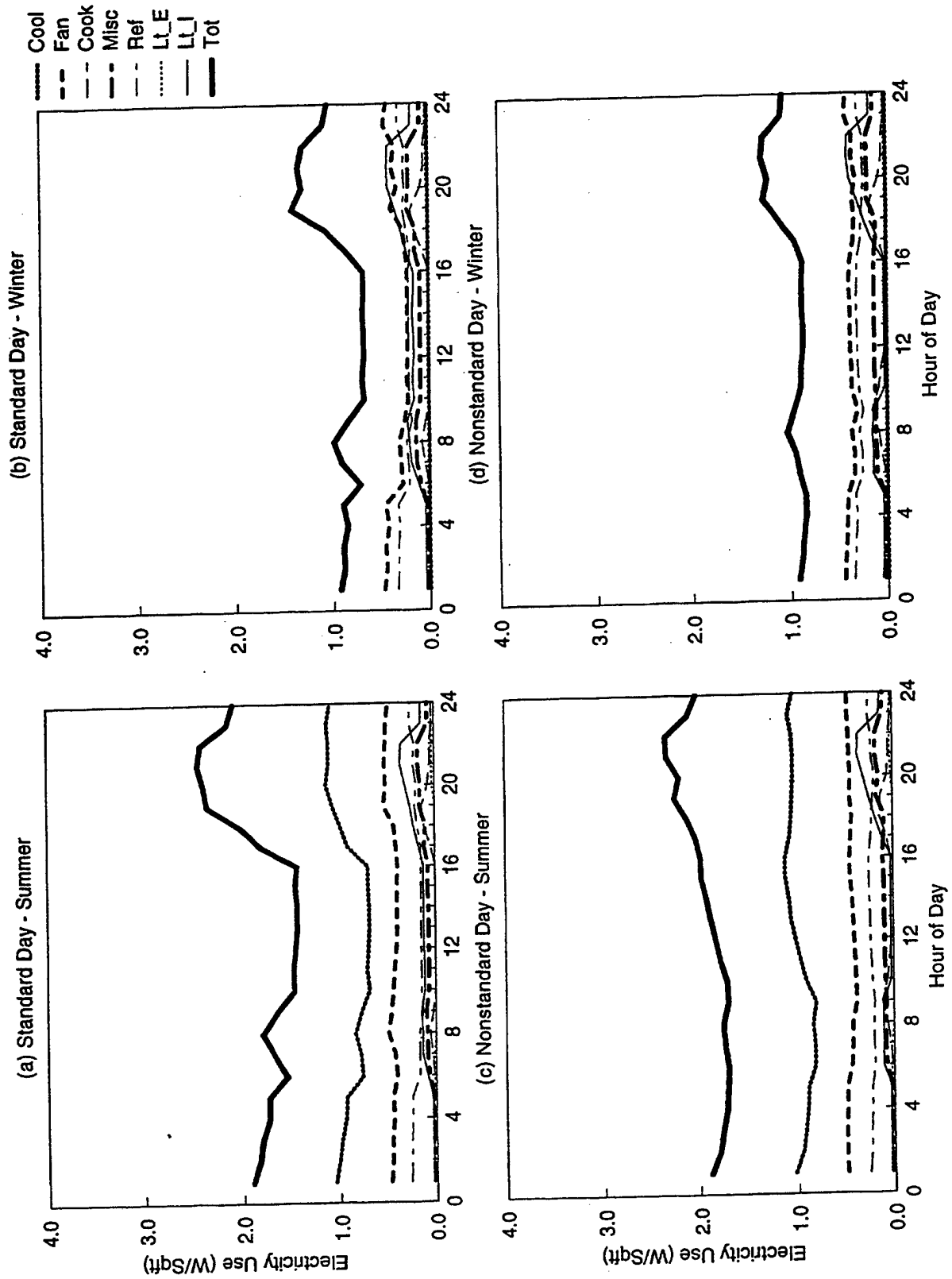


Figure C-7. EDA Reconciled End-use Load Shapes for Rolling Pin Barrack (Weighted 3,10)

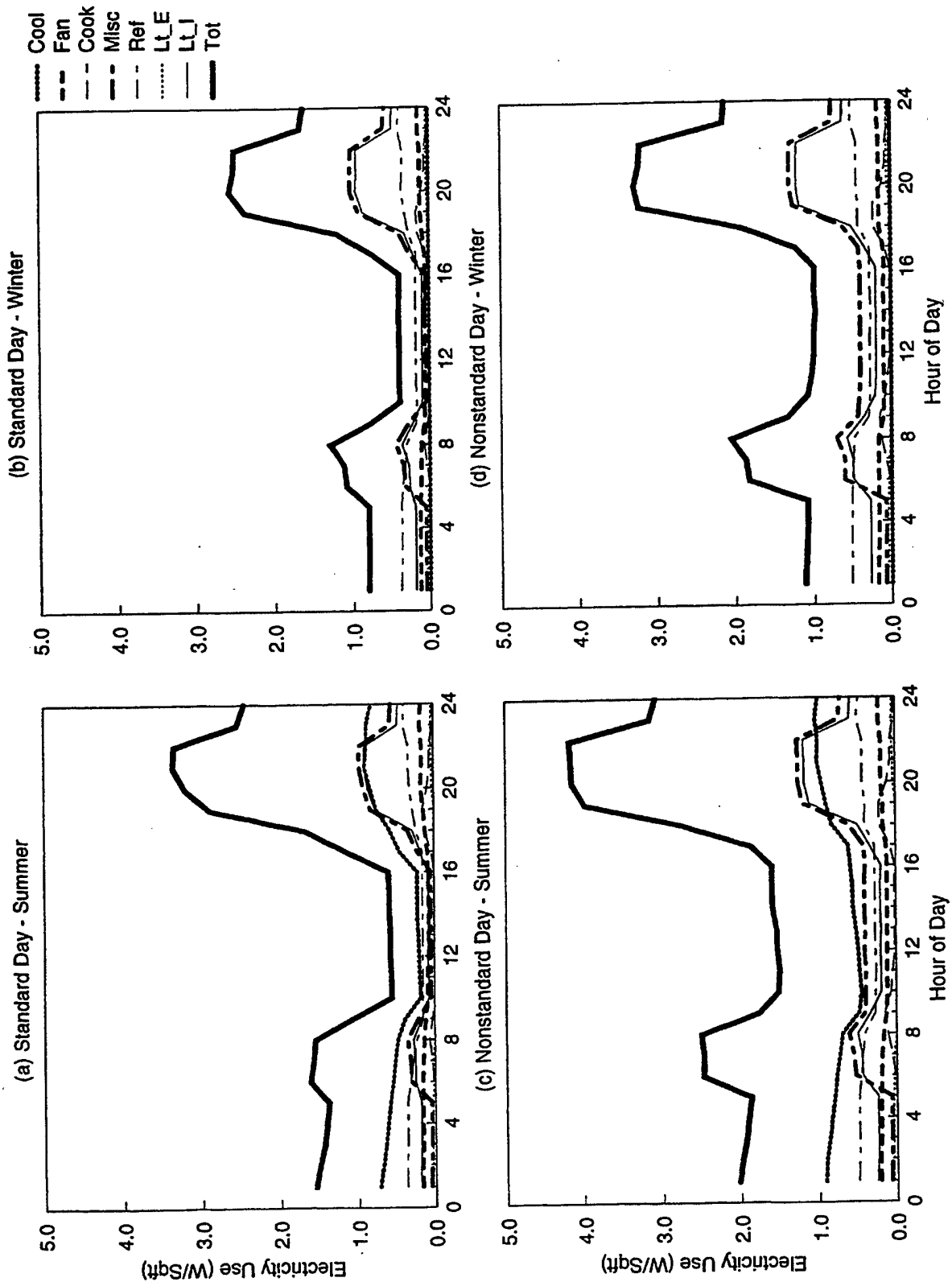


Figure C-8. EDA Reconciled End-use Load Shapes for Modular Barrack (Feeder 2)

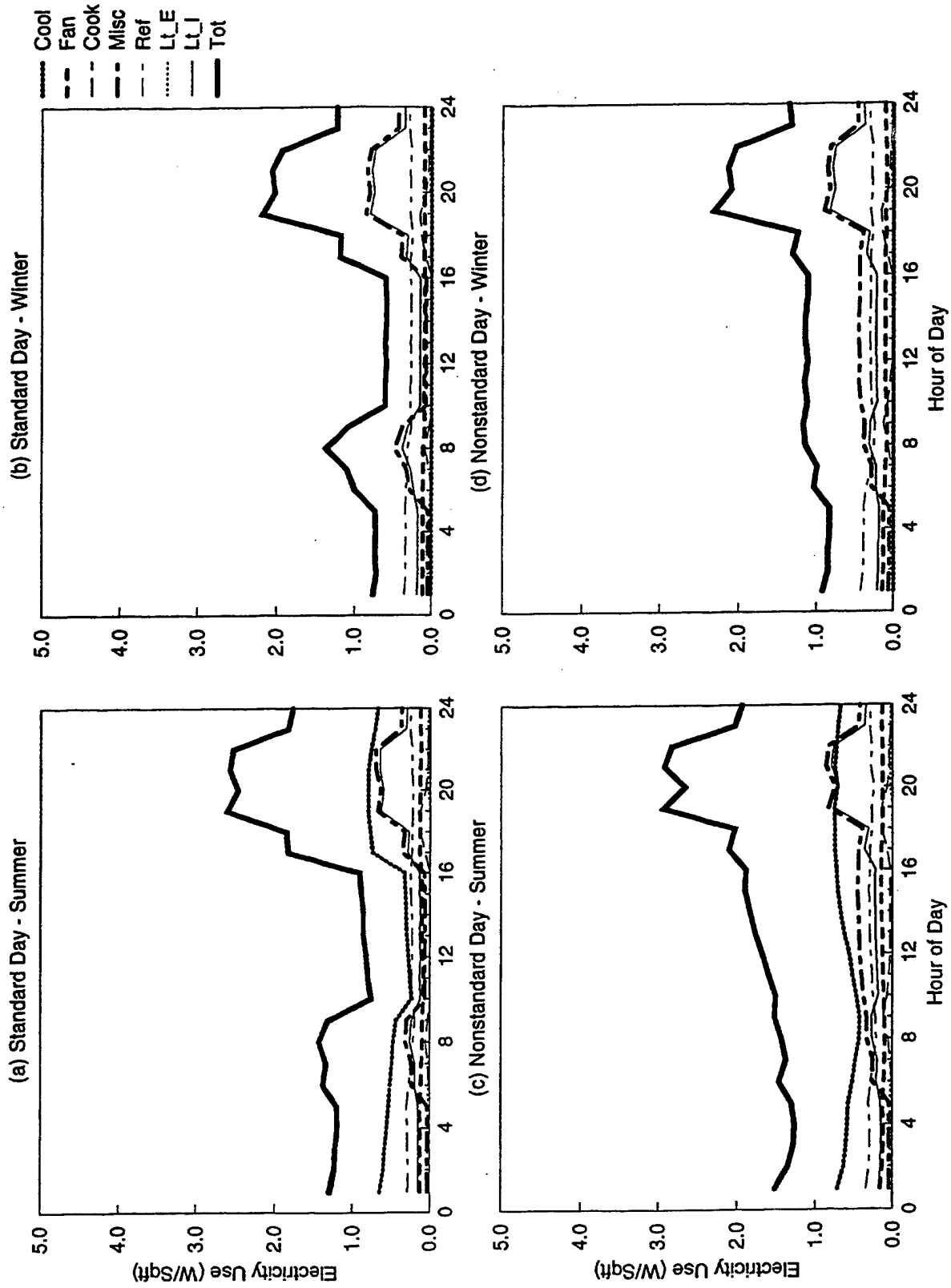


Figure C-9. EDA Reconciled End-use Load Shapes for Modular Barrack (Feeder 5)

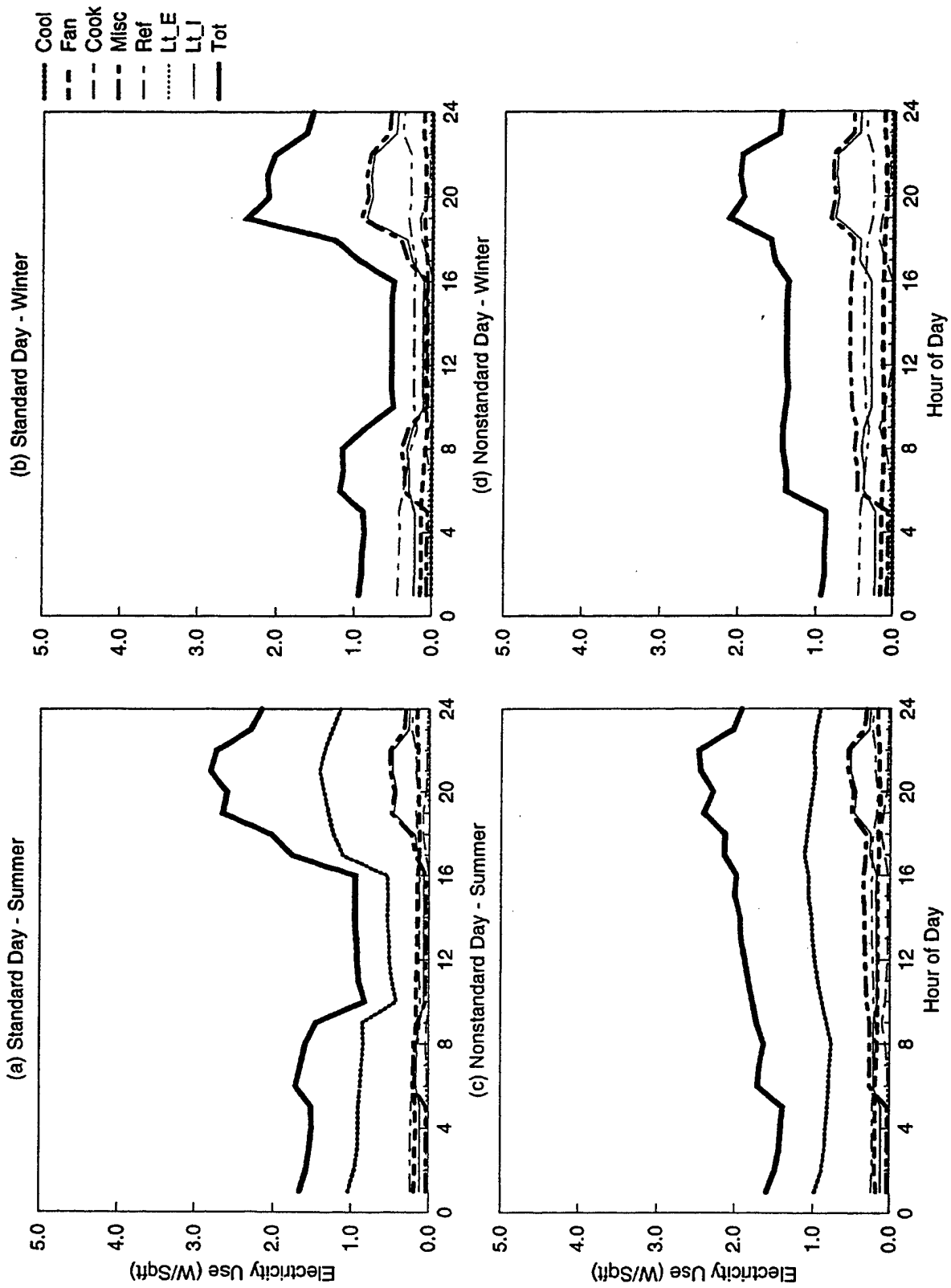


Figure C-10. EDA Reconciled End-use Load Shapes for Modular Barrack (Feeder 15)

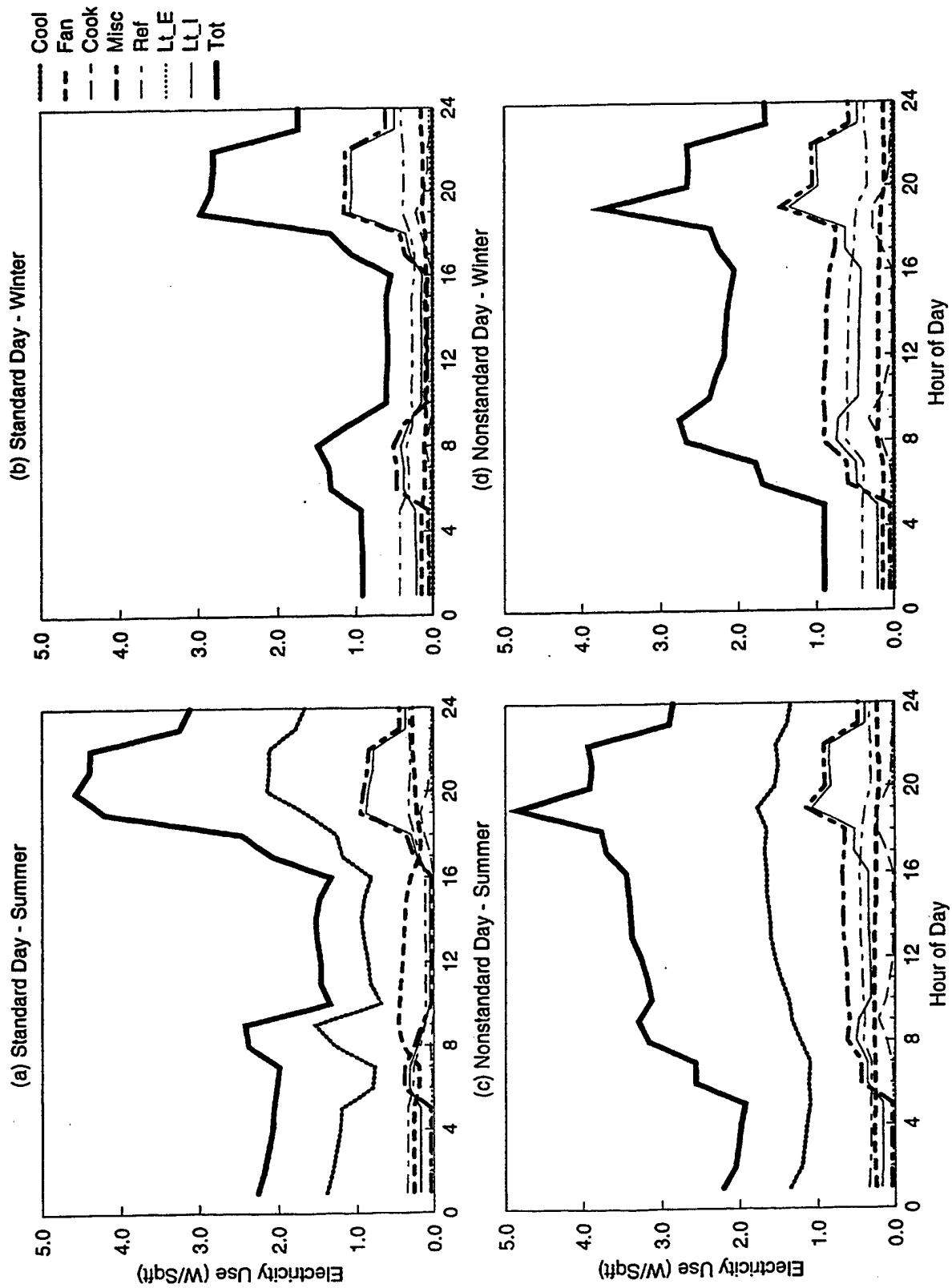


Figure C-11. EDA Reconciled End-use Load Shapes for Modular Barrack (Feeder W6)

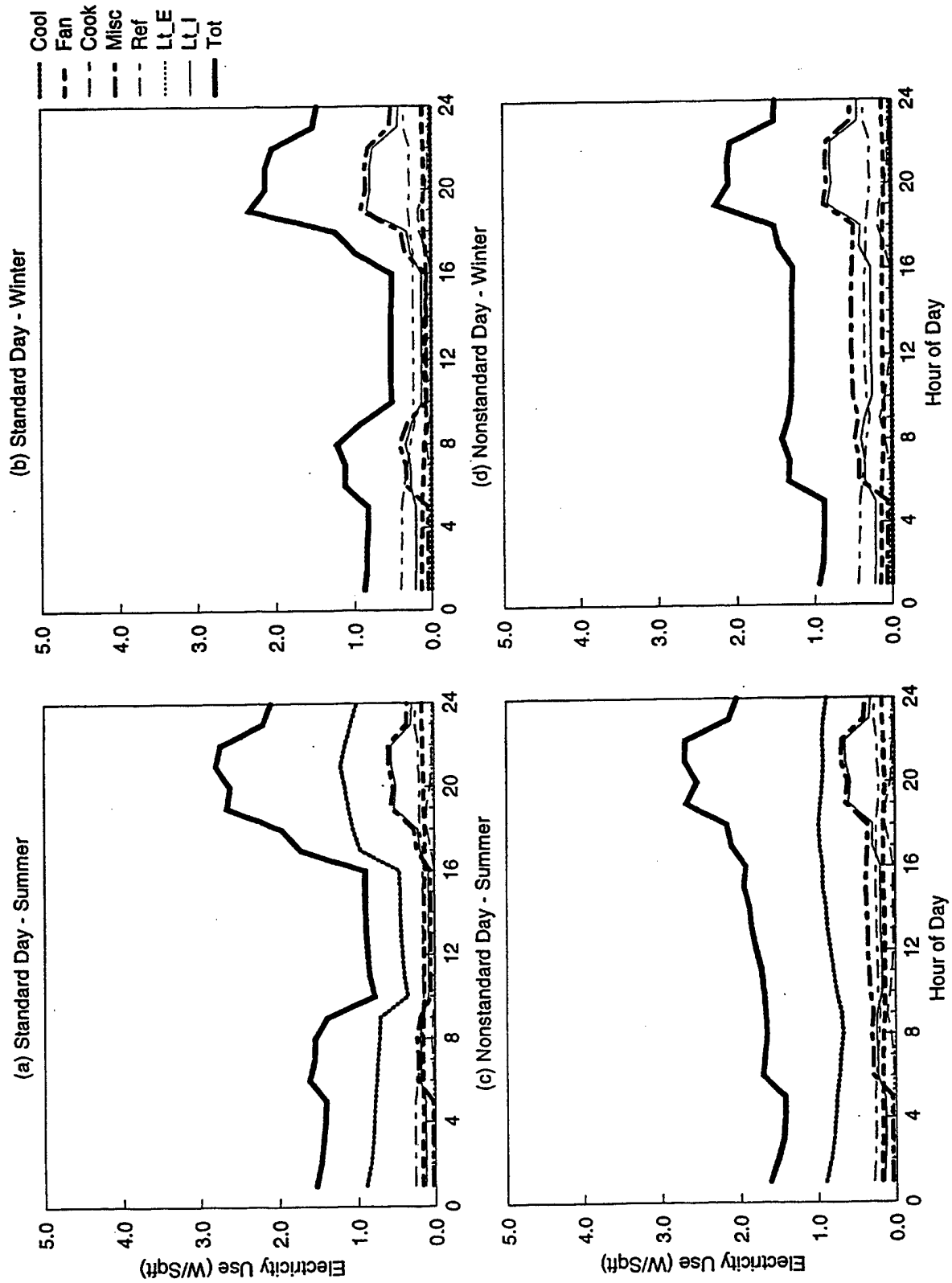


Figure C-12. EDA Reconciled End-use Load Shapes for Modular Barrack (Weighted 2,5,15)

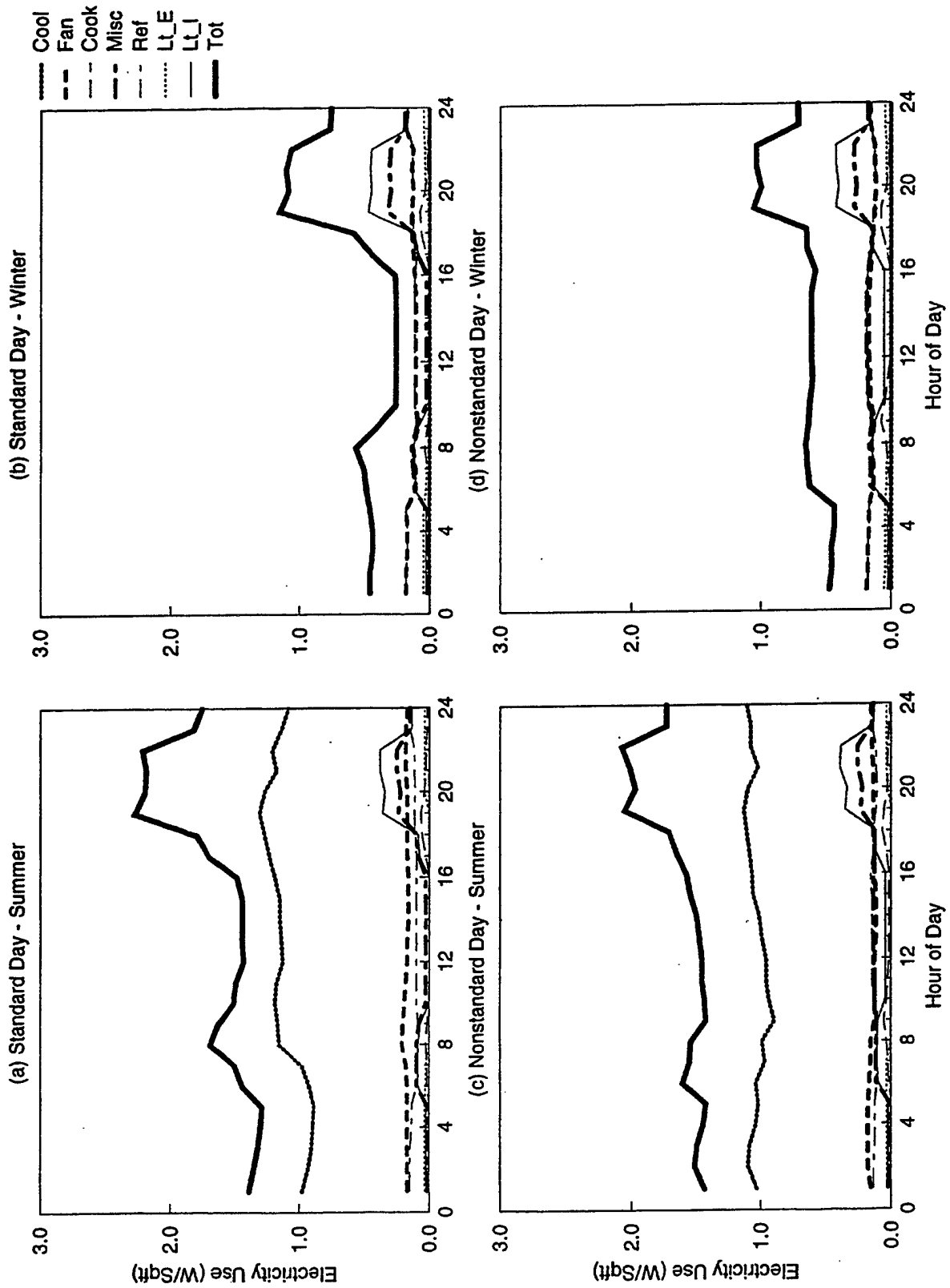


Figure C-13. EDA Reconciled End-use Load Shapes for Small Barrack (Feeder 10)

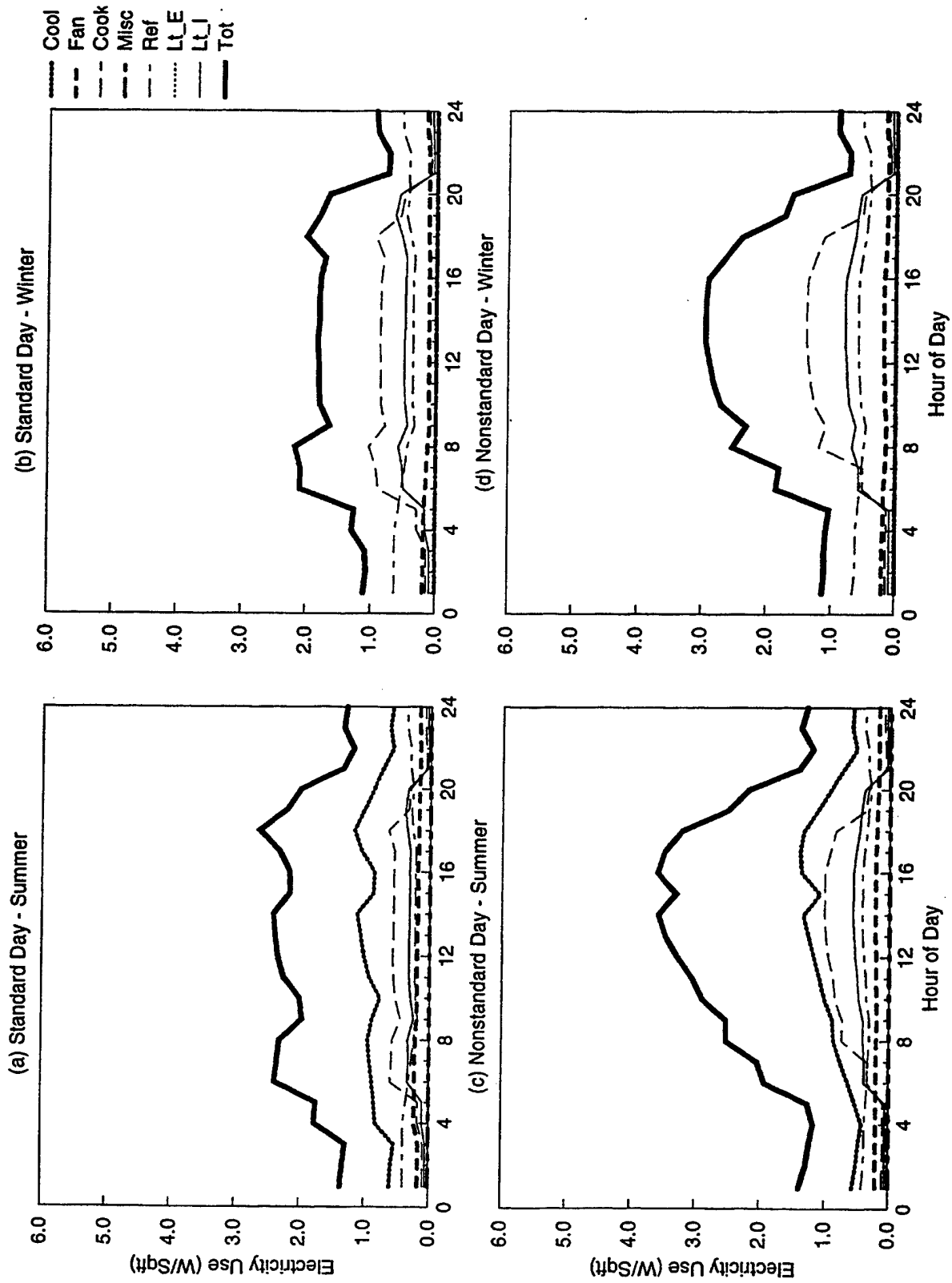


Figure C-14. EDA Reconciled End-use Load Shapes for Dining Hall (Feeder 3)

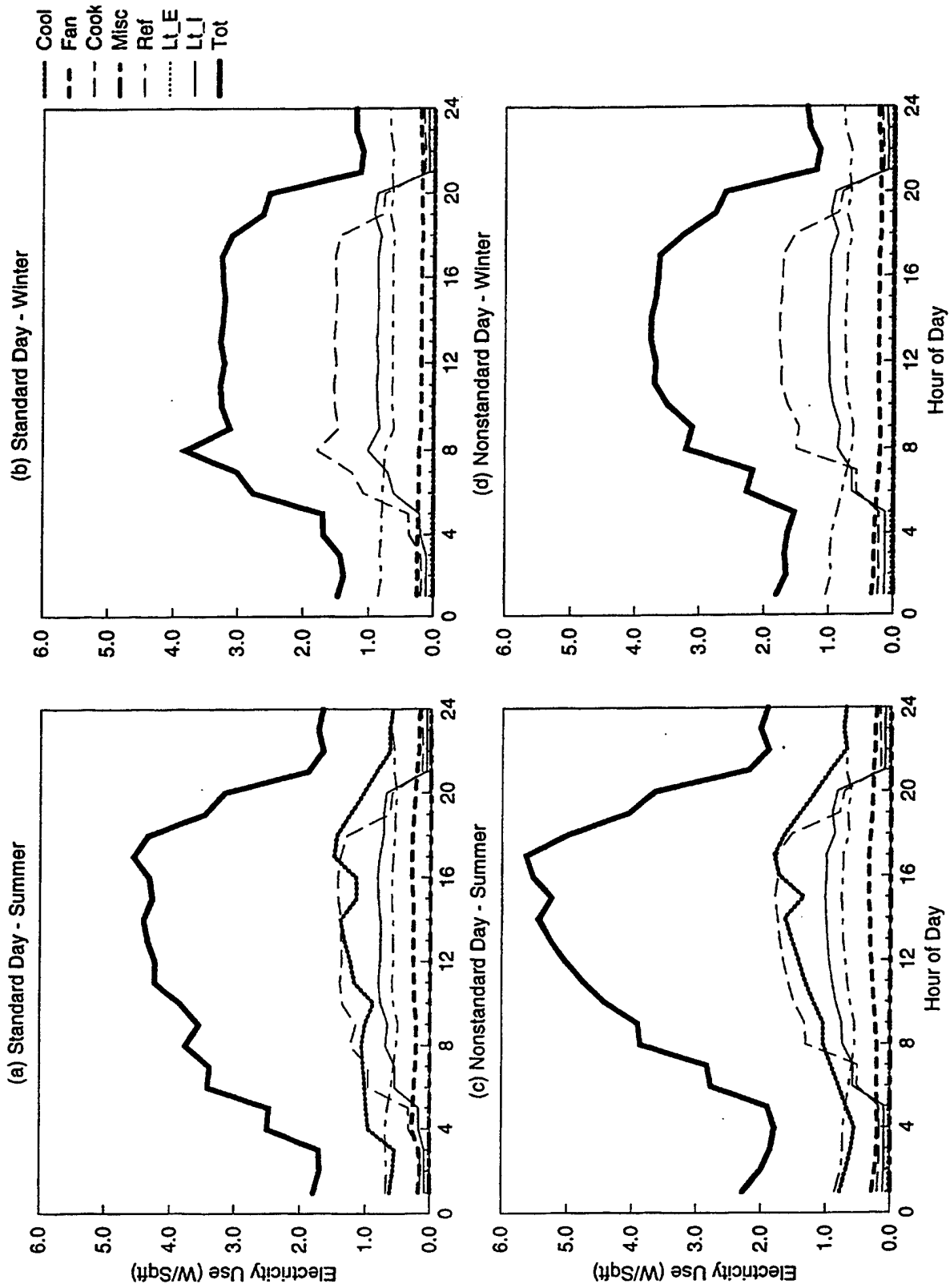


Figure C-15. EDA Reconciled End-use Load Shapes for Dining Hall (Feeder 5)

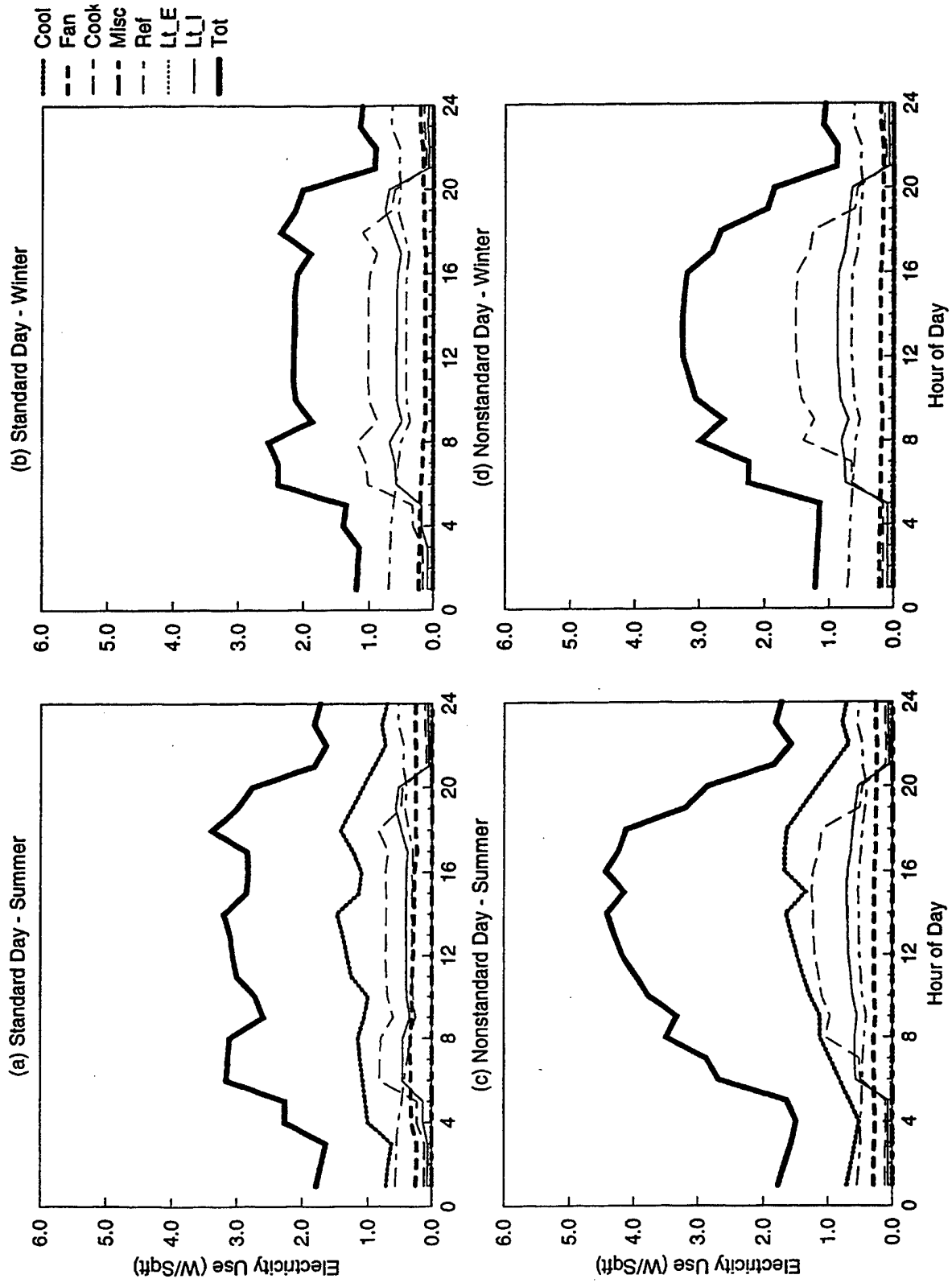


Figure C-16. EDA Reconciled End-use Load Shapes for Dining Hall (Feeder 10)

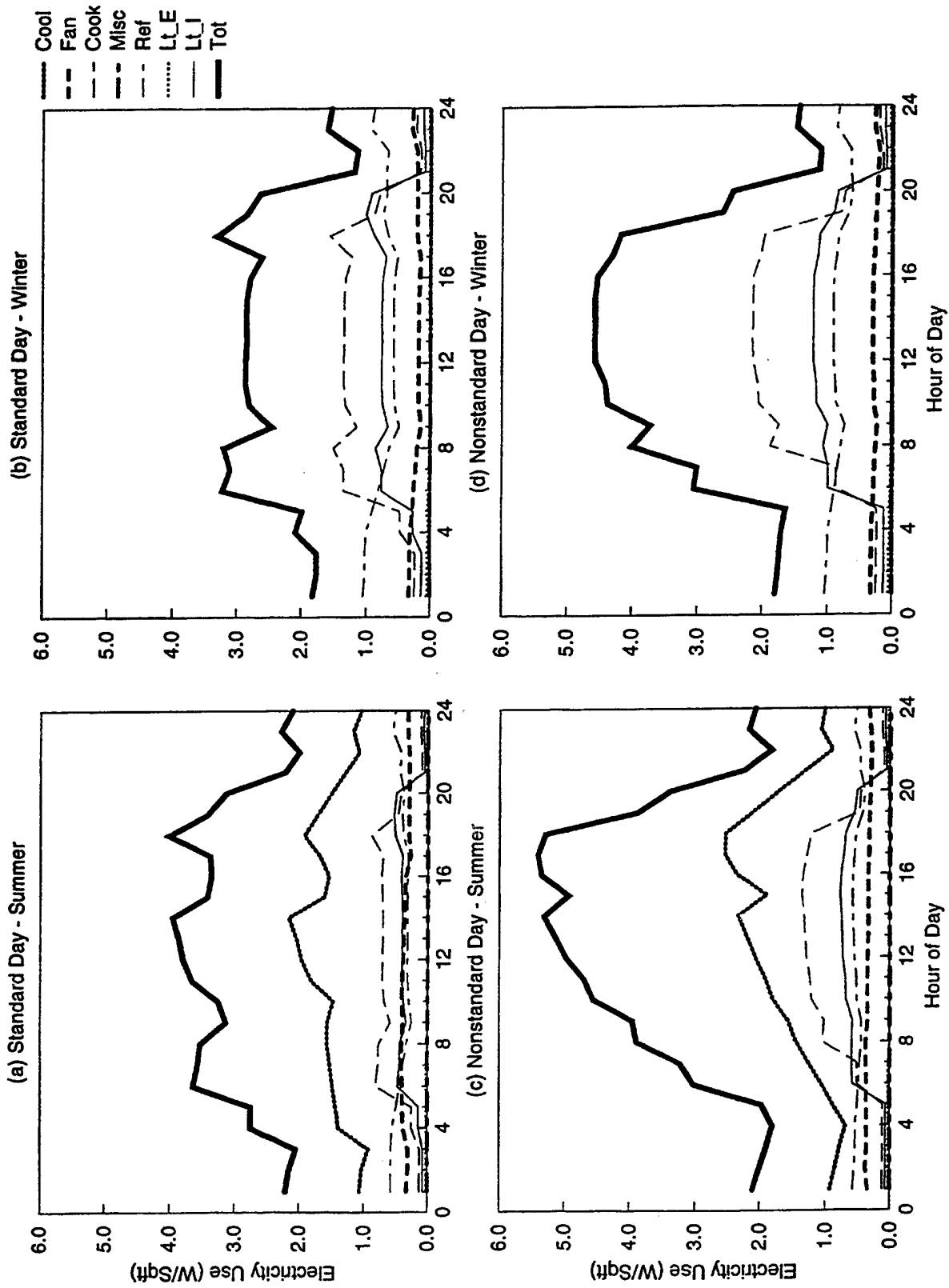


Figure C-17. EDA Reconciled End-use Load Shapes for Dining Hall (Feeder 15)

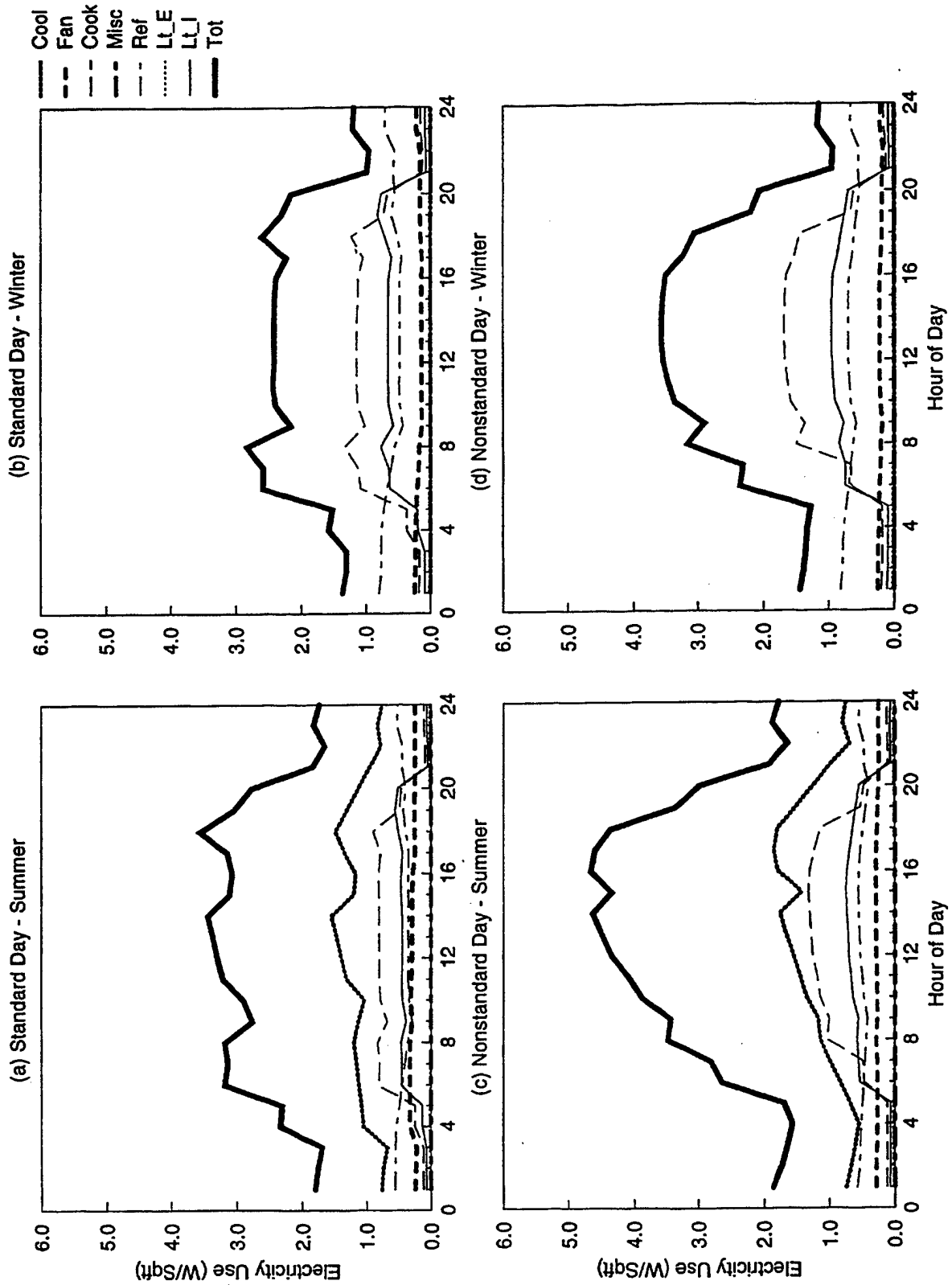


Figure C-18. EDA Reconciled End-use Load Shapes for Dining Hall (Weighted 3,5,10,15)

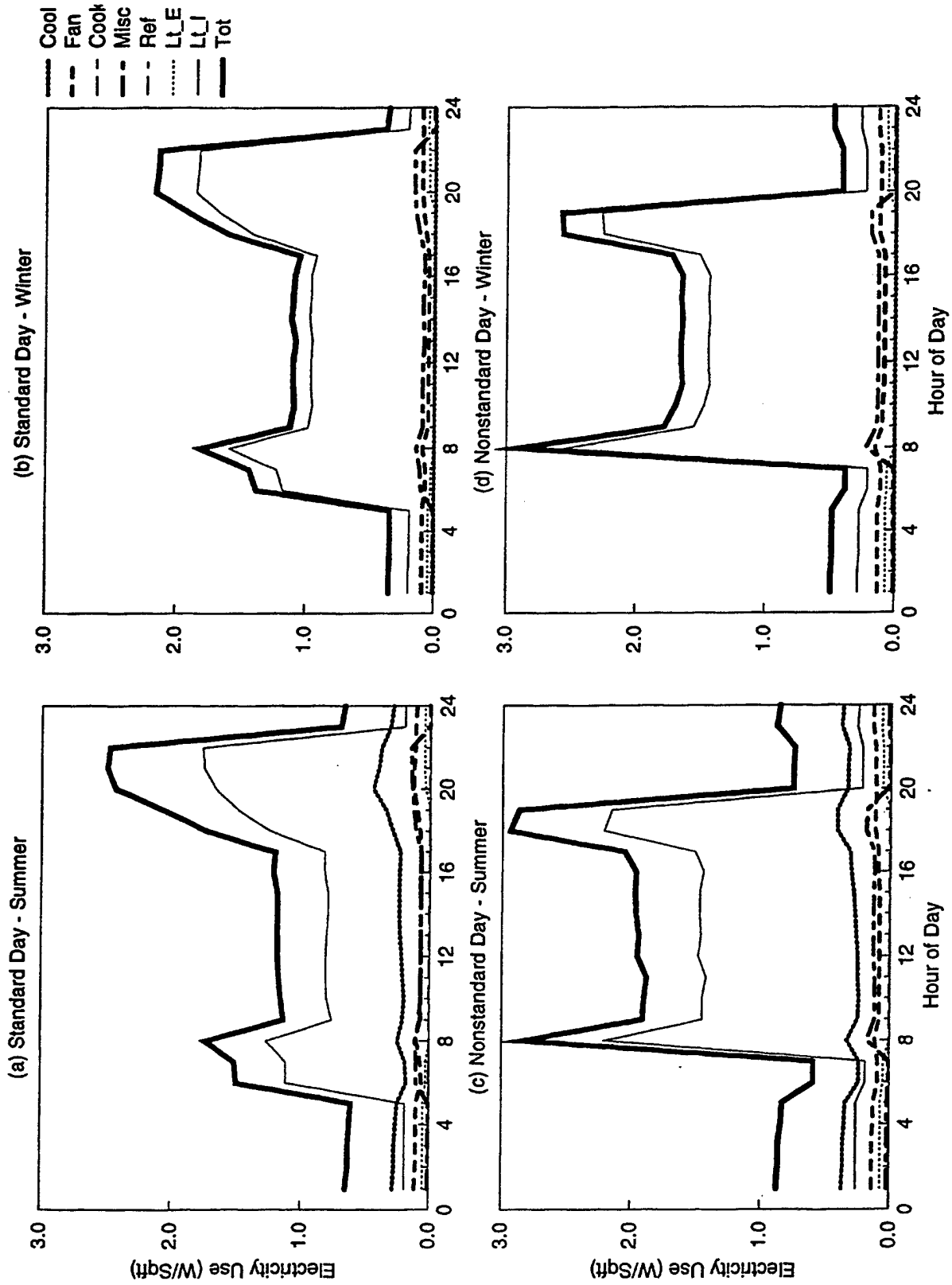


Figure C-19. EDA Reconciled End-use Load Shapes for Gymnasium (Feeder 2)

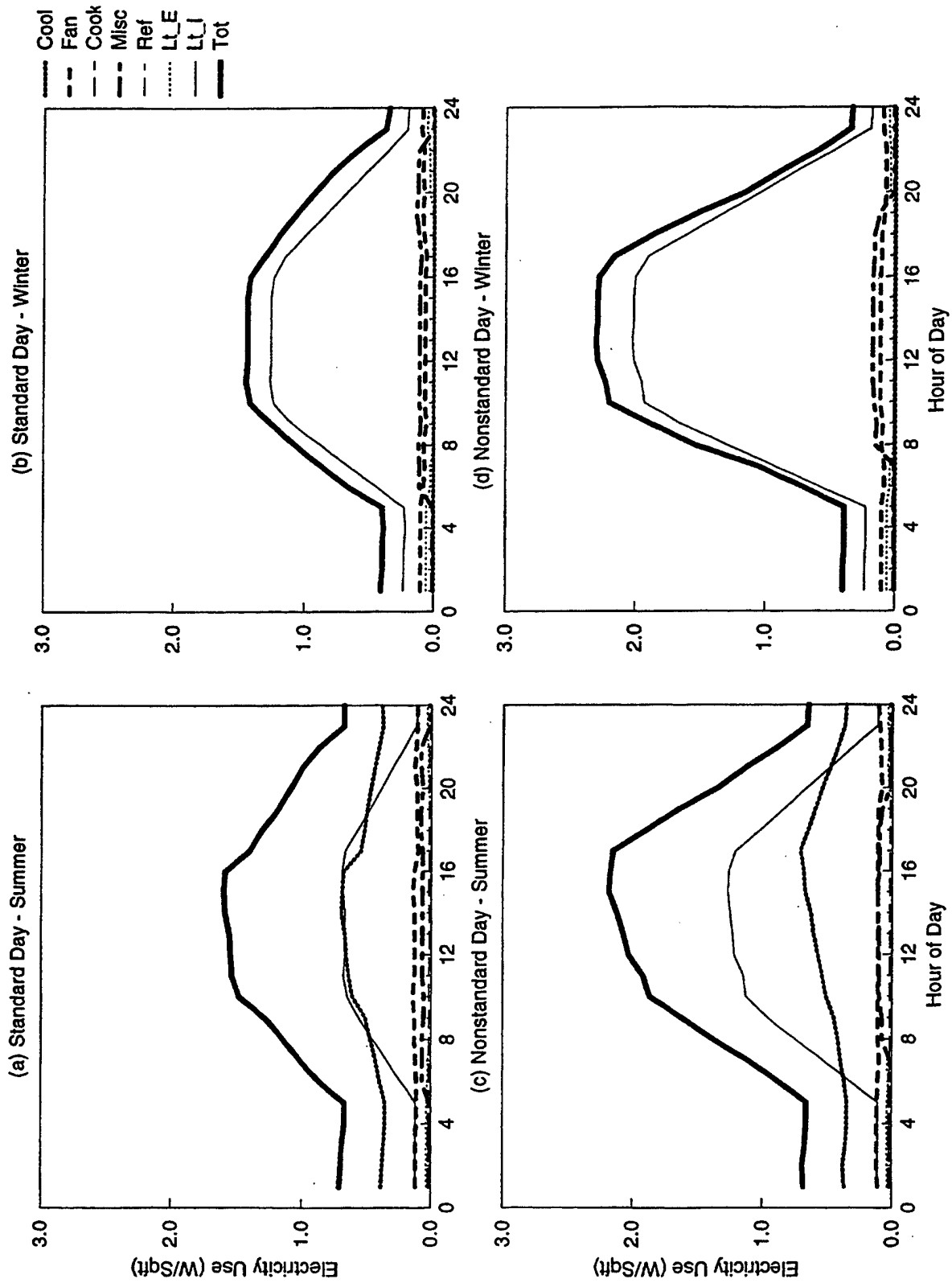


Figure C-20. EDA Reconciled End-use Load Shapes for Gymnasium (Feeder 15)

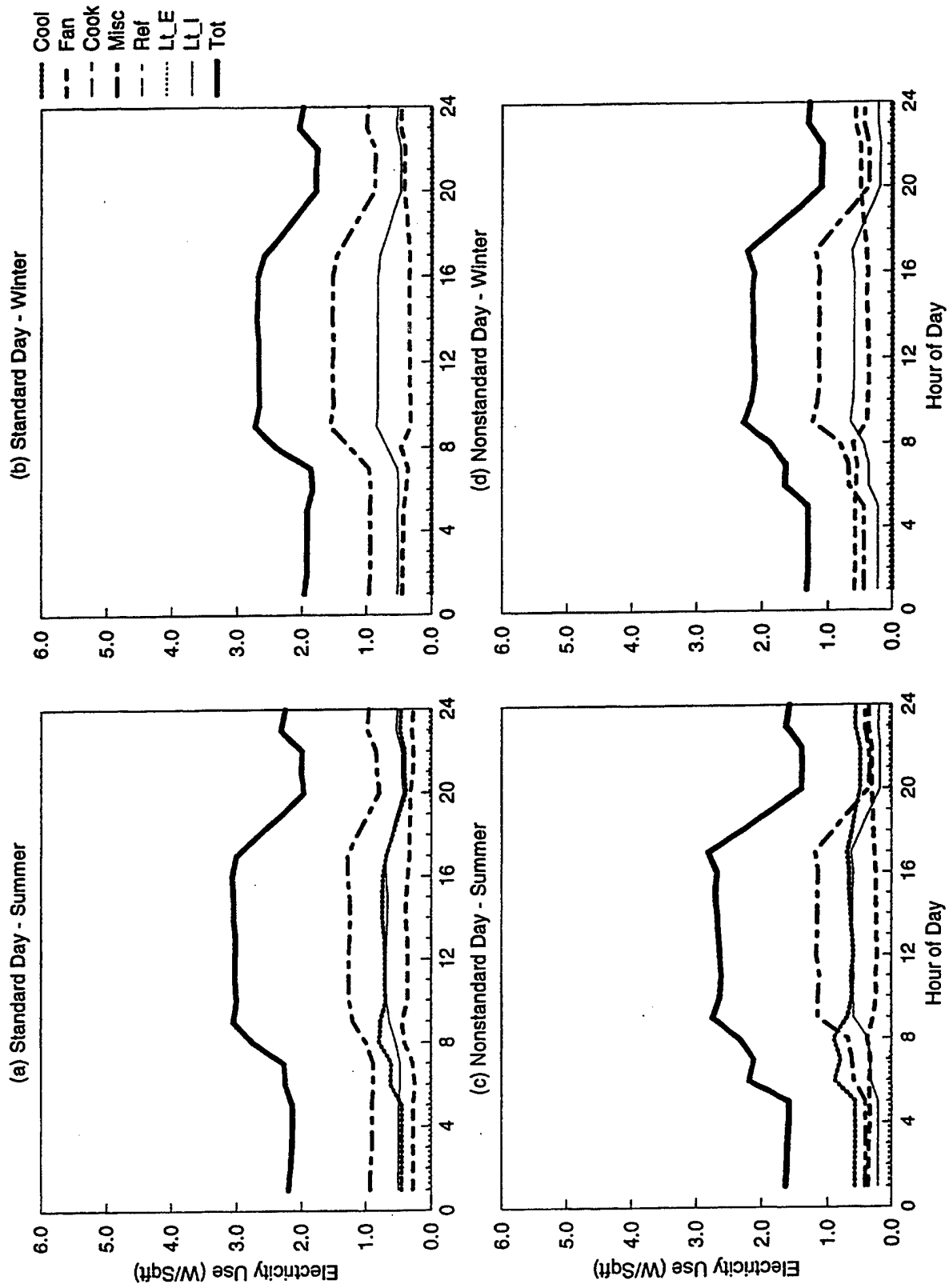


Figure C-21. EDA Reconciled End-use Load Shapes for Large Administration (Feeder 2)

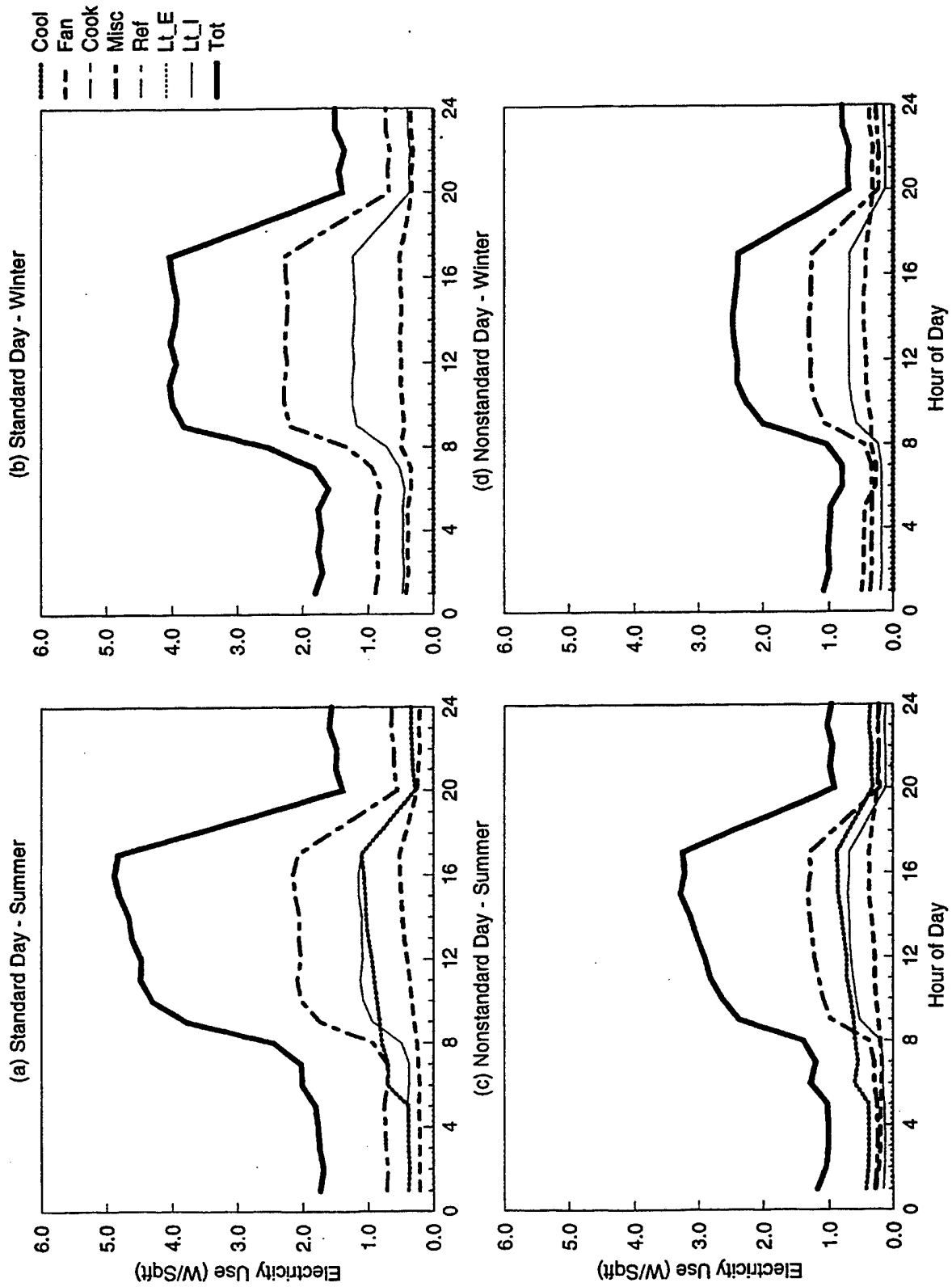


Figure C-22. EDA Reconciled End-use Load Shapes for Large Administration (Feeder 5)

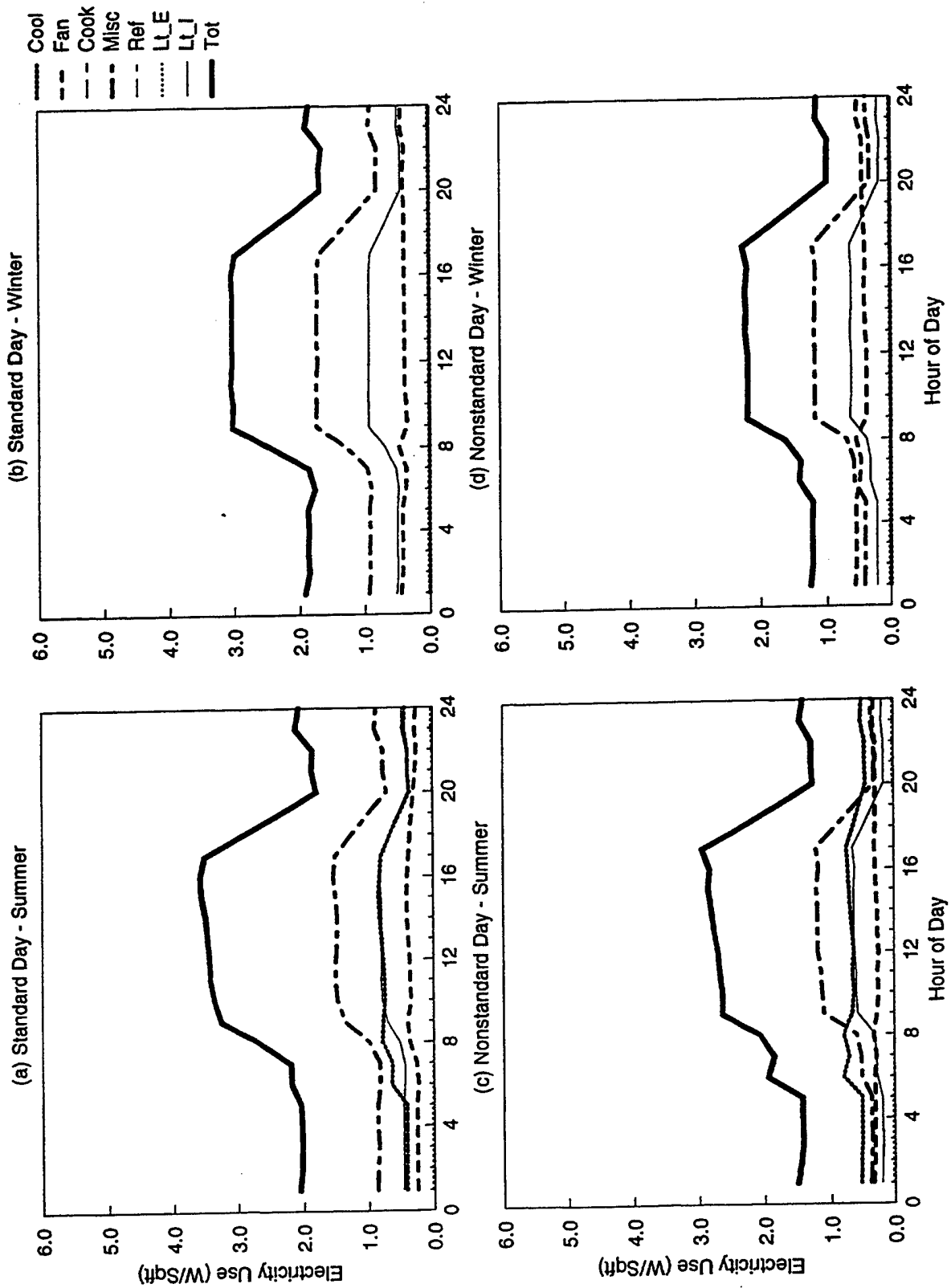


Figure C-23. EDA Reconciled End-use Load Shapes for Large Administration (Weighted 2,5)

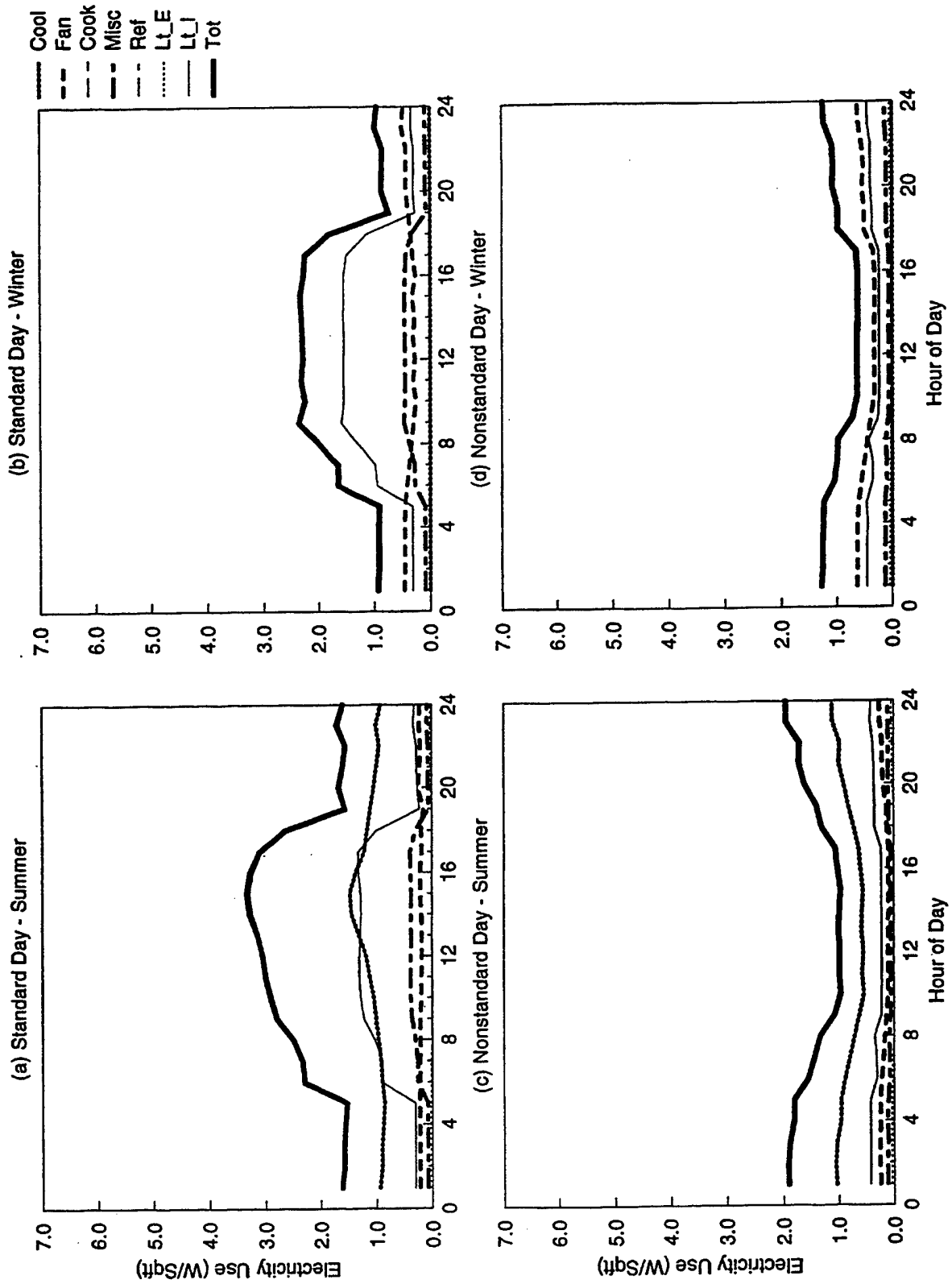


Figure C-24. EDA Reconciled End-use Load Shapes for Small Administration (Old w/ Split DX) (Feeder 2)

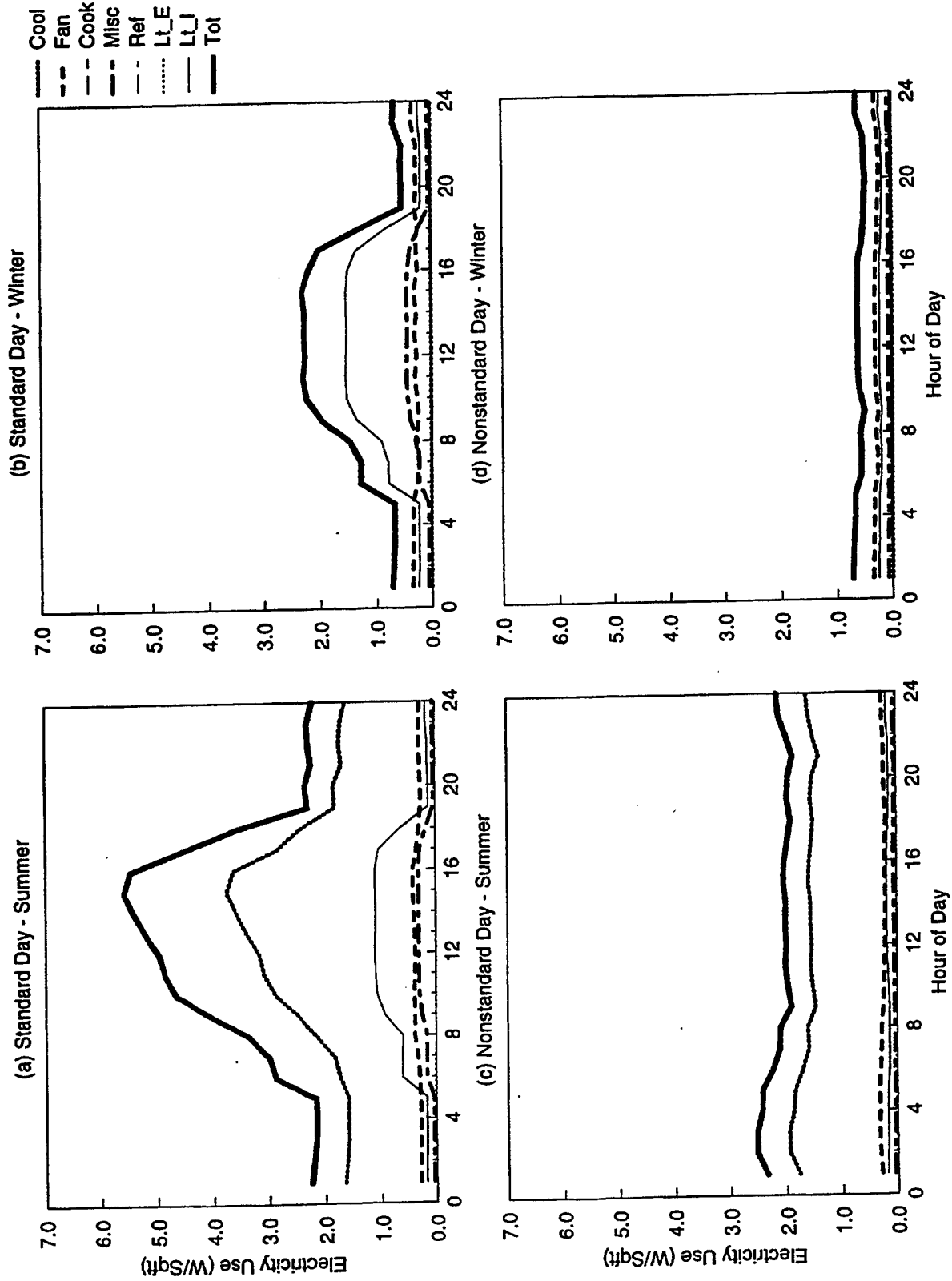


Figure C-25. EDA Reconciled End-use Load Shapes for Small Administration (Old w/ Split DX) (Feeder 10)

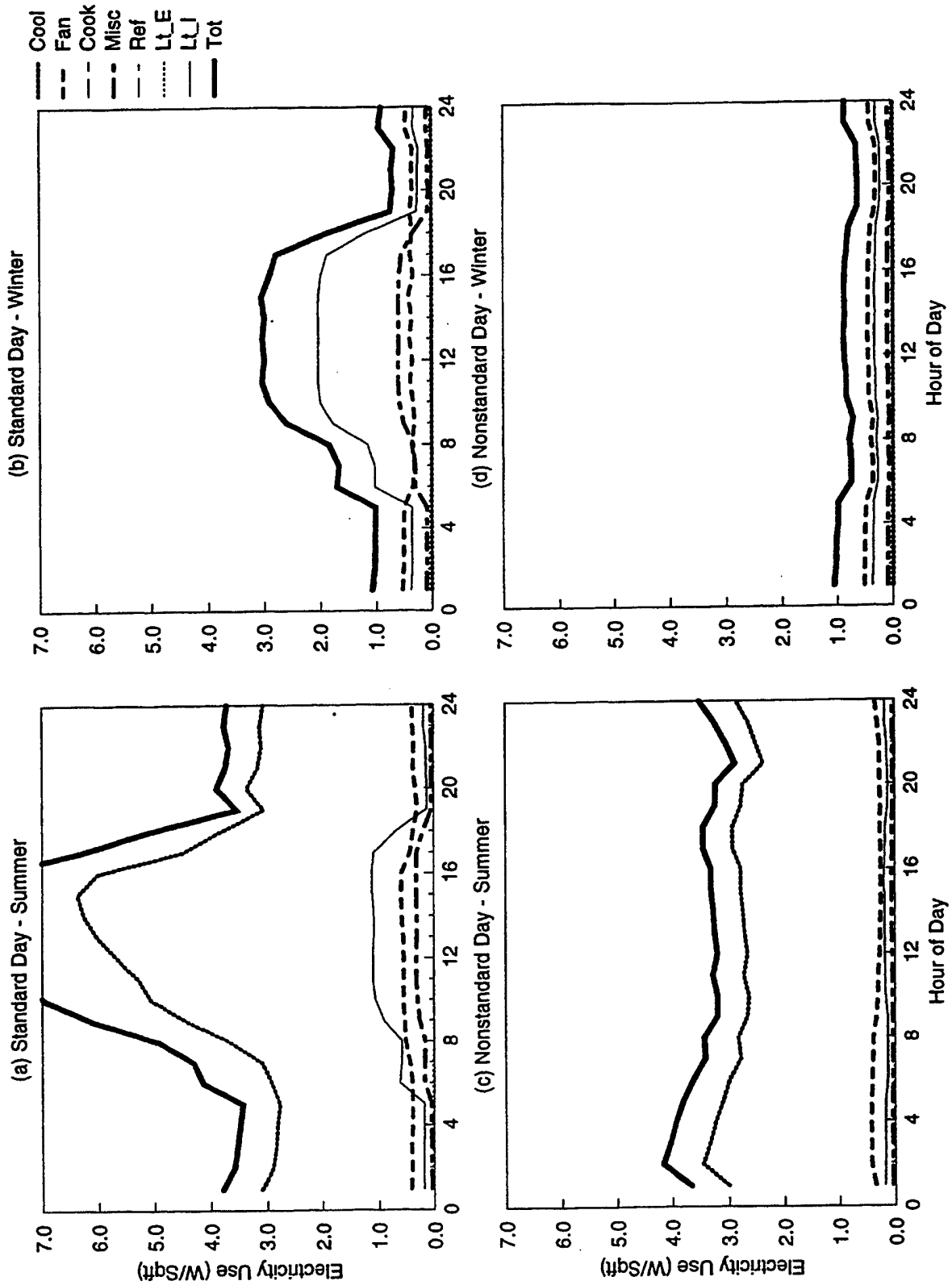


Figure C-26. EDA Reconciled End-use Load Shapes for Small Administration (Old w/ Split DX) (Feeder 15)

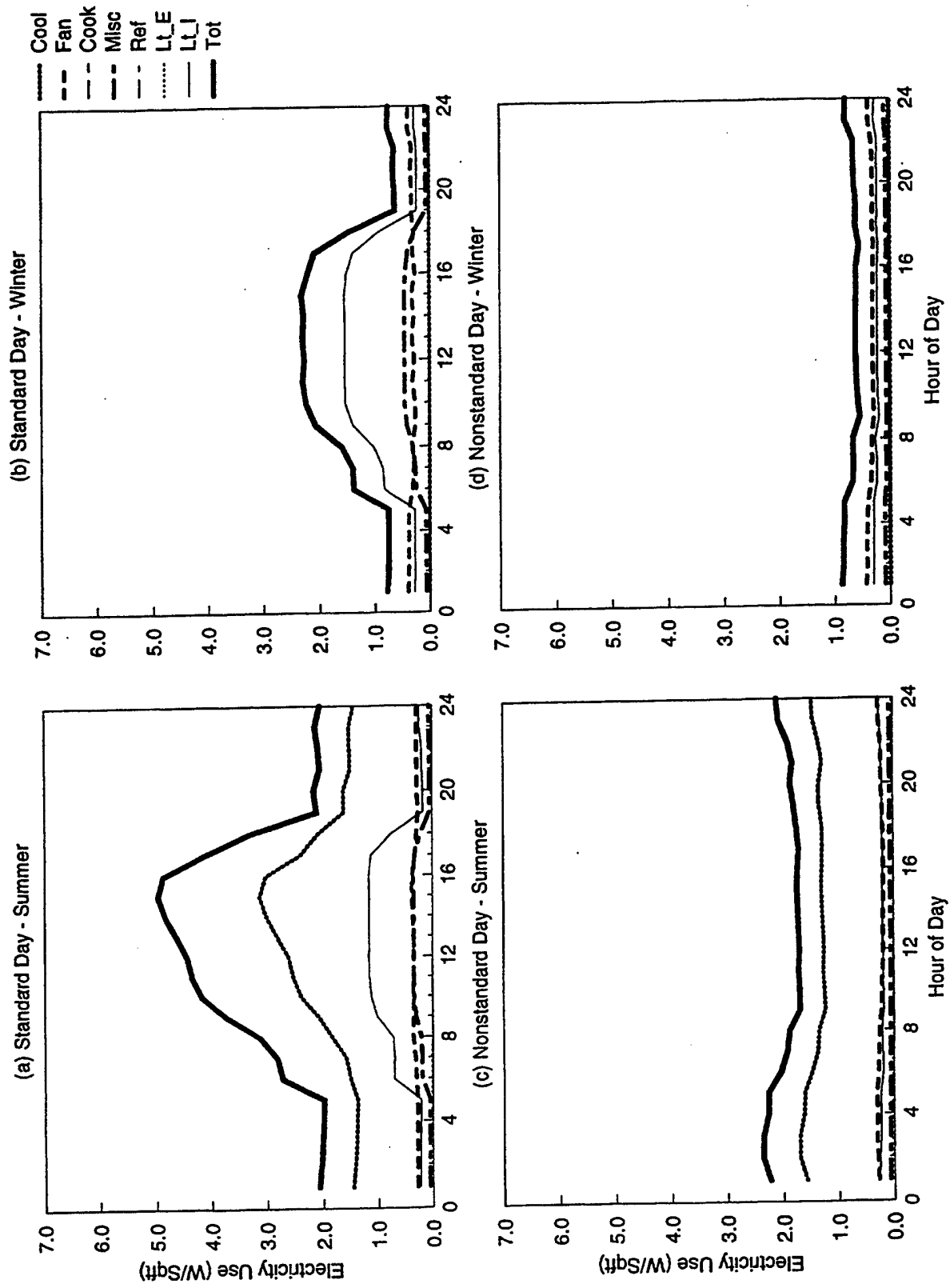


Figure C-27. EDA Reconciled End-use Load Shapes for Small Administration (Old w/ Split DX) (Weighted 2,10)

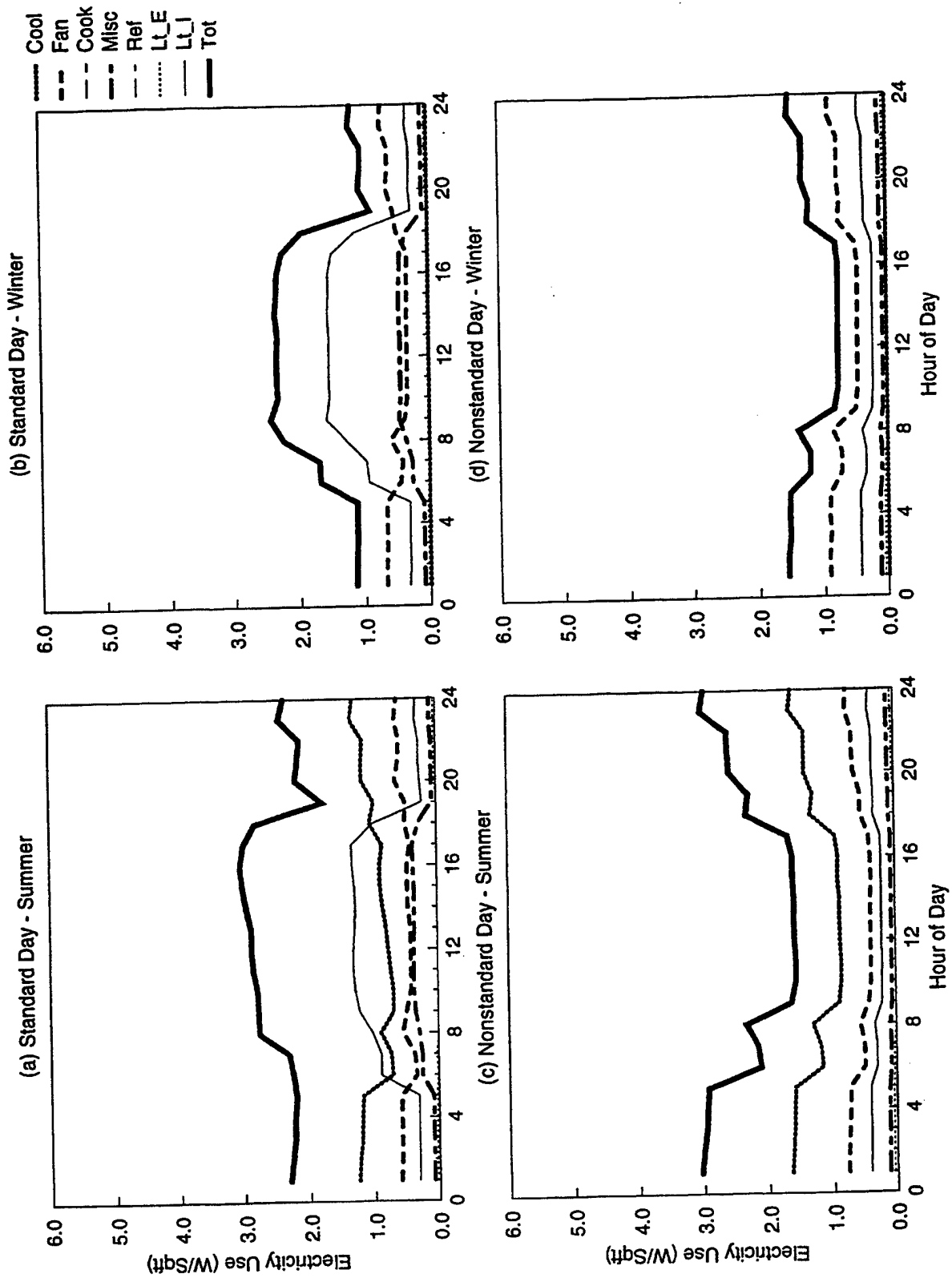


Figure C-28. EDA Reconciled End-use Load Shapes for Small Administration (Old w/ Chiller) (Feeder 2)

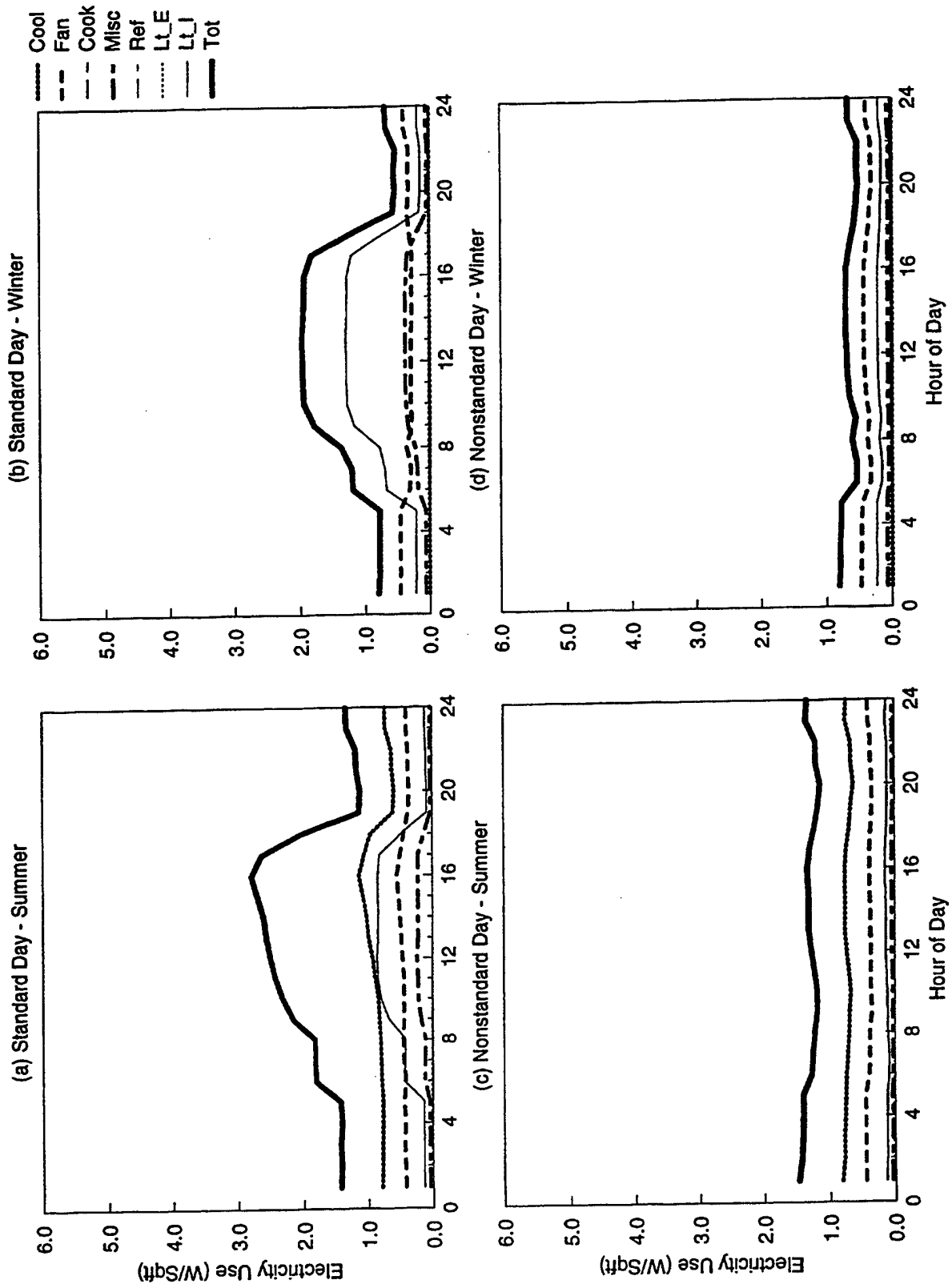


Figure C-29. EDA Reconciled End-use Load Shapes for Small Administration (Old w/ Chiller) (Feeder 3)

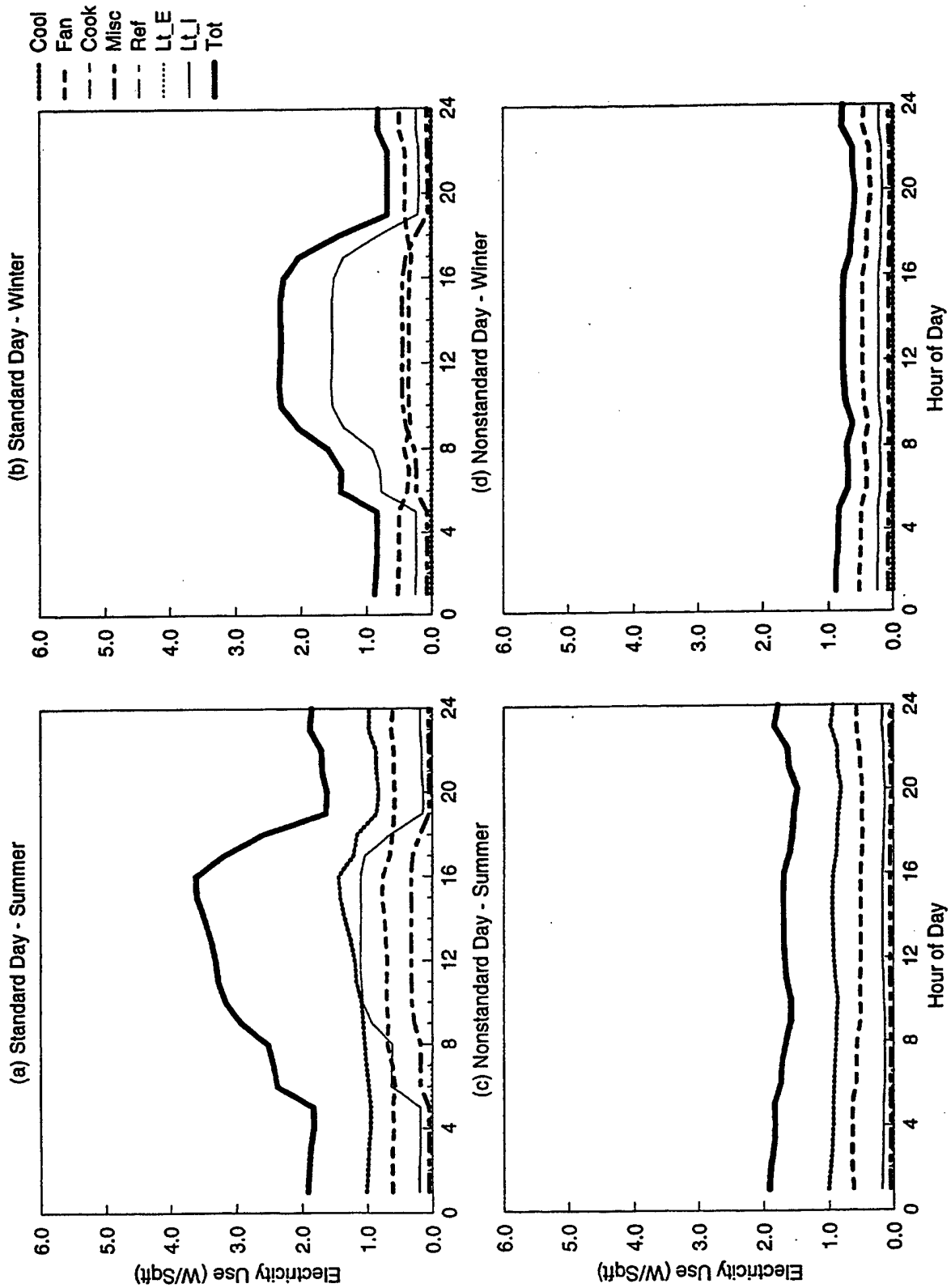


Figure C-30. EDA Reconciled End-use Load Shapes for Small Administration (Old w/ Chiller) (Feeder 10)

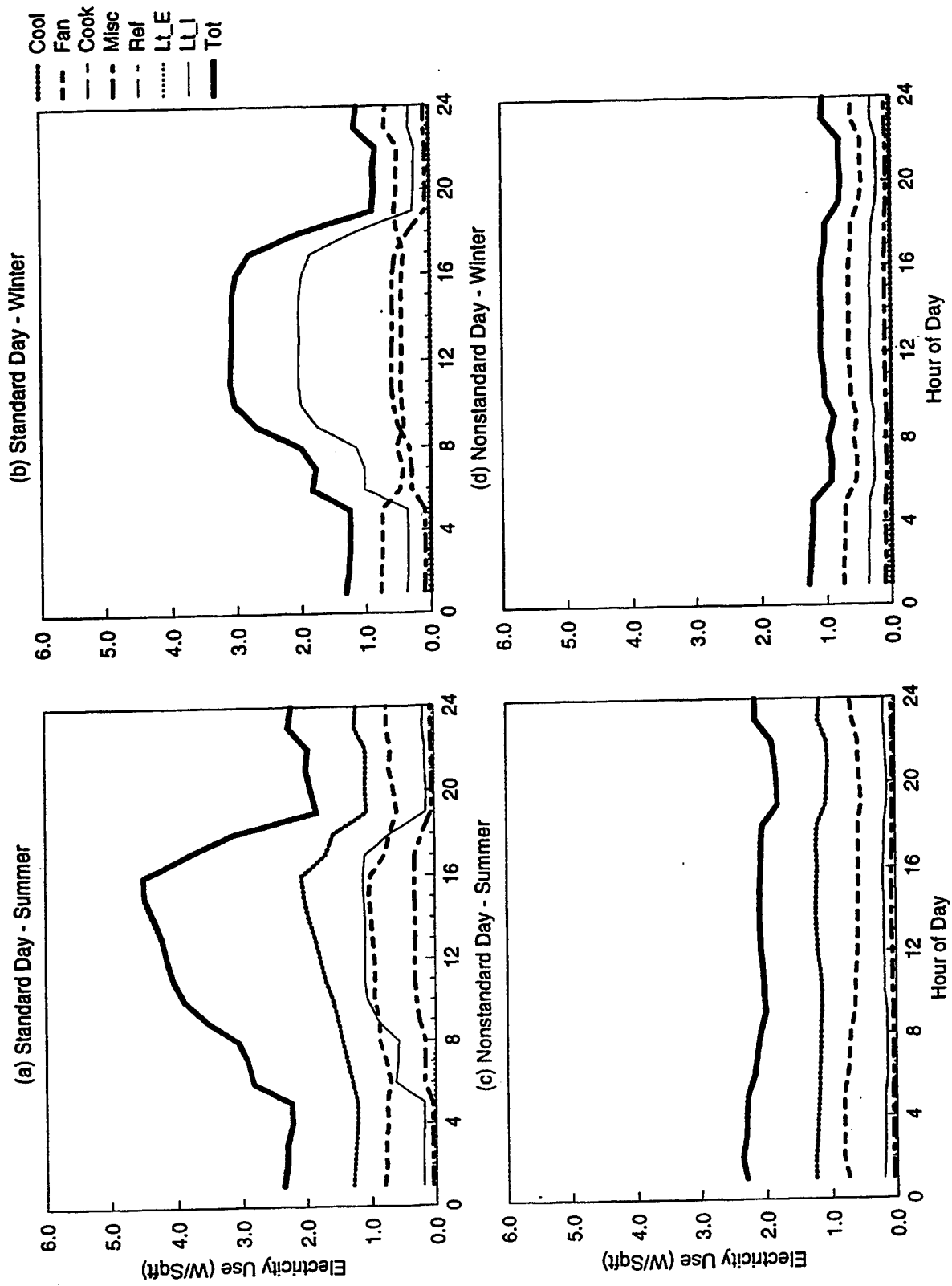


Figure C-31. EDA Reconciled End-use Load Shapes for Small Administration (Old w/ Chiller) (Feeder 15)

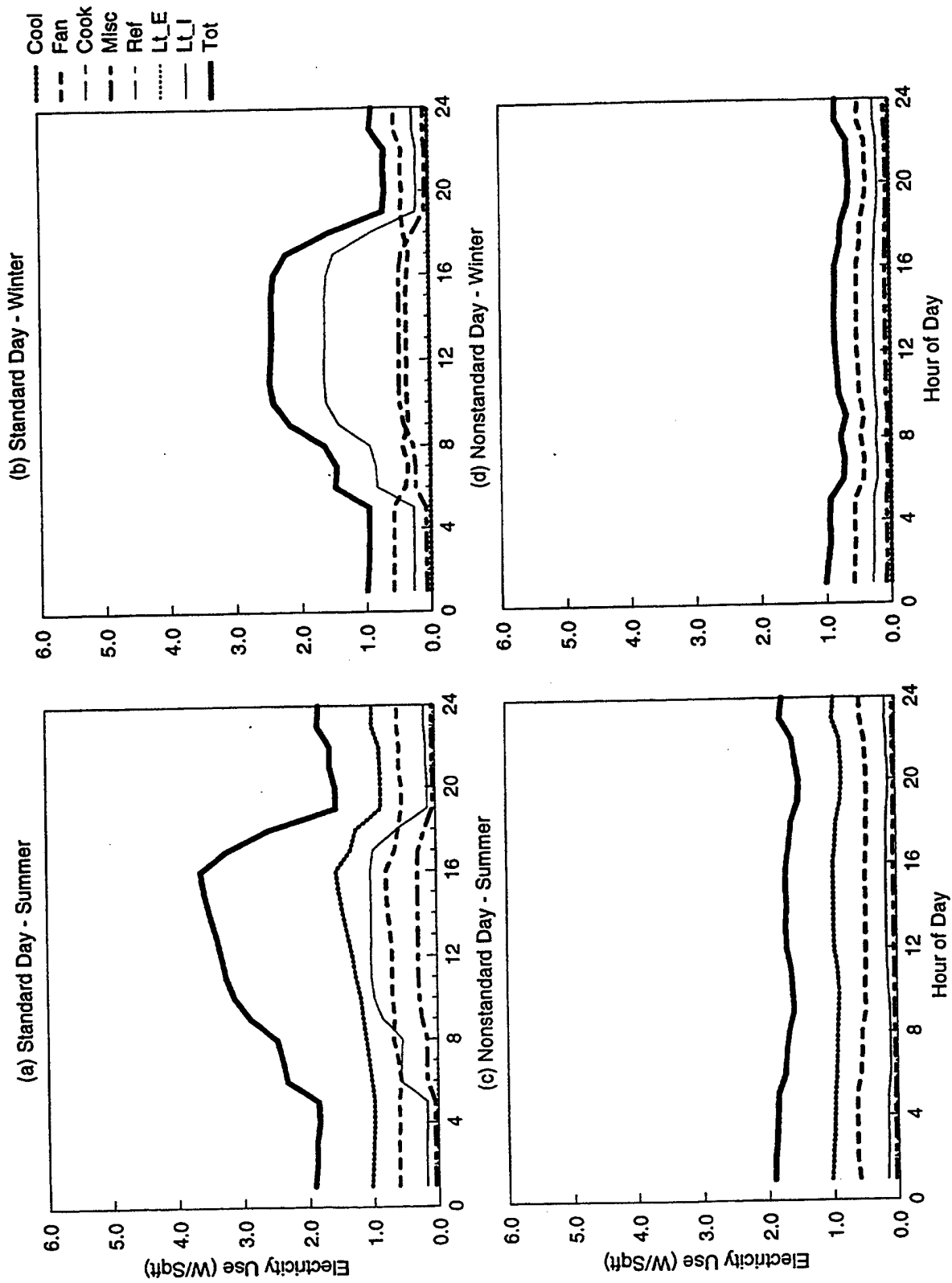


Figure C-32. EDA Reconciled End-use Load Shapes for Small Administration (Old w/ Chiller) (Weighted 3,10,15)

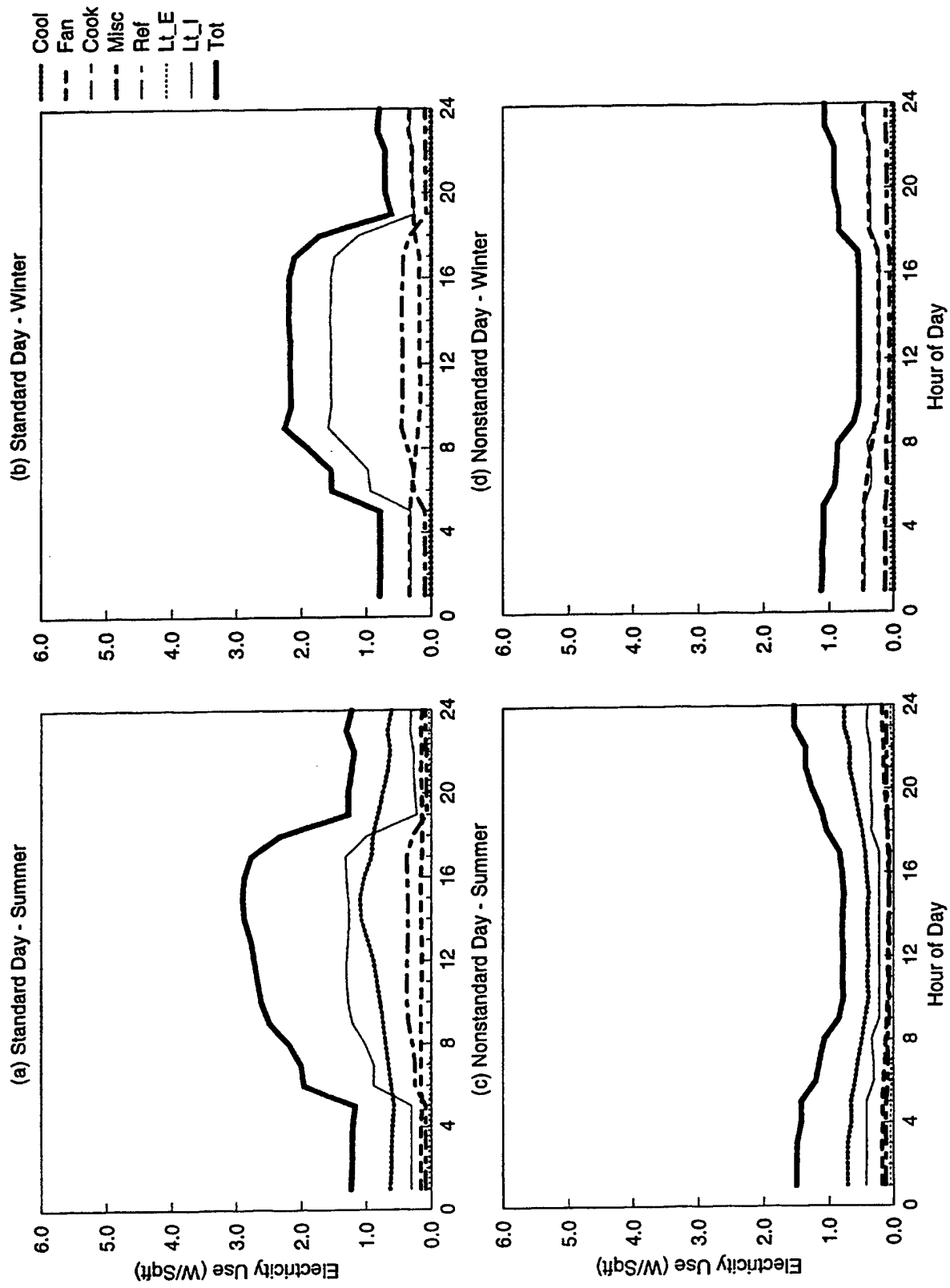


Figure C-33. EDA Reconciled End-use Load Shapes for Small Administration (New w/ Split DX) (Feeder 2)

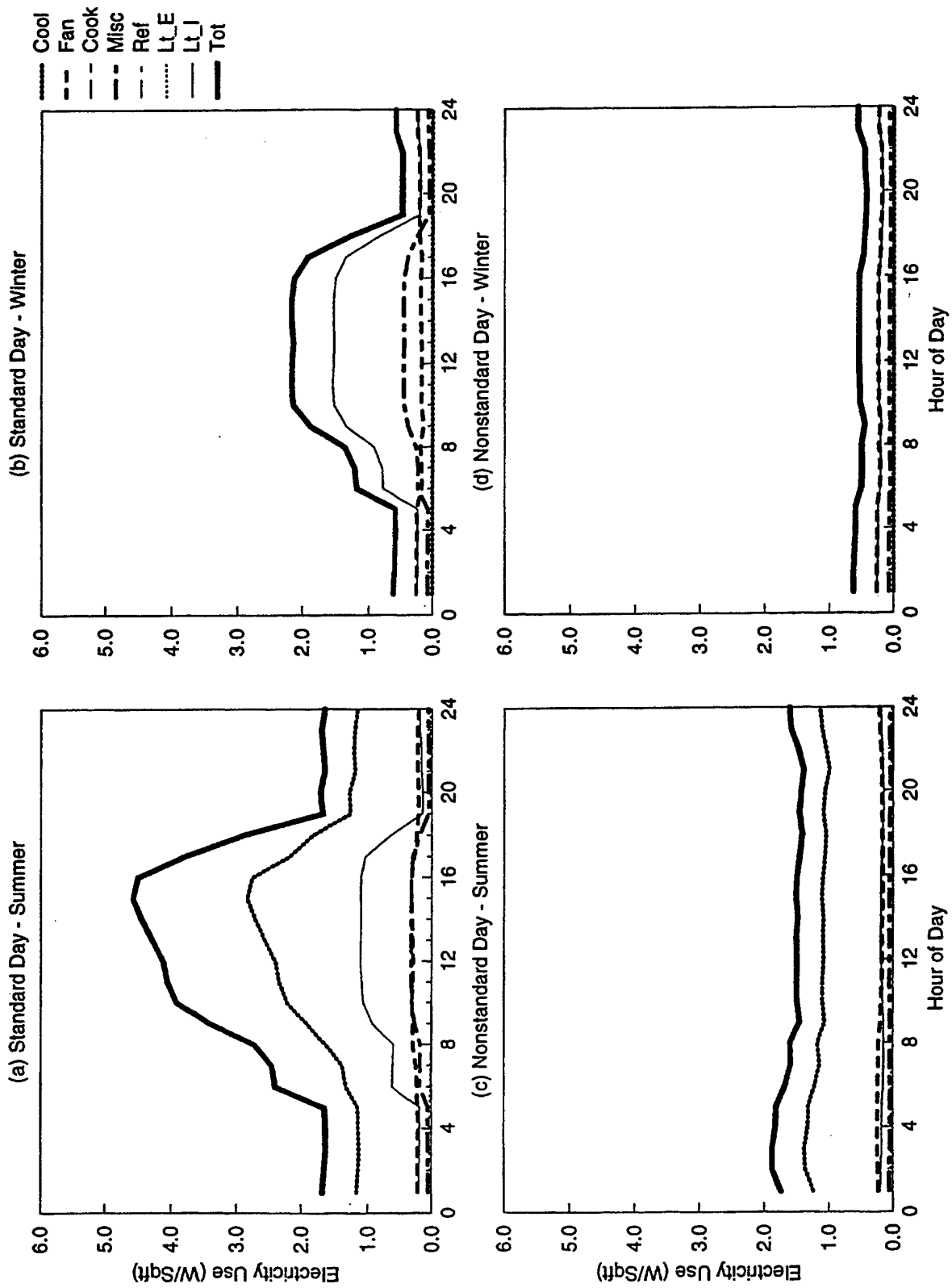


Figure C-34. EDA Reconciled End-use Load Shapes for Small Administration (New w/ Split DX) (Feeder 10)

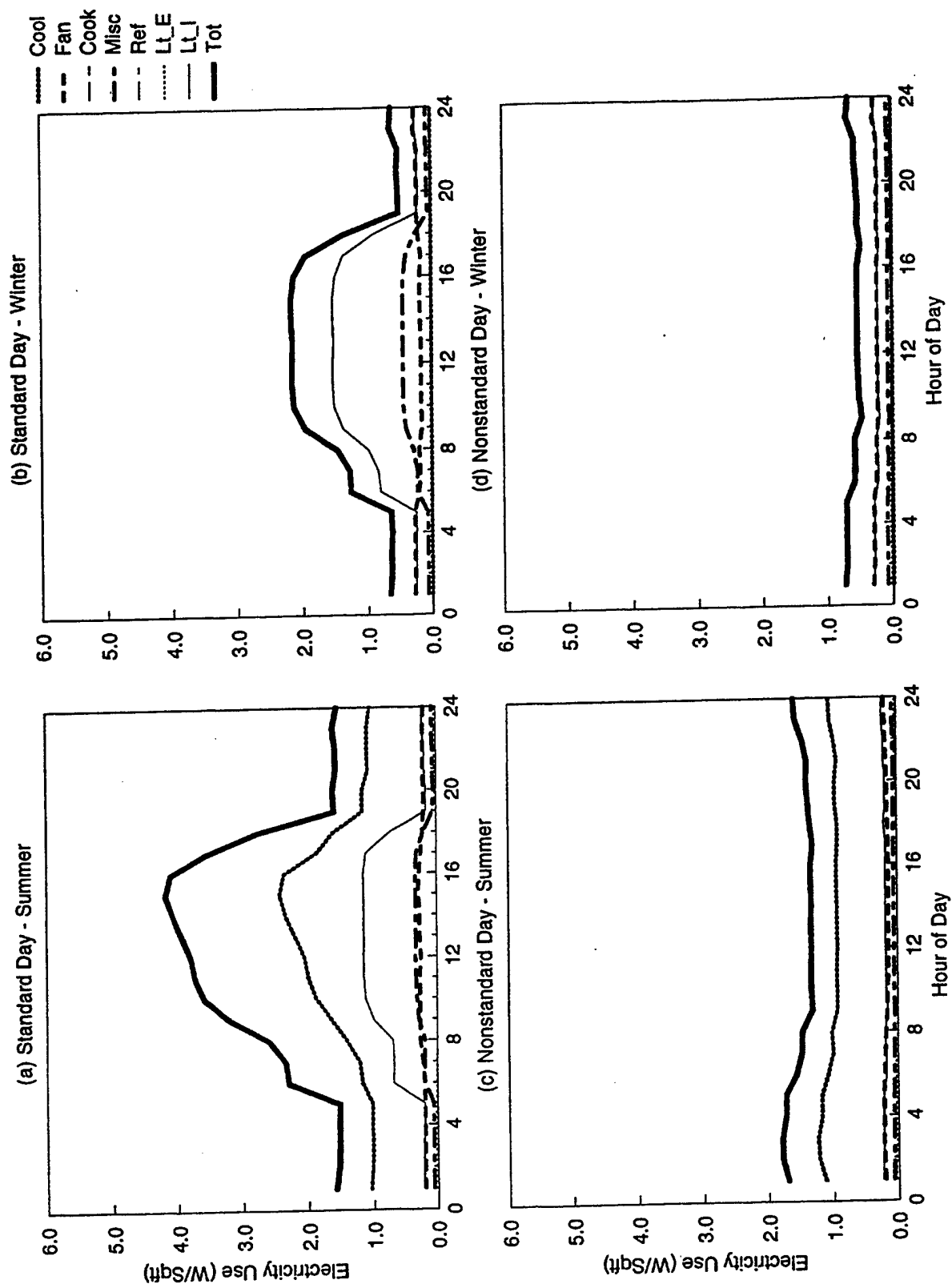


Figure C-35. EDA Reconciled End-use Load Shapes for Small Administration (New w/ Split DX) (Weighted 2,10)

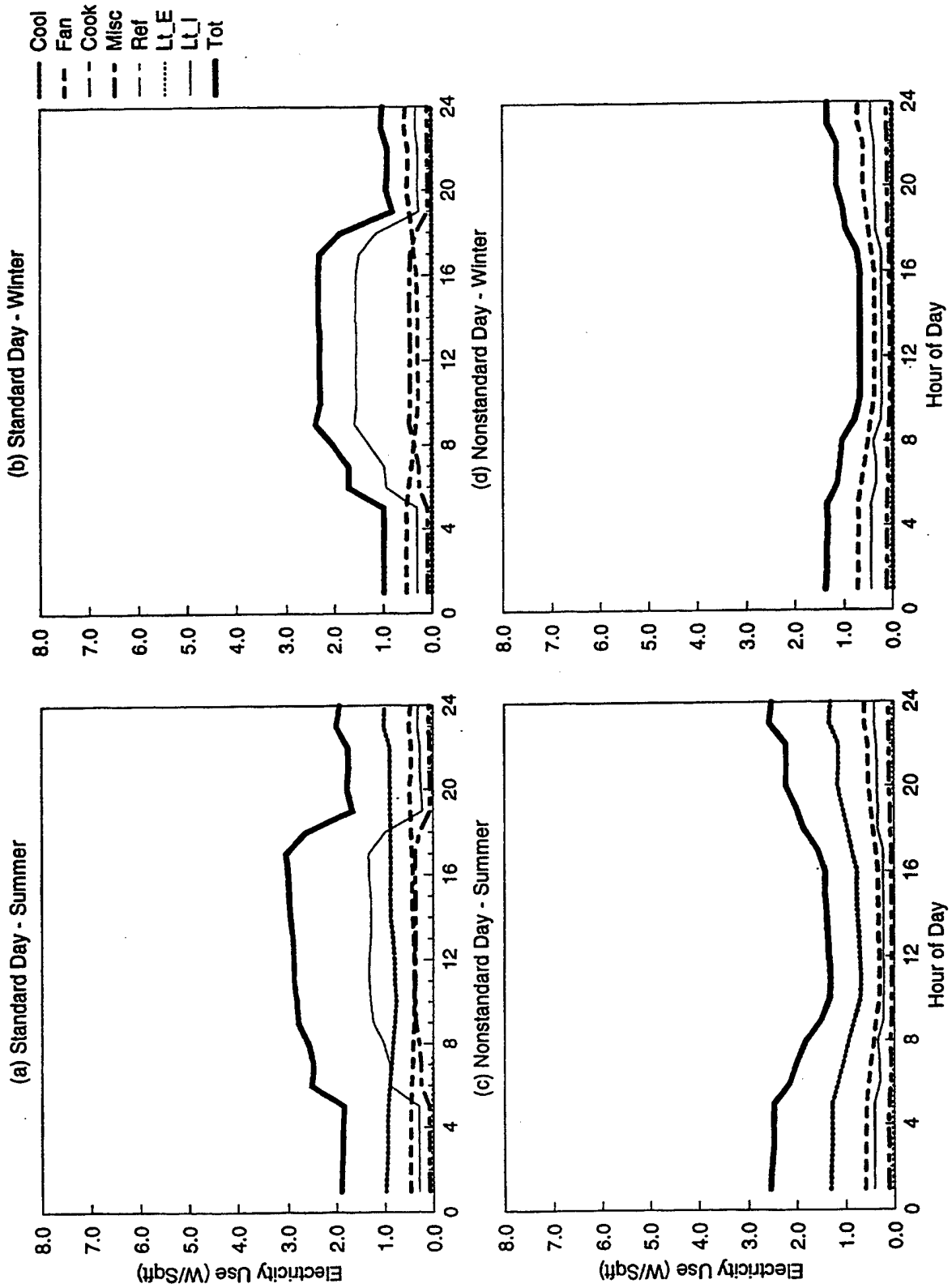


Figure C-36. EDA Reconciled End-use Load Shapes for Small Administration (New w/ Chiller) (Feeder 2)

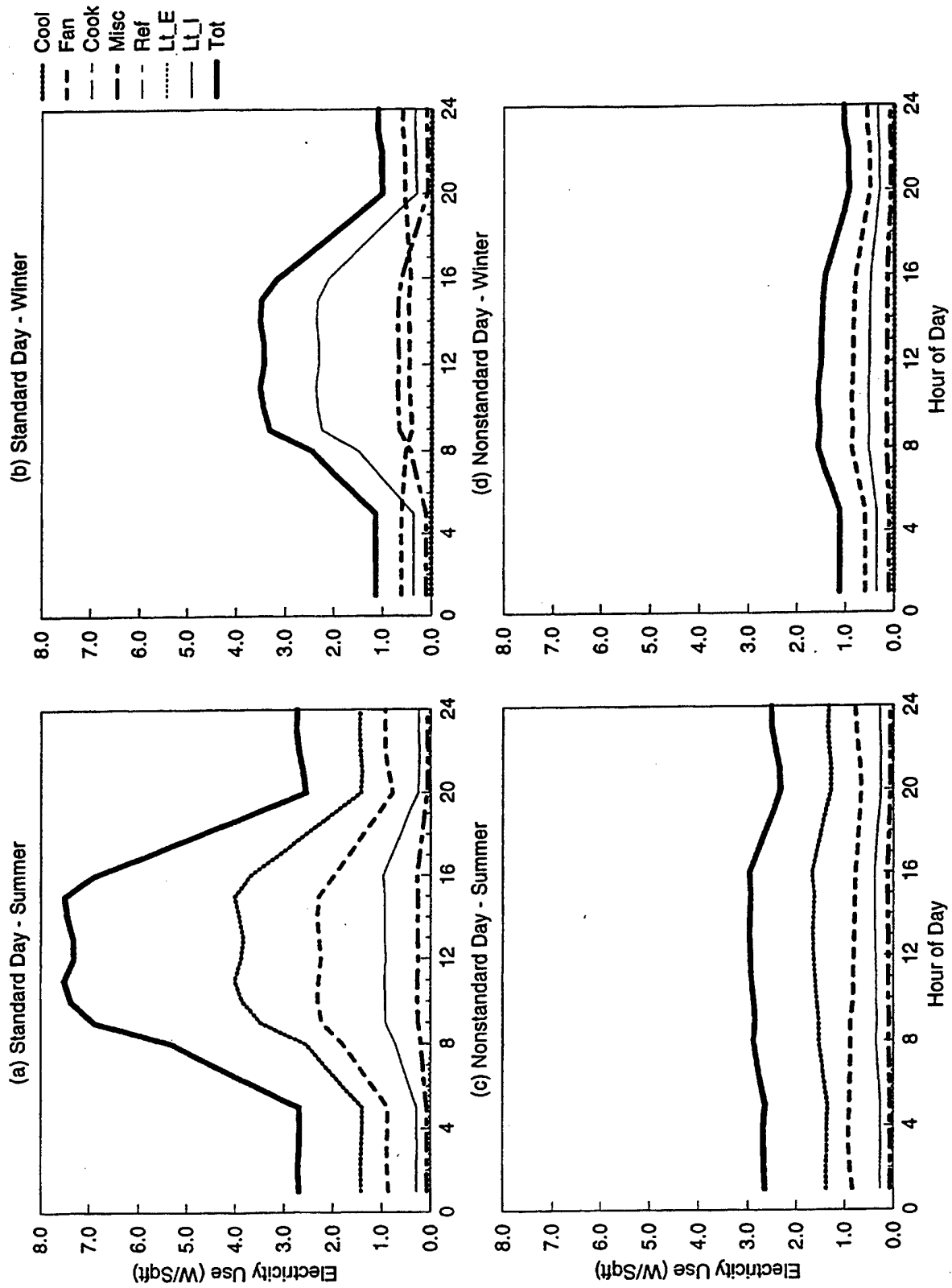


Figure C-37. EDA Reconciled End-use Load Shapes for Small Administration (New w/ Chiller) (Feeder W6)

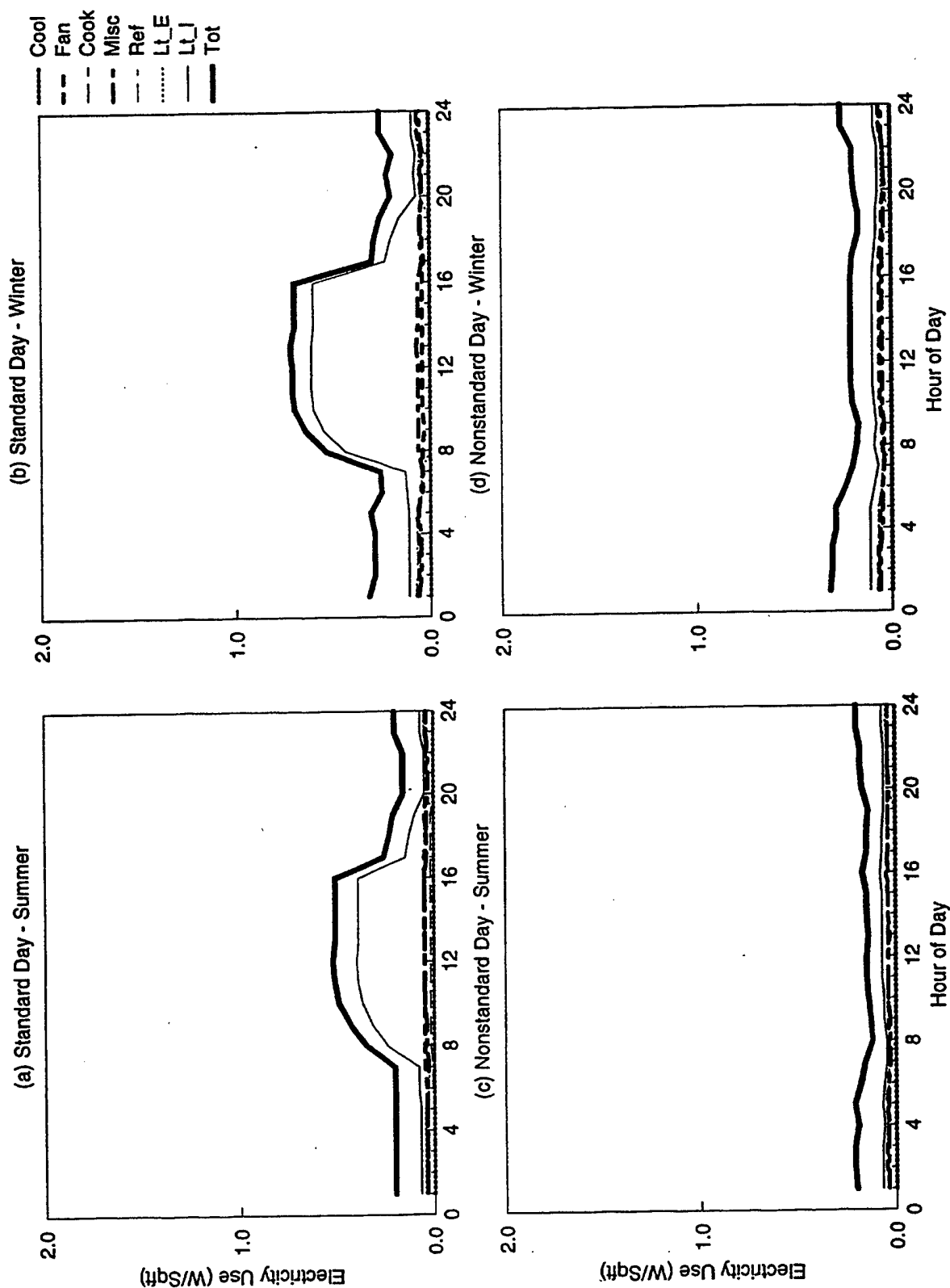


Figure C-38. EDA Reconciled End-use Load Shapes for Small Vehicle Maintenance (No AC) (Feeder 3)

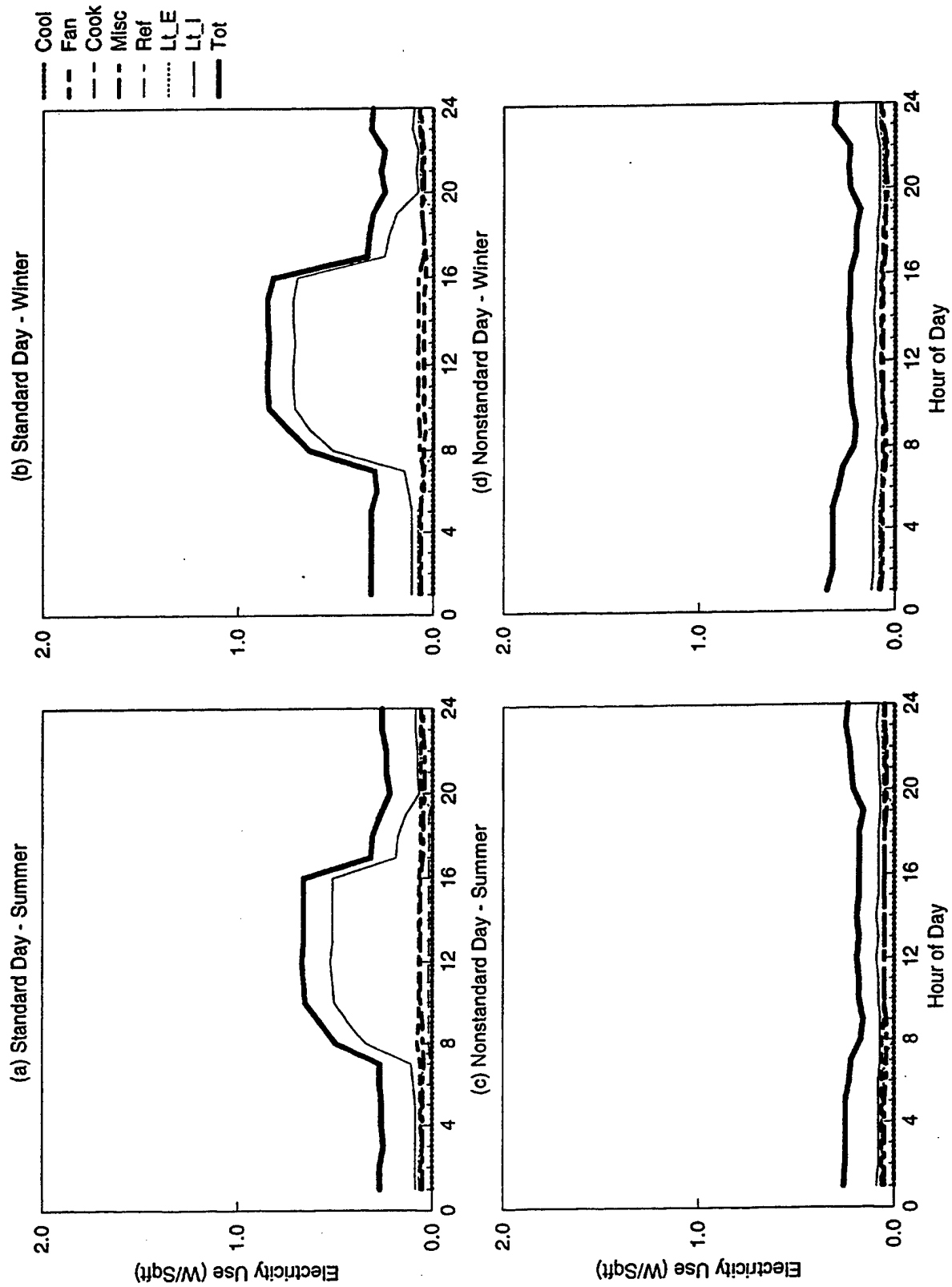


Figure C-39. EDA Reconciled End-use Load Shapes for Small Vehicle Maintenance (No AC) (Feeder 10)

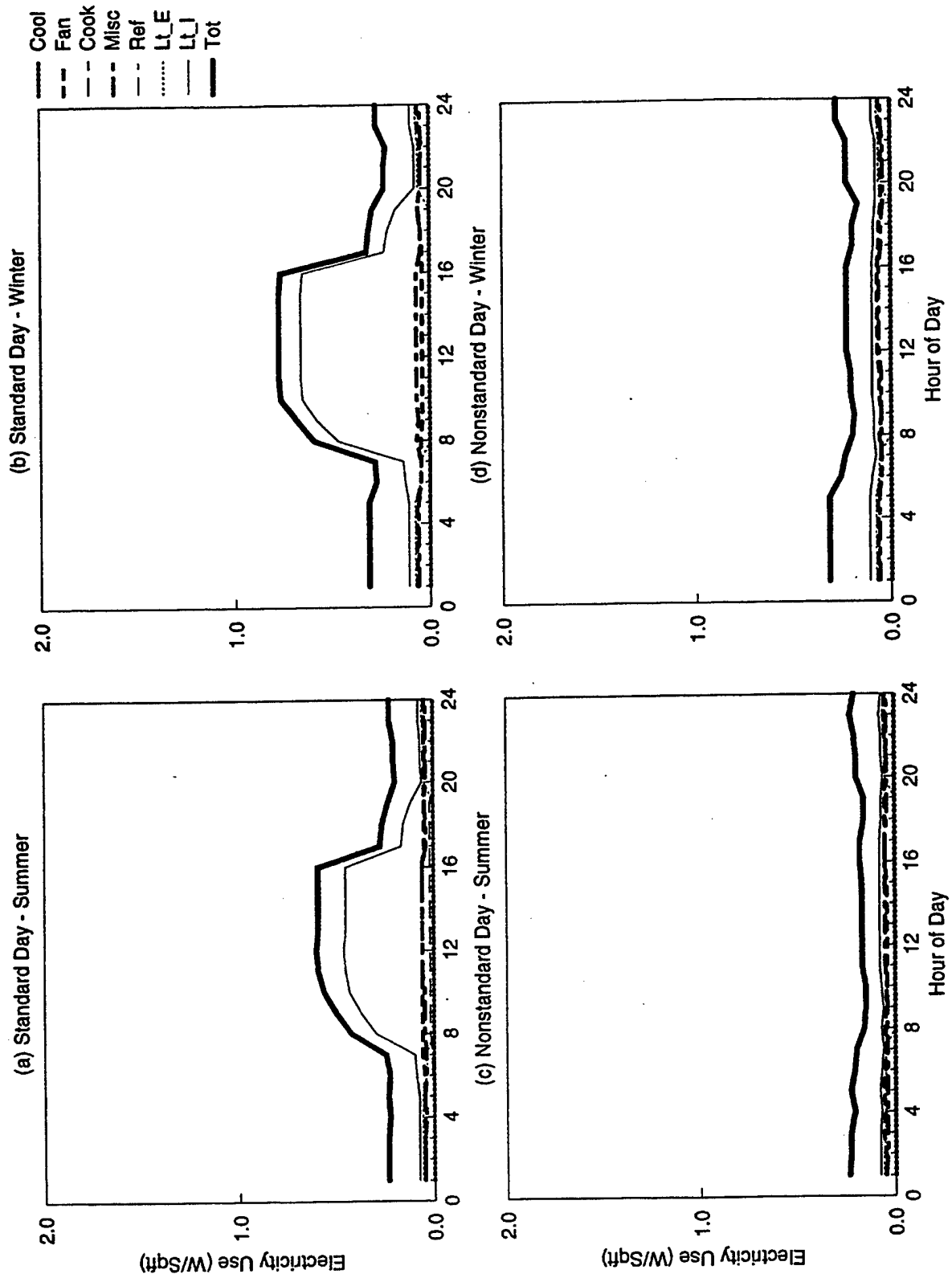


Figure C-40. EDA Reconciled End-use Load Shapes for Small Vehicle Maintenance (No AC) (Weighted 3,10)

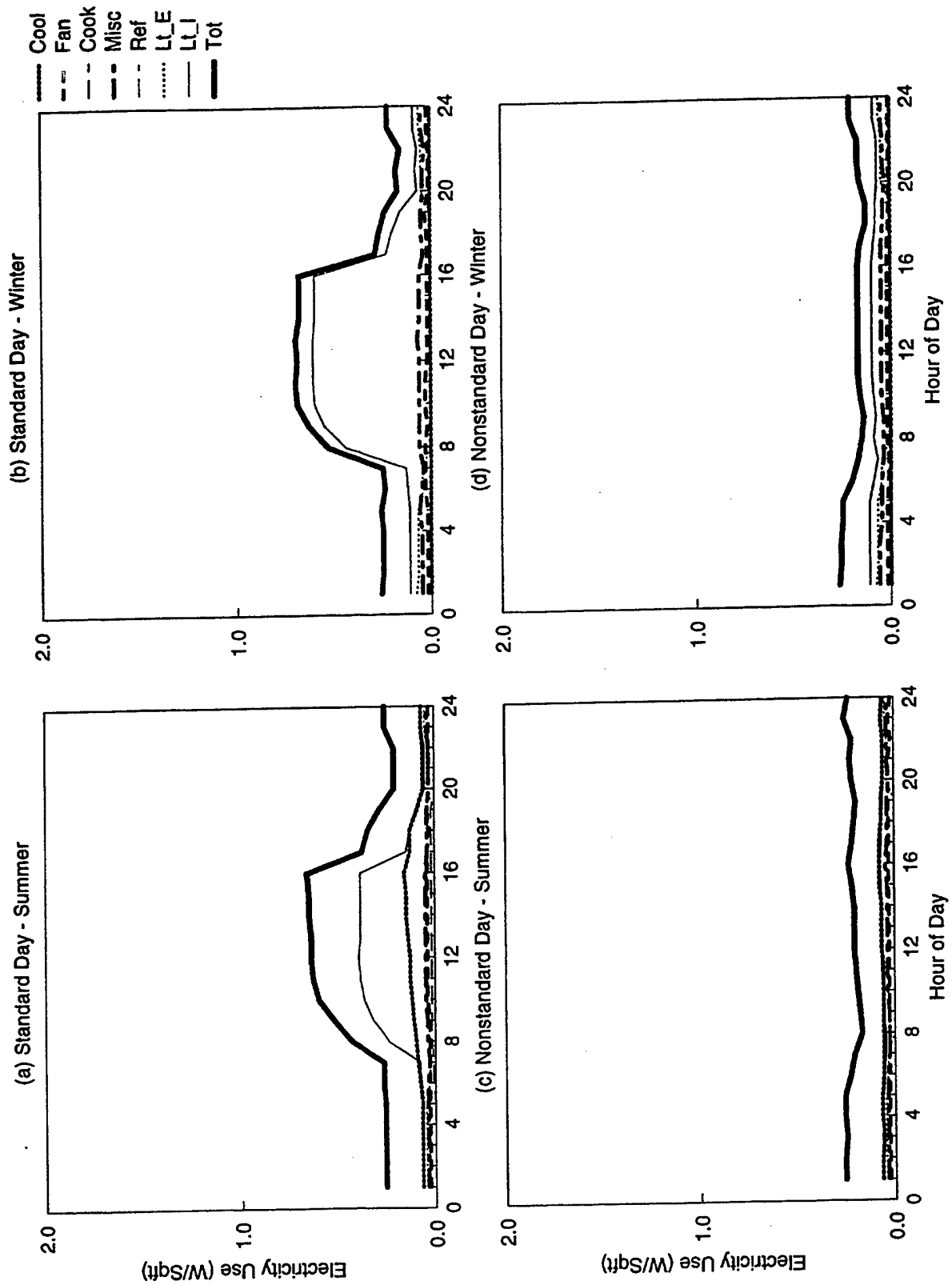


Figure C-41. EDA Reconciled End-use Load Shapes for Large Vehicle Maintenance (Split DX) (Feeder 3)

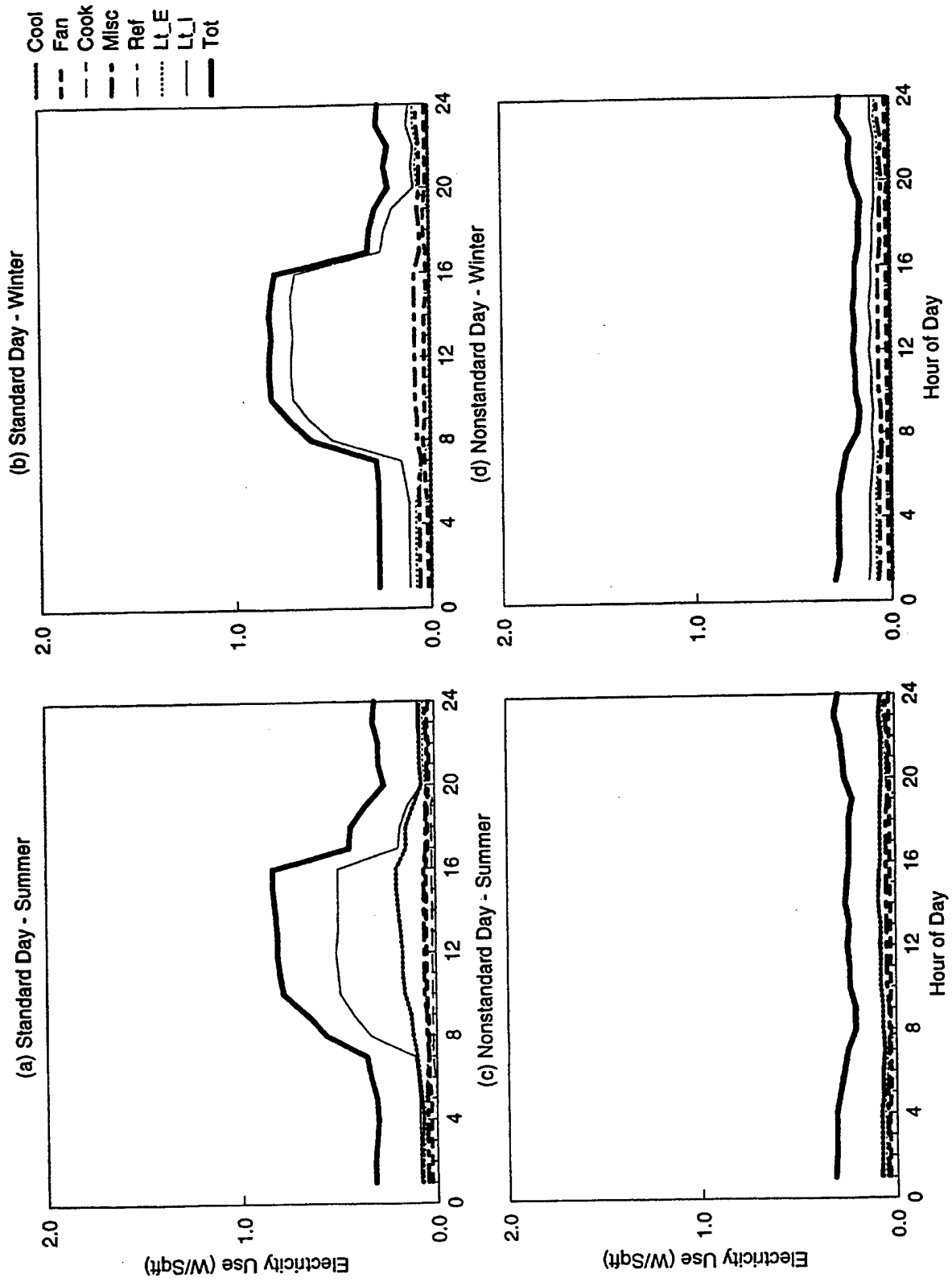


Figure C-42. EDA Reconciled End-use Load Shapes for Large Vehicle Maintenance (Split DX) (Feeder 10)

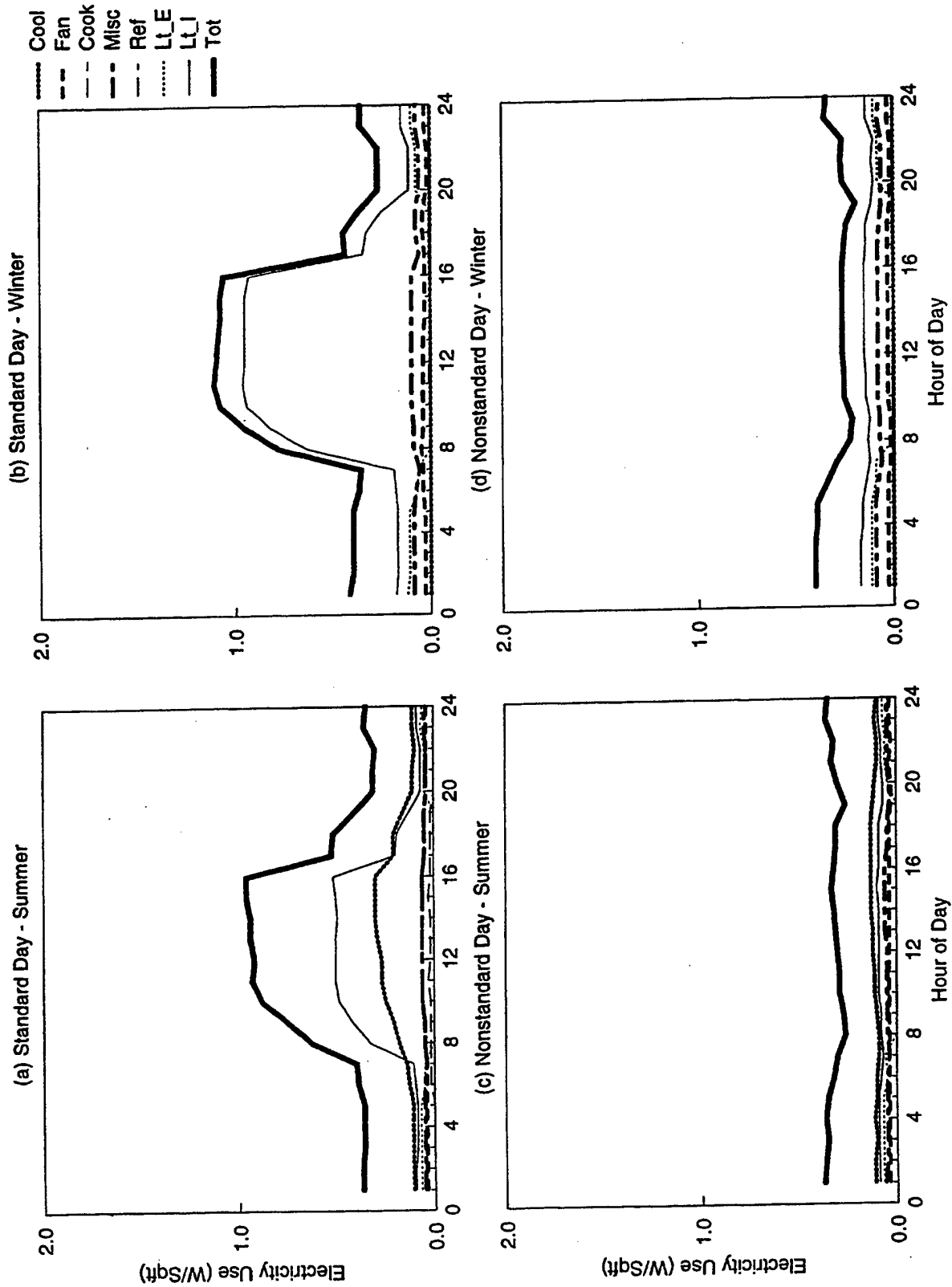


Figure C-43. EDA Reconciled End-use Load Shapes for Large Vehicle Maintenance (Split DX) (Feeder 15)

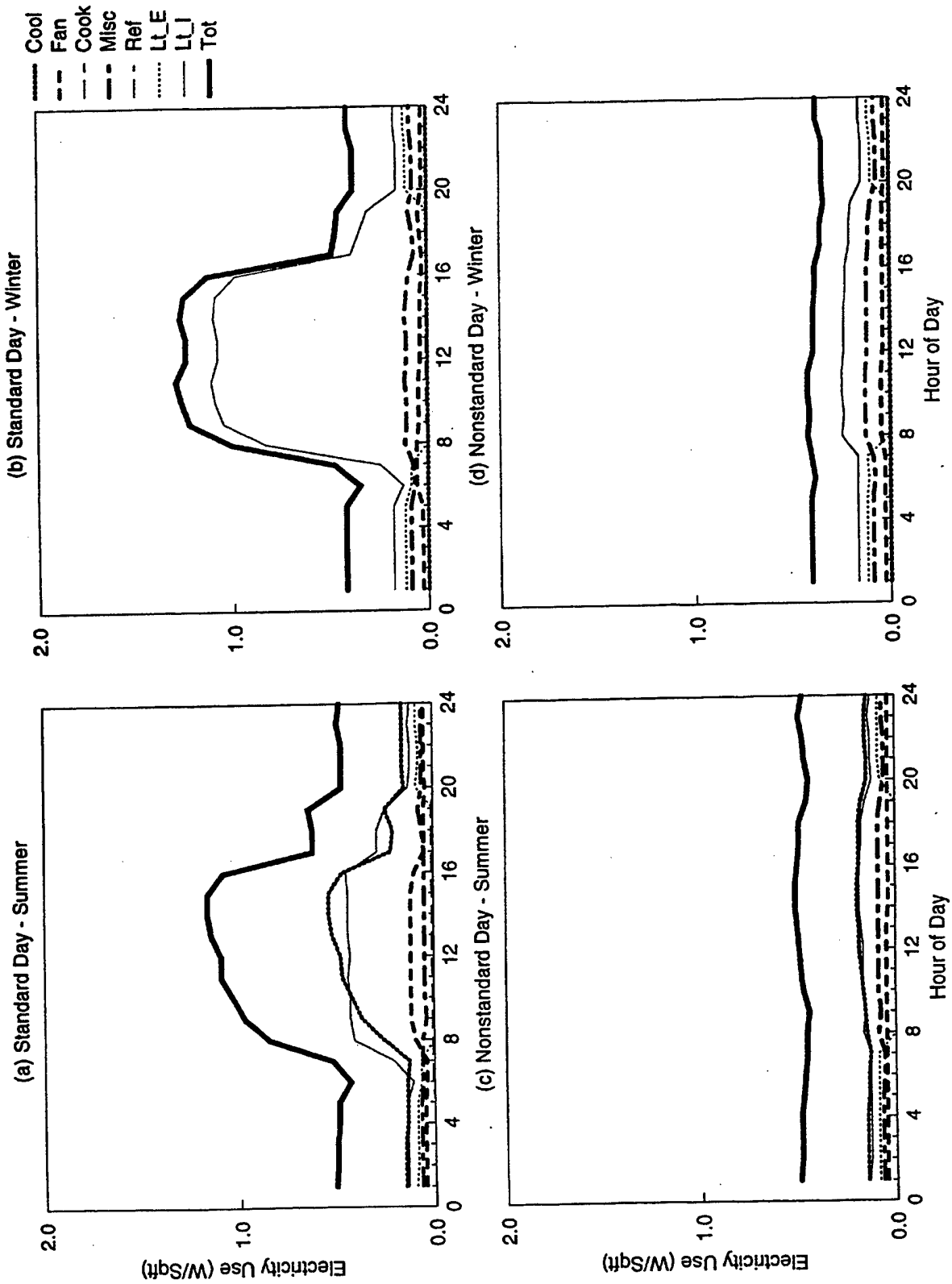


Figure C-44. EDA Reconciled End-use Load Shapes for Large Vehicle Maintenance (Split DX) (Feeder W6)

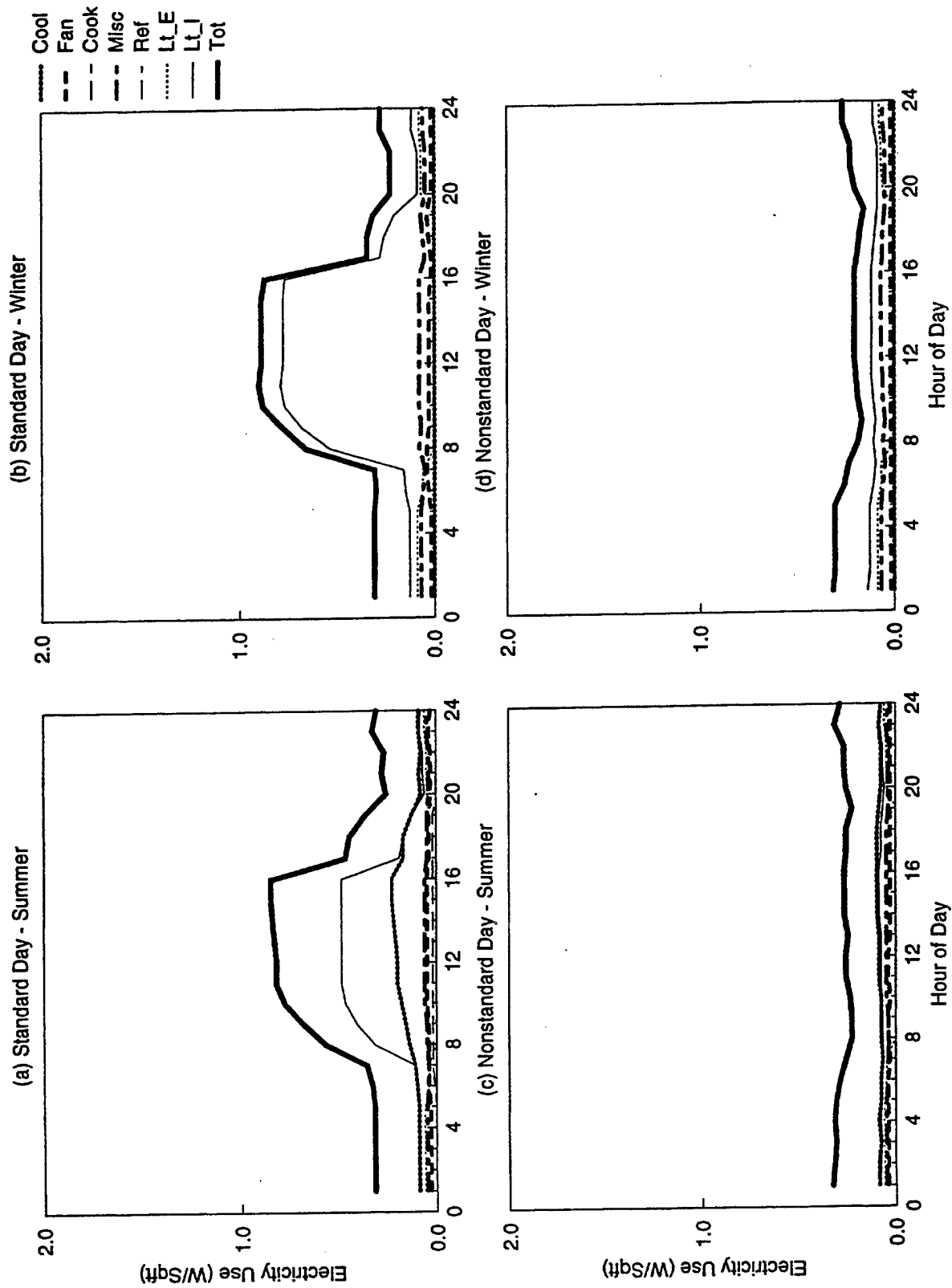


Figure C-45. EDA Reconciled End-use Load Shapes for Large Vehicle Maintenance (Split DX) (Weighted 3,10,15)

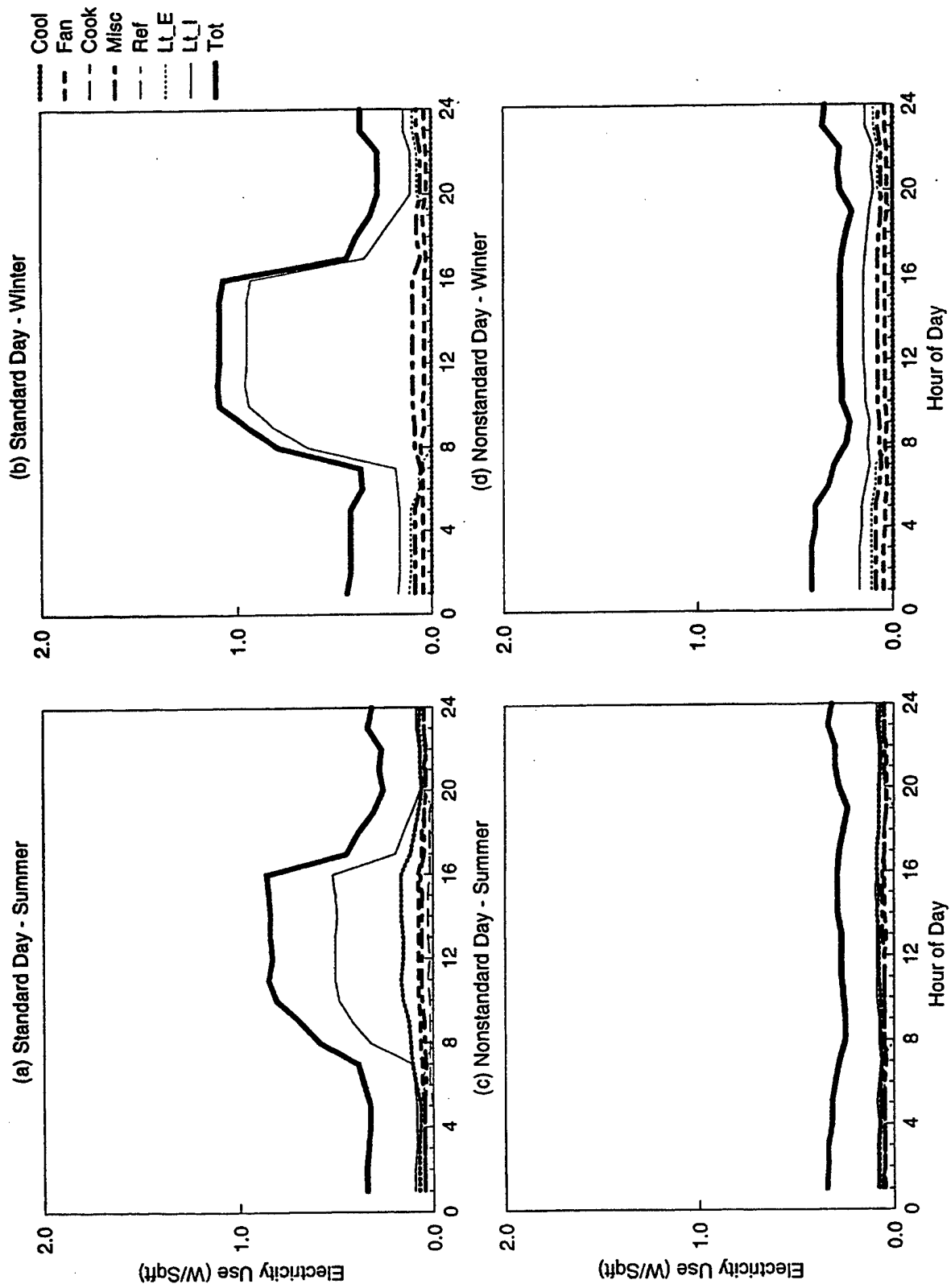


Figure C-46. EDA Reconciled End-use Load Shapes for Large Vehicle Maintenance (Chiller) (Feeder 15)

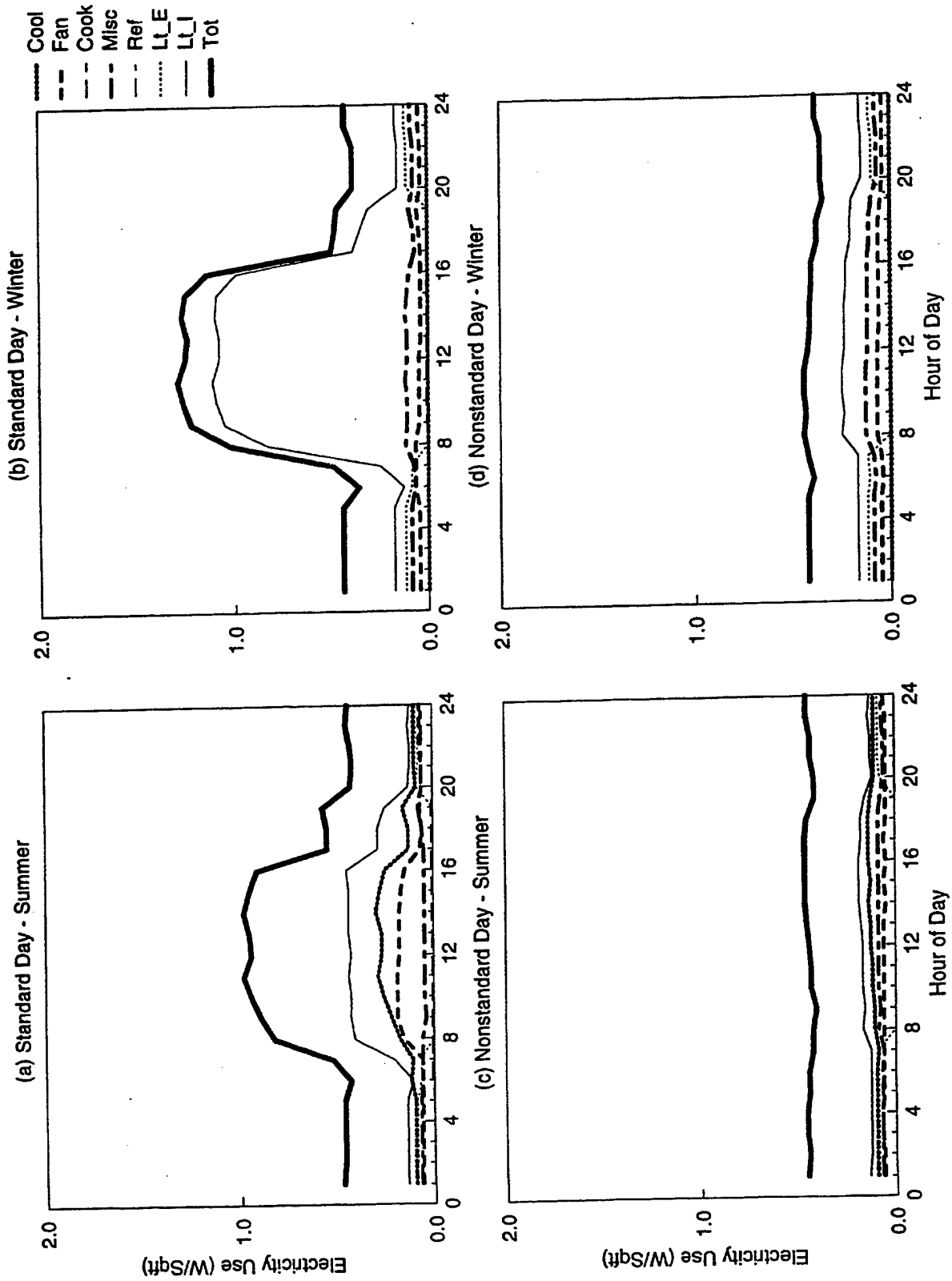


Figure C-47. EDA Reconciled End-use Load Shapes for Large Vehicle Maintenance (Chiller) (Feeder W6)

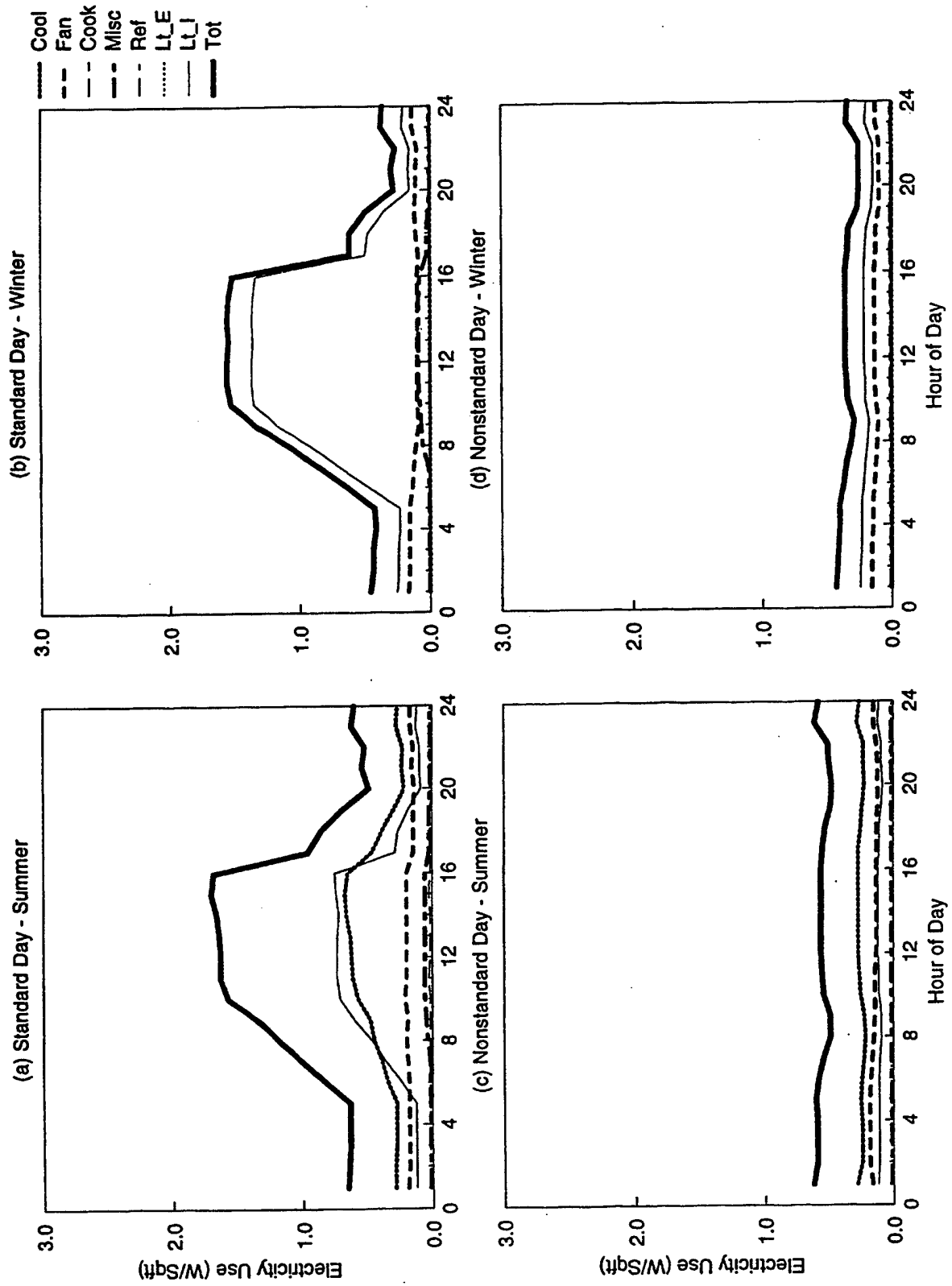


Figure C-48. EDA Reconciled End-use Load Shapes for Hangar (Feeder 15)

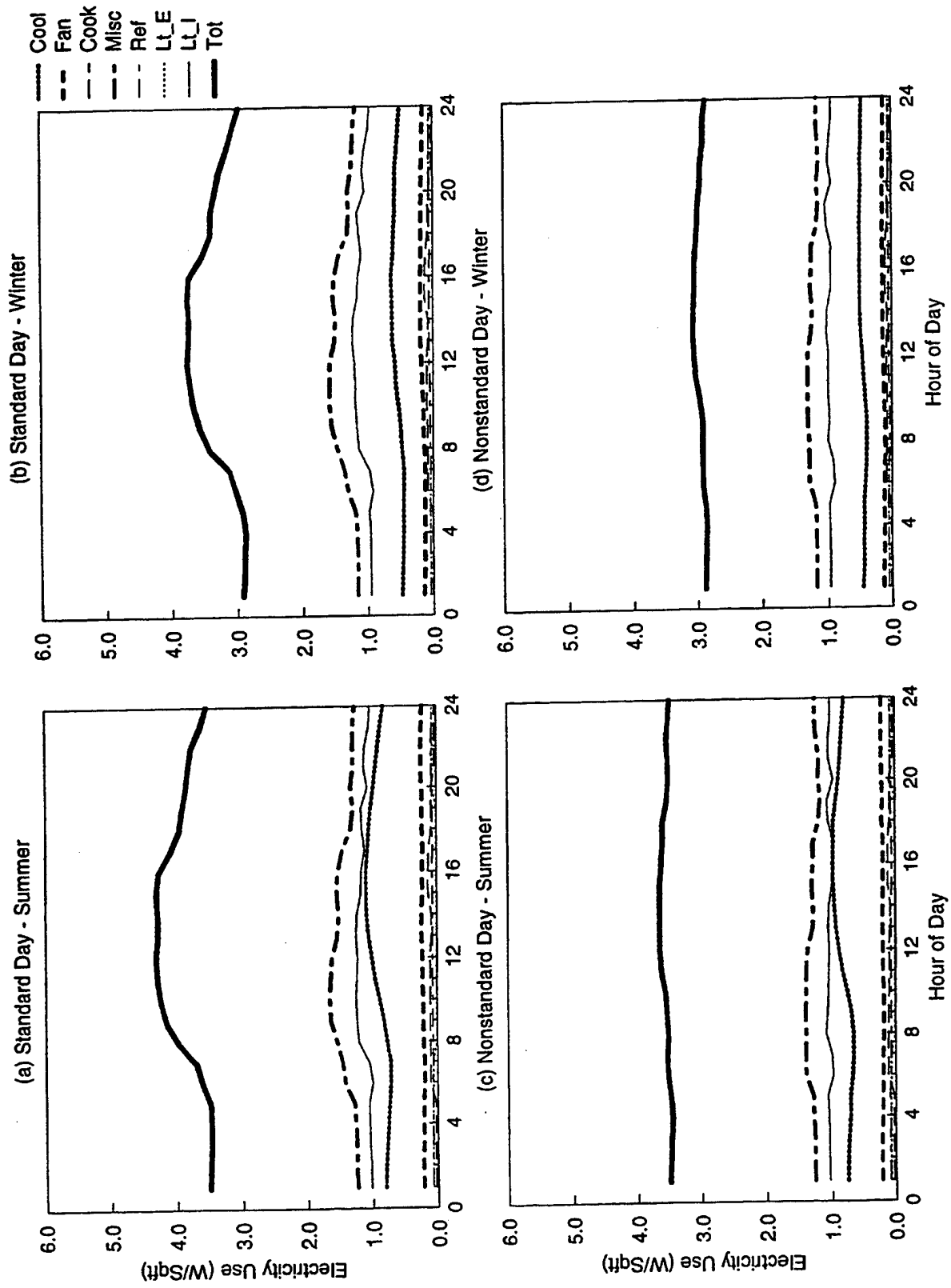


Figure C-49. EDA Reconciled End-use Load Shapes for Hospital (Feeder 9)

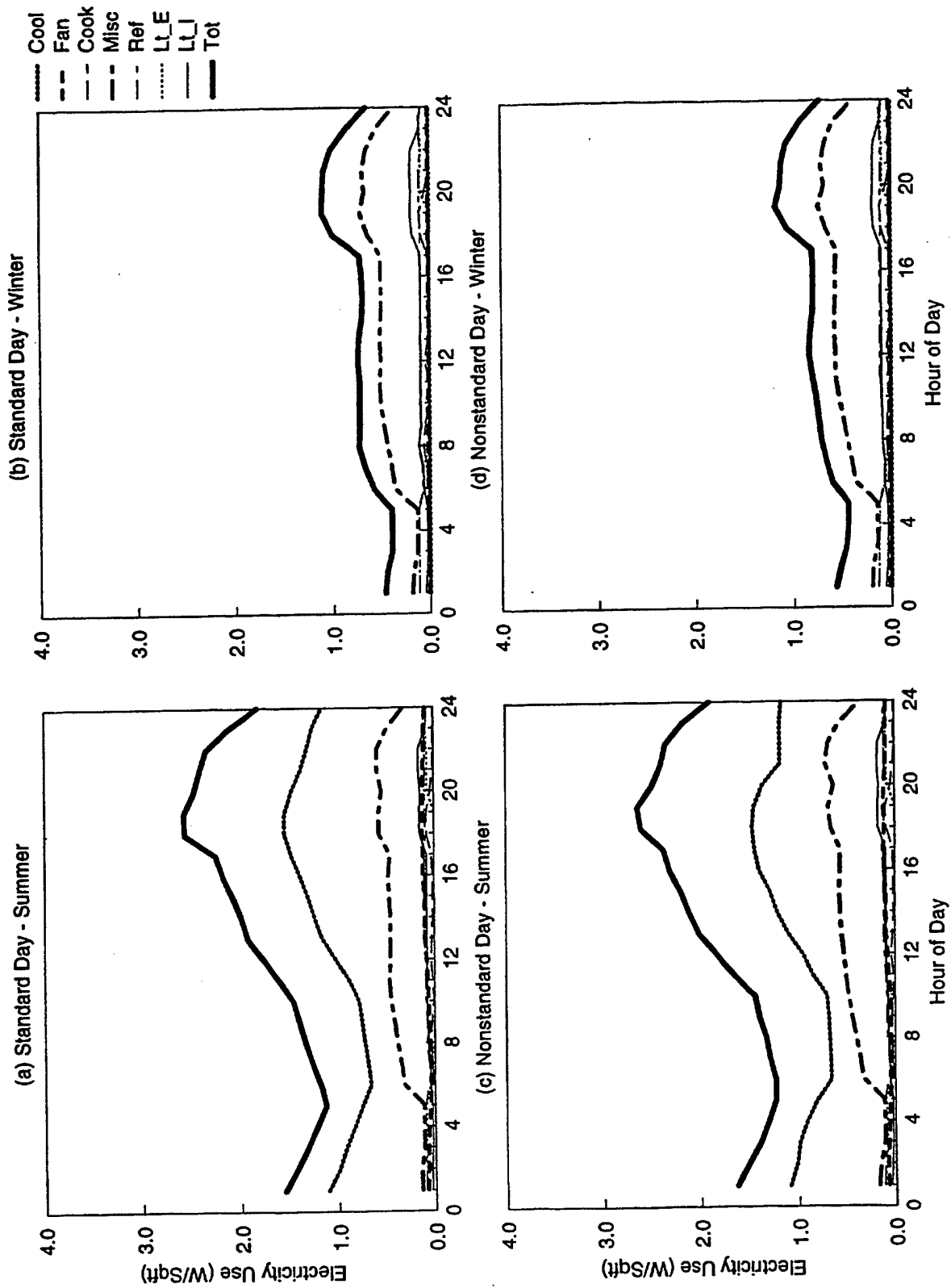


Figure C-50. EDA Reconciled End-use Load Shapes for Detached Residential (Feeder 5)

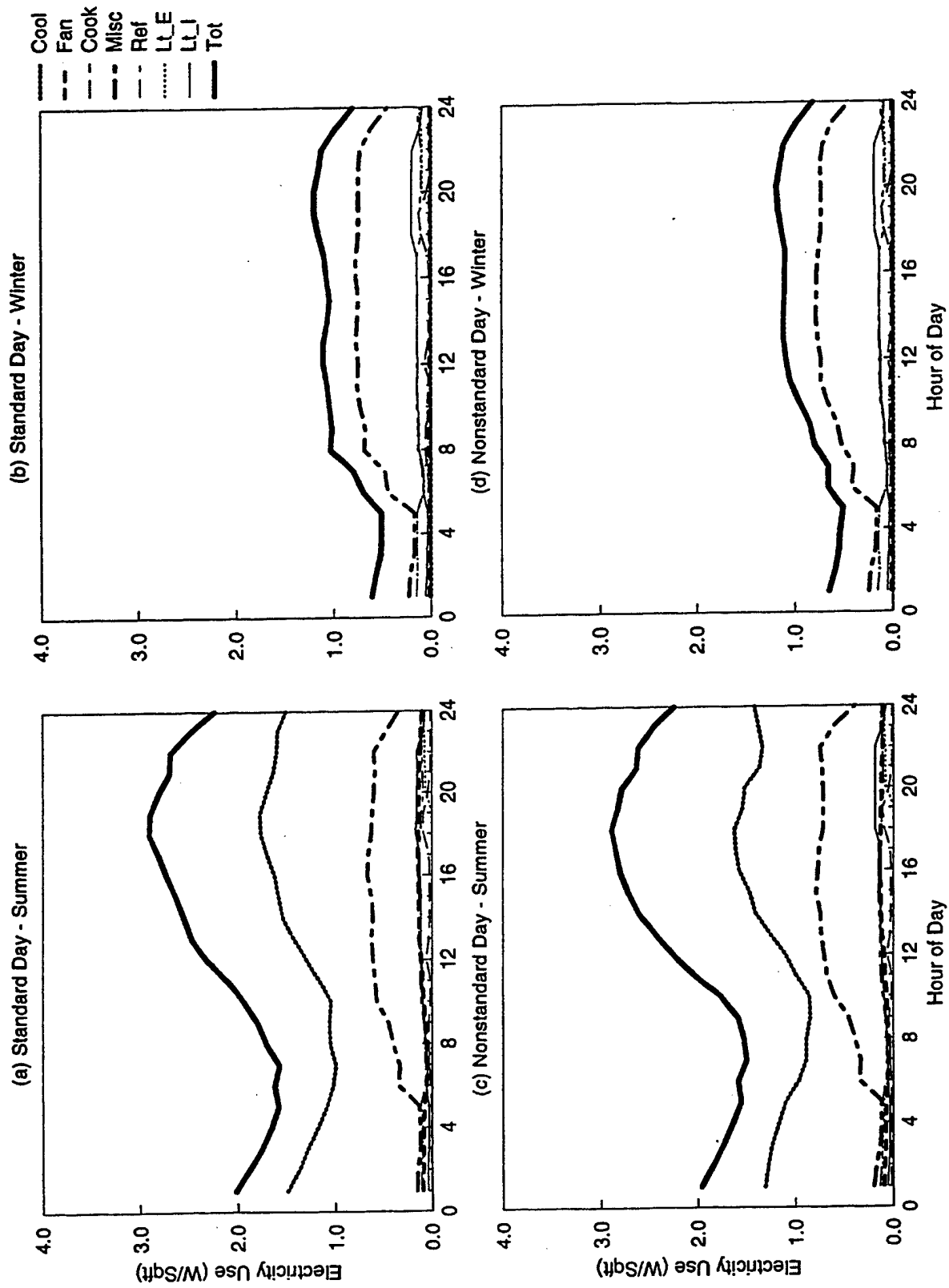


Figure C-51. EDA Reconciled End-use Load Shapes for Detached Residential (Feeder 12)

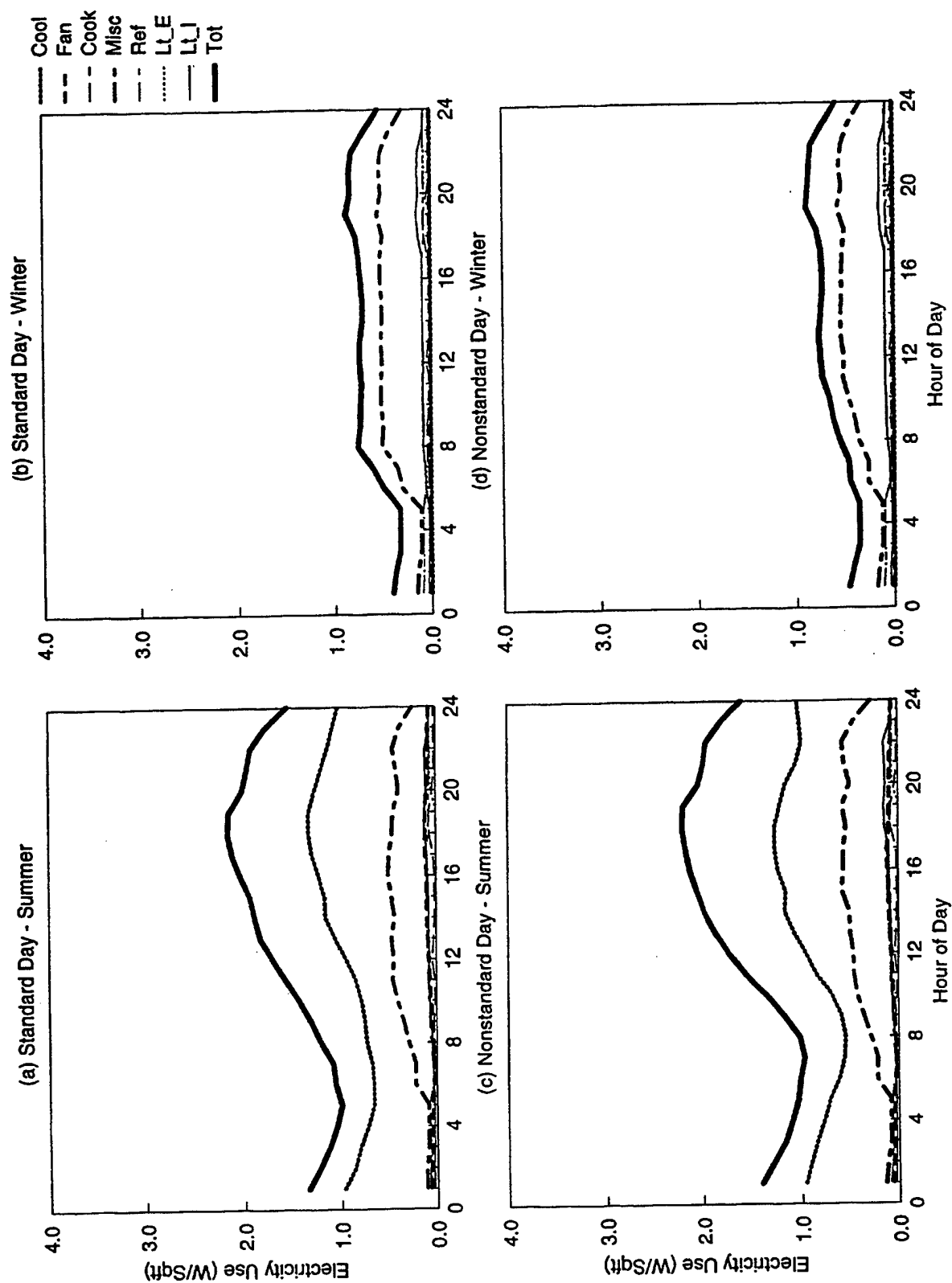


Figure C-52. EDA Reconciled End-use Load Shapes for Detached Residential (Feeder W4)

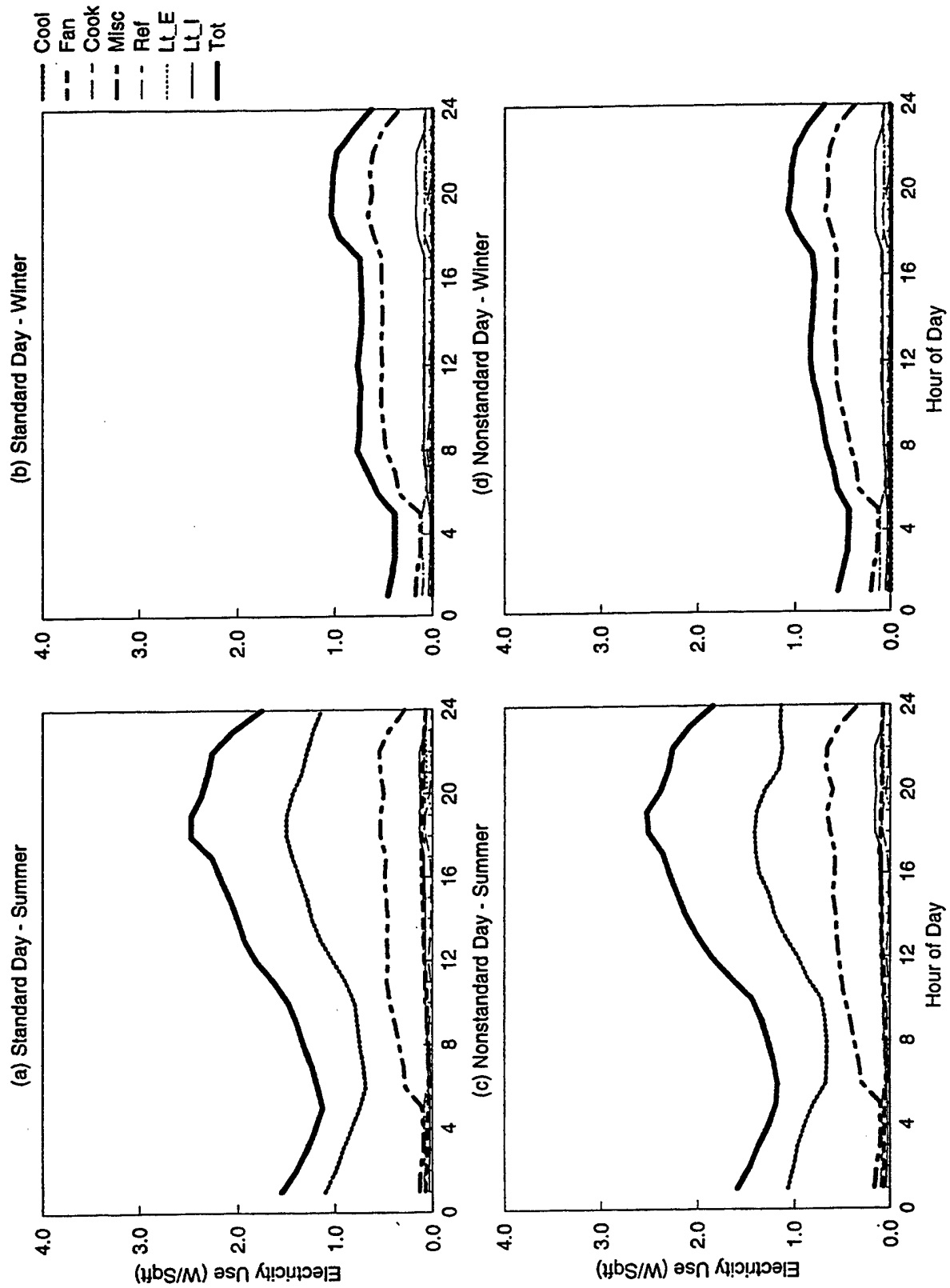


Figure C-53. EDA Reconciled End-use Load Shapes for Detached Residential (Weighted 5,12,W4)

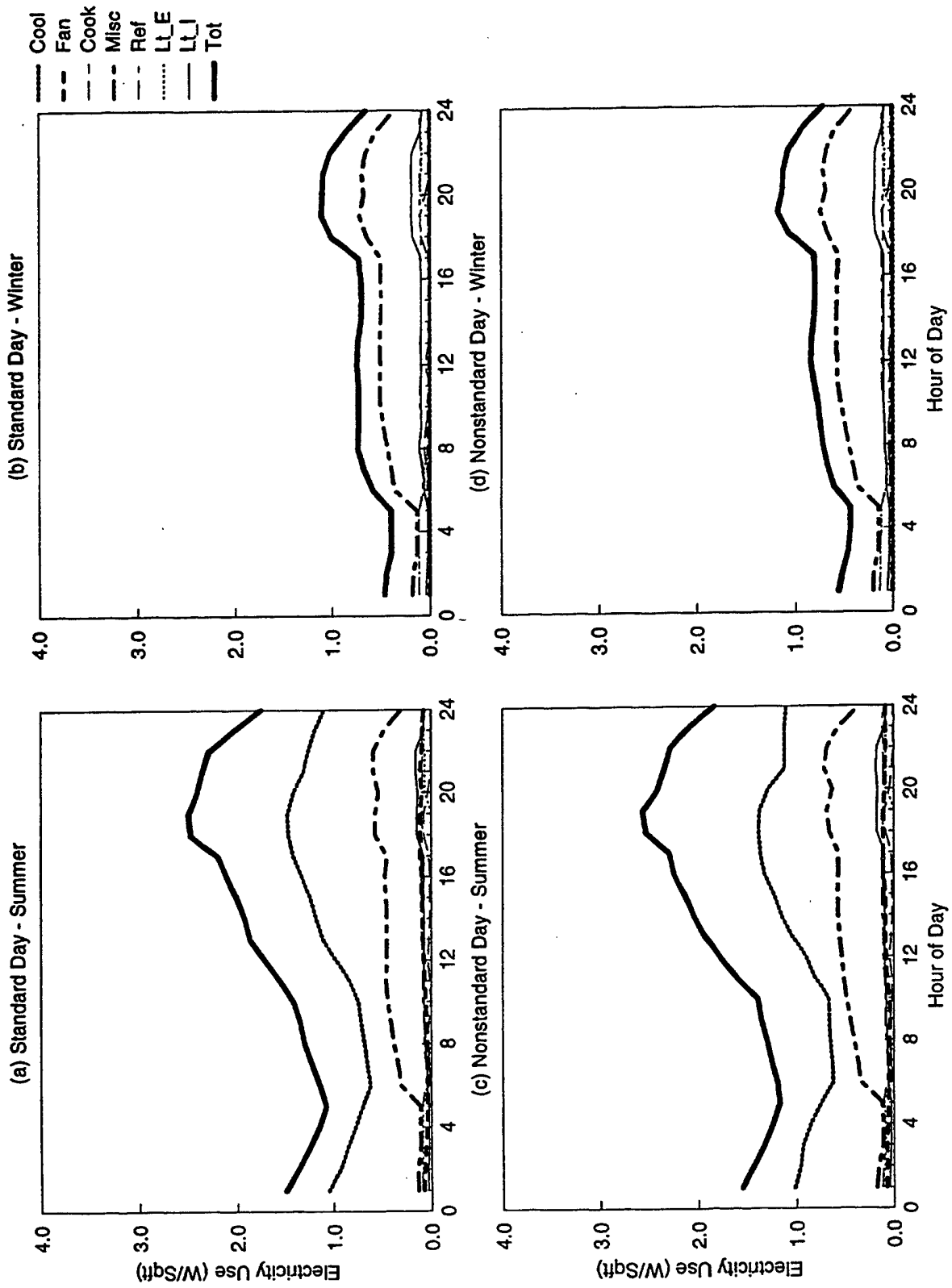


Figure C-54. EDA Reconciled End-use Load Shapes for Two-Plex Residential (Feeder 5)

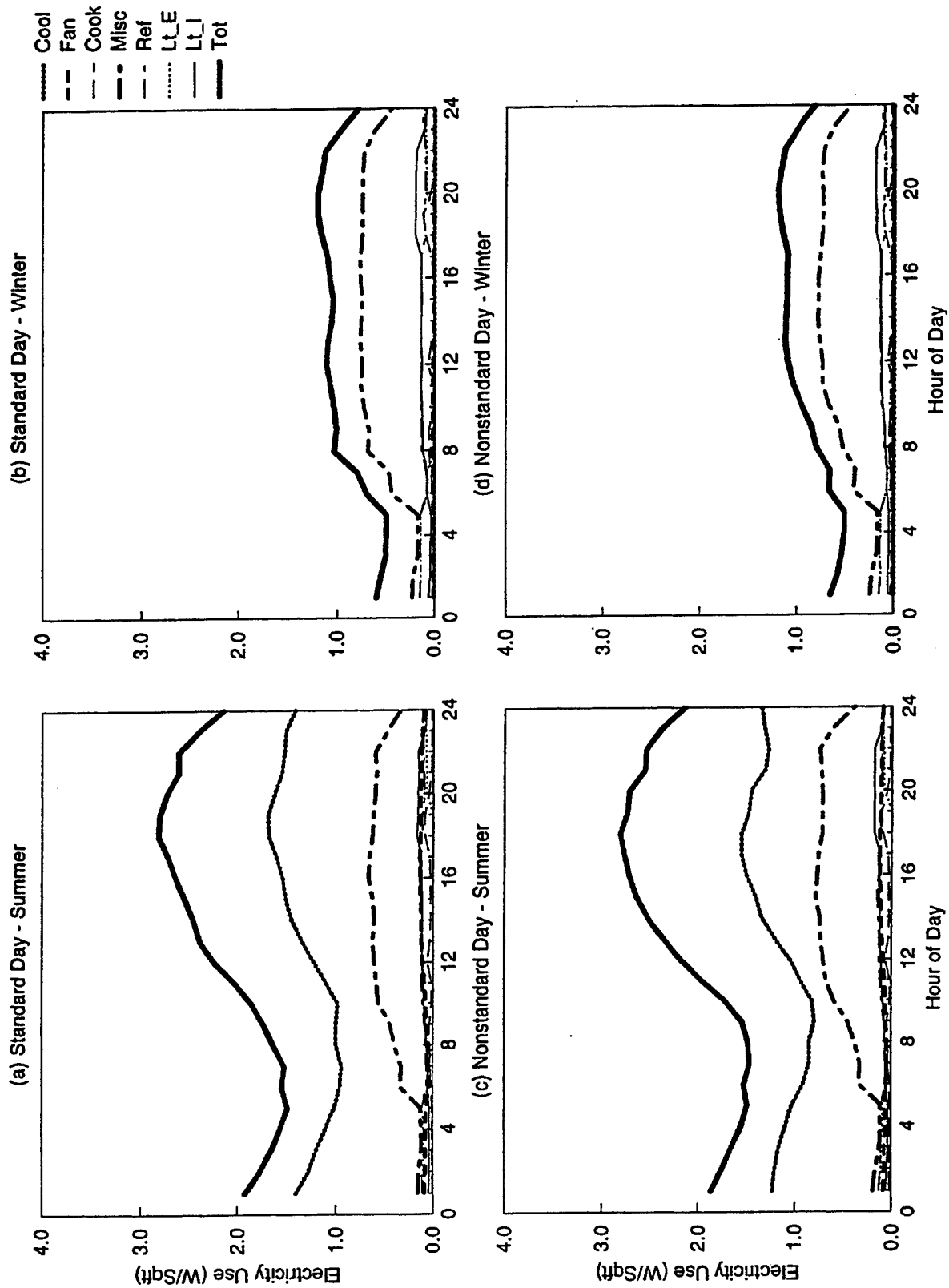


Figure C-55. EDA Reconciled End-use Load Shapes for Two-Plex Residential (Feeder 12)

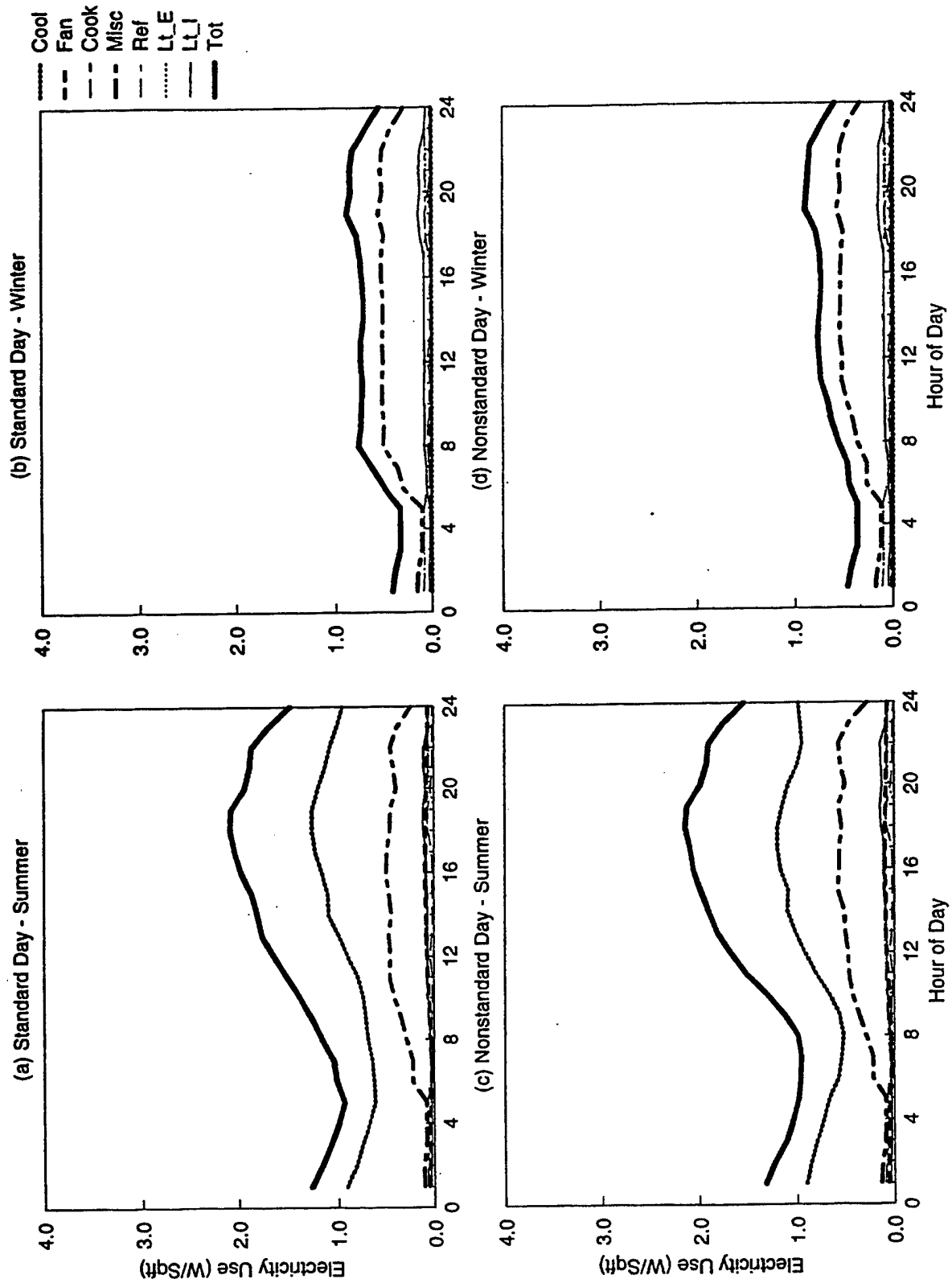


Figure C-56. EDA Reconciled End-use Load Shapes for Two-Plex Residential (Feeder W4)

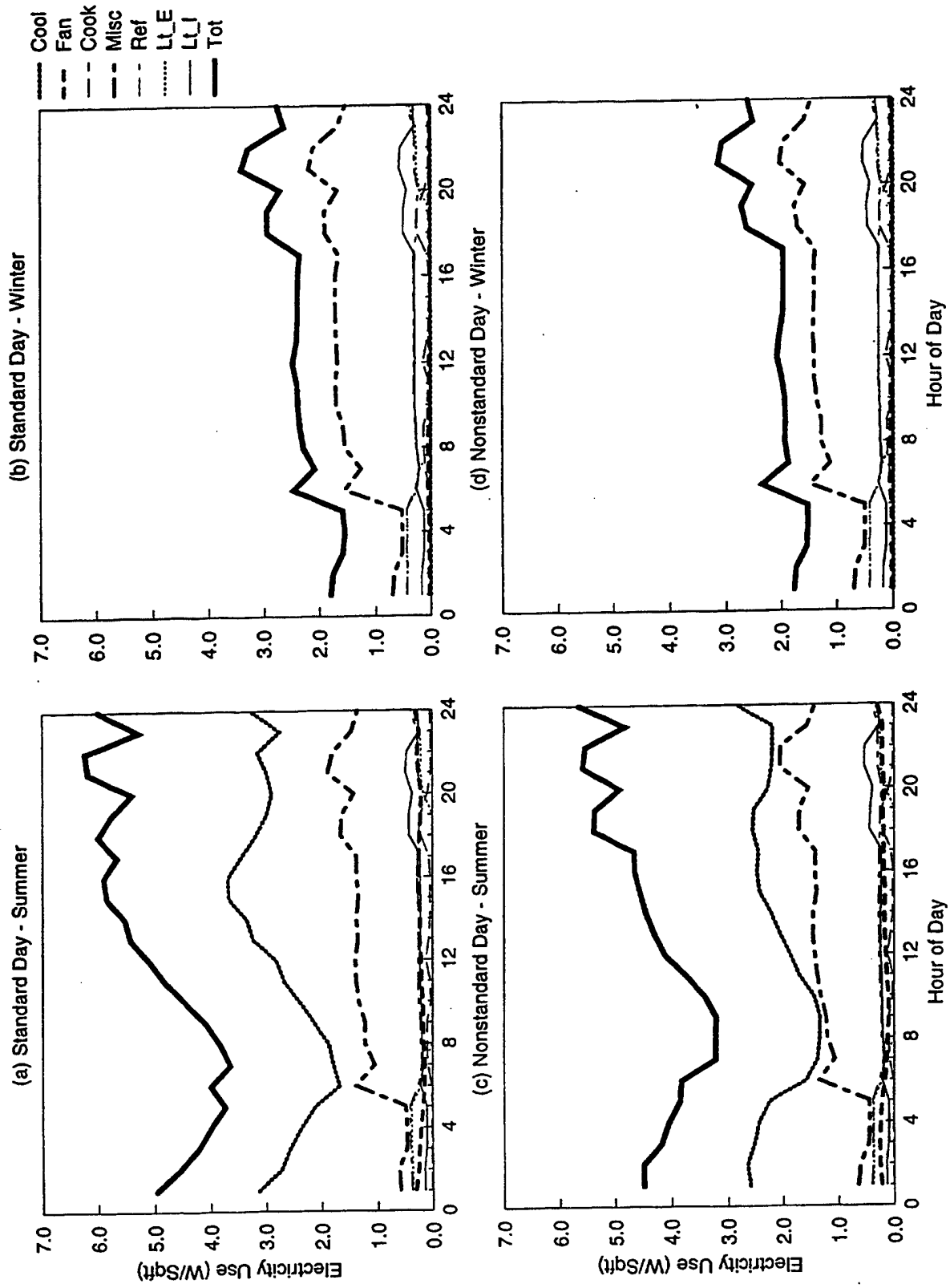


Figure C-57. EDA Reconciled End-use Load Shapes for Two-Plex Residential (Feeder W5)

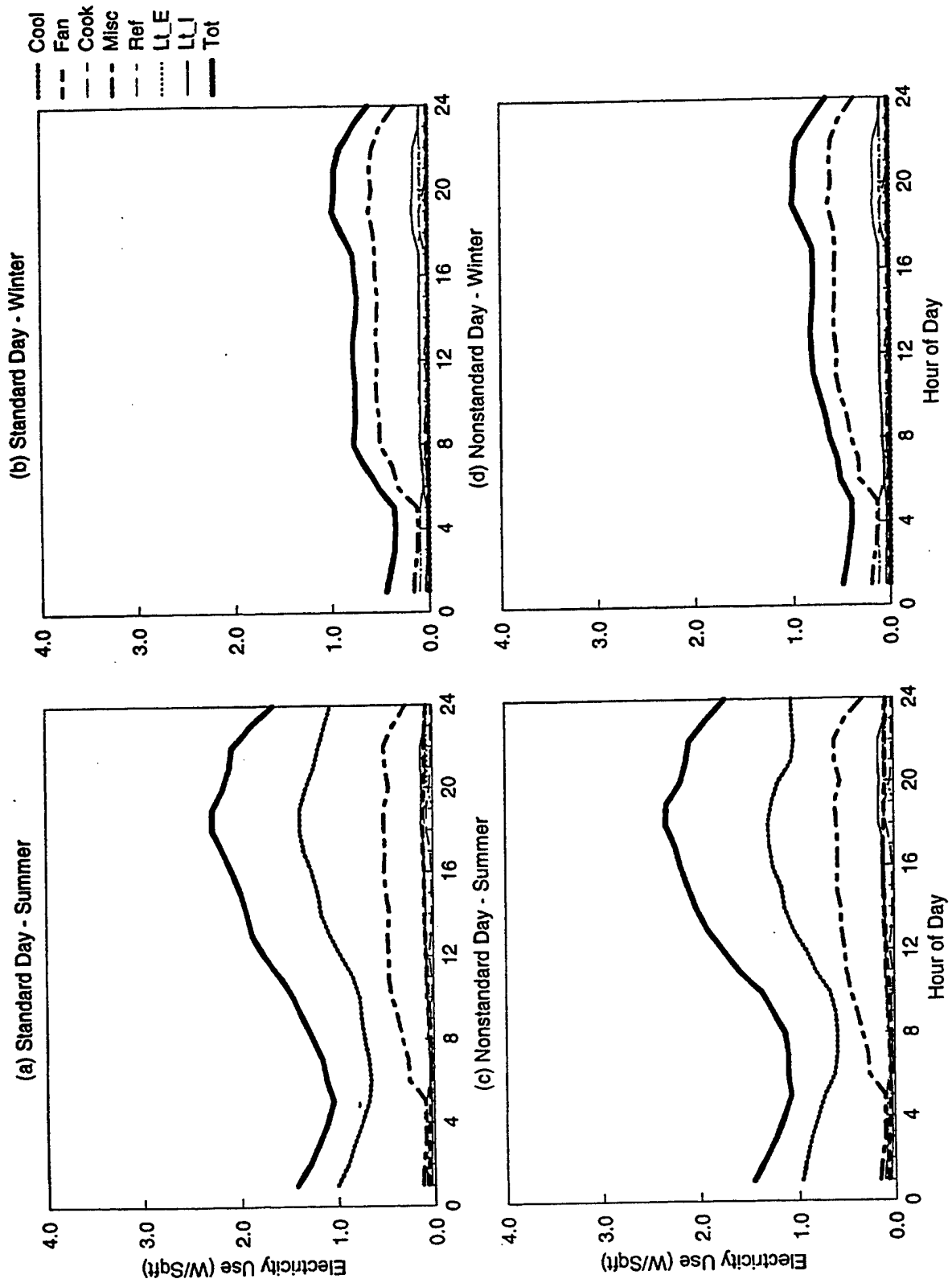


Figure C-58. EDA Reconciled End-use Load Shapes for Two-Plex Residential (Weighted 5,12,W4)

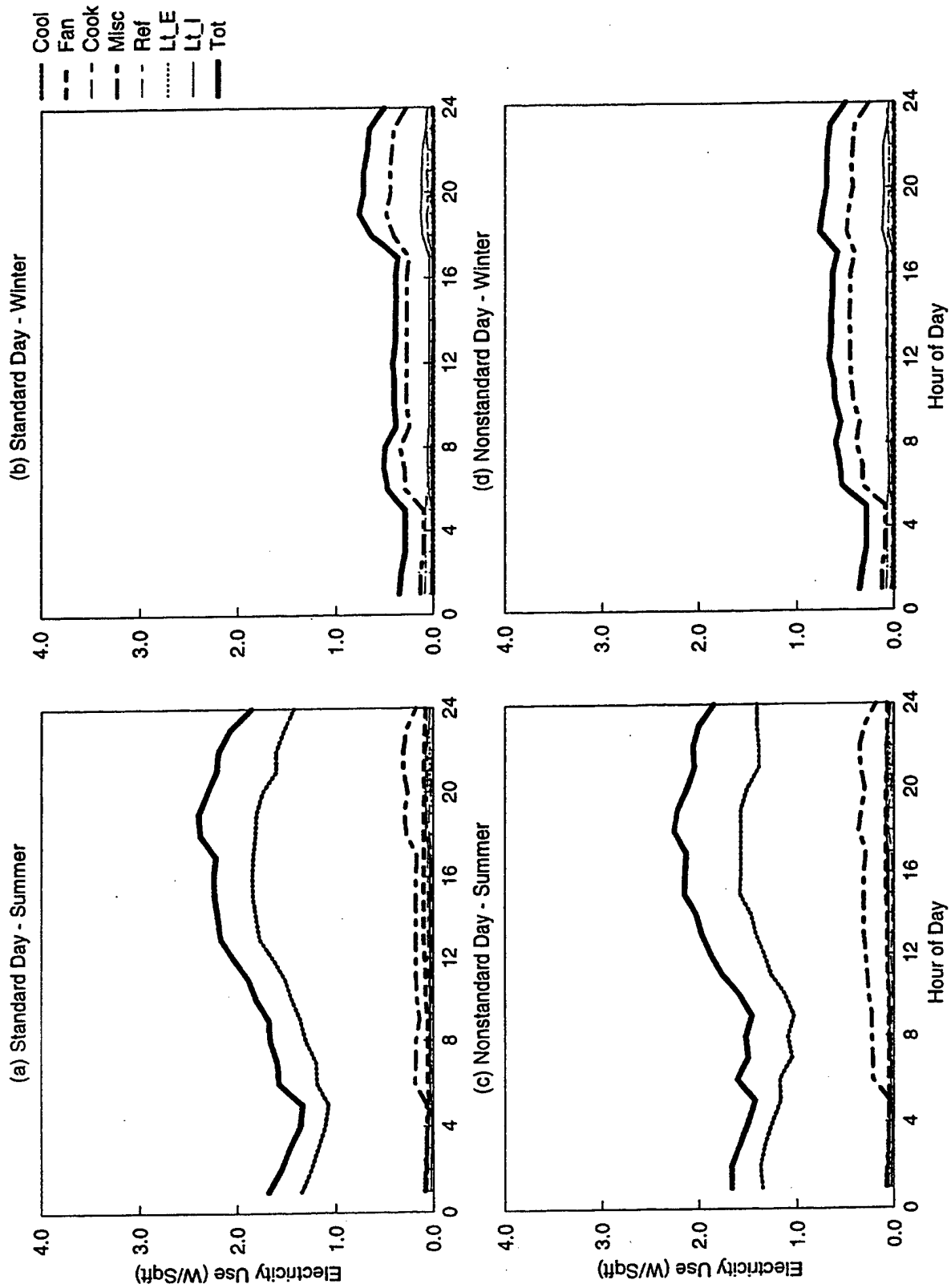


Figure C-59. EDA Reconciled End-use Load Shapes for Four-Plex Residential (Feeder 3)

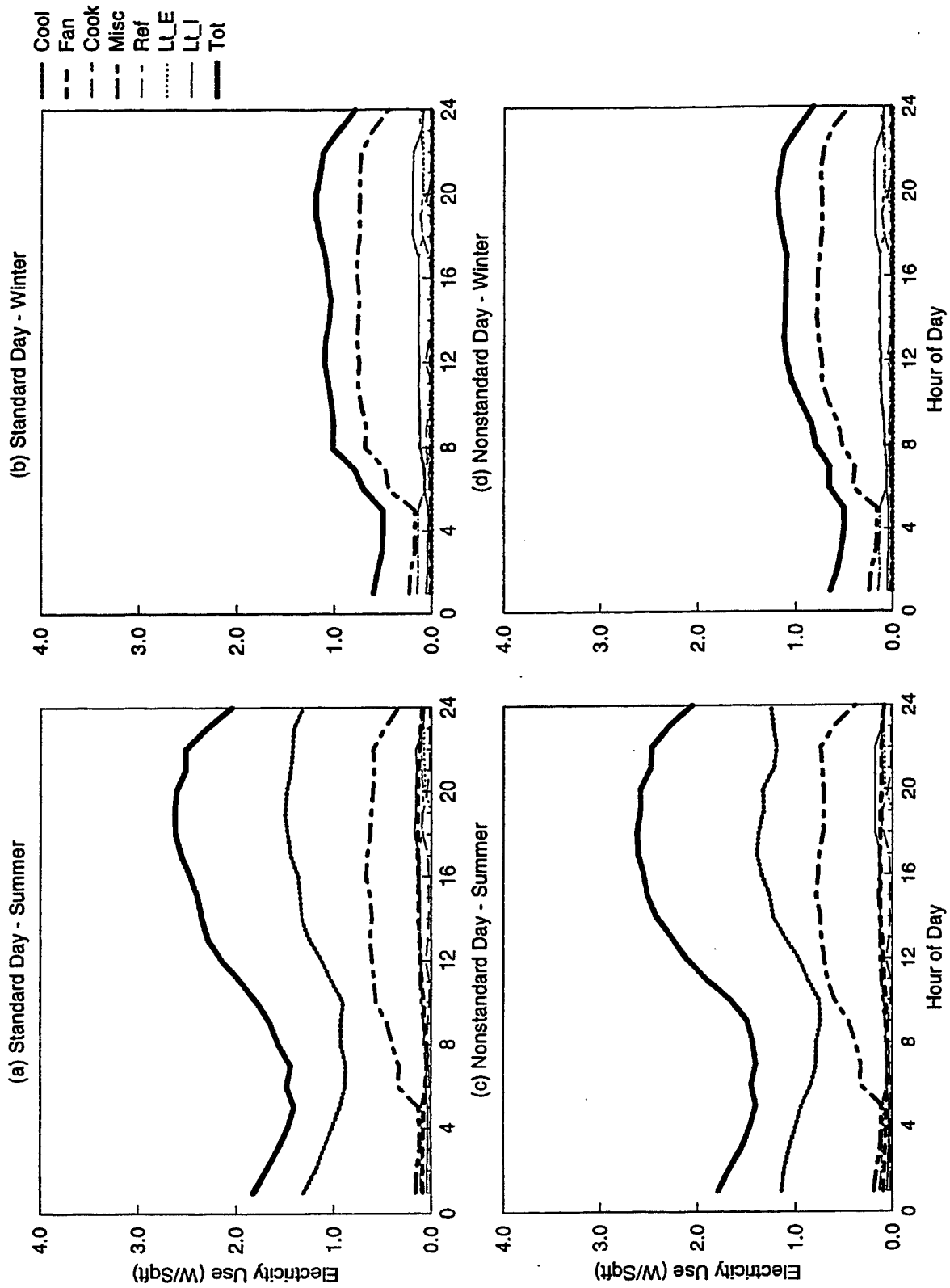


Figure C-60. EDA Reconciled End-use Load Shapes for Four-Plex Residential (Feeder 12)

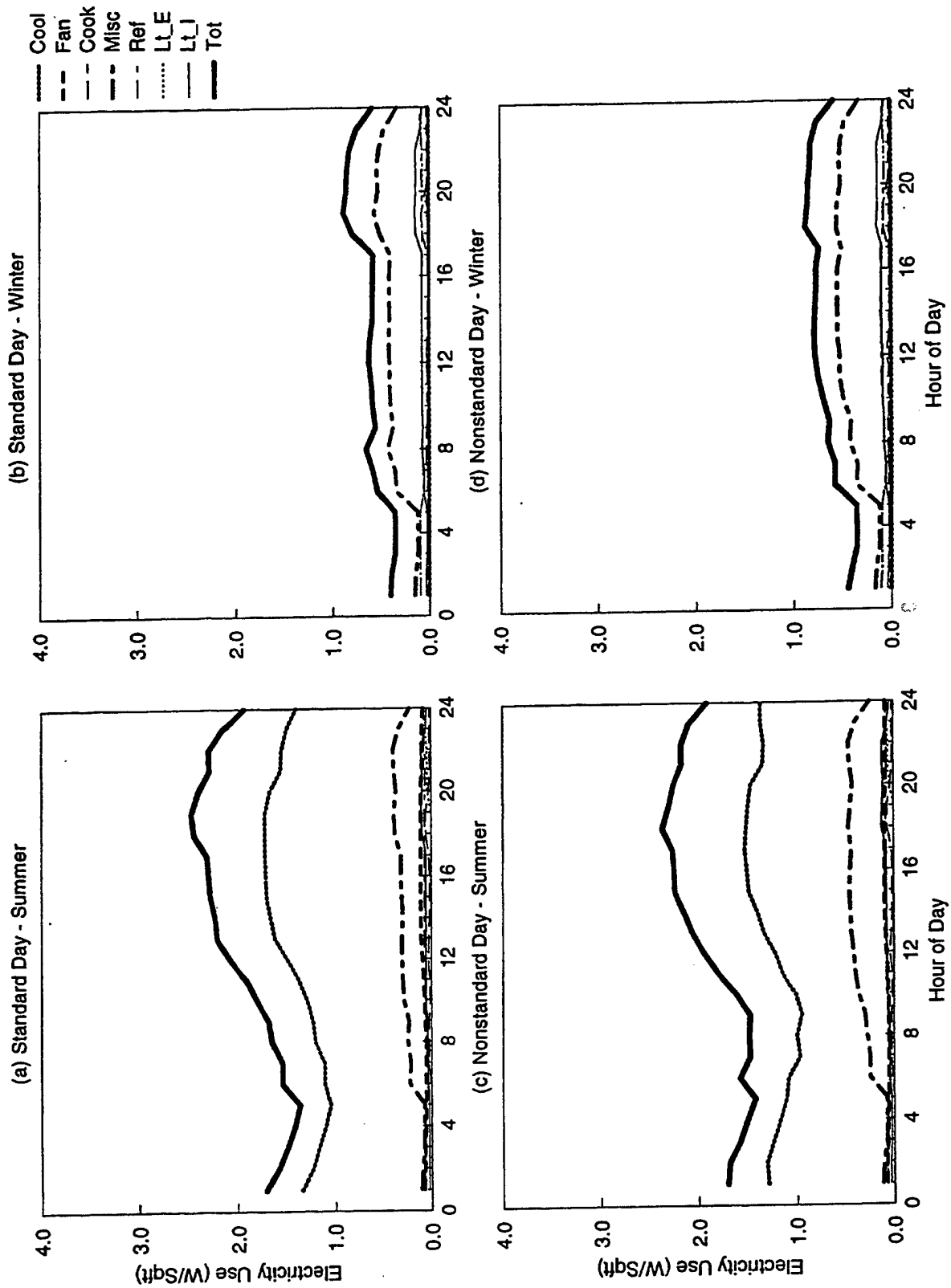


Figure C-61. EDA Reconciled End-use Load Shapes for Four-Plex Residential (Weighted 3,12)

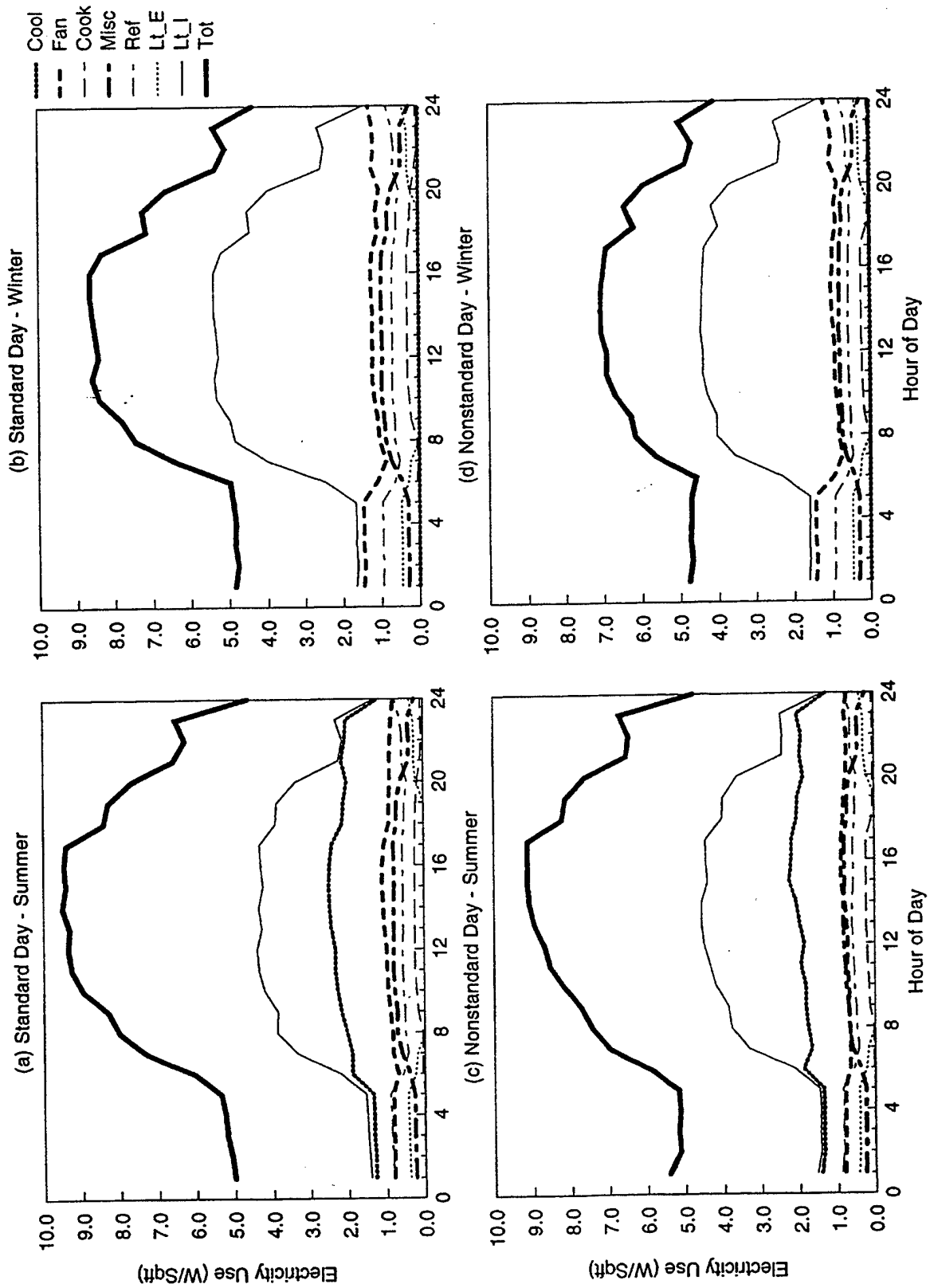


Figure C-62. EDA Reconciled End-use Load Shapes for Large Retail (Feeder W5)

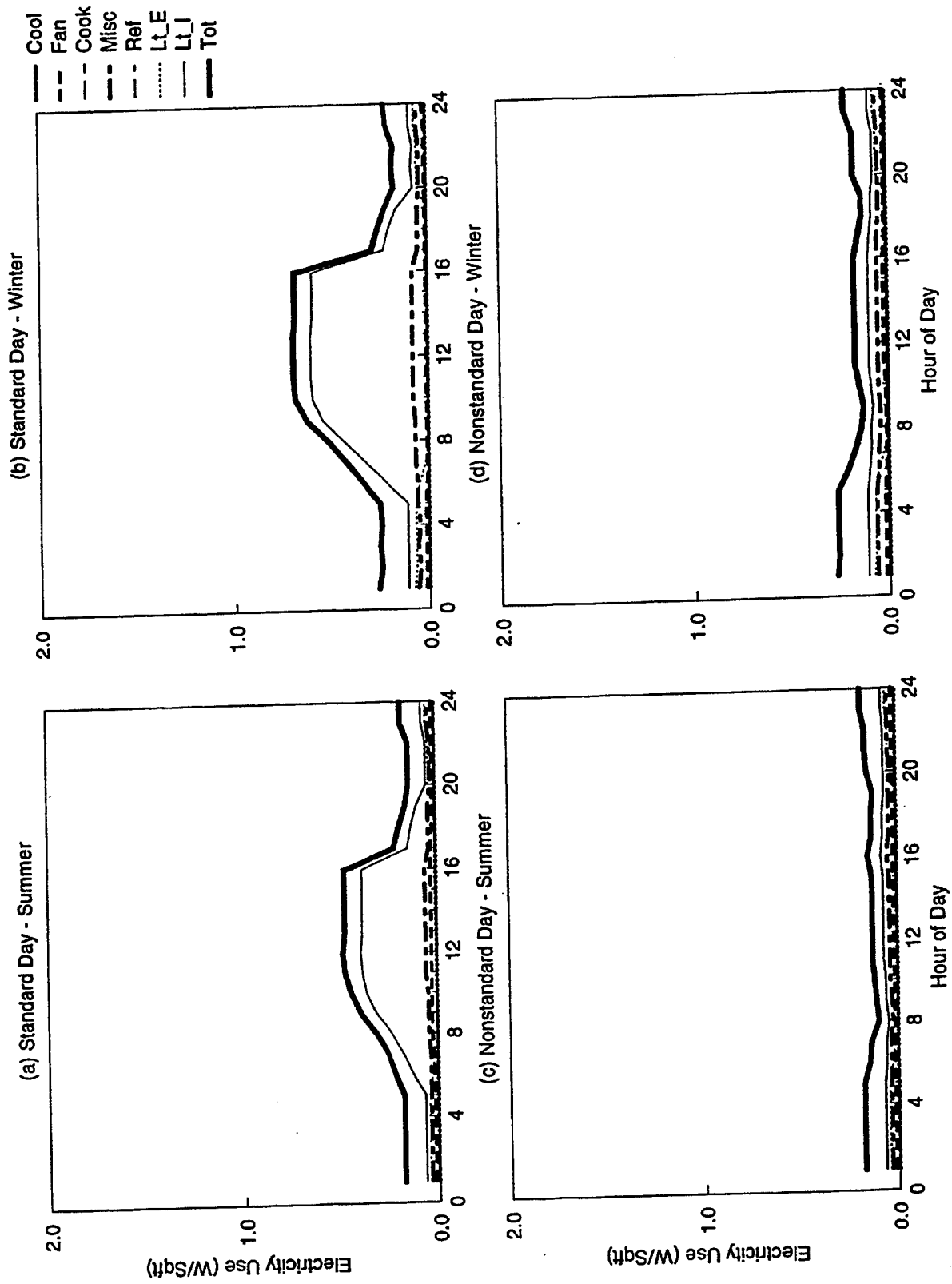


Figure C-63. EDA Reconciled End-use Load Shapes for Warehouse (No AC) (Feeder 3)

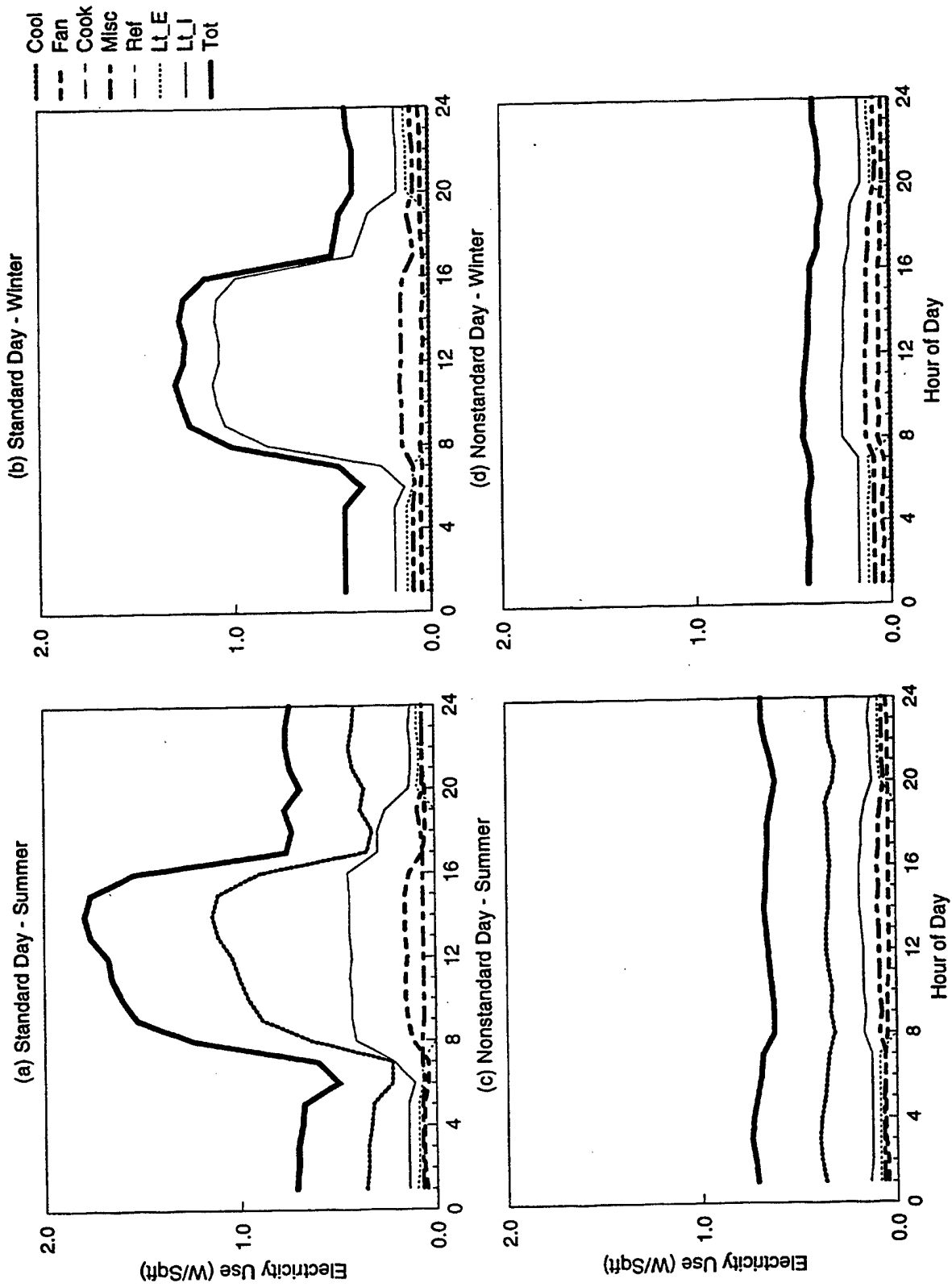


Figure C-64. EDA Reconciled End-use Load Shapes for Warehouse (Split DX) (Feeder W6)

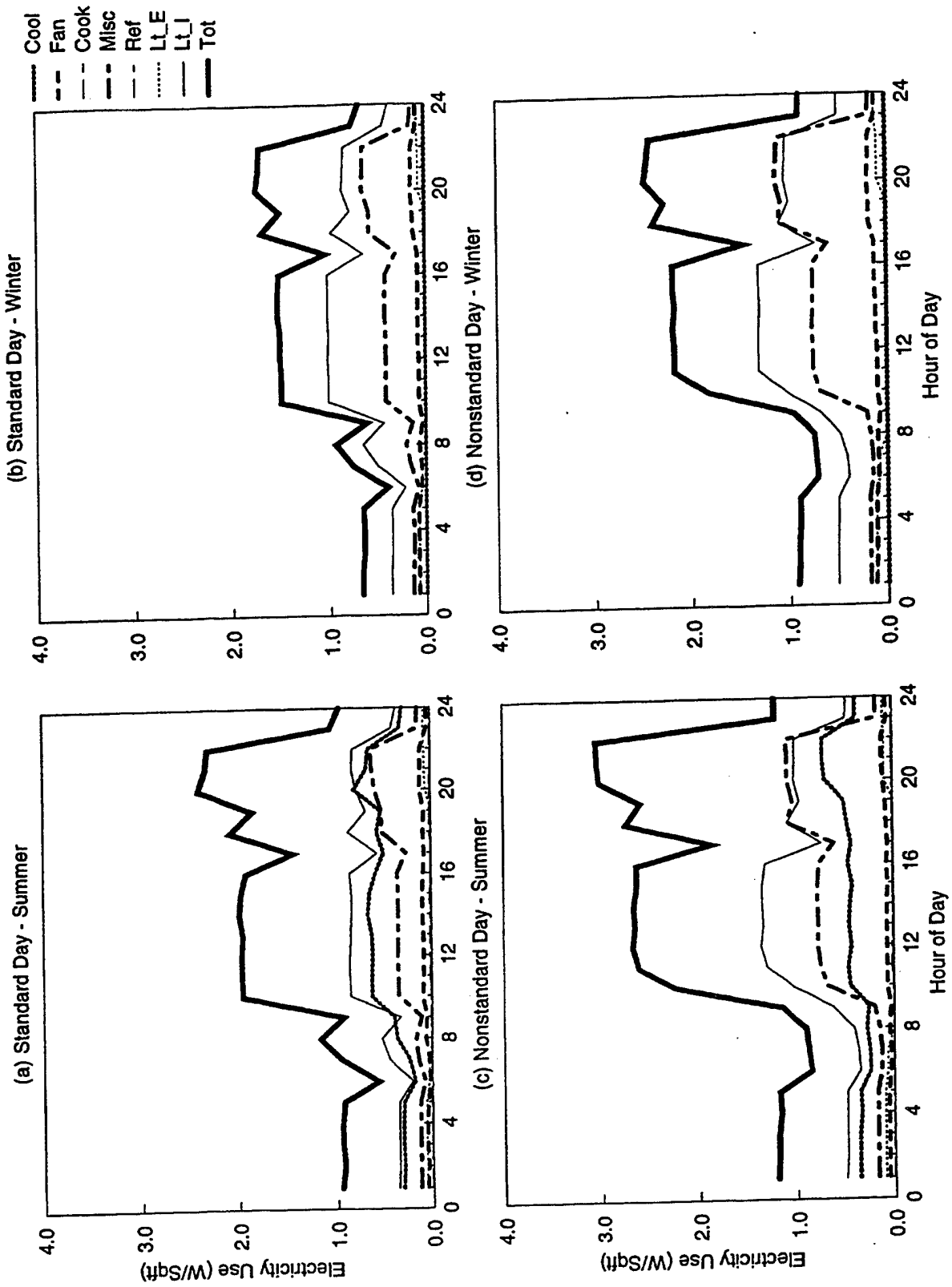


Figure C-65. EDA Reconciled End-use Load Shapes for Miscellaneous (Feeder 2)

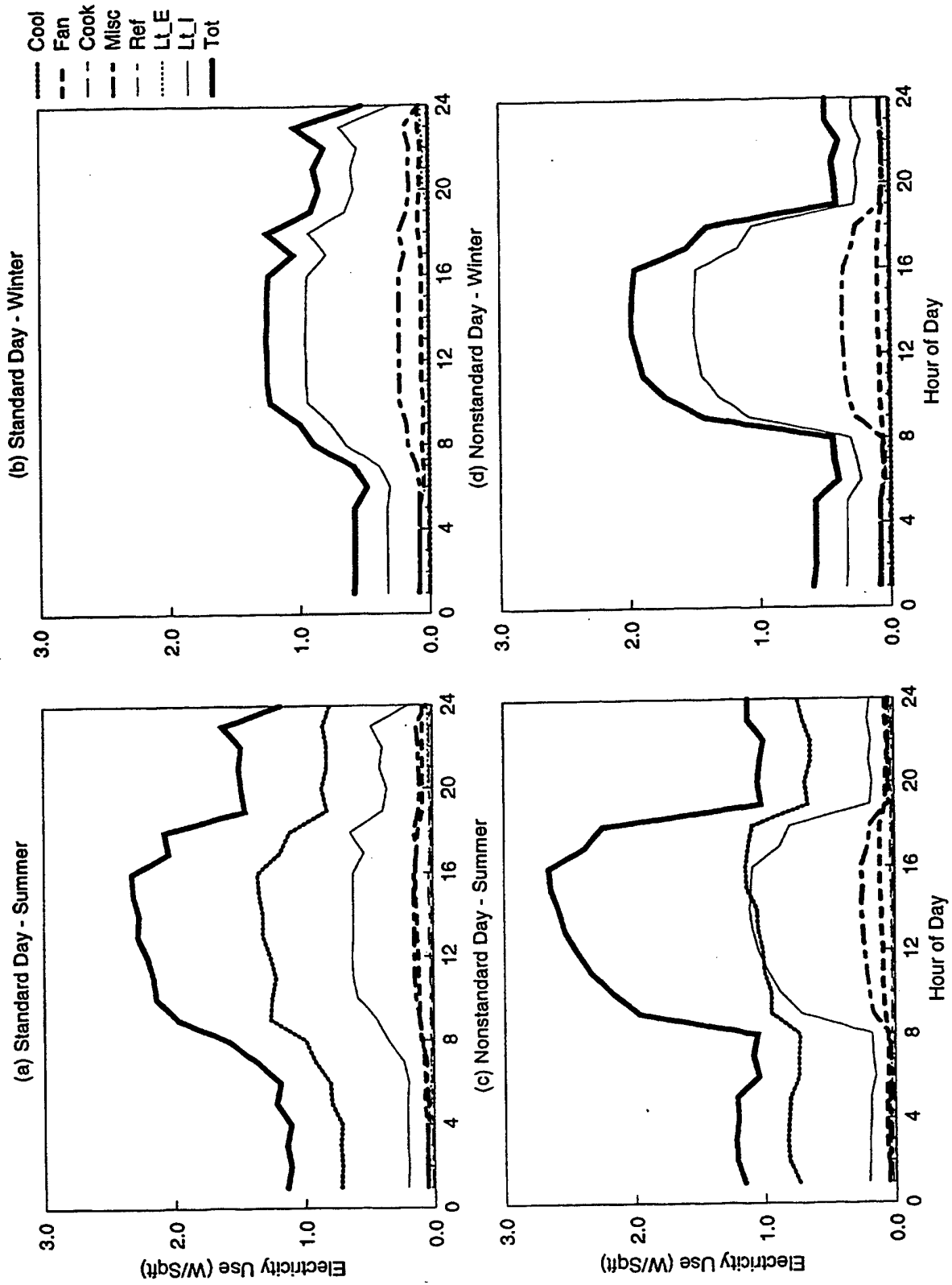


Figure C-66. EDA Reconciled End-use Load Shapes for Miscellaneous (Feeder 3)

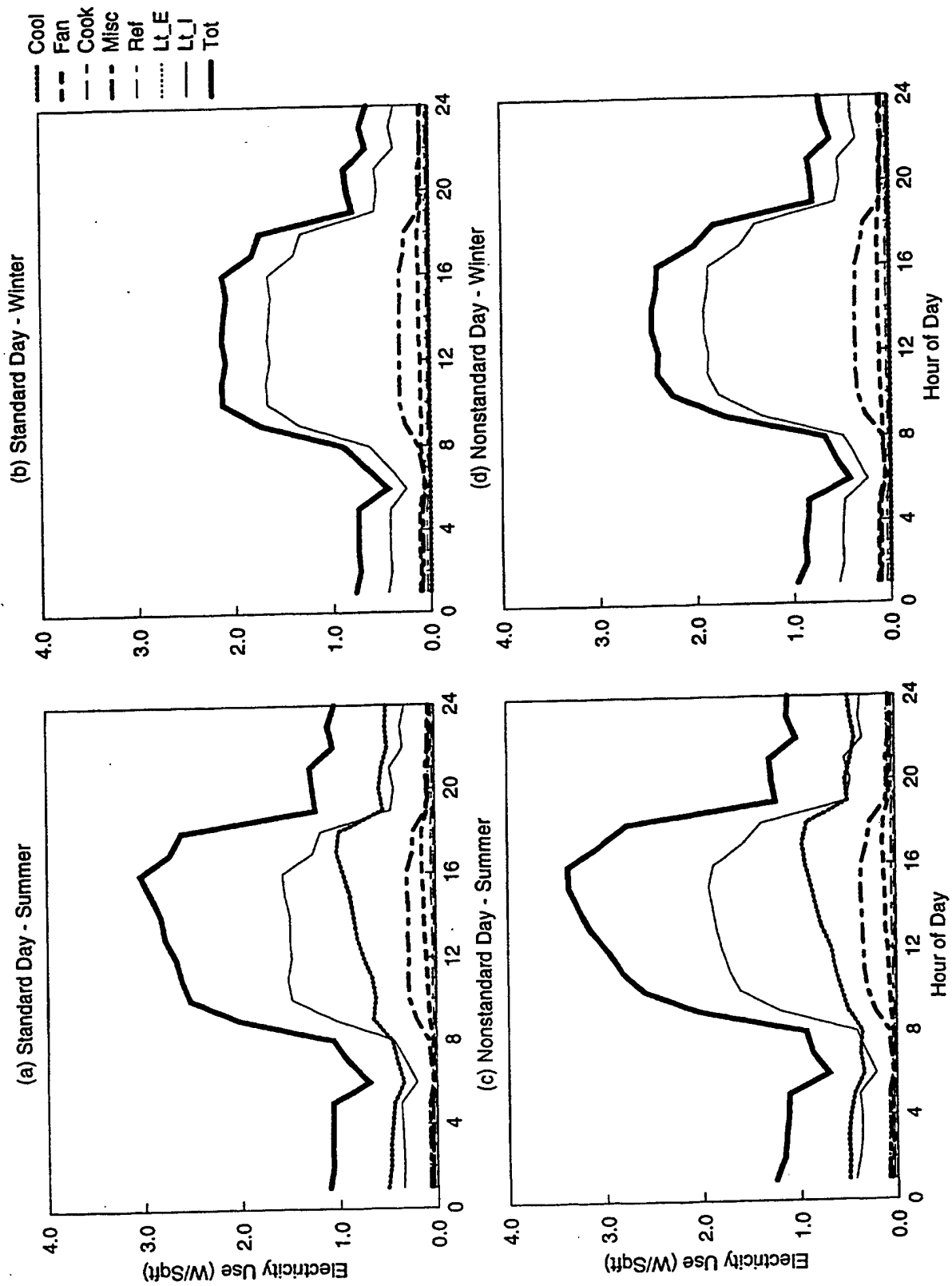


Figure C-67. EDA Reconciled End-use Load Shapes for Miscellaneous (Feeder 5)

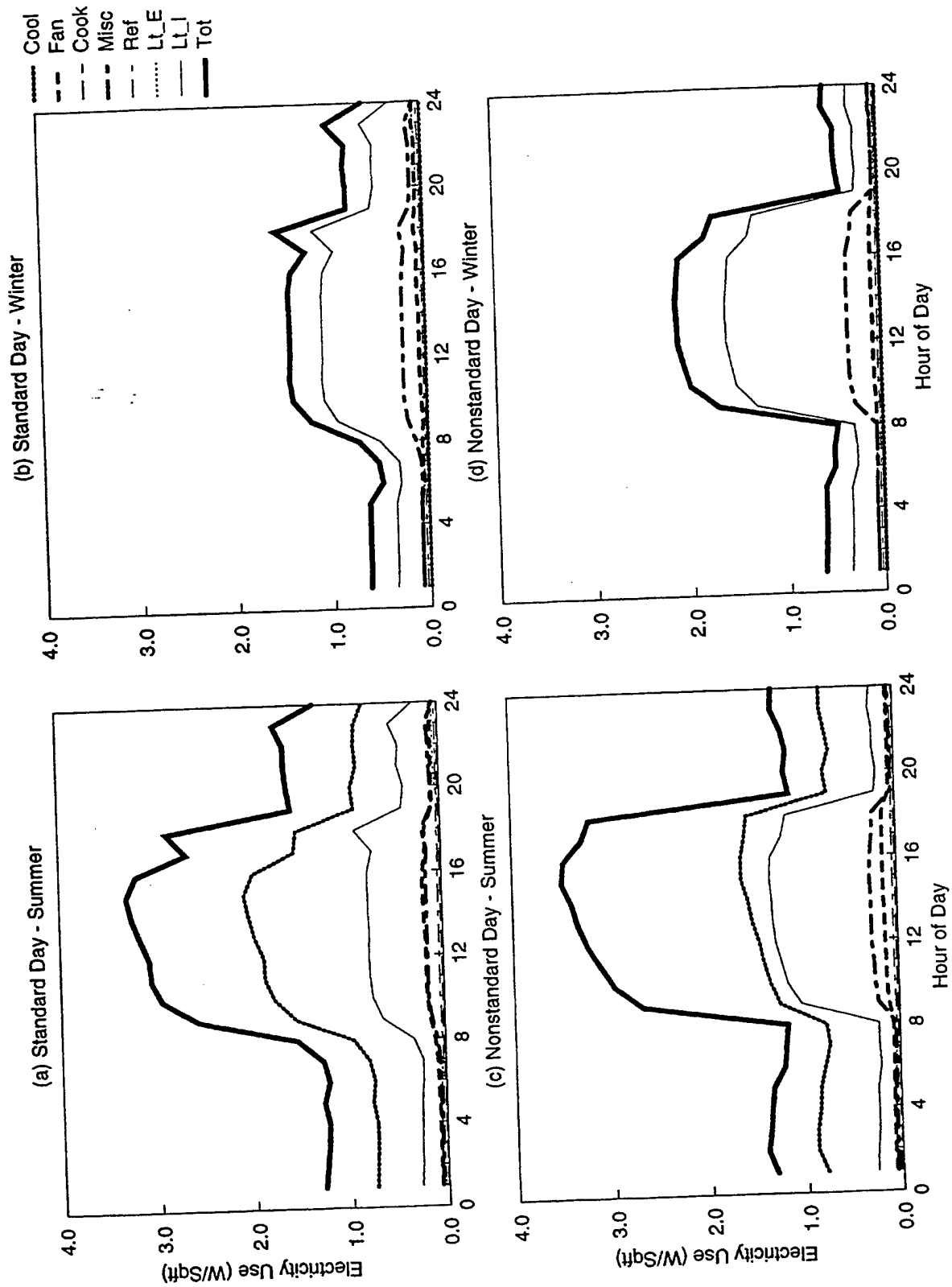


Figure C-68. EDA Reconciled End-use Load Shapes for Miscellaneous (Feeder 10)

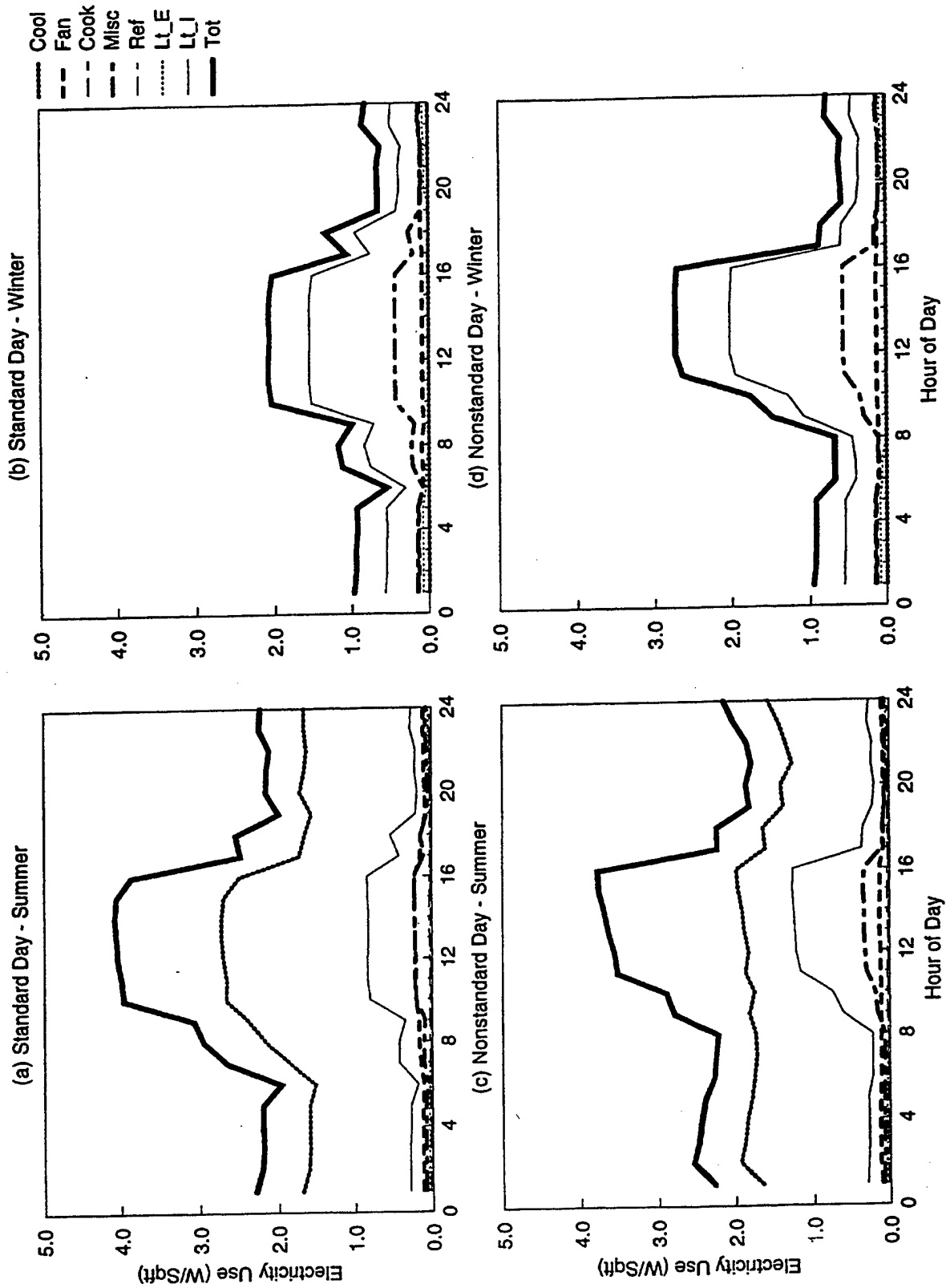


Figure C-69. EDA Reconciled End-use Load Shapes for Miscellaneous (Feeder 15)